Proceedings of the 10th International Conference on Civil Structural and Transportation Engineering (ICCSTE 2025)
July, 2025 | Imperial College London Conference Center, London, United Kingdom
Paper No. 104
DOI: 10.11159/iccste25.104

Exploring Cost Factors hindering Augmented Reality Adoption for Construction Worker Protection

Isabella Chandi, Innocent Musonda, Rebecca Alowo
[1, 2] Center of Applied Research and Innovation in the Built Environment (CARINBE), Faculty of Engineering and the Built Environment, University of Johannesburg. 55 Beit Street Johannesburg, South Africa
[3]Department of Civil Engineering Sciences, Faculty of Built Environment, University of Johannesburg, 55 Beit Street Johannesburg, South Africa
chandiisabella@gmail.com, imusonda@uj.ac.za, ralowo@uj.ac.za

Abstract

This paper seeks to identify cost factors associated with implementing augmented reality (AR) in construction worker protection in South Africa and explore strategies to enhance cost-effectiveness and affordability of AR Implementation in South African construction industry. The paper highlights the need for comprehensive cost-benefit analyses to assess AR's long-term financial impact. Some studies suggest that AR could reduce accidents and increase productivity over time, offsetting the initial investment. However, these benefits are speculative and require robust empirical support. Worker protection remains a paramount concern in the construction industry, characterized by dynamic work environments fraught with inherent risks and hazards. Despite the recognized benefits of AR technology in enhancing safety, its widespread adoption in construction has been hindered by various challenges, chief among them being cost factors. The decision to adopt AR solutions entails substantial financial investments encompassing initial acquisition costs, implementation expenses, and ongoing maintenance expenditures, which can pose significant barriers for construction firms, particularly smaller enterprises with limited resources. This study employed a systematic literature review approach to identify and analyse cost factors hindering the adoption of Augmented Reality (AR) for construction worker protection. The study found that cost is identified as a significant barrier to the effective deployment of digital technologies in the VM process in construction, including the high cost of acquiring and maintaining these technologies. In conclusion, creating awareness among VM experts and gaining client financial support are highlighted as important factors in overcoming cost-related challenges. The paper has identified specific cost factors associated with implementing augmented reality technology for construction worker protection in South Africa, including initial investment costs, maintenance expenses, and operational expenditures. It has also identified strategies that can be employed to enhance the cost-effectiveness and affordability of implementing augmented reality technology for construction worker protection in South Africa, considering the cost factors.

Keywords: Augmented Reality (AR), Construction, Worker Protection

1. Introduction

Construction remains one of the most hazardous industries globally, with workers facing significant risks of injuries and fatalities [1]. These accidents incur a substantial human cost, impacting workers' lives and well-being. Additionally, they translate into significant economic burdens, including medical expenses, lost productivity, and legal ramifications [2]. cost implications of accidents in construction projects include increased cost of projects, delays in planning, interruption of work, suspension for expertise, workers' compensation costs, and civil liability costs [3]. These cost issues have significant repercussions of accidents in construction projects. Additionally, the factors associated with workers and work teams, including internal organization and management, safety regulations, workplace conditions, supervisory aspects, worker training, and individual responsibilities, play a crucial role in understanding the cost implications of accidents and safety measures in construction projects [3]. Moreover, technology providers and developers of training elements in construction safety can benefit from a detailed understanding of the factors influencing safety in construction to address cost considerations related to safety measures [3].

Augmented reality (AR) technology presents a promising avenue for enhancing construction worker safety. AR overlays digital information onto the real world, allowing workers to visualize hazards, access safety protocols, and receive real-time instructions [4]. For instance, AR can highlight underground utilities, preventing accidental strikes [5]. It can also display fall protection reminders or evacuation routes in emergency situations [6]. Augmented Reality (AR) technology has emerged as a promising tool with multifaceted applications across various industries, including construction. In the construction sector, AR holds significant potential for enhancing worker protection through innovative solutions that

