International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 7, 2025
https://www.theaspd.com/ijes.php

Fundamental Framework for Safety and Sustainability Management of High-Rise Buildings Through BIM: KSA Perspective

Dr. Abdullah Mohammed Alshehri
Department of Civil and Environmental Engineering, College of Engineering, Majmaah University, Al-Majmaah 11952, Saudi Arabia, a.m.alshehri@mu.edu.sa

Abstract
This study addresses the critical gap in safety and sustainability management for high-rise construction projects by integrating Building Information Modelling (BIM) with a mixed-methodology approach. The research aims to develop a comprehensive BIM-based safety framework, focusing on mitigating risks in high-rise projects. Through a review of existing literature, 24 safety risk factors were identified. A quantitative survey was conducted construction industry respondents, and the Relative Importance Index (RII) was calculated, revealing that "No Safety Record Keeping" and "Lack of Safety Checking" ranked highest with RII values of 0.726 and 0.716, respectively. The study also highlights the significance of innovative BIM techniques, such as drone monitoring and augmented reality, for effective risk mitigation. The findings contribute to enhancing worker safety by providing a structured framework that integrates these techniques to address the identified safety and sustainability factors, thereby promoting sustainable safety practices in high-rise building projects.
Keywords: *High Rise Building Projects, Sustainability, Safety Management, Building Information Modelling.*

INTRODUCTION

In densely populated areas of the KSA, skyscrapers are a common sight because to the booming building industry. Construction of tall buildings presents special challenges due to their size and the related risks. Statistics show that every year over a thousand construction workers worldwide and between fifty and one hundred in the KSA lose their lives due to accidents that occur on high-rise building sites (Manu, 2013). Unhappy workers have slowed the pace of high-rise building projects due to the lack of proper safety precautions on the job sites. When it comes to the safety of construction workers, the industry is constantly on the lookout for cutting-edge methods. As more people express an interest in living in high-rises, more people are also becoming aware that the safety measures used in such structures are continuously insufficient. Existing research trend shows that a variety of physical risk factors, the most severe of which is the incorrect use of mechanical equipment, are having a negative impact on the projects (Lemberg-Pedersen, 2013). Permit applications for high-rise buildings may not always be processed within the stipulated timescales owing to changes in the amount of applications the building management team has received. Permit applications are filed far in advance of their due dates to ensure timely approval; nevertheless, some buffer time is always recommended (Yi, Zhang and Calvo, 2015).

The findings also lend credence to the argument that criteria, evaluation, expectations, and supply chain monitoring may need some extra attention throughout the bidding process (Garzia and Lombardi, 2018). To ensure that health and safety management in BIM is considered at the design phase, implemented and monitored during construction, and utilized for asset management after completion, the government client may play a catalytic role by promoting the resistive culture and increasing rigor in policy directives (Rebelo *et al.*, 2019). Multiple studies have concluded that more than 80% of injuries sustained in high-rise buildings are fatal, and that major repercussions will always be produced along the path of sustainable growth of such projects if proper precautions are not followed. This has made high-rise building unsafe and necessitated immediate improvements.

Various methods have been proposed to increase worker security during the construction of high-rises. The majority of the solutions that have been presented to far do not deal with the modern issues of high-rise building safety. BIM, on the other hand, has become one of the most important resources for every professional working in the construction industry. While BIM use is on the increase across the board, it has yet to catch on in the KSA's tall-building safety environment (ICONTEC, 2019). This knowledge gap hampers efforts to create a safety management system that may significantly improve workers' protection on tall-building construction sites. Implementing the most current technologies for building information modeling and establishing a framework that must also cover the theoretical research gap are necessary to solve the problem of maximizing safety in construction projects. This will be a cutting-edge answer in the context of using BIM to modernize the British construction industry (Yang *et al.*, 2019). The trend of high-rise construction projects will continue to increase in the future because, in their view, more opportunities present themselves for urban areas to expand in the vertical direction rather than in the horizontal direction. Practical difficulties, however, are again present in terms of implementing the very sophisticated methods of safety management in the construction projects where the workers are dying because of improper safety considerations (Chapuel and Reyes, 2019). Conducting the new study will provide an advantage in terms of analyzing the efficiency of building information modeling specifications for the tall building projects that are going to develop in the overall landscape of the construction in the future. Further, the problem needs to be solved in the context of the high-rise construction sector, where safety considerations are always important for the workers and maintained at the best possible level while still resulting in accidents.
It is the aim of this research to develop BIM integrated framework for resolving safety management issues in high rise building projects. The research will be entirely focusing on development of the framework that will help to increase safety of high-rise building projects. Objectives are as follows,

- To review the existing literature for identification of common safety factors.
- To determine the ranking of identified safety factors by quantitative survey.
- To identify the most effective and innovative BIM based mitigation techniques from secondary data.
- To propose a BIM integrated safety framework based on ranked safety risk factors and mitigation techniques for high rise building project workers.

In order to ensure the safety of construction workers, it is essential that the building information modeling framework be improved for tall building construction in the KSA. The building information modeling technologies used today are cutting edge and will facilitate the continued growth of the KSA's construction industry. This will help the building information modeling industry grow in the KSA as a consequence of the country's already robust manufacturing sector for these diverse technologies. The study's limitations stem from its insistence on zeroing in on developing a framework for implementing BIM-based remedies to a broad variety of safety challenges plaguing KSA high-rise construction projects. The key advantage of using technology is that it speeds up the reporting process. Use of working space and clearance zones, for instance, used to need visual inspection but are now accessible to automated risk analysis and safety evaluation. BIM might thus potentially reach out to new data users, increasing the scope of its influence. Numerous issues have been raised, many of which relate to the use of metaphors. Methods involving the use of virtual worlds for modeling and testing. For instance, digital data may be organized to provide customers a glimpse into a variety of scenarios, enabling them to consider the benefits and drawbacks of each choice before making a final decision. In fact, cost planners already utilize this method when proposing alternative materials or methods for a project and recalculating the financial effect of these changes. But today, with the ability to quantify risks in terms of monetary value, individuals may weigh the possible costs and benefits of a particular action on their health and appetite. The order in which activities are performed may have an effect on workplace safety, and this may be analyzed by include time as a variable.

LITERATURE REVIEW

High rise building projects

A high-rise building is defined as a structure that is too tall for most people to comfortably stroll to the upper floors without the aid of an elevator. While most of the time we're talking about things like apartment buildings, hotels, and office buildings, we also sometimes talk about things like retail centers and universities (Shaawat, Almohassen and Al-Hamd, 2020). The mixed-use building is a newer form of building that combines different functions. Since high-rises are among the largest buildings ever built, and since they often contain commercial and office functions, their square footage costs more than average. The vertical gravity loads that tall buildings' structural systems must withstand get much of the attention, but the lateral loads that must be considered due to factors like wind and earthquakes are not to be overlooked. In the guts of continents, maximum 100-year-interval wind intensities average about 100 kilograms per square meter (20 pounds per square foot) at ground level. Cyclonic storms, such as hurricanes and typhoons, may generate peak wind speeds of over 100 kilometers per hour and peak wind pressures of over 250 kilograms per square meter along the shore. Wind forces increase in parallel with building height to a constant or gradient value when the effect of ground friction diminishes (Attrill and Mickovski, 2020). When designing a building in a typhoon zone, architects must account for wind speeds of up to 840 pounds per square meter.

The effects of wind on tall buildings are twofold. Consider a tall skyscraper to be a cantilever beam, with one end fixed to the ground; when wind exerts force on it, the beam will bend, with the most pronounced curvature happening towards the building's zenith. Unstable vortices form on the leeward side of the structure and break away downwind, swapping sides every minute or two (Liu, Zhang and Wang, 2021). Due to the shift in pressure that occurs as a vortex disperses, the structure takes on a swaying or periodic motion that is perpendicular to the direction of the wind. Because of this, towering buildings are held to stringent performance standards when exposed to wind. The expected longevity of the structure is the fourth consideration (Quoc Toan, Thi Tuyet Dung and Thi My Hanh, 2021). The swaying cantilever motions during this stage of the vibration cycle have the potential to develop in magnitude to the point where they inflict significant damage to the structure, or even cause its collapse. It is important that the building's natural period be smaller than one minute because of the potential for vibration due to the discharge of wind vortices. When working at a height, worker safety is of the highest significance. Construction equipment like tower cranes, as well as falsework and formwork, continue to provide new challenges, but they are met with ever-increasing ingenuity from the industry. As the world's population continues to concentrate in large cities, there will be a greater need for expensive and potentially dangerous high-rise structures to accommodate the growing number of people who want to see them. These structures' exteriors are glass curtain walls supported by steel or concrete (Kim, Lee and Choi, 2020).

Due to its lack of strength, the curtain wall must be fastened to the steel or concrete framework of the structure. Tube structures are the project of a design change that was essential for steel-framed buildings to endure the lateral strains of winds and, perhaps, the effects of an earthquake. The exterior or perimeter walls of a tube building were responsible for supporting the structure's weight (Liu, 2021). The phrase "steel-framed reinforced construction" defines a form of structure that combines reinforced concrete with steel framing. A steel-framed structure with a concrete shear core and composite floors made with steel decking may serve as an example. Mixed construction is another term used to describe these towers. Rather than being noted for their original designs, tower cranes are notorious for their reliance on routine maintenance to stay in operation (Huang, 2020). Despite this, improvements in tower crane technology have been driven by a concern for worker safety.

Crane decks provide a secure platform for workers to transfer and handle objects, and have been found to greatly increase workplace safety. Australian-based Active Crane Hire is a frontrunner in the mini- and medium-sized construction crane rental market (Yu, 2021). Tower cranes play a crucial part in high-rise building, and its principal objectives are innovation and safety. Both structural and geotechnical engineers encounter novel challenges when constructing skyscrapers, whether because of the structures' height or because of geotechnical risk factors like excessive compressibility or bay mud in the underlying soils. In addition, there are two common building components that are technically deemed high-rises but are typically excluded from high-rise construction restrictions, ordinances, and standards. For starters, there is a developing demand for high-rises due to the expanding, largely urban, population (Torrecilla-García, Pardo-Ferreira and Rubio-Romero, 2021). Global urbanization and urban population density are both on the increase since the majority of the world's population currently lives in urban areas. The amount of arable land lost to suburban development is increasing. Many more people can be accommodated in one tall building than in the same number of low-rise structures. A tall building is one that is constructed vertically rather than horizontally. They also provide substantial obstacles for firefighters attempting to react to emergencies in skyscrapers. Even in a somewhat slow-moving industry like construction, the year 2030 nonetheless represents a time frame in which considerable changes in practice may be expected.

To a large extent, this will cause people to become even less tolerant of traffic delays caused by, instance, construction projects. In the past, buildings like housing complexes and office towers were never used for anything other than their intended use (Liu, Zhang and Wang, 2021). Experts in the industry, however, are beginning to look beyond the building to the people it attracts and the opportunities it provides. An important service that high-rises provide their tenants and visitors is the creation of distinct communities based on shared interests and needs (Kim, Lee and Choi, 2020; Huang, 2020). Attractive features of high-rises include their convenient locations in the city and the wide range of high-tech facilities they provide its occupants, such as swimming pools, fitness centers, grand lobby entrances, and quick elevators. Construction of a skyscraper usually receives no expense spared by builders because of the developer's ability to demand higher prices for the finished project.

