Penerbit Akademia Baru

Journal of Advanced Research Design

Journal homepage:
https://akademiabaru.com/submit/index.php/ard
ISSN: 2289-7984

The Integration of Building Information Modeling (BIM) in Fire Safety Evacuation Process

Wong Boying[1,*], Aimi Sara Ismail[1], Kherun Nita Ali[1]

[1] Faculty of Built, Environment and Surveying Universiti Teknologi Malaysia Johor, Malaysia

ARTICLE INFO

Article history:
Received 10 March 2025
Received in revised form 9 June 2025
Accepted 14 September 2025
Available online 28 October 2025

Keywords:
Building Information Modeling, Fire Safety Evacuation, Systematic Review, PRISMA

ABSTRACT

In recent years, the construction industry has been actively exploring the applications of Building Information Modelling (BIM) in various areas, including building disaster-prevention management. BIM provides a three-dimensional (3D) visualization of facility layouts and allows for the inclusion of objects and information related to disaster prevention. However, the traditional approach to obtaining approval for building plans still relies on two-dimensional representations, despite the growing demand for stricter controls in the construction industry in Malaysia since the 1980s, including fire safety. Past studies have explored the integration of BIM in evacuation planning, simulation, and analysis methods to improve overall fire safety outcomes. This paper presents a systematic literature review (SLR) conducted to gain insights into integrating BIM in fire safety evacuation processes. The review analyzed the approaches and techniques employed, the key findings, limitations, and recommendations for future works that could be utilized for future development in the Malaysian construction industry. The SLR identified 65 relevant BIM-fire safety evacuation case studies and examined the applied BIM-fire safety evacuation workflows in detail. Among the reviewed studies, 24 applied BIM during the early design stage. The paper highlights the process and outcomes of the SLR, shedding light on the challenges and opportunities in integrating BIM into fire safety evacuation processes. By leveraging BIM technology, stakeholders can improve coordination, enhance information sharing, and ensure better decision-making for the design, construction, and management of safer built environments. The findings of this review contribute to the body of knowledge on BIM integration in the fire safety evacuation process, subsequently assisting researchers, practitioners, and policymakers in creating safer built environments.

1. Introduction

The integration of Building Information Modeling (BIM) technology into fire safety evacuation processes has garnered significant global attention in recent years due to its potential to enhance the safety and efficiency of building evacuation procedures [1]. Across various countries, ensuring the safety of occupants during emergencies remains of paramount importance. The incorporation of BIM

* *Corresponding author.*
E-mail address: boying@graduate.utm.my

https://doi.org/10.37934/ard.146.1.5971

in fire safety evacuation processes presents a valuable opportunity to address prevailing challenges and elevate emergency preparedness within the built environment. This introductory segment will discuss the relevance of BIM in fire safety [2], touch upon common fire safety regulations, and underscore prevalent issues on a global scale.

Fire safety regulations worldwide are typically governed by local building codes and standards that outline guidelines and requisites for constructing safe and compliant structures. More specifically, fire safety regulations in Malaysia are primarily governed by the Uniform Building By-Laws 1984 (UBBL 1984), which outline the guidelines and requirements for constructing safe and compliant buildings [3]. UBBL 1984 addresses various aspects of fire safety, including the provision of escape routes, fire protection systems, and emergency evacuation plans. While UBBL 1984 provides a comprehensive framework, the conventional methods of designing evacuation plans are often limited to two-dimensional representations, which may not adequately address real-world complexities.

The prevailing situation worldwide demonstrates that despite existing regulations, fire safety and evacuation processes within buildings can still pose challenges. The current scenario in Malaysia shows that despite the existence of UBBL 1984 and other regulations, fire safety and evacuation processes in buildings can still be fraught with challenges. Conventional evacuation planning may not fully account for critical factors such as spatial navigation, dynamic occupant behavior, and accessibility for people with disabilities. Moreover, in large or complex structures, visualizing the entire evacuation process using traditional methods can be arduous and prone to errors.

Herein lies the significance of integrating BIM into fire safety evacuation processes. BIM offers a collaborative and data-rich approach to designing, visualizing, and simulating building models in a three-dimensional environment. It allows stakeholders to create detailed virtual representations of buildings, including structural elements, spatial layouts, and safety features, enabling a more accurate and immersive assessment of evacuation strategies.

By adopting BIM for fire safety evacuation planning, the relevant parties can potentially overcome existing challenges and enhance overall building safety. This integration facilitates the development of intelligent evacuation plans, considering factors such as occupant flow, fire spread, and time-critical decision-making processes. Additionally, BIM-driven simulations enable stakeholders to conduct virtual fire drills, identifying potential bottlenecks or hazards before construction even begins.

