Application of digital technologies for prevention of accidents in construction of high-rise building projects: A review

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Abstract. Over several decades, the building sector has been regarded as a high-risk sector with a low degree of creativity and a reluctance to adopt change. Likely reasons for building incidents include human misconduct, unsafe work practices, faulty machinery and dangerous working conditions. Furthermore, to have a better and safer operating climate, the company can take advantage of new health and safety technology. This paper seeks to investigate the use of various emerging innovations and how they can be used to improve health and safety in the construction of high-rise building projects. Detailed analysis of a previous study on new technologies and interventions for construction site safety such as Virtual Reality (VR), online databases, Building Information Modelling (BIM), RFID, 3D Computer-Aided Design (3D CAD), 4D Computer-Aided Design (4D CAD), wearable robotics, and sensor-based technologies was carried out. It was evidenced from the analysis that not only the utilisation of these new technologies can contribute in improving health and safety in high rise building projects, but also the viability of their implementation in the building industry.

1. Introduction
The building sector is considered to have one of the worst safety and health records worldwide [1]. Building work is deemed to be carried out in dangerous, unsafe environments and low and extremely unhealthy working conditions [2]. Despite strict health and safety laws, there has been no substantial reduction in the number of building injuries [3]. The common causes of construction site injuries and mortalities are deprived of facilities, dangerous working areas and unsafe operating conditions [4]. Different types of technologies and strategies were developed to avoid injuries, incidents and to improve worksite safety [5].

Since the advent of emerging technology, several studies have shown that using such technology will offer a lasting solution to the building OHS problems [6]. Several types of studies have mainly focused on the application of newest technologies for instance online databases, Building Information Modelling (BIM), Virtual Reality (VR), Unmanned Aerial Vehicle (UAV), Geographic Information Systems (GIS), 4D Computer-Aided Design (4D CAD), laser scanning, wearable robotics, sensor-based technologies and photogrammetry for preventing injuries and on-site health [5].

Automation is a practical choice that will boost the modern safety data processing and strengthen the building atmosphere to ensure increased safety efficiency [7]. The use of modern technology offers...
substantial opportunities to better health and welfare of staff and to increase the performance of construction activities [8].

This paper intends to analyse the numerous latest technologies used for building health and safety. A systematic analysis of previous literature is undertaken to assess the implementation and application of new technology as stated in a variety of studies and to identify emerging future developments that may have a possible effect on construction safety.

2. Concerns related to OHS in the Building Sector
Health in the workplace is a significant feature and attempts to raise knowledge in the building sector continue to increase, to report zero injuries and deaths [1]. Construction is one of the riskiest industries, accounting for around 50% of accidents and fatalities at worksites [9]. Bad safety practices on building sites typically lead to injuries or death [8]. The execution of health and safety at building sites, thus significantly lowers risks at the site and exceeded cost arising from injuries at work [10].

The causes of building-related incidents include overexertion and strenuous movement, method of lifting and moving machinery as well as trapped between objects [11]. Consequently, the causes of these injuries were regarded as inadequate conditions on the site, human fault, lack of a secure atmosphere for workers on the part of organisations, and a lack of knowledge of negligence as the principal cause for workplace injuries [7]. The Organisations need to develop a healthy safety culture by investing in protective devices, education, employees’ skills and leadership. The integration of innovative emerging technology and techniques with these factors also helps to address building safety and security issues [9].

3. Modern era building technology trends
Modern technology in the building sector has remained in operation since hard helmets and protective goggles. In the modern era, the synthesis of big data, engineering genius and structure has recently enhanced the health of employees on building sites. The use of technology continues to draw attention to the advancement of emerging technologies [8]. Several instruments are created to help contractors ensure protection in their infrastructure projects. Several researchers have discussed the use of emerging technology for instance: automation and robotics, VR and AR, drones, GIS, sensing and warning technologies, 4DCAD, Unmanned machinery, BIM [8]. Such technologies and innovations are discussed in more depth in the subsequent sections.