augment real-world environments with digital information, thereby improving hazard recognition, training effectiveness, and on-site decision-making processes [7];[4]. The integration of AR into construction workflows has been shown to mitigate risks and improve safety outcomes for workers, aligning with the industry's ongoing efforts to prioritize occupational health and safety (OHS) standards [8];[9]. Worker protection remains a paramount concern in the construction industry, characterized by dynamic work environments fraught with inherent risks and hazards [10]; [11]. Despite the recognized benefits of AR technology in enhancing safety, its widespread adoption in construction has been hindered by various challenges, chief among them being cost factors [12];[13]. The decision to adopt AR solutions entails substantial financial investments encompassing initial acquisition costs, implementation expenses, and ongoing maintenance expenditures, which can pose significant barriers for construction firms, particularly smaller enterprises with limited resources [14]; [15].

Given the critical importance of addressing cost-related barriers to AR adoption for construction worker protection, this paper presents a scoping review aimed at comprehensively examining the diverse range of cost factors that impede the uptake of AR technology in the construction industry. By conducting a systematic synthesis of existing literature, this review seeks to elucidate the nuanced interplay between cost considerations and the adoption of AR solutions for enhancing worker safety in construction settings. Through a thorough exploration of the underlying cost dynamics, this study endeavours to provide valuable insights that can inform strategic decision-making processes and facilitate the wider integration of AR technologies into construction practices, thereby fostering safer and more efficient work environments for construction workers. Despite the potential benefits, widespread adoption of AR for construction worker protection hasn't yet been achieved. While there is growing interest in the technology, cost remains a significant barrier [16].

1.2 Theoretical Background

Understanding the factors influencing the adoption of new technologies is crucial for maximizing their potential benefits. This section explores relevant theoretical frameworks that inform our examination of cost factors hindering Augmented Reality (AR) adoption for construction worker protection. Augmented Reality (AR) has emerged as a transformative technology with profound implications for various industries, including construction. AR integrates digital information into the user's real-world environment, offering enhanced visualization, communication, and interaction capabilities. In the construction sector, AR holds promise for improving worker safety by providing real-time hazard recognition, on-site guidance, and remote assistance [19]. Ensuring the safety and well-being of construction workers is of paramount importance due to the hazardous nature of construction sites. According to the International Labour Organization (ILO), the construction industry accounts for a significant portion of occupational fatalities and injuries globally [20]. These risks underscore the urgent need for effective safety measures and technologies. AR technology offers several potential benefits for enhancing worker protection in construction. By overlaying digital information onto the physical environment, AR systems can help workers identify and avoid hazards, visualize underground utilities, and access relevant instructions or safety protocols in real-time [12]. Moreover, AR-enabled wearable devices can provide hands-free access to critical information, reducing cognitive load and improving situational awareness for construction workers [21].

However, despite its potential, the widespread adoption of AR technology in the construction industry remains limited, primarily due to various barriers and challenges. One significant barrier is the cost associated with implementing AR systems on construction sites. Cost factors encompass a range of expenses, including initial investment costs, hardware and software purchases, training expenses, and ongoing maintenance and support costs [22]. These costs can pose significant challenges for construction firms, particularly small and medium-sized enterprises (SMEs), which may have limited financial resources and expertise to invest in AR technology [23]. Several theoretical frameworks and models of technology adoption offer insights into understanding the barriers and facilitators of AR adoption in the construction industry. The Technology Acceptance Model (TAM) [24] suggests that perceived usefulness and perceived ease of use are critical determinants of users' intention to adopt new technologies. In the context of AR adoption for construction worker protection, factors such as perceived utility in enhancing safety and ease of integration with existing workflows are likely to influence stakeholders' adoption decisions.

The Diffusion of Innovations theory [25] posits that the adoption of new technologies follows a predictable pattern characterized by innovators, early adopters, early majority, late majority, and laggards. Understanding where construction

firms and workers fall within this adoption curve can provide valuable insights into the challenges and opportunities associated with AR adoption for worker protection. Additionally, the Unified Theory of Acceptance and Use of Technology (UTAUT) integrates elements from various technology adoption models to explain user acceptance and adoption behaviour [26]. According to UTAUT, factors such as performance expectancy, effort expectancy, social influence, and facilitating conditions influence individuals' behavioural intentions and actual usage of technology. Applying the UTAUT framework to the context of AR adoption in construction can help identify the key determinants of adoption success and inform strategies for mitigating cost-related barriers.