However, to realize the full potential of BIM in fire safety evacuation processes, it is crucial to address certain implementation challenges. These may include the need for specialized BIM training for relevant stakeholders, establishing industry-wide BIM standards, and ensuring interoperability between different BIM software platforms [4, 5].

As nations across the world strive to create safer and more resilient built environments, integrating BIM into fire safety evacuation processes emerges as a promising solution. This study seeks to explore the feasibility and effectiveness of BIM implementation, aligned with local building codes and international best practices, to foster comprehensive fire safety strategies for buildings on a global scale. By harnessing the capabilities of BIM, countries can pave the way for more efficient and dependable fire safety evacuation processes, thereby ensuring the protection of occupants during emergency scenarios.

2. Methodology

The present study aims to address the need for a more comprehensive analysis of systematic reviews in the field of Building Information Modeling and fire safety evacuation, with a particular

focus on the specific guidelines followed in these reviews. To achieve this, the study utilizes the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol [6]. PRISMA is a well-established protocol for conducting systematic reviews, comprising a 41-item checklist and a four-phase flow diagram (see Fig. 1). Originally designed for the medical field, PRISMA was created by a group of 29 scholars to enhance the transparency and accuracy of literature reviews.

The choice of PRISMA over other existing protocols is justified by its recognized comprehensiveness and extensive use in various disciplines worldwide, extending beyond the medical fields. Additionally, PRISMA's potential to promote consistency across reviews influenced its selection for this study. By analyzing systematic reviews in the related fields through the lens of PRISMA, the research seeks to shed light on the criteria employed in conducting these reviews, providing valuable insights into the quality of existing research in this domain.

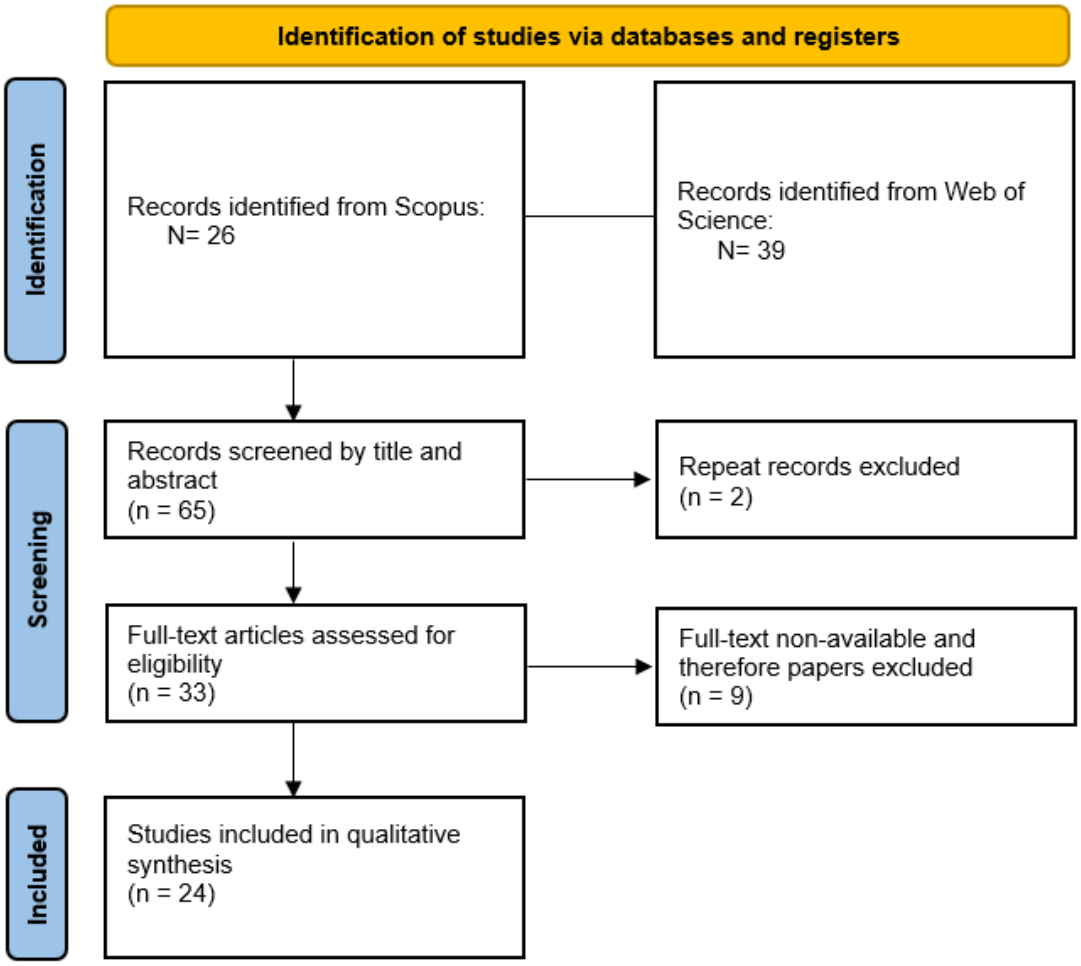

Fig. 1. The PRISMA flow diagram

2.1 Data Sources and Search Strategies

The analysis focused on articles that formed a representative sample of international scientific output published in scientific journals [7]. We systematically searched two electronic databases, Web of Science and Scopus, covering the period from 2013 to 2023. These databases were chosen due to their high value and comprehensive coverage for advanced search capabilities and bibliometric analysis, making them suitable for our study.