Safety risk factors in high rise buildings

When building a massive structure like a skyscraper, careful forethought is crucial. It is essential that all safety laws be followed, and that adequate precautions be taken at all times to significantly lessen the likelihood of any accident. This is why it is so important for construction workers to get safety training. Although workplace safety is always a top priority, it may be especially challenging to achieve on construction sites with several stories. Managers and workers alike are susceptible to many risks, so it's crucial to zero in on the most pressing ones as soon as possible during the planning phases of any project to better prepare for them (Kim, Lee and Choi, 2020; Attrill and Mickovski, 2020). One example of a post-construction risk dilemma is worry about how the public could react to glass facades. Due to the inherent unpredictability of working at such a height with such materials, ongoing risk management is essential. Keeping yourself and your assets adequately insured is a crucial part of any comprehensive risk management strategy (Yu, 2021; Liu, Zhang and Wang, 2021). In addition to all-risks building and construction protection, insurers often provide policyholders coverage for physical structural damages stemming from faults in design, materials, or workmanship. The choice of building materials is even another challenge. Glass must be thicker and more durable for higher floors, and concrete mixes must change to account for the different loads that occur as structures grow in height. Because high-rises are so vulnerable to fires during both construction and occupation, fire safety is a top priority for building designers. Timely evacuation of a large population from a multi-purpose structure like a hotel, restaurant, apartment complex, shopping mall, or office building is crucial in the event of an emergency.

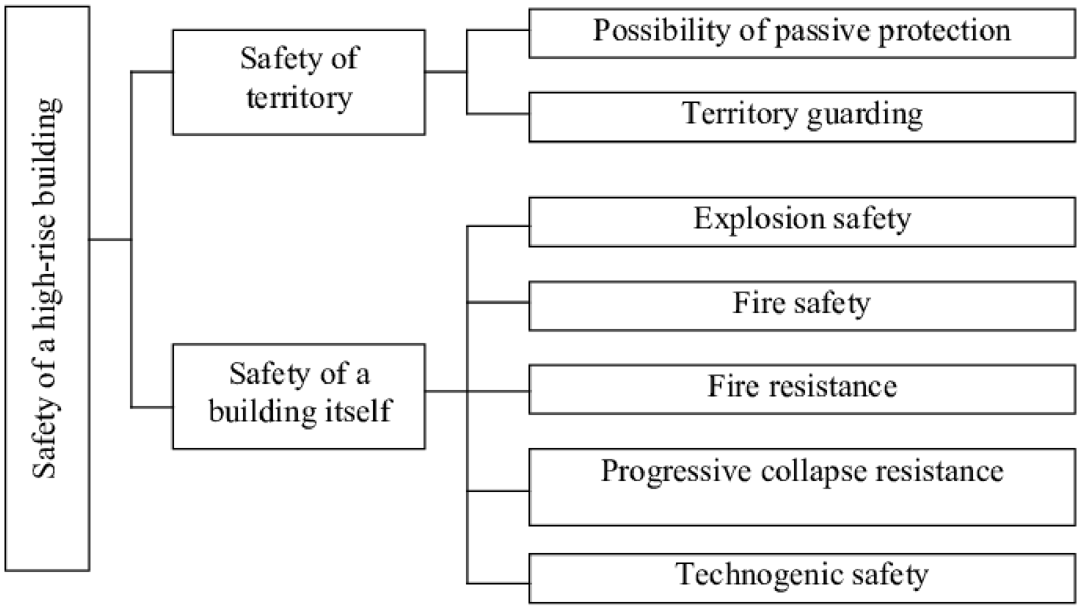

Figure 1 Some high rise building safety factors (Garzia and Lombardi, 2018)

That's why it's so important to plan ahead for fire safety by include things like sprinklers, exits, and fireproof materials. The complexity of supertall and megatall building designs is another defining feature (Quoc Toan, Thi Tuyet Dung and Thi My Hanh, 2021; Liu, Zhang and Wang, 2021). An ambitious project like the Kingdom Tower requires at least five years to complete. Joint ventures, consumers, consultants, subcontractors, and suppliers can only thrive with strong bonds of cooperation and collaboration. Subcontractor and supplier management requires a dedicated and experienced team. Having good management is important to the final success of such a massive undertaking. On a consistent basis, management must be provided with updates on the building's condition and any new security risks. The structural integrity of a high-rise structure is very important since it must support much greater weight than a single- or double-story house (Liu, 2021; ICONTEC, 2019). Load calculations are often done iteratively before construction starts to account for the building's design, materials, and planned usage. A high-rise must be planned and constructed with fire safety as a top priority.

Because of this, builders seldom use a wide variety of concrete additives, insulation, and decorative accents. It is essential to minimize the usage of such flammable materials since the risk of a catastrophic fire in the structure increases. High-rise buildings are now compartmentalized for the primary purpose of preventing fires. A thick layer of concrete and steel reinforcement separates each floor, keeping any fire contained to its own floor. Some multi-story structures have been outfitted with fireproof corridors between floors. A building's fire risk may be mitigated by making sure it has many, easily accessible points of egress and a well-maintained fire suppression system. This is why modern high-rises are equipped with sprinklers, several water sources, and multiple exits (Quoc Toan, Thi Tuyet Dung and Thi My Hanh, 2021; Liu, 2021). The fire safety of the building will be improved with the installation of these elements. Construction of skyscrapers rapidly depletes available resources. Construction is a heavy drain on resources, including time, energy, money, and human and natural capital. When anything goes wrong with a building project, it may be very expensive and time-consuming to rectify the issue. That's why it's so important to think this approach through carefully and thoroughly. The importance of picking the right location cannot be overstated. It's important to consider the soil's stability and load-bearing capacities when picking a location for a building or agricultural project. In addition, it is important to consider how earthquakes, floods, cyclones, and other natural catastrophes have occurred in the past. Global positioning systems (GPS) and geographic information systems (GIS) are assisting planners in selecting viable building sites. These technologies monitor the surrounding area, analyze historical data, and create predictions regarding the best places to build in terms of safety. Such methods may be used to examine regional climate change and anticipate how it will affect a certain area. Rarely do major issues with the project's structural safety surface during construction. However, here is where worries about workers' safety are most prominent (Liu, Zhang and Wang, 2021).

If employees get accidents on the job, progress on the project might be significantly hampered. In order to guarantee the project's success, it is crucial to ensure the health and safety of the site's workers. Ensuring the safety of all employees is of equal importance. The use of fireproof and earthquakeproof materials may considerably enhance a building's structural security (such as foundation isolators). For any construction project to be successful, it is essential that adequate amounts of high-quality materials be used (Liu, 2021; Huang, 2020). To save corners and keep the project under budget, contractors often substitute cheaper materials or use much less of essential construction components like steel reinforcement, cement, and concrete than is recommended. The project management experts are essential at this stage for carrying out the needed quantity of materials procurement and performing the required quality assurance program. When people start calling a structure home, that's when security becomes critical (Attrill and Mickovski, 2020).

There should be more fire and earthquake escape systems for those living on higher floors. Sprinkler systems and smoke detectors are lifesavers in the event of a fire. As part of the building itself, there should be conveniently accessible fire escapes (Kim, Lee and Choi, 2020). Fire escape plans and floor layouts should be prominently displayed by building management on every floor of a high-rise. In addition, it must ensure that all the individuals who live and work in these buildings get regular updates on safety measures. Regular training and practice in safety procedures is essential. An earthquake assembly area should be planned for in the early stages of building construction. A post-construction audit should be performed on high-rises as well, to check for any structural weaknesses or distortions and guarantee the building's integrity.

BIM and Safety Management

Building information modeling (BIM) is being hailed as a game-changing innovation in the construction industry. Using a digital model of the completed building, BIM allows architects and engineers to better communicate and cooperate on a project. Theoretically, BIM might improve site safety by allowing for the earlier discovery of potential threats due to its ability to present a more comprehensive picture of the project. Workers may be able to avoid injury by using a 3D BIM model that includes the placement of two cranes to foresee the risk of a collision and make the required modifications to the site design (Chapuel and Reyes, 2019). There is no question that BIM has the ability to significantly improve site safety, but there are also certain difficulties to consider. To set the stage, Building Information Modeling (BIM) is still a relatively new technology with an accompanying learning curve. As more health and safety software built on BIM becomes accessible and as contractors begin utilizing BIM in more aspects of their businesses, the learning curve will decrease. And there are a few creases that require ironing out (Liu, Zhang and Wang, 2021).

The older generation is concerned that the extensive use of digital models, will lead to fewer physical inspections being undertaken. This is essential for people's wellbeing and protection. At any point in the project's lifecycle, potential problems might arise. If buildings, for instance, are tested for safety before they are actually constructed, design problems may be fixed before any accidents happen (Shaawat, Almohassen and Al-Hamd, 2020). By incorporating BIM at the commencement of a project, risks to workers' health and safety (health and safety) may be identified earlier, and countermeasures may be implemented before any physical construction is carried out. It is becoming more clear that the benefits of health and safety extend beyond the first stages of a building's life cycle (the planning, design, and delivery stages). The research confirms that the lack of a uniform strategy toward BIM throughout the nation and a culture that is reluctant to adapt to new ideas and technology are key barriers to its widespread adoption in Australia (Kim, Lee and

Choi, 2020). A contract with a government client sounds like a smart method to stimulate increased BIM adoption in ways that address or overcome these limits.
There are still far too many fatalities and injuries each year in the construction industry, despite everyone's best efforts. Many in the construction business are using building information modeling (BIM) to increase output and earnings, but it's probable that few are also considering the safety of their employees. Even in a down economy, construction remains one of the most important sectors. Though the construction industry has seen a huge decline in injuries over the last two decades, it is remains one of the most dangerous in the world. The purpose of this paper is to discuss the importance of considering health and safety while using BIM for construction projects. Although it is intriguing to see the design ideas behind the building, the model is not an as-built record and is thus of limited use after construction is complete (Yang *et al.*, 2019; ICONTEC, 2019). Despite being essential to any economy, the construction sector is well-known for its dangerous working conditions. The construction industry has improved greatly over the last two decades, yet it is still one of the most hazardous in the world. Out of a total of 148 fatal injuries in 2012-2013, 39 happened on construction sites, according to the Health and Safety Executive (HSE) of the KSA. Construction accounts for nearly 33% of all workplace deaths in the KSA, although employing just around 5% of the country's workforce. Information suggests that the current capacity of traditional injury prevention strategies in the construction industry has been reached. Given this, maybe it is time to reconsider the way we apply new safety measures. Studies show that the efficacy of safety program components decreases significantly as the project progresses. These factors fare best in the planning and conceptualization phases of a project. The construction market is often compared to the car sector (Liu, Zhang and Wang, 2021; Huang, 2020).
The main difference is that vehicles are increasingly being manufactured at the same facility where they are also developed. This has led to a more streamlined approach to design, manufacturing, and health and safety. Traditionally, designers were responsible for the well-being of the end users, while constructors were deemed liable for the security of their own workforce. Each step of the construction process is an opportunity to develop a new beneficial application with the potential to improve occupational health and safety (Kim, Lee and Choi, 2020; Attrill and Mickovski, 2020). Data is abundant in the BIM environment, and so are the means by which it may be used, including but not limited to strengthening links between documents, facilitating user-guided information discovery, and eliminating superfluous data.
When new knowledge is learned and put to use, value is produced. Databases, spreadsheets, and design authoring software are just a few examples of the many information repositories used in the area of building information modeling (Huang, 2020; ICONTEC, 2019). Other sources include cost calculation and model checking software, as well as construction specification software and BIM tools. The primary value of building information modeling (BIM) is that it provides a platform on which disparate data sources and formats may communicate and exchange information, which can be used at any stage of a project's development. Information may be categorized, coordinated, and disseminated so that it may be found and understood in a different setting. Information gleaned from a building's floor plan, for instance, may be prioritized according to the amount of risk associated with each level, with a subsequent report and schedule sent to the relevant subcontractors. Data gathered for one purpose, the specification in this case, may be used for another. Data concerning the potentially harmful properties of materials, for example, may be translated into a visual picture of the most effective methods to install such materials during a practice session. The benefits of time-synchronized data have been discussed at length.

