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Evaluating the Awareness, Barriers, and Level of Adoption of Innovative Digital Technologies in the Health and Safety of High-Rise Construction in South Africa

Alireza Moghayedi[1], Mark Massyn[1], Karen Le Jeune[1] and Kathy Michell[1]

[1] Sustainability + Oriented Cyber Unit for Built Environment, Department of Construction Economics and Management
University of Cape Town, Cape Town, 7700, South Africa
alireza.moghayedi@uct.ac.za

Abstract

Innovative technologies have been used globally to improve health and safety practices in construction projects. This adoption has been proven to directly lead to significant decreases in the number of incidents experienced on construction projects. However, limited research has been done in South Africa to evaluate the level of awareness, adoption and barriers of Health and Safety (H&S) innovative technologies in high-rise construction projects. Therefore, this research seeks to fill this knowledge gap. A questionnaire survey was undertaken to collect data from H&S officers of high-rise construction projects across South Africa to answer the study objectives. Statistical analysis was employed to analyze the collected data. The study found that the South African H&S officers are moderately aware of the innovative technologies that can be implemented on high-rise construction projects to improve health and safety management practices. However, the adoption of innovative technologies in these types of construction projects is less than 20%. Furthermore, the study determined the initial cost of technology, non-availability of technologies and high skill shortage as the main barriers to adopting innovative technologies in South African high- rise construction projects. The study concludes that the extent of adopting innovative technologies in construction projects could be increased with an awareness of innovative technologies' performance and availability. The acquisition of the technical knowledge associated with the technology-based construction processes and the recognition of the use of innovative digital technologies (IDT) in H&S of high-rise construction projects in building requirements and regulations were recommended in the study.

Keywords

Level of adoption, Barriers, Health and safety, High rise construction, Innovative technologies.

1. Introduction

The Health and Safety (H&S) of construction workers in a workplace cannot be overemphasized, as scholarly works continue to acknowledge the unsafe, risky and hazardous nature of the industry (Wuni and Shen, 2020). This is because of the numerous risks inherent in undertaking construction activities on site. As much as it is almost impossible to undermine the importance of the construction industry, its uncertain and dangerous nature remains a huge concern. In undertaking construction engagements such as buildings, infrastructure repair and maintenance, some health and risky occurrences are inevitable (Wuni and Shen, 2020). Faulty equipment associated with accidents, falling from heights, high-frequency noise (that may lead to hearing dysfunctions), the collapse of structures (which sometimes cause deformities), among others, are likely factors that lead to accidents occurring (Hulme et al., 2019). Hence, many traditional models and methods have been employed by various scholars to address some of these resilient accident-related problems in the past decade (Wuni and Shen, 2020).

However, it is believed that the swift and effective implementation of innovative technology will leverage significant gains in construction project implementation and performance (Wuni and Shen, 2020). So, many scholars globally are recently advocating for an imminent shift to advanced technologies; like artificial intelligence and the use of robotics, Internet of Things (IoT), Building Information Modelling (BIM), Drone, Virtual Reality (VR), and

Augmented Reality (AR), wearables, laser scanning, photogrammetry, and sensor-based technologies, to provide a better and safe working condition (Hulme et al., 2019; Okonkwo and Wium, 2020). The trend is thus changing globally.

Great strides have been achieved in other industries to reduce injuries and fatalities and improve H&S through progressive IDT usage. However, the construction industry in many parts of the world is still grappling with this contemporary change. It is yet to grasp the opportunity that these tools and approaches offer fully, and the ultimate benefits of IDT have not been fully harnessed and capitalized upon by stakeholders in the industry, and significant changes are yet to be seen (Akinosho et al., 2020; Pradhananga et al., 2021). The industry remains a conventional, slow and fragmented, high-risk industry in adopting this transformational digital change. Unlike manufacturing, aviation and electronics, finance, entertainment, healthcare and education, construction currently trails behind (Okonkwo and Wium, 2020; Pradhananga et al., 2021).

Abdalla et al. (2017) reiterate that although virtually every job entails some risk for injury, the magnitude of risk varies widely across jobs, sectors, geographic regions, and individuals. Accordingly, the South African construction industry is rife with H&S challenges and has yet to adopt IDT, just like many other developing countries (Okonkwo and Wium, 2020). Several studies proved that using IDTs as a proactive mechanism to prevent accidents in real-time significantly improves the H&S practices in construction projects (Manzoor et al., 2021; Okonkwo et al, 2020). However, the benefits of IDT incorporation in the H&S aspects of high-rise construction are not extensively utilized and documented in South Africa. Moreover, very few empirical studies exist that establish the awareness levels of stakeholders and identify the incentives and challenges to their adoption, just like many other developing countries.

