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Article

INTEGRATING BUILDING INFORMATION MODELLING AND WEARABLE TECHNOLOGIES FOR FALL-FROM-HEIGHT MANAGEMENT IN NEW ZEALAND CONSTRUCTION SITES

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ABSTRACT

The New Zealand construction sector is considered one of the most hazardous industries, with fall-from-height being one of the most dangerous hazards. Despite health and safety policies, workplace safety is often overlooked. The lack of implementation of safety regulations and a lack of understanding of the hazards on construction sites are contributing factors to the high numbers of fall-from-height incidents. The construction sector has begun adopting technology-based solutions to manage worker safety better. Building Information Modelling and wearable technology have shown promise in improving construction safety management, but it is not yet widely adopted. This research provides insight into the potential benefits of adopting technology-based solutions in the construction sector to improve worker safety and reduce the number of fall-from-height incidents. The research was conducted using various online databases and publications that focused on developing or applying Building Information Modelling and wearable technologies for fall-from-height management in construction.

Keywords: building information modelling, wearable technologies, fall-from-height, construction safety management, smart helmet, smart vest.

INTRODUCTION

The New Zealand (NZ) construction sector has been identified as a complex and dynamic environment that poses significant risks to workers, particularly from fall-from-height incidents which are one of the leading causes of fatalities and injuries in the construction sector (Auckland Council, 2013; International Labour Organization [ILO], 2023; WorkSafe New Zealand, 2020a; WorkSafe New Zealand, 2020b). Despite efforts to improve safety in the construction sector, fall-from-height incidents remain a significant challenge. Due to the limitations of traditional safety measures in predicting and preventing future mishaps on construction sites, companies have begun to adopt technology-based solutions to improve worker safety management (Walch, 2020; Zhang et al., 2015).

This research investigates the feasibility of combining Building Information Modelling (BIM) with wearable technology to manage fall-from-heights on New Zealand (NZ) construction sites drawn from relevant scholarly publications. The adoption of BIM in NZ has experienced a substantial change (Ministry of Business Innovation and Employment, 2021). The Government has created a BIM Acceleration Committee (BAC), a nationwide alliance of companies and government founded in February 2014 to coordinate efforts to enhance the usage of BIM in NZ (BIM Acceleration Committee, 2020). The BAC promotes the advancement of BIM to benefit the NZ construction sector positively (Ministry of Business Innovation and Employment, 2017). The BAC has developed a BIM execution plan and manual to serve as a consistent indicator or standard way to implement BIM (BIM Acceleration Committee, 2017). From 2014 to 2021, the construction sector's technical adaptability of BIM has increased to 70% (BIM Acceleration Committee et al., 2021).