Identified Safety Factors

Most of the injuries that happened in high-rise buildings were related to falls. As a building's height increases, it becomes very uncertain whether it will improve worker safety because workers can fall and suffer serious injuries or even death. According to the literature, the majority of fall injuries that occur or are related to a lack of egg production on the perimeter of buildings and it result in workers falling from great heights and eventually dying (Manzoor, Othman and Waheed, 2022). The presence of high-rise buildings is also important in all parts of the world, and any issues with visibility can pose significant hazards to workers, who may then fall, resulting in serious injuries. Scaffolding is always used in high-rise building construction to support the work when it's done from the exterior, and any sort of failure can result in immense loss of life (Asih and Latief, 2021). Inappropriate folding settings are also linked to an increase in the frequency of fall injuries on higher secondary metallic surfaces, which can be very dangerous for construction workers.

The equipment used in high-rise buildings is always made up of cranes that operate at greater heights, and if any sort of failure occurs in the grains, it always causes serious interiors among workers (Kim *et al.*, 2021a). It is for this reason that understanding the risk associated with crane failure is always a major requirement when setting up the high-rise building construction site, because it can seriously cause injuries and eventually the death of a worker, which will be highly negative in accordance with current industry requirements (Manzoor, Othman and Manzoor, 2021). It is found in the literature that the poor skills related to operating the crane can immediately reduce the chances of surviving any sort of injury, and their lack can also affect the overall scenario where overloading the crane can happen because of carelessness (Putra *et al.*, 2021). It is always suggested by the existing research to significantly focus on improving the safety of crane operations, as they can also cause injuries to the surrounding area when they fall. The loading pattern is one of the significant factors in high-rise building construction because if it is not appropriate in accordance with the design of the building (Lakhiar, Lakhiar and Abdullah, 2021), it will reduce the chances of maximizing the safety of workers. Difficulties are always present in terms of effectively coordinating the crane overturning mechanism because these are highly damaging to the workers' safety if not properly monitored (Kim *et al.*, 2021b).

On a personal level, it has been discovered that worker coordination is important in terms of maximizing safety because most disasters occur on the working side due to poor coordination between the work (Manzoor *et al.*, 2021). Most of the employees working on the high-rise building construction site are from diverse backgrounds, which can easily cause communication problems when sharing crucial information, whether it is related to safety or normal operations (Baalisampang *et al.*, 2021). This is one of the major factors that contributes to an increase in personal error, which can result in serious or minor injuries (Lakhiar, Abdullah and Sohu, 2021). Personality issues also contribute to an increase in the risk of injuries because when workers do not behave appropriately, they end up causing conflicts in the projects, and a high level of performance is not always required because it is seriously harmful to worker health and safety (Ahn *et al.*, 2022). In high-rise building construction, the existence of personal factors is inappropriate because it can lead to communication failures and also because the main project management plan cannot be implemented, which could compromise the safety of workers (Panuwatwanich *et al.*, 2020).

Safety checking is not highly important in terms of high-rise building construction, as it ensures that all the swift standards are in place and the work is being done in accordance with expected behavior in the market (Li *et al.*, 2020). Poor safety checking processes are implemented when resources are scarce in construction organizations, resulting in compromises in the safety checking principles commonly used in current scenarios (Liu *et al.*, 2020). The safety checks also result in compromising most of the important safety factors that are necessary for the workers to remain effective on the site. Record keeping is also important in terms of understanding how things work in safety control, and it is linked to incorrect safety assessments because existing literature has identified poor safety checking mechanisms as the critical cause of safety failures (Martinez, Gheisari and Alarcón, 2020). It is also known that a variety of factors contribute to compromising the safety checks because they are dependent on the performance of workers as they have to follow the plan to implement the safety checks. Improper safety testing can lead to high-rise building failure.

Safety signs are always very important in high-rise building construction, and it has been discovered that the majority of incidents that occur in high-rise building construction are always related to the improper implementation of safety signs (Ransford Tetteh and Liang, 2020). Different markings are always very important to be implemented on the site so that the workers know the boundaries within which they have to work in order to improve safety (Susanto *et al.*, 2020). Improper handling of this issue ultimately results in compromising the safety of workers, and this is very bad in terms of maximizing understanding of safety signs. It is identified from the literature that a poor hydraulic system on the site is also one of the significant reasons that can cause injuries because workers are present at different locations in high-rise buildings and the space is always confined in terms of time, which ultimately results in any sort of injury. Furthering the appropriate knowledge compromises the safety of workers, because if the worker does not know the meaning of a safety sign, then there is no potential outcome of implementing it on the site (Muhamad Zaini *et al.*, 2020). This is also important in the sense of the current requirements of industry, where high-rise building construction must comprehend certain policies under which safety signs are critical.

From the work condition perspective, it is identified that different working conditions are present and that mostly high-rise building construction is currently happening in areas where the climate is harsh or it is not suitable. Workers can die because of high-temperature working conditions, and the working space itself can become hazardous because of poor logistics at higher floors of high-rise building construction (Goh *et al.*, 2016). It is extremely detrimental to maximizing working conditions because it can easily contribute to affecting site management and eventually creating issues that are extremely difficult to handle in the current environment (Arifuddin, Latief and Suraji, 2020). It is also a critical factor in managing the site that the working space needs to be managed properly, but it is not always the major objective of getting appropriate potential outcomes, and ultimately, this results in rejection of overall behavior. The working conditions there need to be improved, but they ultimately depend on effective safety planning, which is lacking in the scenario sphere where these types of accidents happen and cause damaging outcomes (Ratnaningsih *et al.*, 2019).

Personal protective equipment is very important in high-rise building construction, but as it is not present on the side where accidents mostly happen, it can result in compromising the quality of the safety management plan and also cause potential issues that ultimately reflect the unavailability of personal protective equipment on the site (Md Sofwan, Zaini and Mahayuddin, 2016). That further contributes to affecting the safety of workers in high-rise building construction because the improper implementation of personal protective equipment policies can result in long-term failures that are very difficult to handle in the current scenario. Different miner engineers can be avoided with the help of appropriate personal protective equipment, but if it is not provided by contractors on site, it can eventually affect worker productivity (Shin, 2015). This has serious implications for compromising safety and increasing long-term issues in high-rise building projects, which are difficult to manage with traditional safety management controls. Further, it has significant implications in terms of affecting the quality of the safety management plan because, as long as the person's protective equipment is not there, it has a significant impact on the potential outcomes of any sort of safety management activity going on site (Yu, 2021).

Transportation and storage are also very critical for maximizing the safety of workers on site, but as material transportation difficulties are present in most scenarios, they can eventually result in poor handling of safety. The safety becomes further compromised as there are no significant efforts added by project team members to improve the workers' performance through effective management plans so that they can end up increasing the safety. All of the factors discussed have a continuous impact on maximizing worker safety in higher-hazard building construction, as they can eventually cause long-term failures and produce issues that are difficult to handle (Liu *et al.*, 2020; Ransford Tetteh and Liang, 2020). Ultimately, the most important factors are always related to inappropriate implementation of safety science, as they are already there, but the problems lie on the implementation side, where the safety is not implemented effectively. It has serious consequences in terms of obtaining results because it ultimately affects the overall scenario in which safety management is carried out (Arifuddin, Latief and Suraji, 2020). There are various common sense evidence-based factors from literature in high-rise building construction that must always be considered to the best of their abilities in order to improve worker safety.

Table 1 Safety factors identified from literature

Code	Safety Factors	Reference
1	**Falls**	
F1	No Edge Protection	(Manzoor *et al.*, 2021)
F2	Visibility Issues	(Zhang and Geng, 2019; Kim *et al.*, 2021b)
F3	Scaffolding Failure	(Manzoor, Othman and Manzoor, 2021; Putra *et al.*, 2021; Lakhiar, Lakhiar and Abdullah, 2021)
2	**Crane Overloading**	
F4	Crane Failure	(Martinez, Gheisari and Alarcón, 2020; Liu *et al.*, 2020)
F5	Poor Skill of Crane Operator	(Panuwatwanich *et al.*, 2020; Asih and Latief, 2021)
F6	Improper Loading Pattern	(Kim *et al.*, 2021a; Lakhiar, Lakhiar and Abdullah, 2021)
3	**Personal Factors**	
F7	Poor Coordination of Workers	(Ahn *et al.*, 2022; Lakhiar, Abdullah and Sohu, 2021)
F8	Communication Problems	(Kim *et al.*, 2021b; Manzoor, Othman and Manzoor, 2021)
F9	Personal Behavior Issues	(Li and Zhou, 2017; Ahn *et al.*, 2022)
4	**No Safety Check**	
F10	Lack of Safety Checking	(Arifuddin, Latief and Suraji, 2020; Goh *et al.*, 2016)
F11	No Safety Record Keeping	(Md Sofwan, Zaini and Mahayuddin, 2016; Shin, 2015)
F12	Improper Safety Assessments	(Goh *et al.*, 2016)
5	**No Safety signs**	
F13	Lack of Safety Signs	(Ratnaningsih *et al.*, 2019)
F14	Poor Warning System on Site	(Arifuddin, Latief and Suraji, 2020)
F15	Lack of Knowledge about Safety Signs	(Muhamad Zaini *et al.*, 2020)
6	**Work condition**	
F16	High Temperature Working Condition	(Ransford Tetteh and Liang, 2020; Susanto *et al.*, 2020)
F17	Hazardous Working Space	(Liu *et al.*, 2020)
F18	Poor Site Management	(Panuwatwanich *et al.*, 2020; Martinez, Gheisari and Alarcón, 2020)
7	**Personal protective equipment**	
F19	Poor Quality of PPE	(Asih and Latief, 2021; Li *et al.*, 2020)
F20	Lack of Proper PPE	(Baalisampang *et al.*, 2021)
F21	Negligence in using PPE	(Kim *et al.*, 2021b, 2021a)
8	**Transportation & Storage**	
F22	Material Transportation Difficulties	(Lakhiar, Lakhiar and Abdullah, 2021)
F23	Poor Logistics Plan on Site	(Manzoor, Othman and Manzoor, 2021; Putra *et al.*, 2021)

F24	Material Storage Hazards	(Lakhiar, Abdullah and Sohu, 2021)

RESEARCH METHODOLOGY

Research philosophy and research approach

Because it is important to combine multiple research philosophies, the research philosophy for the study is chosen based on the major requirements as well as the objectives. From a positivist perspective, it is the main research philosophy that is followed in terms of a quantitative approach, which easily reflects the inclusion of information from primary data, while the second research approach is entirely based on a qualitative approach (Lê and Schmid, 2022; Barbrook-Johnson and Carrick, 2022). This is related to the interpretivism research approach because it is based on the interpretation of secondary information that has already been published in literature, and it is acting as a significant factor in providing the outcomes with the help of an appropriate combination of both philosophies. In terms of a qualitative approach, it is always a requirement to exclude the unbiased data collection approach because it is an element of primary data collection and is further structured to provide information that is crucial in terms of maximizing the research methodology in the current environment (Drawson, Toombs and Mushquash, 2017; Lo, Rey-Martí and Botella-Carrubi, 2020).