In every six fatal accidents, one occurs on a construction site, and one fatal accident occurs every 10 minutes (Okonkwo and Wium, 2020). The construction industry is responsible for about 30% to 40% of all work-related fatalities universally and worse in developing countries due to a lack of safety in the contractor organization and less robust health and management systems. As a result, fatal accidents statistics in the construction industry of developing countries far exceeds that of developed countries and are about 3 to 6 times more than their developed countries' counterparts (Okonkwo and Wium, 2020).

As construction projects increase in complexity, alternative modern construction methods and design should increase popularity. Today's complex high rise construction projects require these contemporary IDTs in design and methods, which should not be ignored. This can be addressed through a construction industry that minimizes risks and streamlines activities systematically through DIT (Newman and Humphrys, 2020). Technological transformation and innovation align with the industry 4.0 requirements needed to transform the industry into smart construction through an effective holistic transformation. Hence, by analyzing data from stakeholders of high-rise buildings, their level of awareness, incentives, challenges, and a well IDT informed working environment might be developed to mitigate H&S in the south African construction industry of high-rise buildings. However, studies did not give extensive analysis and understanding of the challenges and incentives to adopting innovative H&S technologies in high-rise construction concerning the familiarity and awareness of the H&S professionals with these technologies and their application in H&S of high-rise construction.

Hence, it becomes vital to specifically investigate the complex relationship between awareness as a skill of experts to be aware and mindful of new and popular technology that has been gaining widespread acceptance across concerned industries or markets, incentives and challenges to adoption and extent of use of these IDT in H&S of high-rise construction by professionals. Therefore, there is a need for a deep understanding of their complex relationship in order to determine the impact of awareness, the incentives required and challenges facing adoption. Thus, this study aims to provide a deep understanding of the nexus and impact of influencer factors (awareness, challenges and incentives) to the extent of IDT adoption in South African H&S professionals. This understanding will, in turn, promote the adoption of IDT H&S of high-rise construction as one of the most challenging and hazardous construction projects and provide a valuable reference for H&S professionals in decision-making and policymaking on the use of innovative H&S technologies. To achieve this aim, the following research questions will be answered:

What is the level of awareness of South African H&S professionals on innovative technologies used in high-rise construction?

What are the key incentives and barriers posed to the adoption of innovative H&S technologies in South African high-rise construction?

2. Methodology

A questionnaire survey was undertaken to determine the level of adoption of the seven most innovative H&S technologies in the construction of high-rise buildings in South Africa and their incentives and challenges in adopting these technologies.

All primary data were collected through a structured survey questionnaire. The questionnaire comprised four parts. Part 1 was designed to collect the general background, including job title, level of education, experience, company affiliation and type of high-rise buildings. Part 2 used 5 Likert scales to obtain information on the level of awareness with innovative H&S technologies. Part 3 of the questionnaire were focused on incentives and challenges on the adaptation of innovative H&S technologies, and finally, Part 4 used 5 Likert scales to evaluate the level of adoption of innovative H&S technologies in high-rise buildings by respondents' companies.

The study population consisted of all the H&S professionals that recently completed a high-rise building in South Africa. A total of 55 H&S officers were identified from the registered H&S professional with SACPCMP. A copy of the questionnaire survey was sent to all target populations (55) of the study. As a result, 47 valid responses were returned (85% response rate), and these were used for the data analysis. The data collected were analyzed using descriptive and inferential statistical techniques such as percentage, frequency, Mean Score (MS) and Relative important Index (RII).

Prior to analyzing data, the consistency of collected data was tested. The results of Cronbach's Alpha are between 0.7 and 0.95, which indicate a good consistency between the participants' responses.

3. Results

3. 1 Profile of respondents and their projects Results

Figure 2 shows that most of the respondents (64%) worked at high-rise projects as H&S officers, while 36%respondents concurrently held other job titles in addition to the H&S responsibility. The results indicate that majority of the respondents (32%) have an advanced certificate, closely followed by 30% of the respondents who have post-graduate qualifications. Advanced certificates are the minimum requirement to become an H&S professional. The findings on the respondents' experience show that 41% of respondents have between 11 and 15 years of experience with high-rise projects. In comparison, only 2% of respondents had less than five years of experience working in high-rise buildings. The demographic results of respondents indicate the credibility of the respondents. All the respondents have some level of professional qualification, and almost all (98%) have extensive experience working on high-rise projects.