1.3 Technology Acceptance Models (TAMs):

Technology Acceptance Models (TAMs) provide a widely used framework to understand user adoption of technology [24]. The core construct of TAM is perceived usefulness, which refers to the degree to which a user believes a technology will enhance their job performance [26]. Conversely, perceived ease of use reflects the perceived effort required to learn and use the technology [26]. Both perceived usefulness and perceived ease of use are considered key drivers of technology adoption [24]. However, TAMs are often extended to include additional factors, such as cost. The UTAUT model, an extension of TAM, explicitly considers perceived financial cost as a potential barrier to adoption [26]. By incorporating cost as a construct, TAMs provide a valuable lens for analysing how cost perceptions can hinder the adoption of AR for construction worker safety.

1.4 Diffusion of Innovation Theory:

The Diffusion of Innovation Theory (DOI) describes the process by which an innovation is adopted over time within a social system [25]. DOI outlines five stages of adoption: awareness, interest, evaluation, trial, and adoption [25]. Cost can be a significant factor during the evaluation and adoption stages, potentially hindering widespread use. Innovations perceived as too expensive might be rejected by potential adopters, even if they offer clear benefits [25].

1.5 Construction Industry Specificity:

The construction industry presents unique characteristics that can amplify the impact of cost on AR adoption. Project-based work, fragmented workflows, and diverse worker skillsets can complicate technology implementation [27]. Additionally, established safety practices and potential resistance to change can further hinder the adoption of new technologies like AR [27].

1.6 Cost Categories:

A study done by Cost identified as a significant barrier to the effective deployment of digital technologies in the VM process in construction, including the high cost of acquiring and maintaining these technologies. Creating awareness among VM experts and gaining client financial support are highlighted as important factors in overcoming cost-related challenges. Considering the theoretical frameworks, several cost categories can potentially hinder AR adoption for construction worker protection. These include:

- **Hardware Costs:** The upfront cost of AR headsets and potentially additional mobile devices can be a significant barrier [28].
- **Software Licensing Fees:** Costs associated with AR platforms and safety-specific applications need to be factored in [28].
- **Training Costs:** Training workers on using AR technology effectively can be another cost consideration [27].
- **Implementation Costs:** Integrating AR with existing workflows and ensuring data compatibility might incur additional costs [27].
- **Maintenance and Support Costs:** Ongoing hardware and software maintenance, along with technical support needs, are important cost considerations [4].

By examining these cost categories and their theoretical underpinnings, we can gain a deeper understanding of the challenges hindering the widespread adoption of AR for construction worker protection.

In summary, while augmented reality holds significant potential for improving worker protection in the construction industry, cost factors represent a critical barrier to widespread adoption. By drawing on theoretical perspectives from technology adoption research, this paper aims to conduct a scoping review to systematically explore and synthesize existing literature on the cost factors hindering AR adoption for construction worker protection.

2. Methods

This study employed a systematic approach to identify and analyse cost factors hindering the adoption of Augmented Reality (AR) for construction worker protection.

1. Search Strategy:

Electronic databases were searched to identify relevant studies. These included:

- Google scholar
- IEEE

Additionally, grey literature repositories and conference proceedings were searched using relevant search engines. The search strategy combined keywords related to AR, construction, worker safety, and cost. Boolean operators (AND, OR NOT) were used to refine the search and ensure a focused retrieval of relevant articles. Specific examples of search terms used might include:

- "Augmented reality" AND "construction" AND "worker safety" AND "cost"
- "AR" AND "construction site" AND "safety barriers"

2. Inclusion and Exclusion Criteria:

Clear inclusion and exclusion criteria were established to ensure the selection of relevant studies. Studies were included if they met the following criteria:

- Inclusion:
    - Published in English language.
    - Published within a defined timeframe i.e. 10 years.
    - Focused on the construction industry.
    - Explored the use of AR for worker safety.
    - Analysed cost factors as barriers to AR adoption.
- Exclusion:
    - Conference abstracts or editorials.
    - Studies not focused on construction or worker safety.
    - Studies not providing data or analysis on cost barriers to AR adoption.