It is also an aspect of the research methodology that it is interpreting the existing literature from the perspective of high-rise building safety factors, and it is also critical in the sense of understanding the way in which existing researchers have provided outcomes as well as those related to building information modeling. The main research approach will be applied to the effective ranking of high-rise building safety factors, while the interpretation will be done for building information modeling interventions that could be used against all the ranked safety factors (Nind *et al.*, 2020). This combination is suitable in terms of getting the best outcomes from the study while analyzing the certain outcomes already published in Reset from a building information modeling perspective. The integration between both can be effectively utilized to get the best outcome in the form of an effective building information modeling framework, and the research philosophy will reflect the potential outcomes stated in the research objectives.

Research strategy

The mix methodology strategy is chosen for the study, which employs both quantitative and qualitative methods. From the quantitative method perspective, it is a major requirement to include the question survey because it will be very important to collect data from the primary result perspective, while from the qualitative data perspective, it is the secondary literature. Included secondary literature information is critical for effectively utilizing building information modeling interventions appropriate for high-rise building construction and the corresponding designs suitable for maximizing the outcomes (Matta, 2022).

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 7, 2025
https://www.theaspd.com/ijes.php

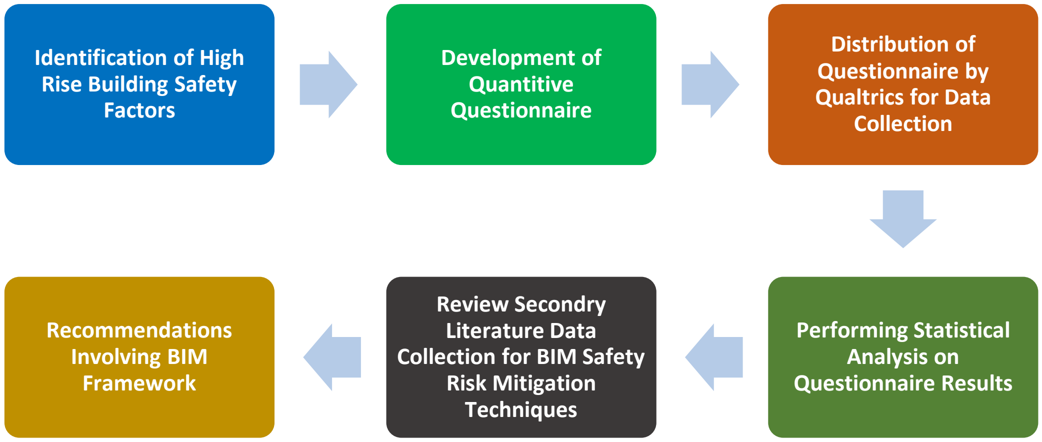

Figure 2 Research strategy

For that reason, the inclusion of appropriate information from a research strategy perspective is a critical requirement, and it has to follow the essential guidelines provided by existing research in order to provide an effective conclusion. Further, because of the inclusion of multiple methods in the strategy of the study, it is highly subtracted to get the relationship between the two methods of production because it is the only way by which certain outcomes can be produced, and for that reason, it can help to identify the most important safety risk factors for high-rise building construction (LKSAosch and Comes, 2019). The main problem that will be solved with the help of a quantitative research strategy is the effective ranking of high-rise building safety factors, while the quantitative analysis will solve the problem of recommending the building information modeling interventions suitable for mitigating health and safety risk factors in high-rise building construction (Nind and Lewthwaite, 2020). Therefore, the quantitative method will be done initially, after which the qualitative approach will be applied in terms of getting the best outcomes while recommending suitable building information modeling interventions that could create a positive impact on overall research outcomes. It is the only way that effective business output can be produced, and it can further enhance sustainable development in terms of research approaches.

Research Design

Research Tool

The research tool is a quantitative questionnaire, from which it is necessary to collect the primary data. Because it can be sent directly to people involved in high-rise building construction, the tool can be used effectively to collect primary information, creating significant advantages in terms of obtaining the best possible data for the study. It is important to consider the questionnaire research tool because this already provides evidence from existing research in terms of increasing the adequacy of the study while also maintaining its significance in terms of providing appropriate research outcomes as well (Hayward *et al.*, 2021).

Questionnaire Design

The questionnaire is broken up into several sections. The first section has three different questions about the person's background. In the literature, 24 safety factors have been identified. Their importance must be judged from the point of view of those who are directly involved in building high-rise buildings. It makes perfect sense if you understand the question and how it is made, since it is meant to collect information in the form of Likert scale scores from 1 to 5.

Sampling size and sampling technique

The sample size for this questionnaire was decided to be a minimum of 40 and a maximum of 100. It is because the revealed population, from the perspective of this sample size, is completely appropriate in the sense of high-rise building construction safety professionals working only in the KSA. It is for this reason that this low-level sample size can provide appropriate outcomes by just providing information regarding the ranking of safety factors. Also, it can be subtracted enough to get the right information for maximizing the quality of the research and ranking all of the safety factors in the study.

Data Collection

The data collection started with the development of a questionnaire and then using the Qualtrics online platform to obtain the shareable link. This link was sent to people who work in high-rise building construction in the KSA and were found through online resources like social media and the website of a construction company. The link was sent to people chosen at random, so its primary function was to send the link and wait for a response. Physical contact was avoided because it goes against the ethics of the study. As a result, all precautions were taken to make sure the study was done in a way that was both legal and ethical. The human participants were therefore contacted with reference to the university so that data collection can be made more authentic, and it was also made sure that responses were only included in the study. The informed consent was also added at the beginning of the questionnaire so that all human participants had to agree to consent; otherwise, the questionnaire could not be filled out properly. Because overall data collection must be done with real-time statistics visible from the platform used, the benefits of this type of data collection are a good fit. For qualitative data, the major purpose was to review existing literature regarding the implementation techniques of building information modeling in the sense of identifying the potential requirements and also making sure that effective development must be created in terms of the interpretation of information. It is the reason that all the articles that are included in the qualitative review are from after 2018, in the era of building information modeling interventions for building construction. The data that was collected was brought in and sorted further based on how well it fit with the research goals.

Data Analysis

The data analysis was performed according to the middle requirements of research, in which the quantitative data obtained from the questionnaire was only analyzed with the help of statistical analysis while the qualitative information was analyzed using just a theoretical or interpretation approach. It was important that the test be included in terms of statistical analysis of quantitative data, for which initially demographics were analyzed, and after that, a descriptive analysis was performed on the entire questionnaire. Reliability and normality tests were conducted to determine the reliability of all samples. The Cronbach's alpha value and Shapiro-Wilk test were done to determine reliability and normality, respectively (Ma and Zhang, 2020; Abutabenjeh and Jaradat, 2018). After these tests, the main relative importance index was determined with the help of its journal formula, and the main purpose was to perform the ranking of the safety factor from the questionnaire. This ranking was important in terms of fully justifying the initial objectives after the identification of safety factors. Effective implementation of qualitative analysis was also in doubt in terms of analyzing the major building information modeling techniques, which are critical for reducing the risk associated with high-rise building construction safety. This issue was analyzed in the context of maximizing the understanding of the overall behavior of safety management in high-rise building construction and obtaining suitable recommendations by which these safety issues can be resolved, thereby providing sustainable high-rise building infrastructure to the KSA.

FINDINGS AND DISCUSSION

Demographics

According to the demographic results It was discovered, in accordance with Figure 4, that 58% of the participants are between the ages of 18 and 25.37% were between the ages of 26 and 35.5% were between the ages of 36 and 45, with no participant over the age of 46.young professionals were involved in the survey, which indicates effective knowledge regarding the building information modeling implementation while also indicating the variation in safety factors in high-rise building construction. The respondents have appropriately provided the response without indicating any sort of irregular results from the age group perspective.

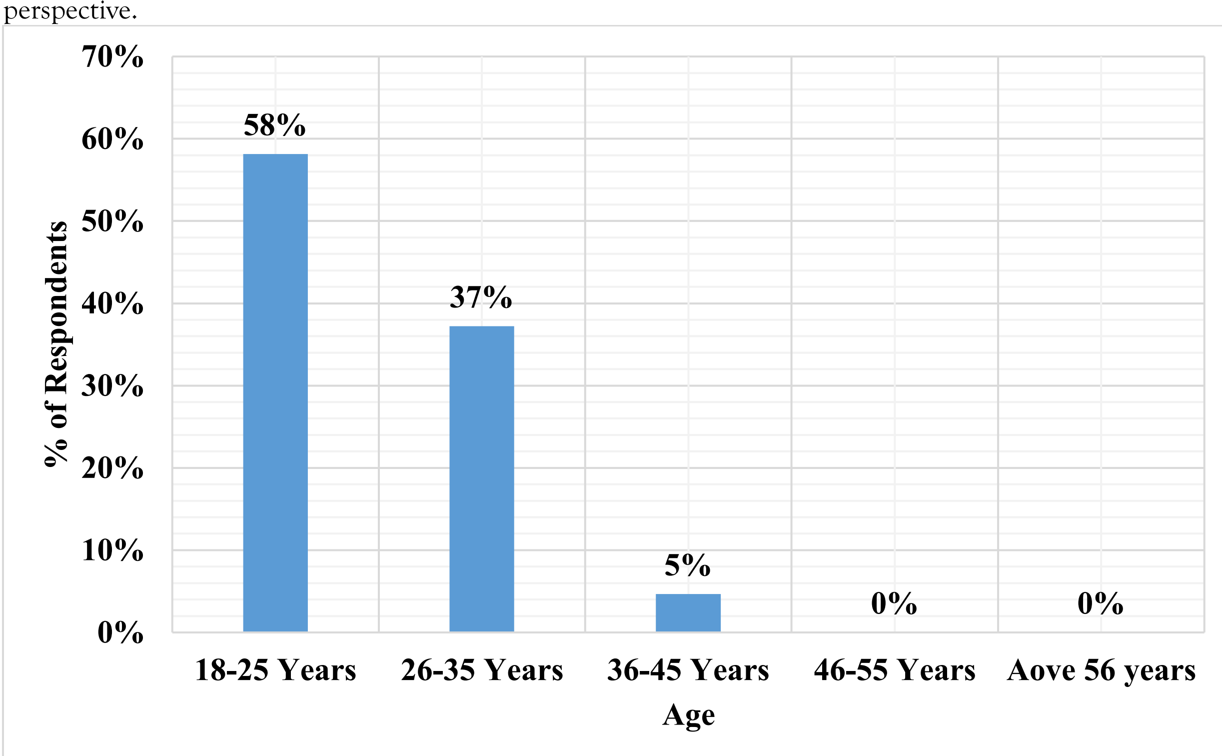

Figure 3 Age distribution of participants

In terms of education, 9% of participants had a high school diploma, while 33% of the 7% head bachelor had a master's degree. The remaining 7% had other types of education, while 5% had a PhD. Most people involved in the questionnaire had an education level of at least bachelor's and master's, which is highly critical in terms of understanding the distribution of education in the high-rise building construction work force, as shown in Figure 5. It is completely appropriate in terms of variation in education while the KSA construction sector is significantly developing, and it is also strengthening the concept by which education has an impact on understanding the different safety factors in high-rise building construction.