Figures 1 presents the demographic analysis of the 47 H&S professionals and their completed latest high-rise project.

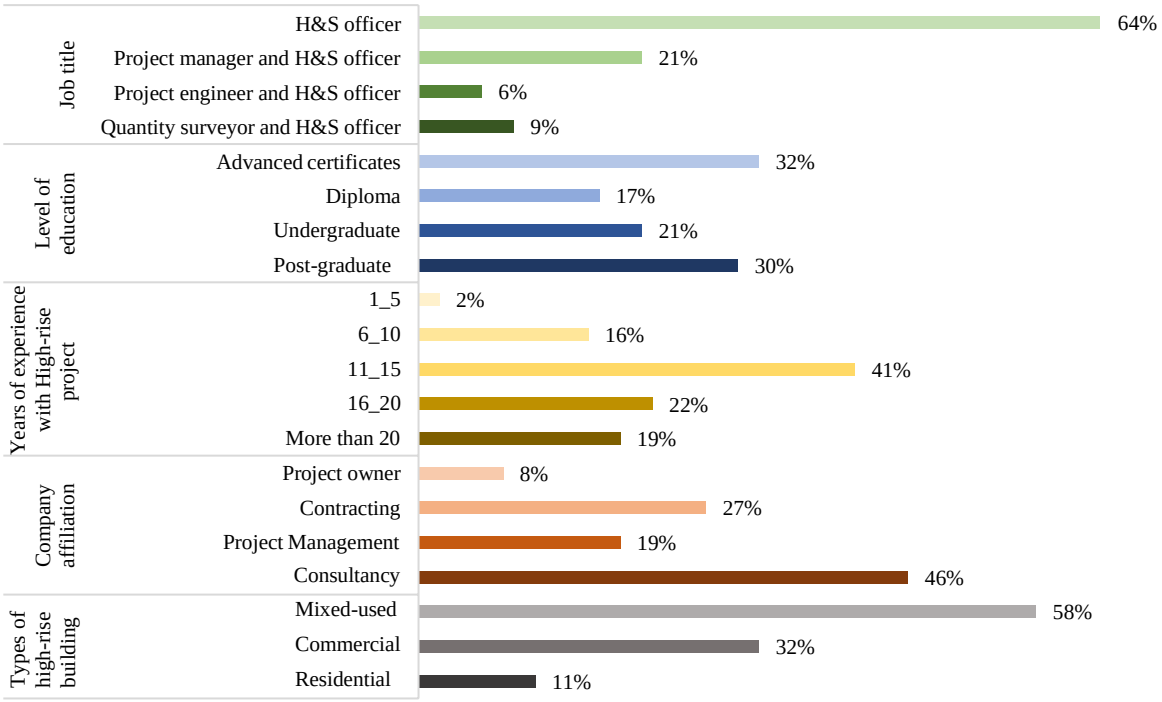

Fig. 31. Profile of respondents

Figure 1 indicates that the most common type of high-rise projects was mixed-used buildings (58%), followed by commercial buildings (32%) and residential buildings (11%). Office blocks have the highest percentage of all the buildings used (75%). The results depict that most respondents were associated with H&S consultancy companies (46%) and contracting (27%), and 19% were associated with the project management company. In contrast, 8% of respondents were project owners. About 90% of the H&S professionals worked in the private sector, and only less than 10% worked in the public sector.

3.2 Level of awareness with innovative technologies

The respondents were asked to indicate their level of awareness and familiarity with the ten suitable innovative technologies in H&S of high-rise construction buildings using a 5 Likert scale. The responses received and their Relevant Importance Index (RII) is calculated and listed in Figure 2. The RII indicates respondents' overall level of awareness with the particular innovative technology.