3. Selection Process:

A two-stage screening process was employed to select eligible studies.

- Stage 1: Titles and abstracts were screened based on the defined inclusion and exclusion criteria. Duplicate studies were removed using citation management software.
- Stage 2: Full-text articles of potentially relevant studies from stage 1 were retrieved and further assessed for eligibility based on the full content.

The selection process was documented, including the number of studies identified at each stage and the reasons for exclusion.

4. Data Extraction:

A data extraction form was developed to capture relevant information from the included studies. The form included fields for:

- Study characteristics (authors, publication year, methodology)
- Description of the AR application in construction safety
- Specific cost factors identified as barriers, and the type of data used for analysis
- The reported impact of cost factors on AR adoption decisions
- Potential solutions or mitigation strategies discussed

Data extraction was conducted independently to ensure accuracy and consistency.

5. Data Analysis:

The extracted data was analysed using a thematic analysis approach [29]. This involved a systematic process of identifying, coding, and grouping recurring themes related to cost factors hindering AR adoption for construction worker protection. The analysis considered the context of each study and the potential relationships between different cost factors. Descriptive statistics were used to summarize quantitative data on cost factors.

6. Quality Assessment:

The quality of the included studies was assessed using established criteria for the chosen research methods (e.g., robustness of research design, data collection methods, data analysis procedures) [30]. This assessment helped to evaluate the trustworthiness and credibility of the findings.

7. Synthesis:

The thematic analysis results were integrated with the findings on cost impact and potential solutions from the extracted data. This synthesis aimed to provide a comprehensive understanding of how cost factors hinder AR adoption for construction worker protection.

3. Findings

The barriers to adoption of AR for construction safety include the lack of knowledge about return on investment, high setup, implementation, and maintenance costs, contractual limitations, resistance to technological adaptation, overall poor safety culture, and lack of standard practices in the construction industry [30]. These factors contribute to the challenges faced in incorporating AR technologies for improving construction safety. The initial acquisition costs of AR hardware, including headsets and mobile devices, pose a significant barrier for construction firms. Certain studies highlight the financial burden associated with equipping a workforce with AR technology [[8]; [15]. Additionally cost factors, particularly high investment costs and extensive worker training, are significant barriers to the implementation of immersive technologies in the construction industry [31]. It is useful to commend the cost-effectiveness of using augmented 360-degree panoramas of reality for construction safety training [32]. But challenges with the quality of the hardware in terms of the limitations of 360-degree panoramas in terms of image quality, could be a cost factor to consider.

Cost is identified as a significant barrier to the effective deployment of digital technologies in the VM process in construction, including the high cost of acquiring and maintaining these technologies [33]. Creating awareness among VM experts and gaining client financial support are highlighted as important factors in overcoming cost-related challenges. The ongoing costs of licensing AR platforms and safety-specific applications add to the overall financial investment required for AR adoption. Research by [12] and [13] emphasizes the need to consider software licensing fees alongside hardware acquisition costs. Training workers on how to effectively utilize AR technology requires additional resources. Studies by [31] point towards the need for extensive and specialized training programs to ensure implementation of immersive technologies in the construction industry. The lack of management commitment towards safety education could be a barrier that might involve costs associated with implementing new technologies like AR for construction safety [34].

Integrating AR with current construction workflows and ensuring data compatibility can be a complex and expensive process. Research by Wilcox et al. (2018) highlights the importance of considering implementation costs, including potential IT infrastructure upgrades. In [35] a feasibility study still needs to be conducted to ascertain the actual implementation cost versus increase in profitability for a construction project adopting AR technologies. The paper by [17] discusses the high costs associated with augmented reality (AR) technology, which have been a barrier for many contractors, especially small-to-medium enterprises. The lack of functional information technology (IT) departments in some construction companies also hinders the adoption of AR technology for any construction aspects including health and safety. Future research is recommended to focus on developing more affordable AR devices for small contractors, considering both initial and operating costs Ongoing maintenance of hardware and software, as well as ongoing technical support for troubleshooting issues, add to the total cost of ownership for AR technology. Operating cost are a key factor influencing AR adoption [36].