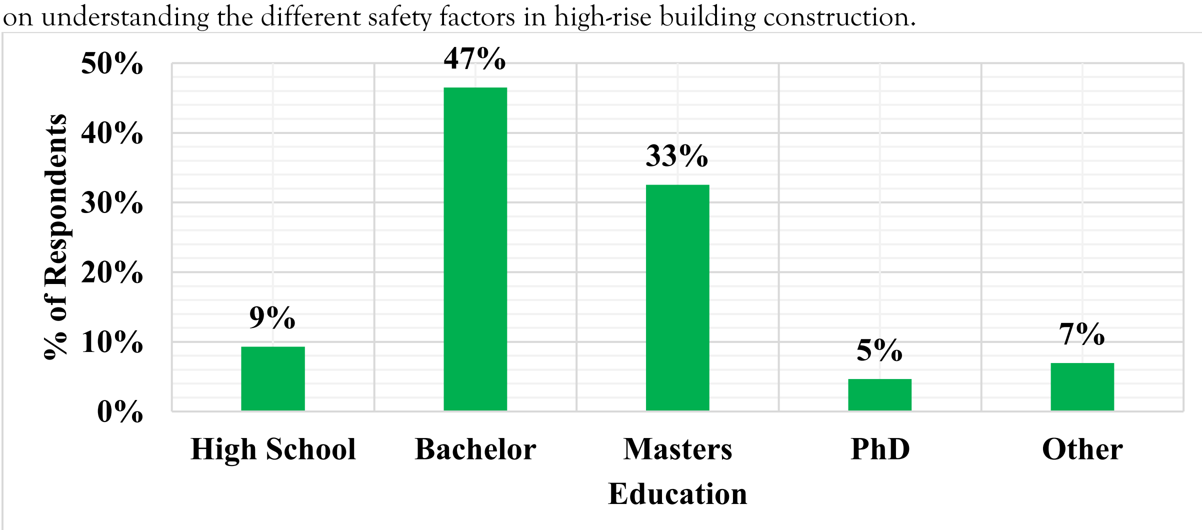

Figure 4 Education of Participants

In terms of experience, it was found that 74% had less than 5 years of experience. 14% had 5 to 10 years of experience. 7% had 10 to 15 years of experience, and the remaining 5% had 15 to 20 years of experience. Most participants involved in the survey had at least five years of experience, and in accordance with the high-rise building construction trend in the KSA, it is evident that the experience distribution is completely appropriate, as shown in Figure 6. The overarching demographics have indicated a positive impact on outcomes without indicating any sort of irregularity in the data.

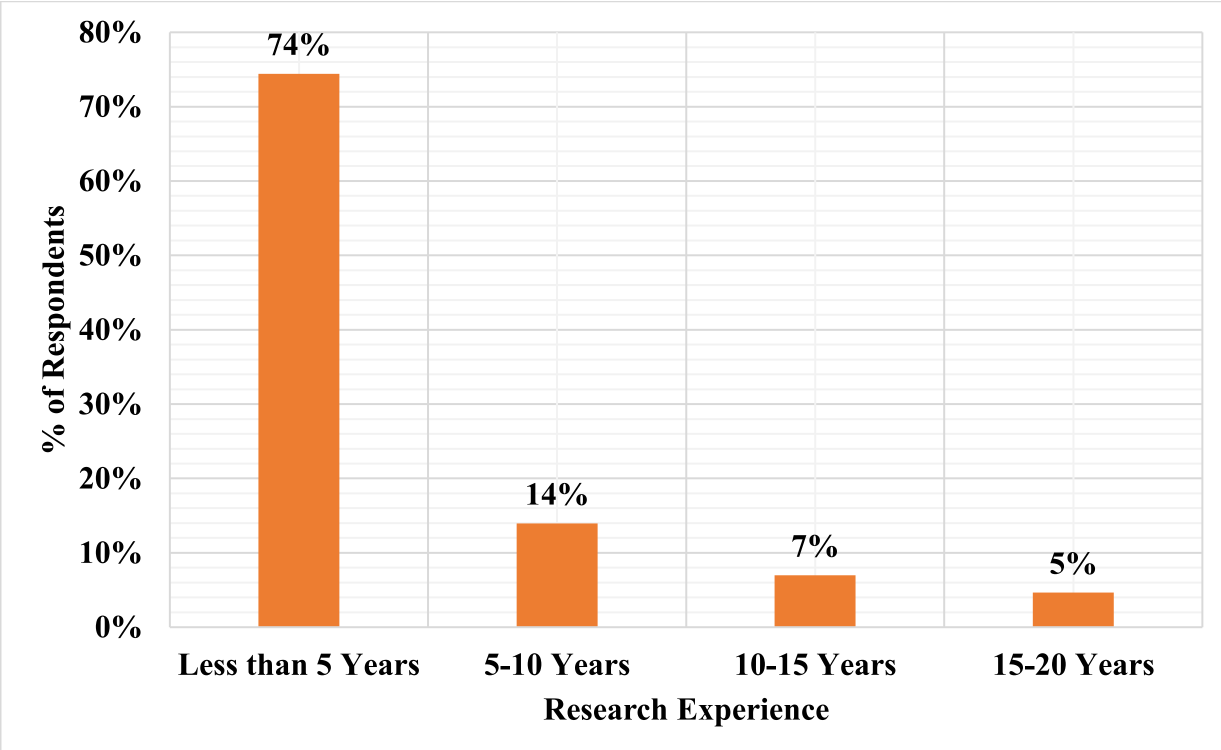

Figure 5 Experience of participants

Descriptive Analysis

From a descriptive analysis perspective, it is found that the overall mean value obtained for the data is above 3, which indicates an appropriate level of significance for all of the safety factors included in the analysis. Further, it is indicating that the standard deviation involved in the data is almost less than 1.3 for most of the factors included in the analysis, and few factors have gone above 1.3 standard deviation, which is still acceptable in the data with respect to the overall number of responses. The data is also not secured significantly because most of the values are less than negative 0.5, which is still appropriate in terms of understanding the impact on the data as indicated in Table 2. The overall scenario is completely appropriate in terms of data collection, as it indicates a high level of significance and there is no inappropriate behavior observed in the data that could potentially reduce the significance of the data to be used in further statistical analysis. This also indicates a high level of acceptance in terms of descriptive results, and there is no appropriate factor in the analysis that could indicate a low level of impact in the statistical evaluation.

Table 2 Descriptive statistics

Code	N	Mean	Std. Deviation	Variance	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
F1	43	3.00	1.291	1.667	-.209	.361
F2	43	3.09	1.109	1.229	-.081	.361

F3	43	3.12	1.138	1.296	-.238	.361
F4	43	3.33	1.210	1.463	-.332	.361
F5	43	3.16	1.290	1.663	-.248	.361
F6	43	3.23	1.324	1.754	-.386	.361
F7	43	3.28	1.368	1.873	-.358	.361
F8	43	3.47	1.316	1.731	-.283	.361
F9	43	3.33	1.210	1.463	-.078	.361
F10	43	3.58	1.159	1.344	-.544	.361
F11	43	3.63	1.196	1.430	-.449	.361
F12	43	3.40	1.330	1.769	-.337	.361
F13	43	3.28	1.297	1.682	-.276	.361
F14	43	3.21	1.337	1.788	-.215	.361
F15	43	3.21	1.245	1.550	-.340	.361
F16	43	3.37	1.092	1.192	-.117	.361
F17	43	3.21	1.245	1.550	-.185	.361
F18	43	3.09	1.269	1.610	-.109	.361
F19	43	3.12	1.276	1.629	-.011	.361
F20	43	3.12	1.179	1.391	-.052	.361
F21	43	2.93	1.261	1.590	-.013	.361
F22	43	3.07	1.352	1.828	-.132	.361
F23	43	3.02	1.244	1.547	-.279	.361
F24	43	3.05	1.344	1.807	-.150	.361

Reliability and Normality Analysis

From a reliability perspective, it is evident that the Cronbach alpha value is 0.936. Any value above 0.9 is always indicative of the high level of reliability of the information collected from a quantitative survey, and the data is totally acceptable from the perspective of the reliability test. Further, it is showing the significance of outcomes as the overall number of items involved in analysis is completely fine, and it is indicating a high level of reliability. in response to the current trend indicated by the data. Table 3 and Table 4 show the results of reliability and normality. Shapiro Wilk Test results of normality are also appropriate because the significance value is less than 0.05 for all the factors included in the analysis, justifying the criteria by which the normality can be rejected. Further, it is identified from the analysis that the overall data is free of normal behavior, and further, it is the actual information obtained from a qualitative survey with full reliability. This can be very helpful in further analysis because the overall data is confirmed with respect to the statistical evaluation of reliability and normality. Any irregularity is not observed in the information, which significantly conforms to the validity of the information collected from the quantitative survey, and therefore it is credible enough to be used for the development of the final framework.