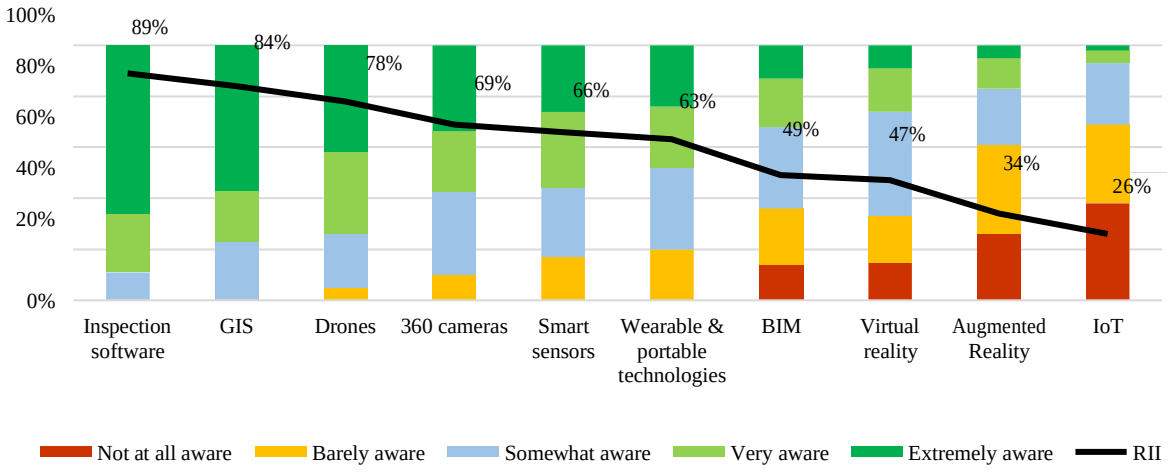

Fig. 2. Respondent's familiarity with innovative technologies

The results of respondents' awareness indicate that most of the H&S professionals who participated in the study were aware and familiar with inspection software (89%), GIS (84%), Drones (78%), 360 cameras (69%), smart sensors (66%), wearable and portable technology (63%), BIM (49%) and Virtual Reality (47%). While fewer participants were aware of Augmented Reality (34%), and limited participants were aware and familiar with IoT (26%). The overall findings on the awareness of the respondents show that the majority of the H&S professionals (60%) were aware of the latest innovative technologies that could be used in H&S of high-rise projects, which this finding is aligned with, Chen, et al. (2021).

3.3 Level of adaption of innovative technologies in high-rise projects

The respondents were asked to reveal the level of adoption of innovative technologies in their latest completed high-rise project by indicating how often they used these technologies through a 5 Likert scale. The responses received and their RII is tabulated in Figure 3. The calculated RII indicates the overall adoption of each innovative technology in 47 high-rise projects studied in this research.

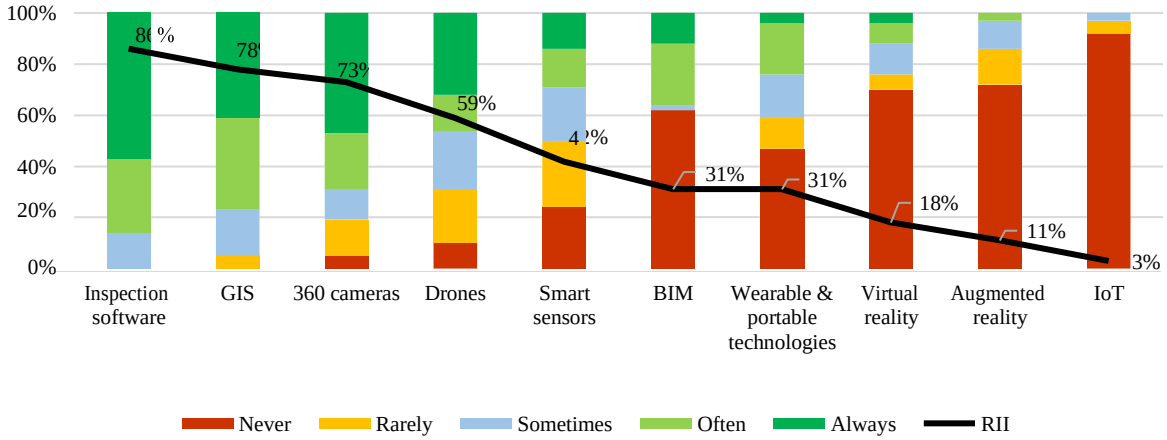

Fig. 3. Level of adoption of innovative technologies

Figure 3 presents all participants who adopted inspection software and GIS in their high-rise projects. Additionally, the level of adoption of inspection software (86%), GIS (78%) and 360 camera (73%) were very high in all the studied high-rise projects. This is supported by Li and Liu (2019). Notably, the adoption of drones as a technology recently introduced in the construction industry was high (59%). Only 10% of high-rise projects could not use the drone as innovative H&S technology. Martinez et al. (2020) also noticed the rapid increase in the adoption of drones in the construction industry.