3.1. Robotics and Automation
Adoption of mechanical structures is a recent fad toward speeding and automating building activities [12]. Recent researches have shown that in the construction industry, the robotic can conduct many different types of work, such as digging, demolition of houses, surveillance of tunnel, and walls construction as seen in figure 1. Thus, robots should be utilised in most unsafe sites to minimise casualties in building sectors worldwide, to eliminate fall-related injuries. It is nevertheless a problem that needs an immense effort to improve contact between human and robots. Whereas Robots are operated by devices and rely on automated detection and control, robots have been used for autonomous installation and distribution of weighty building stuffs, which typically involve tremendous effort, and in the development of structures such as tall buildings [13].

Several new robotic developments such as exoskeletons, welding robots and forklift robots have been recently launched and could be used in construction [14]. Wearable robots, such as exoskeletons, are used to minimise back pain when carrying and treating large items, which also support elderly workers [15]. For instance, the Suit AWN-03 detects the movement of employees and offers protection for the back, shoulder and thigh of employees, as shown in figure 2. Kyodo [16], whereby commands are transmitted to the motors that rotate the gears as activity happens and reduce the hip and spinal energy needed. As figure 3 shows, Fortis Exoskeleton is additional functional robotic device that improves consumer power and stamina, as shown in figure 3 [17].
Figure 1. Major application of robots to the building industry helping to minimise fatal injuries.

Figure 2. AWN-03 Powered Exoskeleton Suit

Figure 3. FORTIS Exoskeleton
3.2. Online databases
Several aspects of construction safety have been developed using online systems for instance awareness and training about safety, hazard recognition, safety surveillance and safety assessment, and inspecting safety. Online databases can be used to classify possible site threats and determine competency [18]. Yu [19], developed a web prototype tool to assist prospective designers, contractors and coordinators in their evaluations The online framework uses Artificial Intelligence to assist with risk identification and evaluation, gather and evaluate information during the assessment process [18].

The CSHM is a web-based surveillance program which recognises possible sites threats and provides warning signals for immediately intervening activities [18]. The framework facilitates the fast searching, uploading, collecting and documenting of data through remote access [11]. Safety and Health metric are recognised from various programmes, and useful knowledge is given to strengthen the OHS management. For a specified period, project performance is tracked by evaluating the scores for different parameters [19]. For many ventures, Azmy and Zain [11] has developed a real-time communication framework for monitoring the safety of buildings. A consolidated database is often used to preserve transmitted information and site manager analyses them to guide building site judgements. This program provides an online forum to collect health and safety information and data from the building sector.

3.3. Building Information Modelling (BIM)
Implementation of BIM allows for visual site evaluation and defining possible risks [20]. As a result of BIM being incorporated into the building, videos for health and safety training for employees are being produced (ibid). The BIM model helps site employees to enhance their perception of current site conditions through visual health and safety training [21]. Prior to the execution of building work, construction workers are provided with adequate time for safety strategic planning.

The BIM can effectively reduce the risk of site incidents by reviewing the data collection process and using sensors for data collection [22]. In construction planning, the implementation of the BIM system addresses health and safety issues with a more straightforward structure layout and safety plans, including techniques for site information management, as well as facilitating collaboration between projects stakeholders on health and safety through time-controlled simulation [20]. Ku and Mills [23], assessed BIM’s potential as a safety tool. Their study shows that BIM encourages teamwork among project stakeholders utilizing automated specifications and guidelines, including codes and regulatory details. The effectiveness of BIM for protection was tested by using a theoretical method. Based on the concept introduced by Ku and Mills [23], Qi et al. [24], created the safety management system for construction work such that this program scans BIM for fall hazards automatically.

3.4. 3D and 4D CAD
The 3D CAD is used by related health and safety experts to plan, investigate accidents and maintain facilities [25]. Furthermore, 4D CAD is also used to design safety procedures to show components of safety and hazardous areas throughout the project [20]. In the early building stages, 3D and 4D technologies can be used to assess possible risks by the project team [26]. Early risk detection minimises costs overruns due to design changes [11]. Benjaoaran and Bhokha [27], developed a rule-based construction safety management system using the 4D CAD visualisation model. The course was designed to automatically recognise height fall dangers because accidents and injuries in fall were more common compared to other building site accidents [11].