Table 3 Reliability statistics

Cronbach's Alpha	**N of Items**
.936	24

Table 4 Reliability and normality test results

Code	**Cronbach Alpha**	**Shapiro-Wilk**		
		Statistic	**df**	**Sig.**
F1	.933	.899	43	.001

F2	.933	.910	43	.003
F3	.935	.911	43	.003
F4	.933	.907	43	.002
F5	.933	.905	43	.002
F6	.934	.878	43	.000
F7	.932	.879	43	.000
F8	.933	.879	43	.000
F9	.933	.898	43	.001
F10	.932	.883	43	.000
F11	.935	.883	43	.000
F12	.933	.884	43	.000
F13	.933	.903	43	.002
F14	.935	.901	43	.001
F15	.933	.897	43	.001
F16	.934	.904	43	.002
F17	.934	.906	43	.002
F18	.933	.910	43	.003
F19	.933	.910	43	.002
F20	.934	.918	43	.005
F21	.932	.913	43	.003
F22	.933	.894	43	.001
F23	.933	.885	43	.000
F24	.933	.900	43	.001

Relative Importance Index (RI)

The relative importance index was calculated with the help of all values obtained from the questions, and the main element utilized in the calculation of the relative importance index is the variation between responses for each value of the scale of measurement used in the questionnaire. The findings are completely appropriate because they present the corresponding relative importance index for all 24 safety factors included in the analysis, and for each individual safety factor, that relative importance index is calculated. After that, the ranking is performed in terms of descending order, where the highest value of the relative importance index is required for the maximum rank of every safety factor included in the analysis. Because the relative importer index values resulted in a ranking of the 24 factors, the observed behavior is completely acceptable. It is found that the least relative importance index is 0.586, which is greater than 0.5 and, therefore, confirms the validity of outcomes, while the highest relative importance index obtained from the analysis is 0.726. The observed values are at an acceptable rate, and for this reason they are predicting the ranking of safety factors, which was one of the significant objectives of the study. On the basis of the outcomes, it can be easily established that the second objective of the study is totally fulfilled. The results of the relative importance index are presented in Table 5. The calculation of RII was performed by following formula,

$$Relative\ Importance\ Index = \frac{5 \times n5 + 4 \times n4 + 3 \times n3 + 2 \times n2 + 1 \times n1}{5 \times N}$$

Table 5 RII results

Code	**Safety Factor**	**n1**	**n2**	**n3**	**n4**	**n5**	**N**	**RII**	**Ranking**
F1	No Edge Protection	8	6	12	12	5	43	0.600	23
F2	Visibility Issues	4	7	18	9	5	43	0.619	18

F3	Scaffolding Failure	4	9	12	14	4	43	0.623	15
F4	Crane Failure	4	6	13	12	8	43	0.665	6
F5	Poor Skill of Crane Operator	6	7	11	12	7	43	0.633	14
F6	Improper Loading Pattern	6	8	6	16	7	43	0.647	10
F7	Poor Coordination of Workers	6	8	6	14	9	43	0.656	8
F8	Communication Problems	3	9	9	9	13	43	0.693	3
F9	Personal Behavior Issues	2	11	10	11	9	43	0.665	6
F10	Lack of Safety Checking	3	3	14	12	11	43	0.716	2
F11	No Safety Record Keeping	2	6	11	11	13	43	0.726	1
F12	Improper Safety Assessments	5	5	13	8	12	43	0.679	4
F13	Lack of Safety Signs	5	7	11	11	9	43	0.656	8
F14	Poor Warning System on Site	6	7	11	10	9	43	0.642	11
F15	Lack of Knowledge about Safety Signs	6	4	15	11	7	43	0.642	11
F16	High Temperature Working Condition	2	6	17	10	8	43	0.674	5
F17	Hazardous Working Space	5	6	15	9	8	43	0.642	11
F18	Poor Site Management	6	7	14	9	7	43	0.619	18
F19	Poor Quality of PPE	5	9	13	8	8	43	0.623	15
F20	Lack of Proper PPE	4	9	14	10	6	43	0.623	15
F21	Negligence in using PPE	7	9	12	10	5	43	0.586	24
F22	Material Transportation Difficulties	8	5	14	8	8	43	0.614	20
F23	Poor Logistics Plan on Site	8	3	17	10	5	43	0.605	22
F24	Material Storage Hazards	8	6	12	10	7	43	0.609	21

The ranked and sorted safety factors are presented in Table 6. It is important to consider that the paragraphs have identified that no safety record keeping has the highest rank, which means it can seriously cause injuries in high-rise building construction projects in the KSA. It is further important to consider the lack of safety checking, while communication problems are also significant, as identified in the relative importance index. Similarly, improper safety assessments and high temperature working conditions are important factors because they are also present onsite and can individually affect construction workers while increasing the chances of minor and major injuries.

Moving further, the crane failures and personal behavior issues are also significant because they are related to the creation of incidents in the higher secondary construction projects. The least importance is given to negligence in the use of personal protective equipment because it is one of the top priorities in every construction project in the KSA to use personal protective equipment as much as possible. However, the incident occurs because workers on the site do not take appropriate safety precautions, and management is also complicit in failing to address the safety issues that ultimately result in incidents. It should be noted that the overall safety factors used in the question were classified into eight different categories, whereas the relative importance index calculation classifies the factors according to their rank rather than their categories, which were determined based on an existing literature review.

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 7, 2025
https://www.theaspd.com/ijes.php

Table 6 Ranking of safety factors

F11	No Safety Record Keeping	0.726	1
F10	Lack of Safety Checking	0.716	2
F8	Communication Problems	0.693	3
F12	Improper Safety Assessments	0.679	4
F16	High Temperature Working Condition	0.674	5
F4	Crane Failure	0.665	6
F9	Personal Behavior Issues	0.665	6
F7	Poor Coordination of Workers	0.656	8
F13	Lack of Safety Signs	0.656	8
F6	Improper Loading Pattern	0.647	10
F14	Poor Warning System on Site	0.642	11
F15	Lack of Knowledge about Safety Signs	0.642	11
F17	Hazardous Working Space	0.642	11
F5	Poor Skill of Crane Operator	0.633	14
F3	Scaffolding Failure	0.623	15
F19	Poor Quality of PPE	0.623	15
F20	Lack of Proper PPE	0.623	15
F2	Visibility Issues	0.619	18
F18	Poor Site Management	0.619	18
F22	Material Transportation Difficulties	0.614	20
F24	Material Storage Hazards	0.609	21
F23	Poor Logistics Plan on Site	0.605	22
F1	No Edge Protection	0.600	23
F21	Negligence in using PPE	0.586	24

BIM Safety Risk Mitigation Techniques

According to the growing trend in building information modeling utilization for safety in construction, it is evident that a variety of technologies are being introduced, and these are always significant in terms of accelerating the safety management on site and providing effective outcomes to all workers. As the technology significantly increases the implementation of drone monitoring, the aerial view of the site can easily provide effective information to safety managers to make decisions about safety protocols, which can easily strengthen the potential safety outcomes without affecting overall productivity. Similarly, building information modeling is being used for augmented reality and virtual reality technology, both of which are progressing in the construction field while providing significant benefits in controlling safety outcomes. It is found in the literature that with your reality and augmented reality, you provide an effective visualization feature to workers, which is significantly better in terms of training them more and also making them sure about the successful implementation of safety standards on site. Building information modeling-based safety and logistics models are used in a variety of ways to control site logistics and monitoring systems; thus, the literature indicates that these have significant implications for high-rise building construction.

Similarly, effective improvements in building information modeling training and walkthrough systems have provided great reliability to construction workers to improve their safety and protect themselves from an uncertain project environment. This is significant in terms of controlling the building information modeling training output while maintaining effective compliance with safety principles that are needed in the project environment. This also holds true for emergency planning with the building information modeling feature because it is being introduced with progress in technology, and the construction industry is also accepting it as one of the significant technologies for future high-rise buildings. The observed trend indicates better implications for high-rise buildings where effective emergency planning has resulted in improved outcomes, and similar is the case for building information modeling hazard profiling. It is because risk management is being associated with building information modeling technology in recent years, and these can easily provide long-term output in terms of controlling the potential benefits. This has serious implications for improving the sustainability of construction and accelerating development to the point where it is possible for building construction projects to become fully sustainable. Building information modeling based on site risk control is regarded as one of the significant technologies that have resulted in improved worker safety on a variety of projects, including high-rise buildings, in recent years.

This is true in the sense of decision-making models in building information modeling as well, because they are the significant applications of the advent of technology where the machine learning algorithms are being implemented in accordance with improving the accuracy of the decision-making process regarding safety. Similar behavior can be observed in the scenario of building information modeling and cloud communication technology, which are being accelerated because of improvements in systems and are also available worldwide in terms of accelerating worker safety. Similar outcomes can be observed in the scenario of building information modeling-based worker scheduling management, which is known to be a significant factor in managing safety. Building information modeling, which is an effective representation of all types of safety in terms of visualization, is also used to integrate safety information, which ultimately improves worker integrity and brings them together in effective communication. The cloud-based feature of building information modeling is also improving the data sharing on different platforms, which is critical in terms of improving the safety of high-rise buildings, where professionals are always working to improve the safety to critical levels so that they could help in maximizing the performance of high-rise building construction work without having any sort of negative impact on potential business output. That is true in the sense of maximizing the safety of workers and also bringing everything together in response to different safety management challenges going on in the market. Further, it has significant implications regarding the maximization of safety visualization and making sure that information modeling systems can work easily to improve the safety of workers. Table 7 is presenting the summary of secondary analysis including 12 BIM based interventions.

Table 7 BIM mitigation techniques

Sr. #	BIM Applications	References
1	Drone Monitoring	(Kim *et al.*, 2021b; Putra *et al.*, 2021)
2	BIM Augmented Reality and VR	(Lakhiar, Lakhiar and Abdullah, 2021; Martinez, Gheisari and Alarcón, 2020)
3	BIM Safety and Logistics Models	(Martinez, Gheisari and Alarcón, 2020; Lakhiar, Lakhiar and Abdullah, 2021)
4	BIM Training and Walkthroughs	(Kim *et al.*, 2021a; Ratnaningsih *et al.*, 2019)
5	Emergency Planning with BIM	(Ahn *et al.*, 2022; Liu *et al.*, 2020)
6	BIM Hazard Profiling	(Ratnaningsih *et al.*, 2019; Md Sofwan, Zaini and Mahayuddin, 2016)
7	BIM On-Site Risk Control	(Baalisampang *et al.*, 2021; Muhamad Zaini *et al.*, 2020)
8	Decision Making Models in BIM	(Asih and Latief, 2021; Arifuddin, Latief and Suraji, 2020)
9	BIM Cloud Communication	(Liu *et al.*, 2020)
10	BIM Worker Schedule Management	(Kim *et al.*, 2021b)
11	BIM Safety Information Integration	(Liu *et al.*, 2020; Ahn *et al.*, 2022)
12	BIM Cloud Based Safety Visualization	(Susanto *et al.*, 2020; Shin, 2015)

DISCUSSION

On the basis of quantitative and qualitative analysis, the final framework is constructed. According to identified building information modeling technology, these can easily work to mitigate the risk factors associated with high building construction safety, and their implementation can be well suited to multiple safety factors in accordance with their features. The final framework is to be built in accordance with eight major categories of safety factors in order to reduce complexity in the framework and also to present the final building information modeling mitigation techniques that are critical to be used for every safety factor in order to improve worker safety in high-rise building projects in the KSA. It is identified that fall injuries can be reduced with the help of effective improvements in building information modeling training and safety information integration methods, which are highly significant in terms of current research. It will also be important that the fall injuries be mitigated with the help of targeted building information modeling walkthroughs, as they are important in the sense of improving the safety of workers to the maximum possible level.

The crane overloading problems can be resolved with the help of effective drone monitoring, building information modeling safety and logistics models, onsite rich control, and cloud communication. This building information modeling intervention can easily reduce crane overload failures, which are linked to increasing the chances of injuries and affecting worker health and safety in KSA high-rise building construction projects. It will be essential to consider crane overloading as one of the critical factors for improving worker health and safety in high-rise building construction projects because it is linked to the reduction of potential risk and also creates more opportunities for workers involved in the projects to have better potential outcomes in the future. The personal factors are also important to be controlled, and these can be mitigated effectively with the help of building information modeling training and focusing on cloud communication technology, which is critical in terms of developing worker safety.