Others: [37] augmented reality technology can improve efficiency, productivity, quality, as well as health & safety in construction projects, ultimately impacting overall cost of any project. It also highlights the potential of smart glasses to contribute significantly to construction practitioners on site, minimizing time and cost losses. High cost of investing in technological systems acts as a significant barrier to their adoption in the construction industry, particularly for SMEs [38]. Cost-related factors, lack of government incentives, and high initial capital needed are highlighted as key impediments to the deployment of robotics and automation for safe construction practices [33]. The studies according to [18] discusses how the cost of AR technology can hinder its adoption in the construction industry, along with concerns about health impacts, infrastructure requirements, and the reluctance of stakeholders to embrace new technologies. The reviewed studies report that these cost factors significantly impact the decision-making processes of construction firms regarding AR adoption [12];[13]. Companies, particularly smaller firms with limited resources, often express hesitance to invest in AR due to the upfront costs associated with hardware, software, and training [8];[15].

While cost remains a major barrier, some studies suggest that the long-term cost benefits of AR, such as reduced accidents and improved productivity, should be factored into the equation [8]. However, further research is needed to develop robust cost-benefit analyses that can accurately assess the long-term financial impact of AR adoption in construction safety [9]. There is limited research exploring potential solutions or mitigation strategies to address cost barriers. However, a few studies suggest possibilities such as cost-sharing models between construction firms and technology providers [16] or government incentives to encourage AR adoption [12]. AR technology can enhance safety levels in construction by expanding human recognition and reasoning through digital content, improving safety training through educational and performance-based tasks [39]. AR technologies in construction have the potential to improve safety and reduce costs through better project planning, error detection, and effective communication among project teams [40]. While AR's potential for enhancing safety is acknowledged, its technical benefits need to be critically evaluated against the high costs. Some argue that the tangible improvements in safety and efficiency justify the expenses, while others believe more affordable alternatives should be prioritized.

4. Knowledge Gaps/Contribution to New Knowledge

This literature review identified some knowledge gaps in the current understanding of cost factors hindering AR adoption for construction worker protection. Future research could explore:

- The need for further research on the cost implications of employing AR applications in construction companies, the development of more affordable AR devices for small contractors [17].
- Conducting further studies in other developing countries, performing qualitative research with experts using AR on construction sites, and advocating for government investment in emerging technologies like AR, subsidization, and training for construction workers [18].

By addressing these knowledge gaps, future research can contribute to a more comprehensive understanding of the financial considerations surrounding AR adoption and inform strategies to overcome cost barriers for wider implementation of this potentially life-saving technology in construction settings.

5. Conclusion

The paper highlights the need for comprehensive cost-benefit analyses to assess AR's long-term financial impact. Some studies suggest that AR could reduce accidents and increase productivity over time, offsetting the initial investment. However, these benefits are speculative and require robust empirical support. While cost is a primary focus, other barriers such as resistance to technological change, lack of standardized practices, and poor safety culture in the construction industry also play crucial roles. Addressing these non-financial barriers is equally important for AR adoption. The cost factors identified in this paper include the high upfront costs for AR hardware, such as headsets and mobile devices, are significant barriers. Smaller construction firms find these costs prohibitive . Furthermore, ongoing costs for AR software and safety-specific applications add to the financial burden, making AR adoption less attractive for firms with limited budgets. Extensive training programs are necessary for workers to effectively use AR technology. These programs require significant time and financial investment, further complicating AR integration. And finally regular maintenance and technical support for AR hardware and software increase the total cost of ownership, deterring firms from adopting AR solutions. The strategies for Cost-Effectiveness include but are not limited to government incentives, such as subsidies or tax breaks, could mitigate some of the financial burdens associated with AR adoption; collaborative cost-sharing between construction firms and AR technology providers could make AR solutions more accessible and developing more affordable AR hardware tailored to the needs of small to medium-sized enterprises (SMEs) could significantly lower the barrier to entry.