3.5. Wireless networks and smart sensors
Sensors have a significant part to play in integrating protection in the construction by tracking buildings or construction materials in real-time [6]. To avoid incident and worker accidents, machinery crashes, which is sensor-based systems, are implemented to follow the whole atmosphere on building sites.

Wireless sensor networks were designed to strengthen and facilitate the exchange of information between development team at building sites, as shown in figure 4 [28]. The dynamic complexity of the
building world renders it impossible for the network to circulate; nevertheless, wireless systems offer approaches to this issue [29]. However, to provide remote back-end connectivity and internet networking on construction sites where telecommunications coverage is minimal, a wireless network referred to as Wi-MESH created by Ahsan et al. [29].

![Diagram of sensor-based technologies at the building site]

**Figure 4.** The mechanism for sensor-based technologies at the building site

3.6. **Virtual Reality (VR)**

Virtual Reality (VR) is computer created immersive simulation of a real-life scenario [30]. This produces convincing visuals and audible that enable the user to believe like they perceive the virtual world directly. Throughout construction, the safety team used the VR to explore safety connections and organize immense crane pickings on occupied plants that cannot be disrupted, providing efficient means of visualizing and communicating the effect of the leading construction activities on existing structures that might be missed when viewed by conventional techniques [6]. VR also provides an entirely feasible safety training platform for building protection [31].

3.7. **RFID**

Radio Frequency Identification (RFID), which consists of tags, readers and antennas, uses radiofrequency waves to transfer data, gather and stored data to assess the identity of staff and objects. RFID technology is used to illustrate the processing of real-time data [32]. RFID tags are being used to trace the movement of staff, materials and equipment in simulated construction environments, and the resulting Tag data have been tested for a near-miss accident [18]. Such knowledge may even be used to prevent possible incidents and avoid future incidents.

4. **Conclusion**

This paper presented a systematic and conventional analysis of previous researches on the application and implementation of technologies in building sector. Numerous researches on implementation of various types of technology were performed on building safety and health aspects for instance training and edification in site protection, communication and knowledge about safety, and project surveillance. The implementation of numerous safety innovations such as RFID, 3D and 4D CAD, Building Information Modelling, augmented reality, online databases, robotics and automation, and smart sensor and wireless technology, have greatly improved the productivity of OHS at construction sites. Moreover, it has been found that standard working procedures and strategies coupled with the introduction of modern OHS technologies and approaches might allow project supervisor, project managers and coordinators to boost their construction projects' productivity. Therefore, investment in new technology would further enhance the health efficiency of building sites.
5. References

[1] Hinze J W and Jochen Teizer 2011 Visibility-related fatalities related to construction equipment, Safety science 49 709-718

[2] Li R Y M 2018 Building Information Modelling and Construction Safety: In An Economic Analysis on Automated Construction Safety (Singapore: Springer) pp 47-72

[3] Azmy N and A Z Mohd Zain 2016 The application of technology in enhancing safety and health aspects on Malaysian construction project, ARPN J. Eng. Appl. Sci. 11 7209-7213

[4] Li R Y M 2015 Generation X and Y’s demand for homeownership in Hong Kong, Pacific Rim Property Research Journal 21 15-36

[5] Mihic M, Mladen V and I Z 2019 Review of previous applications of innovative information technologies in construction health and safety, Org. Tech. Mngm. Cons Int J. 11 1952-1967

[6] Zhang M, Tianzhuo C and Xuefeng Z 2017 Applying sensor-based technology to improve construction safety management, Sensors 17 1841

[7] Teizer J 2015 Wearable, wireless identification sensing platform: self-monitoring alert and reporting technology for hazard avoidance and training, Electronic Journal of Information Technology in Construction 19 295-312

[8] Zhou Y, Ding L Y and Chen L J 2013 Application of 4D visualisation technology for safety management in metro construction, Automation in Construction 34 25-36