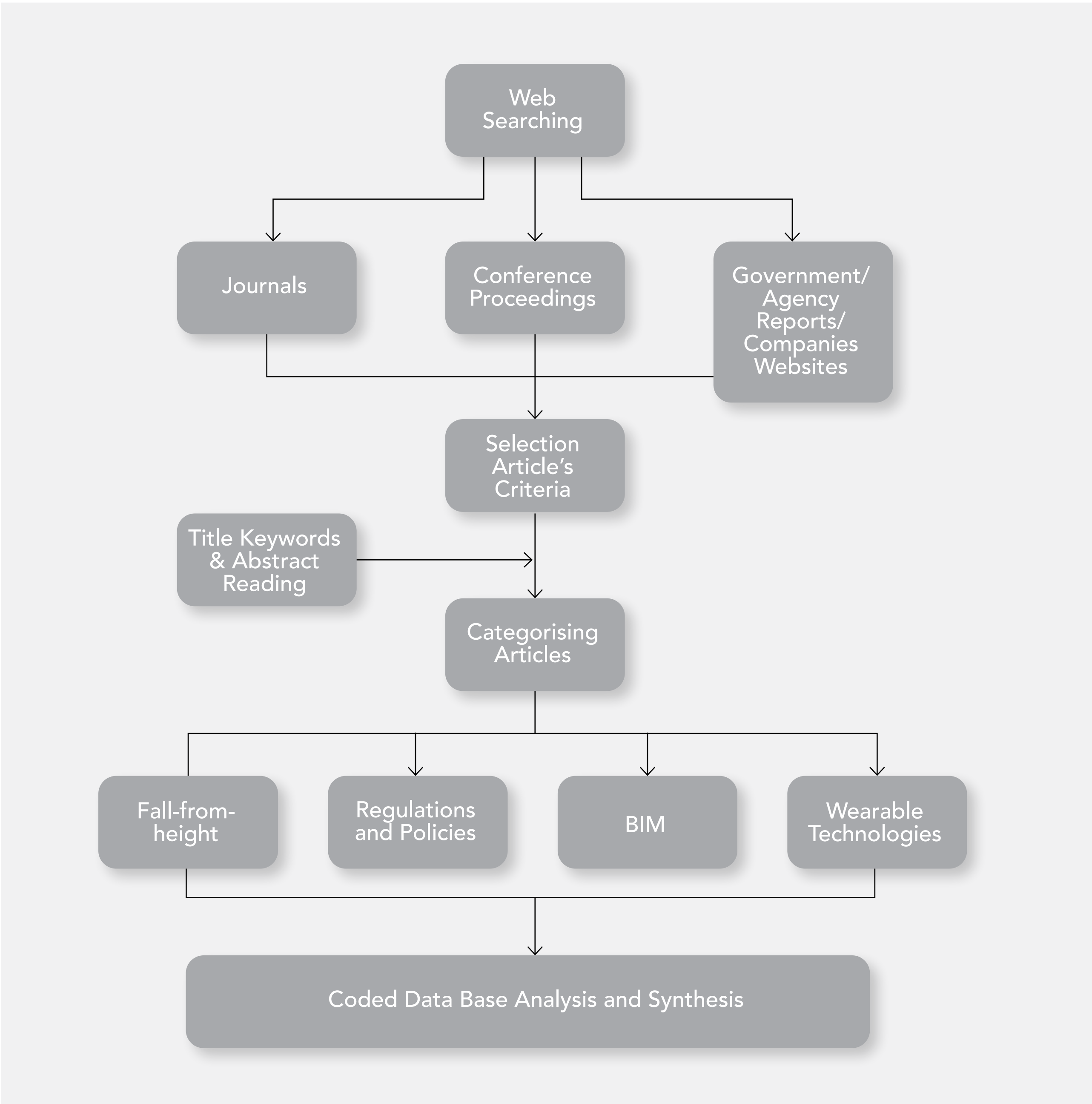
Wearable technology, such as smart helmets and safety vests, can improve construction workers' safety by giving real-time feedback and data collection for analysis (Choi & Kim, 2021). This research aims to provide insight into fall-from-height hazard management on NZ construction sites and technology-based applications to improve construction safety management. In addition, a framework for integrating wearable devices into BIM is proposed to improve fall-from-height mitigation approaches.

METHODOLOGY

This research investigated the construction sector's application of BIM and wearable technology for fall-from-height management. The research approach is depicted in Figure 1. A literature review was conducted using various online databases including Government agencies and companies websites, Google Scholar, Science Direct, Journal Storage (J-STOR), Research Gate, Emerald Insight, Semantic Scholar, and the online Robertson Library. Search terms related to fall-from-heights, BIM, wearable technology, and safety management. Relevant policies and regulations controlling worker safety in NZ were also investigated.

After reviewing numerous publications, relevant selection criteria was used to identify a subset of publications that dealt explicitly with fall-from-height management in the construction sector and developing or applying BIM and wearable technologies for fall-from-height management. Articles that satisfied the criteria of a homogeneous title, bibliographic keywords, and abstracts were included in the database for analysis. The literature review identified 58 publications covering fall-from-height, BIM, and wearable technology. These publications were then grouped into four categories to identify the main variables that served the research aim. However, only 49 subsets of these publications dealt specifically with developing or applying BIM and wearable technologies for fall-from-height management in the construction sector.

Figure 1: Research Approach



LITERATURE REVIEW

Fall-from-height is a critical concern in the construction sector, as it poses a significant risk of injury or death (WorkSafe NZ, 2023; Guo et al., 2018). The Auckland Council (2013) and ILO (2023) noted that fall-from-height negligence could result in serious injuries, fatalities, and severe consequences. The construction sector is searching for solutions to these serious concerns and to revolutionise fall-from-height safety management practices (Guo et al., 2018). Digital technologies have been developed and shown tremendous potential for improving construction safety management, including fall-from-height management (Guo et al., 2021). These technologies include BIM and wearable technology applications, which will be furtherly discussed in this section.