On the other hand, the level of adaptation of smart sensors (42%), BIM (31%) and wearable and portable technologies (31%) were low. The majority of the participants never used BIM, wearable and portable technologies, VR, AR and IoT in their high-rise projects. While IoT (2.8%), AR (11.3%) and VR (17.5%) as more advanced technologies were used marginally in just a few studied high-rise projects. Despite the significant evolution in hardware and software and the increasing amount of technology used in the construction industry, there is still a need for software interoperability in virtual reality usage for displaying overlays of BIM models and laser scans or 360-degree as-built photos in a virtual environment. Hence, research and development in these areas could significantly improve their efficiency and quality (Mayer et al., 2021).

3.4 Reasons and incentives for adoption of innovative technologies in high-rise projects

The respondents who used the innovative technologies in their latest completed high-rise building were asked to choose the reasons and what motivated them to use these innovative technologies on their projects; based on the list of incentives identified from the literature. The responses and the overall score of each reason and incentive are presented in Figure 4.

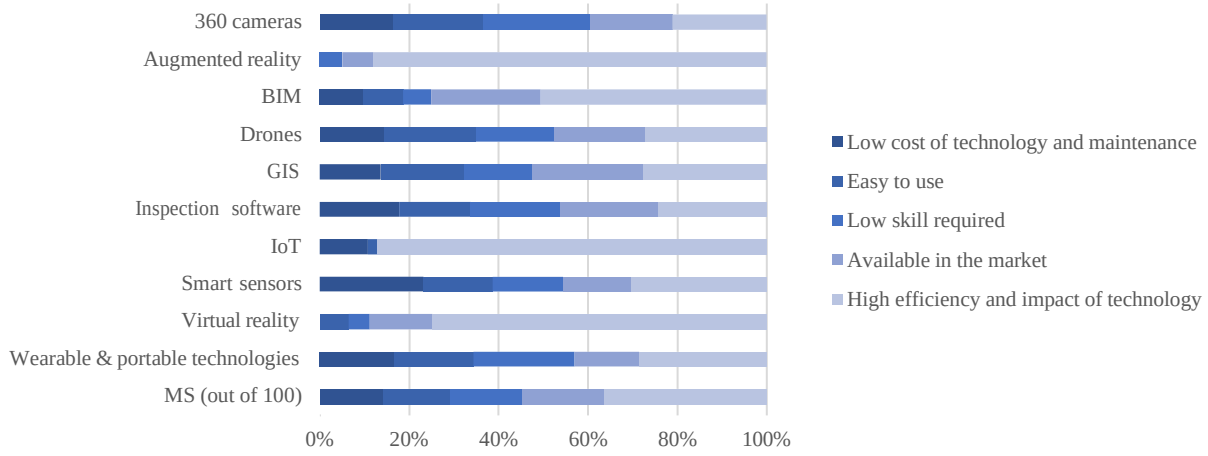

Fig. 4. The reasons and incentives for the adoption of innovative technology

As shown in Figure 4, participants' main reason and incentive to adopt innovative technologies (except 360 camera) was technology's high efficacy and impact on H&S of a high-rise building with an overall 36 score. This finding is supported by the study done by Assadzadeh (2021).
Availability in the market (18), easy to use (15), low skill required (16) and low cost of technology and maintenance (14) were respectively the other reasons for adopting innovative technologies with participants. On the other hand, the results indicate that 360 cameras were adopted because they require a low operating skill.

3.5 Barriers and challenges to adoption of innovative technologies in high-rise projects

Both respondents indicated that they had used or had not used innovative technologies on their most recently completed high-rise project were asked to identify the challenges of adopting the technologies from the provided list of challenges determined from the literature. The data collected and an overall score of challenges are depicted in Figure 5.