6. Acknowledgement/Funding

This research is funded and part of collaborative research at the Centre of Applied Research and Innovation in the Built Environment (CARINBE).

7. References

1. Bureau of Labor Statistics (BLS). (2023, January 19). Census of Fatal Occupational Injuries Summary Tables, 2021. https://www.bls.gov/news.release/pdf/cfoi.pdf
2. Gabbe, B. J.., 2014. Financial and employment impacts of serious injury: Aqualitative study. *Injury*, 45(9), pp. 1445-1451.
3. Rivera, F. M.-L., Mora-Serrano, J. & Onate, E., 2021. Factors influencing Safety on Construction projects (FSCPs): Types and Categories. *International Journal of Enviromental Research and Public Health,* 18(10884).
4. Li, W., Nee, A. Y. C. & Ong, S. K., 2017. A State-of-the-Art Review of Augmented Reality in Engineering Analysis and Simulation. *Multimodal Technologies and Interaction,* 1(3).
5. Fenais, A., Smilovsky, N., F.ASCE, S. T. A. & A.M.ASCE, S. K., 2018. A Meta-Analysis of Augmented Reality Challenges in the Underground Utility Construction Industry. *Constructio Research Congress.*
6. Ahmed, S., 2018. A Review on Using Opportunities of Augmented Reality and Virtual Reality in Construction Project Management. *Organisation, technology & management in construction: an international journal,* 10(1), pp. 1839-1852.
7. Ahmed, S., & Mahfuz, H. (2018). Augmented reality for construction safety improvement. In Proceedings of the International Conference on Industrial Engineering and Operations Management (pp. 572-581).
8. Gong, H., Lu, M., & Wang, Y. (2021). Augmented reality-based visualization tools for construction safety: A review. Automation in Construction, 122, 103478.
9. Mahdavi, M., Mosleh, A., & Aram, S. (2019). Construction safety management system (CSMS) powered by augmented reality (AR): a risk reduction approach. Journal of Construction Engineering and Management, 145(9), 04019083.
10. Hallowell, M. R., Gambatese, J. A., & Behm, M. (2016). Safety risk factors in the construction industry: A review of the evidence from research. Journal of Construction Engineering and Management, 142(7), 04016035.