Fall-From-Height in the Construction Sector

Despite the well-known dangers associated with such incidents, some construction companies may be miscalculating the necessary safety measures (WorkSafe NZ, 2019). For example, a lack of knowledge in hazard identification and confusion with the rules and regulations (WorkSafe NZ, 2019). Another possible explanation is management's lack of enforcement of existing safety regulations, as noted by Nadhim (2016) that some construction companies seem to neglect safety precautions due to inadequate monitoring and implementation by regulatory authorities.

According to a WorkSafe NZ (2019) research, the construction sector and fall-from-height incidents are among the top five sectors and incidents that WorkSafe NZ have tracked since this type of occurrence ranked so highly as a cause of work-related deaths and serious injuries among construction workers. WorkSafe NZ (2023) also reported, there were 717 recorded incidents of fall-from-heights in the construction sector between 2016 and 2022. Only 11 of the 717 incidents resulted in warnings, and only 13 were investigated (WorkSafe NZ, 2023). This implies that the construction sector's management may be failing to adequately monitor and enforce safety regulatory rules and regulations, which puts workers at risk. Also, several studies (Aguma & Musonda, 2015; Alomari & Gambatese, 2015; Guo & Yiu, 2016; Hossain et al., 2018) identified potential factors contributing to these statistics: risky construction activities, sites and environmental conditions, human characteristics, knowledge and experience level, behaviours and health, and company safety management, such as lack of safety equipment, training, and project timelines.

The numbers of incidents are a concern given the legal obligations of health and safety (H&S) management. For example, the H&S at Work Act 2015 makes it an offence to fail to comply with a duty that exposes an individual to the danger of death, severe damage, or disease (New Zealand (NZ) Legislation, 2015). To address this issue, the NZ government has implemented workplace restrictions to prevent fall-from-heights. Under the H&S at Work Act 2015 (General Risk and Workplace Management) Regulations 2016, employers must identify, assess, and control hazards associated with working at heights (New Zealand Legislation, 2016). Adopting a technology-based approach can assist construction management in complying with NZ workplace regulations and managing the risk of fall-from-heights. Building information technology and wearable technology, for example, may be utilised to increase worker safety and reduce the frequency of fall-from-height incidents (Fargnoli & Lombardi, 2020).

Another factor contributing to the miscalculation of fall-from-height management is a lack of understanding of identifying hazards. Some companies fail to detect possible dangers on construction sites and may not fully comprehend the risks associated with fall-from-height incidents or the precautions that may need to be taken (Vigneshkumar & Salve, 2020). This lack of awareness and knowledge is a significant concern, as it shows a failure of management to take the necessary steps to protect their workers from harm.

New Zealand construction companies often rely on the three-metre guideline from Health, Safety and Environment (HSE) Act, which incorrectly assumes that no control measures are needed in an area less than three meters high (New Zealand Legislation, 1995; WorkSafe NZ, 2019). However, reports indicated that more than 50% of falls are from less than three metres (WorkSafe NZ, 2019). This leads to a false sense of security and management can neglect its obligations under the H&S Act to eliminate, manage, and monitor workplaces that pose a significant risk to workers' H&S (New Zealand Legislation, 2015).

This situation raises concerns about the effectiveness of current fall-from-height management in the construction sector and the need for a more comprehensive approach to ensure worker safety. While the three-metre guideline may provide some guidance for workers, it should not be relied upon as the sole criterion for determining fall-from-height risk (WorkSafe NZ, 2019). Instead, management must take a more proactive approach and consider the nature of the work, the height involved, and the potential consequences of a fall when assessing the risk of working at height (WorkSafe NZ, 2019). By doing so, they can protect their workers and reduce the incidence of severe injuries and fatalities in the workplace.