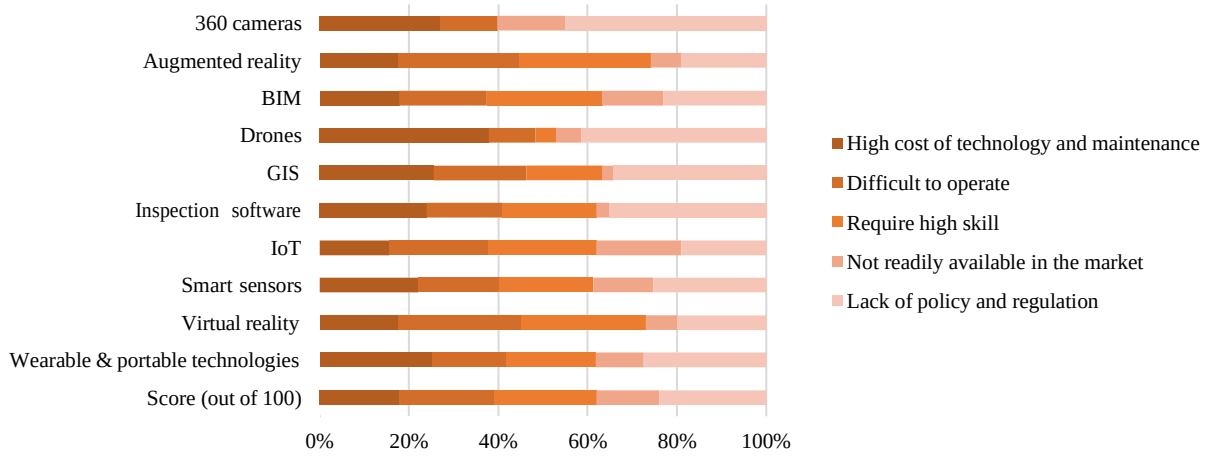

Fig. 5. The challenges on the adoption of innovative technology

The results of challenges on the adoption of innovative technologies reveal the lack of policy and regulation (24), require high skill (23), and difficulty to operate (21) are the main challenges on the adoption of innovative technologies by participants in their high-rise project. These findings are aligned with several studies that stated that policy and rules are non-existent for implementing innovative technologies (Manu et al., 2021) on lack of skill, technical

knowledge (Akinosho et al. 2020), and cost (Pradhananga et al., 2021) are the key challenges to adopt innovative

technologies in H&S of construction projects. Overall these five key challenges aligned with the top five barriers to adopting technologies for occupational safety and health management in construction projects defined by Nnaji and Karakhan (2020).

As shown in Figure 5, the innovative technologies can be divided into two groups based on adaptation challenges. The first group contains the innovative technologies recently introduced in the South African H&S sector, such as AR, VR, IoT, and BIM. The second group comprises the technology in the market for a while. The professionals are more familiar with the second group, such as 360 cameras, drones, GIS, inspection software, smart sensors and wearable and portable technologies. The main challenges in adopting first group technologies were difficult to operate and required high skill. In contrast, the key challenge in adopting second group technologies was the lack of policy and regulation.

4. Discussion

The study found that the South African H&S professionals are moderate to highly aware of the IDTs that can be implemented on high-rise construction projects to improve H&S management practices. In particular, the H&S professionals are extremely familiar with inspection software and GIS. Very familiar with incremental IDTs such as drones, 360 cameras, smart sensors, wearable and portable technologies and BIM. While moderately familiar with disruptive IDTs such as VR and AR and barely familiar with IoT.

Furthermore, the study findings reveal the level of adoption of overall studied IDTs in high-rise construction projects is 43%. This means almost half of the South African high-rise construction projects were adopted the combination of at least two IDTs to monitor and manage the H&S. This mediocre level of adoption of IDTs in South African high-rise construction projects is similar to the level of adoption of IDTs in the majority of developing counties and lower than the developed countries as reported by Okonkwo and Wuim, (2020) and Manu et al., (2019).

While the level of adoption of some incremental IDTs such as inspection software GIS and 360 camera is very high (>70%), the level of adoption of disruptive IDTs such as IoT, AR and VR are very low (<20%) particular IoT (3%). Ringberg et al., (2019) claimed that the extent of use of radical and disruptive innovations is significantly lower than incremental innovations. Additionally, BIM, as a most crucial radical innovation for cloud collaboration and managing project information, including H&S (8D BIM), was never used in the majority (62%) of high-rise studied construction. The low rate of adoption of BIM as an important IDTs in the construction industry could be because of the low level of familiarity of H&S professionals about BIM (49%), which is supported by research findings of Olawumi and Chan (2019) that proved the low level of adoption of BIM in the developing countries construction project is due to the lack of awareness and knowledge of construction stakeholders in developing countries.