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 7, 2025
https://www.theaspd.com/ijes.php

Further, it is identified that the personal factors can be controlled with appropriate safety information integration so that the behavior implications do not create accidents on high-rise building construction projects in the KSA. Similarly, the no safety checks problem can be resolved with appropriate management done with the help of emergency planning, hazard profiling, site risk control, and safety information integration. These interventions can easily work in terms of maximizing the safety of workers and also resolving the problem of implementing appropriate safety checks, which ultimately result in maximizing the worker's health and safety in high-rise building construction projects. When analyzing building information modeling technology, it is critical to consider the factor because it is critical in terms of not jeopardizing worker safety and ultimately deciding on the development's good outcomes. It is also important to consider the safety sign issue with the help of an appropriate safety and logistics model while also deciding about decision making, which is critical in the sense of improving the safety implementation on site and also eradicating the problem of safety signs.

This will be important in terms of understanding the dynamics by which things work in high-rise building construction projects and also how building information modeling can resolve these issues with the help of a proper implementation of building information modeling interventions. For work condition problems, it is important that hazard profiling be used along with on-site risk control as both of these can provide significant benefits. While the interventions related to building information modeling can be implemented, worker schedule management can also be implemented, which is critical in the sense of resolving the issues that ultimately result in the appropriate procurement of workers for the project according to their skills. This conventional method results in maximizing the safety of workers and also eradicating the chances by which it can result in failure from the perspective of safety issues among workers. It will be important to determine the work condition variation in the projects, and significant efforts are needed to mitigate these hazards and also implement certain potential outcomes of business that can eventually improve building information modeling implementation in current high-rise building construction projects. From a personal protective equipment perspective, it is important that the building information modeling interventions be used from the perspective of emergency planning and safety information integration because both are critical as well as suitable in the sense of reducing the failure of safety management in high-rise building construction projects. It will be practical to consider personal protective equipment as one of the key safety factors that can be mitigated with building information modeling technology, and it will ultimately reduce the likelihood of failures that could eventually result in damaging impacts on projects.

The transportation and storage problem can be solved with an appropriate building information modeling safety and logistics model, while cloud safety management can be implemented in terms of appropriately delivering information to all workers and mitigating the risk that any transportation and storage problem causes. It will be important that all the safety factors can be essentially mitigated with the help of appropriate techniques as identified in the literature, because all of these techniques are effectively presented in the existing literature while being associated with identified safety factors. Overall, the outcomes will be positive in terms of understanding the ways in which safety can be improved and the potential adoption of the safety management framework in terms of mitigating the safety problems on high-rise building construction projects in the KSA.

CONCLUSION

Conclusively, a total of 24 safety factors were identified from a literature review, and their ranking was performed with the help of a quantitative survey and using the relative importance index as the main statistical evaluation test. The statistics provided from quantitative analysis are completely appropriate because they predict the relative ranking of each safety factor involved in the analysis, and the provided ranking can be useful in terms of understanding the way in which health and safety risk factors can increase on high-rise building projects in the KSA. The first objective of the study was completed after the identification of 24 safety factors during the literature review section. The study's second goal was to determine the most effective ranking of health and safety factors associated with high-rise building construction projects, and it was completed at the conclusion of the quantitative survey evaluation.

The third objective of the study was to effectively identify the most effective and innovative building information modeling-based mitigation techniques from secondary data. The second objective is completed in accordance with the outcomes of qualitative analysis conducted on secondary data, in which 12 building information modeling techniques were tested and identified that are suitable for high-rise building construction project safety. Therefore, the third objective is completely fulfilled, and the last objective was the effective development of an integrated framework for building information modeling, including the safety factors and the mitigation techniques identified from secondary data. The evolution has effectively provided the development of the framework, which is the ultimate outcome of the study, and therefore the fourth objective is also fulfilled. All the research questions are answered in the form of identified health and safety risk factors associated with high rise building construction in the KSA, and they have further provided appropriate insights on the basis of which the recommendations can be made in terms of implementing the Framework for sustainable improvement of construction safety in high rise building projects. The study's potential outcomes include an effective combination of qualitative and qualitative analysis, which is the main methodology on the basis of mixed design, and it has resulted in an appropriate understanding of health.

Recommendations

Based on the findings, it is recommended that health and safety regulations in high-rise building projects in the KSA be improved, and that the associated building information modeling techniques be implemented as soon as possible. According to the results of the evaluation, it is clear that most safety risk factors are always created as a result of negligence of safety management principles, and it is therefore recommended to effectively improve safety as well as implement innovative technology to prevent accidents from occurring. The fall injuries discovered during the analysis can be resolved using a powerful combination of safety information integration and training provided by building information modeling. It is recommended to begin drone monitoring because it is extremely useful for improving overall construction site visualization and also because it gives managers control over monitoring work progress, which is critical to improving safety implementation in high-rise building projects in the KSA.

It will be essential that the building information modeling be done in accordance with the principles of augmented reality as well as your reality because both are critical in terms of engaging in sustainable progress as well as being able to easily provide more reliable outcomes to construction management. Proper logistic modeling is recommended because it is the future of building information modeling, it can save a lot of time involved in safety planning for the workers, and it also provides them with useful guidance on the basis of which they could easily improve certain interventions. It will also be essential that the overall safety plan follow the effective hazard profile because it is linked with detailed evaluation of the site and planning, which ultimately improves worker safety from uncertain damage. More focus needs to be given to problems like safety checks and also fall injuries because they happen a lot in construction sites, and these can be improved with the help of appropriate building information modeling and visualization technology, including cloud-based safety. It will be appropriate if the management of high-rise building projects focuses on maximizing the adoption of safety regulations that are based on advanced building information levels. Integrating safety into the main project plan is highly important because it can save a lot of time while maintaining good communication over the schedule, which is required in any case of project management. It will be important to consider the development of effective health and safety implementation because the different safety factors can be integrated together with the help of multiple building information modeling technologies.

This can eventually increase the complexity of safety management, but at the same time, proper training and simulation provided to construction workers can help a lot in eradicating the health and safety risk factors. It will also be important to consider the building information modeling mitigation techniques, which are linked with a reduction in worker safety because of a lack of awareness, and their initial training, which must be provided before the implementation of any kind of building information modeling technique. It should be an essential element in the safety planning of high-rise building construction projects in the KSA that local regulations be followed, but then they should be further integrated with building information modeling interventions provided in the study so that sustainable outcomes could be produced without having any sort of negative impact on the schedule of the project. Health and safety workers on high-rise building construction projects should prioritize improving safety sign implementation while increasing safety check frequency to ensure an effective working environment for everyone and preventing any type of minor or major injury.

Limitations

It is a major limitation of the study that it is being conducted in a KSA environment only, and the potential implications observed from the analysis may not always apply in every country where high-rise building construction is happening. The number of participants involved in the analysis was limited in accordance with observed behavior, which is critical in terms of future outcomes because if more people are involved, the results may be different. Further, the mixed methodology study design involved secondary data from the perspective of building information modeling, intervention identification, and inclusion into a framework. This will result in increasing the implementation of all safety factors while identifying appropriate mitigation techniques that are critical as well as suitable in the sense of maximizing safety in construction. It should be noted that the building information modeling interventions discussed in the analysis were only 12, and they are entirely related to high-rise building construction, which limits the study from the perspective of future technology that is still coming and will ultimately improve high-rise building construction in the future. The ranking and overall number of safety factors considered in the analysis are also limited in the sense of having an impact on the final implementation of safety planning in high-rise building construction projects. The research, on the other hand, has had a positive impact in terms of understanding how safety factors are associated with high-rise building construction projects in the KSA and, as a result, providing effective outcomes in terms of further improving the implementation of building information modeling interventions.

Implications

From a theoretical perspective, the implications are huge because they can easily provide valuable outcomes if more research is conducted on effectively improving the safety framework's efficiency. More searches can also be conducted to include multiple factors, and the sample size can be increased in the future to get the best possible results in terms of the current development going on in high-rise building construction projects. It will be important that future research consider the analysis as a foundation in terms of safety factors related to high-rise building construction projects and also the mitigation techniques related to building information modeling. From a practical standpoint, it is critical that the project manager's friend, as well as all safety management personnel working on higher-rise building construction projects in the KSA, consider implementing building information modeling interventions that can ultimately improve worker safety without compromising any factor. It will be important that all the safety measurement principles be implemented in accordance with the safety framework presented in the outcome of the overall analysis, and that could lead to sustainable conclusions regarding the successful improvement in safety for home workers in every high-rise building construction project in the KSA. It will be important that all the practical implications be considered for the safety of workers on high-rise building construction projects in the KSA.