Furthermore, cost concerns are a significant impediment to the introduction of innovative safety measures since they frequently need considerable upfront investment in technology, equipment, and training programmes (Manzoor et al., 2021; Wong et al., 2015). As a result, construction companies may be hesitant to commit resources to these, particularly if they believe the estimated costs outweigh the possible advantages (Whitfield, 2018). Table 1 shows the possible cost construction companies might need to consider for implementing an innovative safety approach. Some companies are unwilling to invest in innovative safety management (Nadhim et al., 2016). This prioritisation of cost over worker safety indicates the construction sector's profit-driven nature (Wong et al., 2015). Considering these efforts, safety management in the NZ construction sector must take proactive steps to reduce the number of fall-from-height incidents. Construction companies are now exploring innovative technologies such as BIM and wearable technology as part of proactive H&S measures (Mihić et al., 2019).

Table 1: Expenses for Technology-based Safety Approach

REQUIREMENTS	AVERAGE BASE SALARY (NZ$/YEAR)	REFERENCE
Autodesk Architecture, Engineering and Construction (AEC) Collection package	5,297	Autodesk (2023b)
Training or Certification	4,128 – 4,546 (Domestic Fees)	Ara Institute of Canterbury (2023)
BIM Technician	79,310	Indeed (2023)
BIM Coordinator	72,090	Payscale (2023a)
BIM Manager	105,480	Payscale (2023b)
Smart Personal Protective Equipment (PPE)	No data found	Not available

Note: Data collected from different websites on the 4th of April 2023

Building Information Modelling for Fall-from-height Hazard Identification and Risk Analysis

Building Information Modelling is a technology that facilitates creating and managing multidisciplinary data throughout a project life cycle, resulting in a detailed digital representation of the building and project site (Autodesk, 2023a). The advantages of BIM include improved connectivity, workflow, and data management across the entire project life cycle, resulting in increased visibility, decision-making capability, cost savings, and sustainability benefits (Autodesk, 2023a). As a result BIM has emerged as a popular innovative technology solution for hazard recognition in the construction sector (Mihić et al., 2019).

Building Information Modelling simulation enables a complete, profound, and strong interpretation of construction site environments and building stages visualisation as well as project hazard identification and analysis, making it a valuable tool for risk assessment (Rodrigues et al., 2022). It allows clash recognition and evaluation during the design period to detect and resolve the fall-from-height hazard before the execution phase (Rodrigues et al., 2022; Zhou, 2012). The ability to combine structured and multidisciplinary data into construction and safety can provide companies with a comprehensive understanding of the potential safety hazards and risks throughout the project life cycle, from planning and design to construction and operations (Azmy & Zain, 2016; Autodesk, 2023a; Mihić et al., 2019).

Incorporating BIM into safety management provides an additional comprehensive and proactive approach to identifying and mitigating potential safety hazards and risks, including the safety precautions that may be taken (Fargnoli & Lombardi, 2020). This results in a safer working environment for workers and improved collaboration and communication among stakeholders, including architects, engineers, contractors, and safety managers (Autodesk, 2023a; Fargnoli & Lombardi, 2020). Furthermore, BIM technology potentially reduces incidents and injuries and saves costs by eliminating the need for costly modifications later in the construction process (Alizadehsalehi, 2017; Azmy & Zain, 2016). Recent advancement in BIM incorporates different technologies, such as wearable technology, for safety management and real-time worker safety monitoring (Mihić et al., 2019).

Wearable Technologies for Real-time Monitoring

Wearable technologies have become a popular focus in recent years due to their potential to improve safety in various industries, including construction. These technologies, such as smart helmets and safety vests, offer workers real-time feedback and alarms and collect data for analysis (Li et al., 2018). Research has discovered that wearable technology can improve construction site safety by enhancing danger identification, communication, and reaction (Li et al., 2021). Initially, wearable devices were intended to monitor workers' physiological conditions to prevent health-related incidents (Awolusi et al., 2018). Recent studies have investigated integrating wearable devices with other applications, such as BIM to enhance real-time monitoring by integrating the data collected into updated the BIM model based on site conditions for risk and safety hazard detection, registration, and visualisation (Park et al., 2016). Workers can get timely alerts and cautions, allowing them to take preventative actions and avoid incidents, lowering the incidence of on-site injuries and fatalities dramatically (Awolusi et al., 2018).