The analysis of the incentives to adopt IDTs proved that technology's high efficiency and the impact was the key reason for adopting IDTs by H&S officers. Moghayedi et al. (2022) also claimed the high efficiency and impact of technology as the main reason to choose and use technologies for improved professional. In addition, availability in the local market, the low skill required, ease of use, and the low cost of technology and maintenance are important incentives to adopting an IDT. These incentives to adopt innovative technologies are supported by several scholars (Pradhananga et al., 2021; Okonkwo, 2020).

Furthermore, the study's findings determined the lack of policy and regulation, requiring high skill and difficulty to operate as the main challenges to adopting IDTs in South African high-rise construction projects. The conclusion of Moghayedi et al., (2021) Research also showed these challenges as the key barriers to adopting innovative technologies in construction projects. Okonkwo, 2020 found that the government policies and technical instructions will, to no small extent, influence innovation in the construction industry.

The study found only those H&S professionals who never implement IDTs on their projects identified cost and maintenance as barriers to adopting IDTs. The last point may be debated because how can those who did not implement the technologies deem it high to use and maintain the technology unless they have had prior exposure to it. This proved that the high cost of technology and maintenance is just a perception of professionals without any insight contributing to adoption reluctance as Okonkwo, (2020). highlighted the reluctance as one of the non-technical issues to adopt innovation in the construction industry. The research findings provide empirical evidence for the need to create awareness about the advantages and application of IDTs in H&S of construction projects and the use of awareness to reduce the effect of challenges and increase incentives to adopt IDTs on high-rise construction projects. At the same time, the negative impacts of the challenges to the adoption of IDTs will be substantially reduced if there is an awareness about the advantages and application of IDTs in the H&S of high-rise construction. This means that the awareness about H&S IDTs will convince the project stakeholders about the short-term and long-term advantages of

H&S IDTs over conventional H&S methods. The implementation of IDTs is advantageous in H&S management of construction projects; however, these advantages are not enough to provoke usage unless there is regular training provided by H&S professional bodies to improve the technical knowledge and awareness of professionals about IDTs, since personal learning gaps may develop, leading to users giving up on adopting of IDTs and ultimately developing negative perceptions towards use IDTs (Pradhananga et al., 2021; Okonkwo, 2020; Wuni and Shen, 2020 Manu et al., 2019). Furthermore, sufficient policies and technical instructions should be instituted by government and professional bodies for facilitating the adaptation of IDTs on H&S management of high-rise construction projects. Improve the technical knowledge of H&S professionals, Improve the efficiency of technology on H&S management, reduce the complexity of technology and accessibility to technologies in the local market.

5. Conclusions

The study sought to determine the level of awareness of H&S professionals on IDTs and incentives and challenges to adopting IDTs on the level of adoption of IDTs in South African high-rise construction projects.

It emerged from the research that the main key influencer on the decision to adopt IDTs in construction dramatically depends on the awareness of the H&S professionals. It was also found that the current negative impact of challenges to the adoption of IDTs could be counteracted by the positive impact of incentives to the adoption of IDTs. However, by addressing the challenges such as implementing appropriate rules and policies for using IDTs in construction projects in developing countries such as South Africa and reducing the complexity of technology, the positive impact of incentives on adopting IDTs will be significantly enhanced.

Based on the research findings, the study concludes that the extent of the adoption of IDTs in construction projects will be increased with an awareness of H&S professionals on the performance and availability of IDTs. Therefore, the technical knowledge acquired with the technology-based construction processes and the recognition of the use of innovative technologies in H&S of high-rise construction projects in contract requirements and regulations are highly recommended.

The findings were generated to cater for the level of awareness of South African H&S professionals, key incentives and challenges to adopting IDTs and finally, the various IDTs employed on the H&S of South African high-rise construction projects.

A large population of South African H&S professionals are unfamiliar with disruptive and radical H&S IDTs, and they cannot implement something they are unfamiliar with IDTs. Therefore, to improve the common knowledge and level of awareness of H&S professionals on IDTs, the important role of public training, such as continuous professional developments providing by H&S professional bodies and technology developers, are undeniable.

Finally, due to the lack of implementing BIM as a digital platform for managing and collaborative information between the various IDTs and project stakeholders, the adopted IDTs in projects could not be used optimally, and the investment in IDTs was not maximized. Therefore, to optimize the adaptation of IDTs and maximize the investment, the study recommends implementing BIM and digital information management in the projects as fundamental IDTs to collect, manage, and share information among all project resources (human and non-human).

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