[9] Abdul Kadir G and Godfaurd J 2015 Integrating Building Information and Health and Safety for Onsite Construction, Health Safe Work 6 39-45

[10] Swallow M and Zulu S 2019 Benefits and Barriers to the Adoption of 4D Modelling for Site Health and Safety Management, Frontiers in Built Environment 4 1-12

[11] Azmy N and Zain A M 2016 The application of technology in enhancing safety and health aspects on malaysian construction projects, ARPN Jr. Eng. Appl. Sci. 11 7209-7213

[12] Chu B 2013 Robot-based construction automation: an application to steel beam assembly, ETASR 32 46–61

[13] Niu Y, Lu W and Liu D 2017 The application scenarios of smart construction objects (SCOs) in Construction Proc. Int. Symp. Adv. Cons. Manag. Real Estate eds Y Wu, S Zheng, W Wang, Z Mo, L Shan (Singapore: Springer) pp 969–980

[14] Alexander R 2016 Robotics in Construction Bachelors Thesis (Worcester: Polytechnic Institute)

[15] Balague C and Abderrahim M 2008 Trends in Robotics and Automation in Construction, Robotics and Automation in Construction (London: Intechopen) pp 389-410

[16] Kyodo 2015 Panasonic to sell robot suits starting in September Retrieved on June 16, 2020 from http://www.japantimes.co.jp/news/2015/07/03/business/tech/panasonic-sell-robot-suits

[17] Li R Y M and Ng P L 2017 Wearable robotics and construction workers safety and health 8th Int. Conf. Appl. Hum. Fact. Erg. (Los Angeles)

[18] Zhou W, Whyte, J and Sacks R 2012 Construction safety and digital design: A review, Automation in Construction 22 102–111

[19] Yu H 2009 A knowledge-based system for construction health and safety competence assessment PhD Thesis (United Kingdom: University of Wolverhampton)

[20] Azhar S, Bahringer A, Khalifan M, Sattini A and Maqsood T 2012 BIM for Facilitating Construction Safety Planning and Management at Jobsite Proc. CIB W099 Int. Conf. Mod. Build. Health and Safety 82 -92

[21] Watson A 2010 BIM - driver for change Proc. Int. Conf. on Computing in Civil and Building Engineering (Nottingham)

[22] Druley K, Musick T and Trotto S 2016 Researcher Explores how to make temporary structures on construction site, Safety and Health 193 290-314

[23] Ku K, and Mills T 2010 Research needs for Building Information Modelling for Construction Safety Int. Proc. Assoc. Sch. Cons. 45th Ann. Conf. (Boston)

[24] Qi J, Issa R R A, Hinze J & Olbina S 2011 Integration of safety in design through the use of building information modeling Computing in Civil Engineering 698-705
[25] Rajendran S and Clarke B 2011 Building Information Modelling: Safety benefits and opportunities Professional Safety 56(10) 44-51
[26] Rwamamara R, Norberg H, Olofsson T and Lagerqvist O 2010 Using Visualisation Technologies for Design and Planning of a Healthy Construction Workplace Construction Innovation 10 248- 266
[27] Benjaoran V and Bhokha S 2009 Enhancing visualisation of 4D CAD model compared to conventional methods Engineering, Construction and Architectural Management 16 392-408
[28] Brilakis I, 2007 Long-distance wireless networking for site – office data communications IT Con 12 151–164
[29] Ahsan S, El-Hamalawi A, Bouchlaghem D and Ahmad S 2007 Mobile Technologies for Improved Collaboration on Construction Sites Architectural Engineering and Design Management 3 257–272
[30] Bouchlaghem D, Shang H and Whyte J, Ganah A 2005 Visualisation in Architecture, Engineering and Construction (AEC) Automation in Construction 14 287–295
[31] Li R Y and Leung T 2017 Leading safety indicators and automated tools in the construction industry 34th Int. Sympo. Auto. Robot. Const.
[32] Lo N H and Lin Y C 2013 Enhancing Worker Onsite Safety Management Using Rfid Technology in Construction Proc. Thirteenth East Asia-Pacific Conf. Struct. Eng. Const. (Sapporo)