In the construction sector, wearable devices have been integrated with PPE. It utilises warning systems, proximity detection, and real-time monitoring to mitigate fall-from-height incidents and enhance the posture stability control of workers (Awolusi et al., 2018). This technology utilises gyroscopes, magnetometers, and accelerometers to alleviate fall-from-height incidents and improve workers' posture control. The gyroscope determines body rotation and angular speed, while the magnetometer identifies the body's positioning in relation to the Earth's magnetic north (Awolusi et al., 2018). Adopting technologically based PPE has helped advance worker safety on the job (Awolusi et al., 2018; Li et al., 2021).

Smart helmets, which contain a variety of electronic gadgets and sensors, are being increasingly utilised in the construction sector to identify workplace hazards, location tracking, real-time monitoring, and danger alarms for workers (Choi & Kim, 2021). Smart helmets contain a range of sensor devices that allows construction companies and managers to accumulate real-time data for data analysis to lower job-related risks and enhance safety. Smart helmets can allow for voice contact between safety managers and workers in order to alert them of unsafe behaviour and potential risks or incidents (Choi & Kim, 2021).

Additionally, smart vests, which include sensors and a microprocessor to detect and monitor workers' motions and body position, have been developed in the construction sector to reduce fall-from-height incidents, which are a significant source of injury and death in the workplace (Howard et al., 2022). The accelerometer sensor measures body force along the x, y, and z axes (Barak, 2021). The gyroscope sensor, on the other hand, measures angular velocity along the x, y, and z axes (Barak, 2021). The inertial measurement unit (IMU) sensor provides time-series data for human activity identification, tracking, and navigation (Barak, 2021, Wang et al., 2020). These sensor technologies are low-cost and frequently used, particularly in smartphone devices (Barak, 2021).

Smart vests can recognise when a worker falls and trigger a mechanism that slows or stops the fall (Howard et al., 2022). According to Abainza (2020), smart vests have the potential to lower the risk of injury and death associated with fall-from-height in the construction sector by monitoring the worker's vital signs and alerting emergency personnel if necessary. This is especially useful when the worker is unconscious or unable to summon assistance (Abainza, 2020; Ahmed, 2021; Howard et al., 2022).

Using technology-based PPE, construction workers can adequately monitor workers, reduce operational risks, and improve safety in their work environment (Abainza, 2020; Ahmed, 2021; Howard et al., 2022). However, as with any technology, it is essential to ensure that these devices are used effectively and that they are only part of a comprehensive safety management plan that includes proper training and other safety measures like hazard detection (Azmy & Zain, 2016).

The Efficacy of Building Information Modelling and Wearable Technology Application

Shanghai Tunnel Engineering Company (STEC), a Singapore-based construction company, established a similar technique for construction safety solutions (Shanghai Tunnel Engineering, 2021). The company has built a virtual reality (VR) training centre that uses BIM, VR, and technology-based helmets (Endeavour Magazine, 2023; 2021; The straits times, 2018). According to the company, it is the only VR training centre in Singapore (The Straits Times, 2018). The VR simulation centre was designed explicitly for tunnelling operations at the Shenton Way construction site to address dangerous human behaviours and allow workers to experience the construction site environment, including working at heights (Endeavour Magazine, 2023; Shanghai Tunnel Engineering, 2021; The Straits Times, 2018).

In addition, the training facility employs a technology-based helmet that vibrates to simulate any construction site risks when they are near 1.5 metres of heavy gear (The Straits Times, 2018). This technological application has assisted the company in overcoming safety difficulties, with more than four million incident-free hours accumulated (Endeavour Magazine, 2023). Furthermore, the company has received multiple health and safety recognition and construction safety innovation awards, which aid in increasing productivity and the project team's morale as a workplace and H&S champion (Endeavour Magazine, 2023; Shanghai Tunnel Engineering, 2021).

Triax Technologies developed another approach for construction site safety solutions that utilises wearable technology (Triax, 2023). Triax is a United States-based company whose products are utilised in the construction sector, and oil and gas and mining industries. They offer a wearable technology solution for fall detection and prevention (Triax, 2023). They provide workers with a wearable device that monitors their movements, detects workers' risky behaviours, and identifies when they are at risk of falling (Triax, 2023). The device alerts the worker, safety manager, and the site medic, if it detects falls on the job and can also be used to track worker location and generate reports on safety incidents. Real-time monitoring data are sent and managed to a Cloud-based system that gives management access to safety data analytics of different insights. This insight turned into action that improved safety and productivity (Triax, 2023).