REFERENCES

1. Abutabenjeh, S. and Jaradat, R. (2018) Clarification of research design, research methods, and research methodology: A guide for public administration researchers and practitioners. *Teaching Public Administration*. doi:10.1177/0144739418775787.
2. Ahn, H., Son, S., Park, K. and Kim, S. (2022) Cost assessment model for sustainable health and safety management of high-rise residential buildings in Korea. *Journal of Asian Architecture and Building Engineering*. doi:10.1080/13467581.2021.1902334.
3. Arifuddin, R., Latief, R.U. and Suraji, A. (2020) An investigation of fall accident in a high-rise building project. In: *IOP Conference Series: Earth and Environmental Science*. 2020 doi:10.1088/1755-1315/419/1/012144.
4. Asih, R.. and Latief, Y. (2021) *Evaluation of Implementation Within Occupational Health and Safety Management System Based on Indonesia Government Regulation Number 50 of 2012 and ISO 45001:2018 (Case Study: Company X)*. In: 2021 doi:10.2991/ahsr.k.210127.063.
5. Attrill, R. and Mickovski, S.B. (2020) Issues to be addressed with current BIM adoption prior to the implementation of BIM level 3. In: *ARCOM 2020 - Association of Researchers in Construction Management, 36th Annual Conference 2020 - Proceedings*. 2020
6. Baalisampang, T., Saliba, E., Salehi, F., Garaniya, V. and Chen, L. (2021) Optimisation of smoke extraction system in fire scenarios using CFD modelling. *Process Safety and Environmental Protection*. doi:10.1016/j.psep.2020.11.036.
7. Banks, C., Kotecha, R., Curtis, J., Dee, C., Pitt, N. and Papworth, R. (2018) Enhancing high-rise residential construction through design for manufacture and assembly - A KSA case study. *Proceedings of Institution of Civil Engineers: Management, Procurement and Law*. doi:10.1680/jmapl.17.00027.
8. Barbrook-Johnson, P. and Carrick, J. (2022) Combining complexity-framed research methods for social research. *International Journal of Social Research Methodology*. doi:10.1080/13645579.2021.1946118.
9. Brockington, R. and Cicmil, N. (2016) Brutalist Architecture: An Autoethnographic Examination of Structure and Corporeality. *M/C Journal*. doi:10.5204/mcj.1060.
10. Chapuel, A. and Reyes, J. (2019) Obtención de una película biodegradable a partir de los almidones de semilla de aguacate (Persea americana Mill) y banano (Musa acuminata AAA) para el recubrimiento de papaya. *Journal of Wind Engineering and Industrial Aerodynamics*.
11. Drawson, A.S., Toombs, E. and Mushquash, C.J. (2017) Indigenous research methods: A systematic review. *International Indigenous Policy Journal*. doi:10.18584/iipj.2017.8.2.5.
12. Dudley, G. and Banister, D. (2018) Expertise in decision-making for large infrastructure projects: from KSA trunk roads to High Speed Rail 2. *Transportation Planning and Technology*. doi:10.1080/03081060.2018.1468969.
13. Garzia, F. and Lombardi, M. (2018) The role of bim for safety and security management. *International Journal of Sustainable Development and Planning*. doi:10.2495/SDP-V13-N1-49-61.
14. Goh, K.C., Goh, H.H., Omar, M.F., Toh, T.C. and Mohd Zin, A.A. (2016) Accidents preventive practice for high-rise construction. In: *MATEC Web of Conferences*. 2016 doi:10.1051/matecconf/20164704004.
15. Hayward, A., Wodtke, L., Craft, A., Robin, T., Smylie, J., McConkey, S., NychKSA, A., Healy, C., Star, L. and Cidro, J. (2021) Addressing the need for indigenous and decolonized quantitative research methods in Canada. *SSM - Population Health*. doi:10.1016/j.ssmph.2021.100899.
16. Hough, M.J. and Lawson, R.M. (2019) Design and construction of high-rise modular buildings based on recent projects. *Proceedings of the Institution of Civil Engineers: Civil Engineering*. doi:10.1680/jcien.18.00058.
17. Huang, Z. (2020) Application Research on BIM+AR Technology in Construction Safety Management. In: *Journal of Physics: Conference Series*. 2020 doi:10.1088/1742-6596/1648/4/042019.
18. ICONTEC (2019) NORMA TÉCNICA COLOMBIANA NTC 6349. *Journal of Wind Engineering and Industrial Aerodynamics*.
19. Kim, I., Lee, Y. and Choi, J. (2020) BIM-based hazard recognition and evaluation methodology for automating construction site risk assessment. *Applied Sciences (Switzerland)*. doi:10.3390/app10072335.
20. Kim, J.M., Bae, J., Son, S., Son, K. and Yum, S.G. (2021a) Development of model to predict natural disaster-induced financial losses for construction projects using deep learning techniques. *Sustainability (Switzerland)*. doi:10.3390/su13095304.
21. Kim, M., Kim, T., Yeo, I.H., Lee, D., Cho, H. and Kang, K.I. (2021b) Improvement of standards on fire safety performance of externally insulated high-rise buildings: Focusing on the case in Korea. *Journal of Building Engineering*. doi:10.1016/j.jobe.2020.101990.
22. Lakhiar, M.T., Abdullah, A.H. and Sohu, S. (2021) Application of digital technologies for prevention of accidents in construction of high-rise building projects: A review. *IOP Conference Series: Materials Science and Engineering*. doi:10.1088/1757-899x/1144/1/012009.
23. Lakhiar, M.T., Lakhiar, M.T. and Abdullah, A.H. (2021) Occupational health and safety performance in high-rise building

projects in pakistan:a systematic literature review *Operational Research in Engineering Sciences: Theory and Applications*. doi:10.31181/oresta20401991.
24. Lê, J.K. and Schmid, T. (2022) The Practice of Innovating Research Methods. *Organizational Research Methods*. doi:10.1177/1094428120935498.
25. Lemberg-Pedersen, M. (2013) Private security companies and the European borderscapes. In: *The Migration Industry and the Commercialization of International Migration*. doi:10.4324/9780203082737-17.
26. Li, C.-H. and Zhou, T.-H. (2017) Application of BIM for Safety Management During Construction. *DEStech Transactions on Engineering and Technology Research*. doi:10.12783/dtetr/mcee2016/6429.
27. Li, W., Li, H., Liu, Y., Wang, S., Pei, X. and Li, Q. (2020) Fire risk assessment of high-rise buildings under construction based on unascertained measure theory. *PLoS ONE*. doi:10.1371/journal.pone.0239166.
28. Liu, P. (2021) Mountain Rainfall Estimation and BIM Technology Site Safety Management Based on Internet of Things. *Mobile Information Systems*. doi:10.1155/2021/1017200.
29. Liu, T., Zhang, S. and Wang, C. (2021) A BIM-Based Safety Management Framework for Operation and Maintenance in Water Diversion Projects. *Water Resources Management*. doi:10.1007/s11269-021-02813-7.
30. Liu, Y., Li, Q., Li, W., Li, H. and Pei, X. (2020) Safety assessment of all-steel-type attached lifting scaffold based on grey Euclidean theory. *PLoS ONE*. doi:10.1371/journal.pone.0238074.
31. Lo, F.Y., Rey-Martí, A. and Botella-Carrubi, D. (2020) Research methods in business: Quantitative and qualitative comparative analysis *Journal of Business Research*. doi:10.1016/j.jbusres.2020.05.003.
32. LKSAosch, H. and Comes, T. (2019) Gaming as a research method in humanitarian logistics. *Journal of Humanitarian Logistics and Supply Chain Management*. doi:10.1108/JHLSCM-06-2018-0046.
33. Ma, W. and Zhang, S. (2020) Research Methods in Linguistics. *Australian Journal of Linguistics*. doi:10.1080/07268602.2019.1574777.
34. Manu, P. (2013) An investigation into the accident causal influence of construction project features [Abstract of doctoral thesis]. *Journal of International Real Estate and Construction Studies*.
35. Manzoor, B., Othman, I. and Manzoor, M. (2021) Evaluating the critical safety factors causing accidents in high-rise building projects. *Ain Shams Engineering Journal*. doi:10.1016/j.asej.2020.11.025.
36. Manzoor, B., Othman, I., Pomares, J.C. and Chong, H.Y. (2021) A research framework of mitigating construction accidents in high-rise building projects via integrating building information modeling with emerging digital technologies. *Applied Sciences (Switzerland)*. doi:10.3390/app11188359.
37. Manzoor, B., Othman, I. and Waheed, A. (2022) Accidental safety factors and prevention techniques for high-rise building projects – A review *Ain Shams Engineering Journal*. doi:10.1016/j.asej.2022.101723.
38. Martinez, J.G., Gheisari, M. and Alarcón, L.F. (2020) UAV Integration in Current Construction Safety Planning and Monitoring Processes: Case Study of a High-Rise Building Construction Project in Chile. *Journal of Management in Engineering*. doi:10.1061/(asce)me.1943-5479.0000761.
39. Matta, C. (2022) Philosophical Paradigms in Qualitative Research Methods Education: What is their Pedagogical Role? *Scandinavian Journal of Educational Research*. doi:10.1080/00313831.2021.1958372.
40. Md Sofwan, N., Zaini, A.A. and Mahayuddin, S.A. (2016) Preliminary study on the identification of safety risks factors in the high rise building construction. *Jurnal Teknologi*. doi:10.11113/jt.v78.8505.
41. Muhamad Zaini, N.Z., Fikri Hasmori, M., Mat Salleh, M.A., Norazam Yasin, M. and Ismail, R. (2020) Crane Accidents at Construction Sites in Malaysia. In: *IOP Conference Series: Earth and Environmental Science*. 2020 doi:10.1088/1755-1315/498/1/012105.
42. Nind, M., Holmes, M., Insenga, M., Lewthwaite, S. and Sutton, C. (2020) Student perspectives on learning research methods in the social sciences. *Teaching in Higher Education*. doi:10.1080/13562517.2019.1592150.
43. Nind, M. and Lewthwaite, S. (2020) A conceptual-empirical typology of social science research methods pedagogy. *Research Papers in Education*. doi:10.1080/02671522.2019.1601756.
44. Panuwatwanich, K., Roongsrisoothiwong, N., Petcharayuthapant, K., Dummanonda, S. and Mohamed, S. (2020) Ambient intelligence to improve construction site safety: Case of high-rise building in Thailand. *International Journal of Environmental Research and Public Health*. doi:10.3390/ijerph17218124.
45. Park, Y.H., Jeon, H., kim, sung-nam and Kim, M. (2018) (Strategies of Major Nations for Economic Cooperation with Africa and Their Implications). *SSRN Electronic Journal*. doi:10.2139/ssrn.2322569.
46. Putra, A.B., Putra, B.A., Meilani, Suhendra, A. and Arumsari, P. (2021) Analysis on risk management of occupational health and safety on ongoing building project. In: *IOP Conference Series: Earth and Environmental Science*. 2021 doi:10.1088/1755-1315/794/1/012025.
47. Quoc Toan, N., Thi Tuyet Dung, N. and Thi My Hanh, N. (2021) 3D-BIM and 4D-BIM Models in Construction Safety Management. In: *E3S Web of Conferences*. 2021 doi:10.1051/e3sconf/202126302005.
48. Ransford Tetteh, A. and Liang, Y. (2020) Investigating the Occupational Health and Safety Practices in High-Rise Building

Construction Sites. *International Journal of Science and Research (IJSR)*. doi:10.21275/sr20313084800.
49. Ratnaningsih, A., Arifin, S., Suyoso, H., Trisiana, A. and Azkha Yusuf, N. (2019) Risk assessment on occupational accident of apartment building structural work with Failure Mode and Effect Analysis (FMEA) method. *MATEC Web of Conferences*. doi:10.1051/matecconf/201927602016.
50. Rebelo, M., Silveira, F., Czarnocka, E. and Czarnocki, K. (2019) Construction safety on scaffolding: Building information modeling (bim) and safety management-A systematic review *U.Porto Journal of Engineering*. doi:10.24840/2183-6493_005.002_0006.
51. Shaawat, M.E., Almohassen, A.S. and Al-Hamd, A.A.A. (2020) A practical framework for improving profitability for high-rise buildings projects in Saudi Arabia. *Industrial Engineering and Management Systems*. doi:10.7232/iems.2020.19.3.484.
52. Shin, I.J. (2015) Factors that affect safety of tower crane installation/dismantling in construction industry. *Safety Science*. doi:10.1016/j.ssci.2014.10.010.
53. Susanto, S., Hendy, H., Winarno, B. and Candra, A.I. (2020) Measurement Of Occupational Safety And Health Risk Levels Of Kadiri University LP3M Building. *KSAaRsT*. doi:10.30737/KSAarst.v4i2.782.
54. Torrecilla-García, J.A., Pardo-Ferreira, M.C. and Rubio-Romero, J.C. (2021) Overall introduction to the framework of BIM-based digital twinning in decision-making in safety management in building construction industry. *Direccion y Organizacion*. doi:10.37610/DYO.V0I74.600.
55. Yang, Y., Pan, W., Yi, Y. and Sanyuan, N. (2019) Supply chains of high-rise modular buildings in high-density cities *CIB World Building Congress*.
56. Yi, S.L., Zhang, X. and Calvo, M.H. (2015) Construction safety management of building project based on BIM. *Journal of Mechanical Engineering Research and Developments*.
57. Yu, Z. (2021) Research on Safety Management of Construction Site Based on BIM. In: *IOP Conference Series: Earth and Environmental Science*. 2021 doi:10.1088/1755-1315/719/3/032012.
58. Zhang, L. and Geng, L. (2019) Application of BIM technology in construction safety management. In: *Conference Proceedings of the 7th International Symposium on Project Management, ISPM 2019*. 2019 doi:10.26689/jwa2017.v1i1.34.