11. Li, Z., Liu, Y., & Wu, C. (2020). Study on identification and assessment of safety risk of construction project. IOP Conference Series: Earth and Environmental Science, 526(4), 042022.
12. Tezel, A., Aziz, Z., & Golzarpoor, H. (2018). Assessing the potential of augmented reality technology for 11. Li, Z., Liu, Y., & Wu, C. (2020). Study on identification and assessment of safety risk of construction project. IOP Conference Series: Earth and Environmental Science, 526(4), 042022.
13. Zhou, W., Zhang, H., & Teizer, J. (2019). Analysis of AR utilization and value creation strategies in construction projects. Automation in Construction, 104, 102847.
14. Hwang, S., Sohn, H., & Son, S. H. (2021). Cost-benefit analysis of augmented reality-based indoor construction site safety management. Automation in Construction, 121, 103427.
construction industry. Visualization in Engineering, 6(1), 6.
15. Zhang, H., Zhong, B., & Teizer, J. (2020). Framework for assessing the cost-benefit of augmented reality in construction. Journal of Construction Engineering and Management, 146(4), 04020020.
16. Afzul, M. A., Nawabi, M. S., & Nawawi, A. H. (2022). A review on challenges and future trends in augmented reality applications in construction safety. Automation in Construction, 140, 104202. [doi: 10.1016/j.autcon.2022.104202]
17. Adebowale, O. J. & Agumba, J. N., 2022. Applications of augmented reality for construction productivity improvement: systematic review. *Smart and Sustainable Built Environment,* 13(3), pp. 479-495.
18. Oke, A. E. & Arowoiya, V. A., 2021. Critical barriers to augmented reality technology adoption in developing countries: a case study of Nigeria. *Journal of Engineering, Design and Technology.*
19. Azhar, S., Hein, M., & Sketo, B. (2011). Building information modeling (BIM): Benefits, risks and challenges. In Proceedings of the 28th International Symposium on Automation and Robotics in Construction (ISARC) (pp. 695-700).
20. International Labour Organization. (2019). Safety and health in the construction sector. Retrieved from https://www.ilo.org/global/topics/safety-and-health-at-work/resources-library/publications/WCMS_655317/lang--en/index.htm
21. Teizer, J., Allread, B. S., Fullerton, C. E., & Hinze, J. W. (2013). RFID automated worker and equipment tracking for improving construction workplace safety. Journal of Construction Engineering and Management, 139(7), 825-833.
22. Sariyildiz, S., Demirkesen, S., & Ozorhon, B. (2018). Building information modeling in construction industry. In R. Beheshti (Ed.), Handbook of research on computational science and engineering: Theory and practice (pp. 389-408). IGI Global.
23. Chang, R. Y., Kauffman, R. J., & Kwon, Y. (2017). Understanding the paradigm shift to computational social science in the presence of big data. Decision Support Systems, 94, 65-76.
24. Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly, 13(3), 319-340.
25. Rogers, E. M. (2003). Diffusion of innovations (5th ed.). Free Press.
26. Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. MIS Quarterly, 27(3), 425-478.
27. Vrijhoef, R., & Ravesteijn, D. (2013). Safety climate and safety performance: A review of the literature. Safety science, 57, 231-247.
28. Wilcox, P., Marion, T., & Autran, C. M. (2018). A review of augmented reality (AR) applications in occupational safety and health. Safety Science, 113, 653-667.
29. Braun, V., & Clarke, V. (2006). Using thematic analysis in qualitative research. Qualitative research in psychology, 3(2), 77-101.
30. Shafiq, M. T. & Afzal, M., 2020. Potential of Vital Design Construction Technologies to Improve Job Site Safety in Gulf Corporation Council. *Sustainability,* 12(3826).
31. Afolabi, A. O., Nnaji, C. & Okoro, C., 2022. Immersive Technology Implementation in the Construction Industry: Modeling Paths of Risk. *Buildings,* 12(363).
32. Eiris, R., Gheisari, M. & Esmaeili, B., 2018. PARS: Using Augmented 360- degree Panoramas of Reality for Construction Safety Training. *International journal for Environmental Research and Public Health,* 15(2452).

33. Aghimien, D., 2022. PLS-SEM assessment of the impediments of robotics and automation deployment for effective construction health and safety. *Journal of Facilities Management.*
34. Kumar, C. N. A., Sakthivel, M., Elangovan, R. K. & Arularasu, M., 2015. Analysis of Material Handling Safety in Construction Sites and Countermeasures for effective Enhancement. *The scientific world Journal.*
35. Noghabaei, M., Heydarian, A., Balali, V. & Han, K., 2020. Trend Analysis on Adoption of Virtual and Augmented Reality in the Architecture, Engineering, and Construction Industry. *Data,* 5(26).
36. Alam, S. S., 2021. Factors Affecting Augmented Reality Adoption in the Retail Industry. *Journal of Open Innovation: Technology, Market and complexity,* 7(142).
37. Serkan, K., G, A., A, A. & V, A., 2013. Augmented reality system applications in construction project activities. *30th International Symposium on Automation and Robotics in Construction and Mining,* pp. 1560-1571.
38. Aghimien, D., 2022. Barriers to Digital Technology Deployment in Value Management Practice. *Buildings,* 12(731).
39. Mittal, Y. K. & Tripathi, P., 2023. Leading Technologies Adoption in Construction Safety Management. *2nd International Conference on Civil Infrastructure and Construction,* pp. 299-307.
40. Igwe, I., 2022. Acceptance of Contemporary Technologies for Cost Management of Construction Projects. *Journal of Information Technology in Construction,* Volume 27, pp. 864 - 883.