Triax and their client's construction company reduced injury claims by 60% while increasing production by 10% (Triax, 2023). It also cut response time by up to 91% and allowed for faster evacuation in an emergency (Triax & Guilbane Building Company, 2023; Triax & Lettire Construction, 2023). They have also been able to respond to and correct dangerous worker behaviours that might result in injuries or incidents using real-time data, avoiding lost time, expenditure, and administrative burdens (Triax & Lettire Construction, 2023).

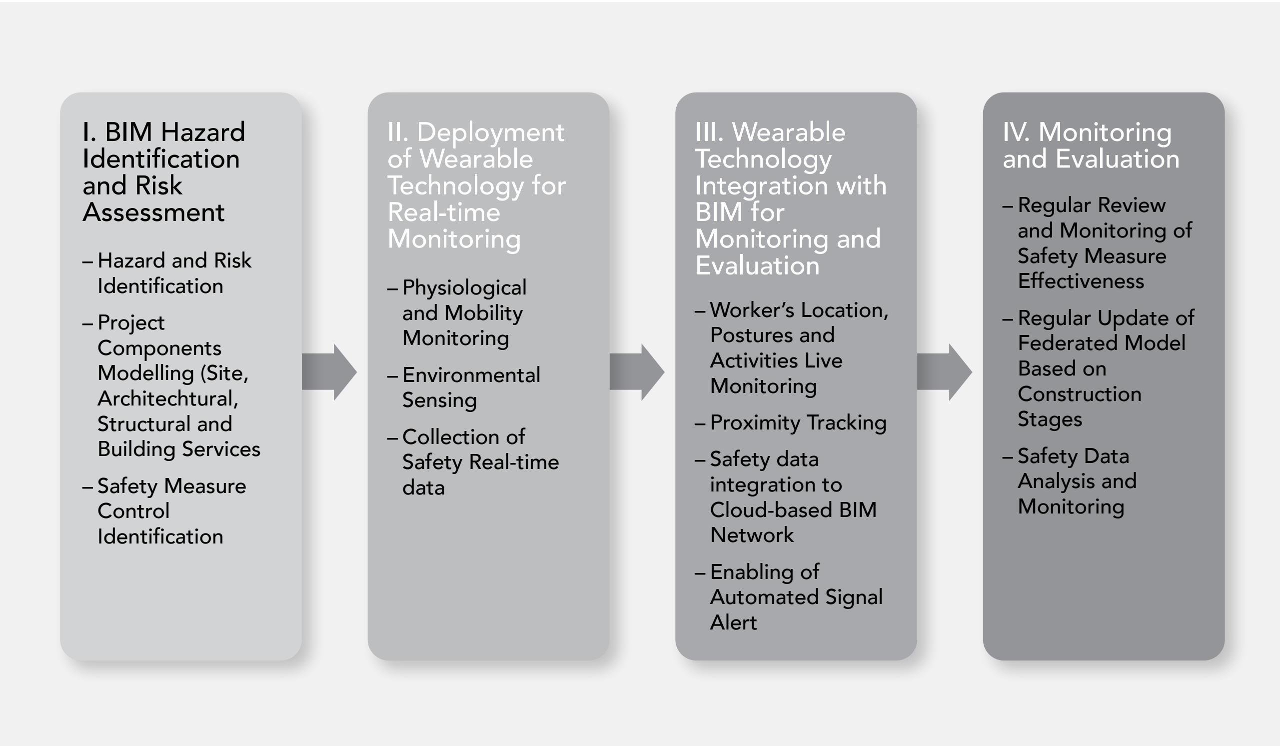
DISCUSSION

This research demonstrates the potential advantages of BIM and wearable technology in fall-from-height management. Additionally, it identified and explored companies who employ BIM and wearable technology for safety management, as well as recommended frameworks for integrating wearable technology into BIM applications.

Building Information Modelling and Wearable Technology Integration for Fall-From-Height Management Framework

This research proposes a framework for a systematic approach for deploying BIM and wearable technologies in fall-from-height management. The framework is divided into four major stages: (1) BIM hazard identification and risk assessment, (2) Deployment of wearable technology for real-time monitoring, (3) BIM integration with wearable technology, and (4) monitoring and evaluation. Figure 2 shows the proposed framework.

Figure 2: Proposed Framework



BIM Hazard Identification and Risk Assessments

The initial stage of the framework is implemented during the design phase, aiming to identify and analyse possible fall-from-height risks on construction sites. This stage involves identifying and visualising the potential fall-from-height hazards on the construction site (Rodrigues et al., 2022). A thorough examination of the construction site and building plans is conducted to create the entire building components using Autodesk Revit Software, including the acquired data from construction site analysis (Rodrigues et al., 2022). The identification of fall-from-height hazards and risks is undertaken to determine safety solutions to prevent fall-from-height (Fargnoli & Lombardi, 2020). Building Information Modelling can detect possible fall hazards associated with building and construction sites, such as exposed edges, insufficient fall prevention measures, and unstable ground (Webb & Langar, 2019; Zhou et al., 2012).

During the design phase, the necessary safety precautions are incorporated into the model to avoid fall-from-height incidents (Rodrigues et al., 2022; Pinto et al., 2018). Construction site access, traffic flow, site barriers, and temporary structures, such as safety railings, scaffoldings, construction platforms, and opening covers, are identified for this purpose and construction planning (Pinto et al., 2018). Following this, federated model is created using Navisworks, a BIM coordination, analysis, and simulation software application (Autodesk, 2023c). The federated model is a combination of models (for example architectural models, structural model, site model and mechanical model) and all project components which every person involve in the project can see and simulate it. The software enables collaboration between project teams collaborating before construction begins to resolve problems and plan initiatives (Autodesk, 2023c). By linking the model in Navisworks, integration issues in the Autodesk Construction Cloud are addressed (Autodesk, 2023c). The Navisworks model integration enables the simulation of the construction evolution, construction, activities, and sequences across time (Kurien, 2018).

Deployment of Wearable Technology for Real-time Monitoring

The framework's second step involves implementing wearable technology to improve fall-from-height management. As indicated in the earlier analysis, wearable technologies make use of several sensing applications for real-time monitoring and location tracking (Awolusi et al., 2018). This incorporates various sensing technologies into PPE, notably a smart safety helmet and a smart safety vest (Awolusi et al., 2018). These sensor systems are utilised for physiological monitoring, environmental sensing, proximity detection, and position tracking of a wide range of construction dangers, vital signals, posture, and mobility monitoring, and can provide construction workers with early warning indicators of safety risks (Awolusi et al., 2019; Kurien et al., 2015; Li et al., 2021).

The smart helmet uses sensor technologies such as radio frequency identification (RFID) for proximity detection and a global positioning system (GPS) for location tracking (Choi & Kim, 2021). The smart helmets also enable voice communication between the safety manager and workers and alert the workers if they are in danger (Choi & Kim, 2021). Smart helmets will also collect real-time data for safety analysis and development of safety measure at a later stage (Choi & Kim, 2021). The smart vest also utilises motion monitoring technology (Barak, 2021, Wang et al., 2020). Accelerometer and gyroscope sensors analyse and identify workers' dangerous postures and IMU devices are used for motion tracking (Wang et al., 2020).

Furthermore, the smart vest features physiological monitoring, which monitors the worker's temperature, heart rate, and oxygen levels, as well as activate an auto alarm system if they fall-from-height and will automatically notify emergency services if the workers become unconscious (Ahmed, 2021; Abainza, 2020; Howard et al., 2022). It will also be used to collect real-time data for safety analysis and control measure improvement (Choi & Kim, 2021).

Wearable Technology Integration with Building Information Modelling for Monitoring and Evaluation

The third stage of the framework involves the integration of technology-based PPE into the federated model generated in the first stage of this framework. The earlier stage identified work fall-from-height hazards and hazard zones on the construction site. The subsequent step involves defining appropriate data collected from technology-based PPE, which will be based on the fall-from-height safety risk (Howard et al., 2022). This data includes the workers' location, postures, and activities (Awolusi et al., 2018; Choi & Kim, 2021; Howard et al., 2022). The data collected will be integrated into a Cloud-based BIM system to enable live monitoring and tracking of workers and an automated alert system (Park et al., 2016).

Once the data is collected, it will be analysed and visualised to identify patterns and trends in fall-from-height risk (Rodrigues et al., 2022). This analysis will use the simulation features of Navisworks to identify areas that require additional safety measures or how to lessen the impact of fall-from-height incidents (Autodesk, 2023c; Rodrigues et al., 2022). For example, management can provide additional safety harnesses or safety nets to mitigate fall-from-height incidents in addition to safety railings (Rodrigues et al., 2022). The federated model will be continuously updated based on the construction life cycle. The Navisworks model integration enables the simulation of the construction evolution, including activities, and sequences across time (Kurien, 2018). Additionally, various scenarios, such as fall-from-height incidents are simulated, and the severity of the fall-from-height is evaluated to assess the potential effects of a fall-from-height and suggests actions that may prevent or mitigate these incidents (Rodrigues et al., 2022). The analysis identifies potential issues and opportunities for workplace changes that are impossible to detect with two-dimensional documentation (Pinto et al., 2018).

Monitoring and Evaluation

The last part of the framework entails tracking and assessing the efficacy of the integrated approach to fall-from-height management. The efficiency of the control measure will be regularly reviewed throughout the construction life cycle based on data collected from BIM and wearable technology. The monitoring and evaluation stage gives insight into the control measures' effectiveness and indicates improvement opportunities. The federated model is constantly updated, and the wearable technologies are also constantly tested to guarantee that they work properly. Data from wearable technology is evaluated continuously to discover new-found trends or patterns, and the integrated system is changed as needed.

CONCLUSION AND RECOMMENDATIONS

To summarise, the NZ construction sector faces challenges in terms of worker safety, notably fall-from-height incidents. Despite attempts to enhance construction safety, fall-from-height incidents continue to be a significant problem. Construction companies began investigating and employing technology-based approaches to improve fall-from-height incident management. Although BIM and wearable technology have shown promise in enhancing construction site safety management, they are not extensively used. Therefore, the following recommendations are worthy of the construction sector considering a technology-based approach for fall-from-height incident management. However, there are still apparent factors that need to be addressed to improve the adaptation of these technologies, especially for small and medium companies. To begin with, the government should enhance its construction sector transition assistance, focussing on the expenses associated with these technologies. Singapore, for example, has adopted a BIM transformation roadmap in the construction sector. This implementation has included training and incentive programmes funded by the Singapore

Government, which cover the costs of training, consulting, hardware, and software for companies (Building and Construction Authority, 2015; BuildSmart, 2015). Although the NZ Government has a BAC strategy plan ready for implementation, the training and expenditure support, especially for small to medium companies, is yet to be approved (Building and Construction Authority, 2015; BuildSmart, 2015).

Industry-academia and E-learning platform collaboration could be used to assist bridge skill gaps and accelerate the rate of adaption required for these technologies (Eagleton, 2021; Linkedin, 2023). E-learning, as illustrated by LinkedIn Learning and other online courses, has become a widely accepted tool for companies to deliver training and development opportunities to their workers and they can use the portal to enrol in courses. It also supports flexible self-paced learning, allowing workers to take courses in their own time. Progress monitoring capabilities enable workers and managers to monitor completion rates and performance on exams, simplifying the evaluation of worker's and team learning progress. Certificates and badges are issued following successful course completion, allowing workers to showcase their newly gained abilities on their LinkedIn profiles or resumes. Companies will no longer need to create a new role to operate this technology while also upskilling their workers. Lastly, the construction sector must capitalise on technological innovations like the "Internet of Things". With these technologies, the interaction of all wearables, digital devices, and computers that integrate the digital and physical worlds may be utilised to improve site H&S and help in information exchange. Investment in technology-based solutions improves H&S performance on construction sites. However, as with any technology, it is critical to ensure that these technology-based applications are utilised properly and as part of a comprehensive safety management plan and approach that includes sufficient training and the incorporation of other safety procedures.

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