In order to maximize the identification of eligible studies, we expanded our search terms and strategies. We adjusted the search terms by incorporating informatics and using Boolean operators. The keywords used for the topic in Web of Science (WoS) and for the article title, abstract, and keywords in Scopus were Building Information Modelling* AND BIM* AND fire safety evacuation* OR fire egress*. Additionally, we manually searched through the reference lists of the eligible articles that were identified during the electronic search.

2.2 Selection of Studies

After exporting the title, abstract, keywords, authors' names and affiliations, journal name, and publication year of the identified records to an MS Excel spreadsheet, the titles and abstracts of the records were independently screened by the reviewer for any papers that clearly did not meet the criteria for systematic reviews, such as empirical, descriptive, and conceptual papers, were excluded from further consideration.

Subsequently, the reviewers will conduct an eligibility assessment by carefully reviewing the full texts of the remaining papers. During this phase, any disagreements between the reviewers were discussed and resolved through a consensus-building process. If consensus could not be reached, the input of a third reviewer would have been sought to resolve the disagreements. All review papers demonstrated, to some extent, explicit, reproducible methods for identifying and selecting the literature, without any preconceived assumptions about the relevance of the selected literature [8, 9, 10].

2.3 Data Extraction Process and Quality Assessment

Subsequently, the reviewers will conduct an eligibility assessment by carefully reviewing the full texts of the remaining papers. During this phase, any disagreements between the reviewers were discussed and resolved through a consensus-building process. If consensus could not be reached, the input of a third reviewer would have been sought to resolve the disagreements. All review papers demonstrated, to some extent, explicit, reproducible methods for identifying and selecting the literature, without any preconceived assumptions about the relevance of the selected literature [8, 9, 10].

2.4 Eligibility Criteria

The process of selecting articles for review involved three rounds of analysis. In the first round, the titles and abstracts of the articles were screened by two reviewers. This initial screening helped identify articles that potentially aligned with the research question. In the second round, a single reviewer conducted a more in-depth analysis of the selected articles. The selection criteria for this round were established based on the research question. The outcomes of this analysis were organized and presented in a table. In the third round, a single reviewer took on the task of reading and integrating all the results from the previous rounds into a single document. This final round aimed to ensure a comprehensive examination of the articles, ultimately deciding which ones would be included in the study.

It is important to note that articles lacking full-text availability were eliminated from consideration at an earlier stage. Additionally, to effectively address the specific research questions, a further exclusion criterion was applied: papers that did not describe research related to the process and outcomes of competence development concerning the integration of Building Information

Modeling (BIM) in fire safety evacuation were excluded from the study. This multi-round selection process highlights the rigorous approach taken to ensure that the articles included in the study were directly relevant to the research objectives and questions.

2.5 Formation of the Analytical Corpus

The studies included in the list were structured according to their publication year and arranged alphabetically by the first author's surname. Each article was assigned a unique numerical code. The thematic content analysis of these articles was conducted using methodologies and approaches outlined by Bardin [11].

A total of 65 articles were obtained through the search using the specified inclusion criteria. Following the implementation of exclusion criteria (depicted in Figure 1), the pool was refined, resulting in 24 articles that align with the focus of the current systematic literature review. Among these, nine articles (n = 9) were deemed unrelated to our research inquiries and subsequently excluded.

2.6 Characteristics of Included Studies

The analysis phase comprised three key stages: thematic analysis, result deliberation, and conclusion derivation. Thematic analysis involved evaluating established categories to showcase their applicability across different stages of the life cycle. The concluding phase encompassed both the presentation and discussion of the obtained outcomes. The organization and delineation of the primary components in this paper align with the guidelines outlined in the PRISMA checklist for literature reviews [13]. PRISMA, standing for Preferred Reporting Items for Systematic Reviews and Meta-analyses, aims to enhance the effectiveness of literature reviews by adhering to a standardized framework for articulating research findings [13].

3. Results

This section unveils the outcomes unearthed from the systematic review process mentioned earlier. These results have been systematically structured in alignment with the research inquiries that shaped both our investigation and analysis.

The chosen articles encompassed various types of publications, with journal papers comprising 54.2%, articles presented in conference proceedings making up 41.7%, and review papers accounting for 4.1%. Among the total sample of 24 articles, 15 were sourced from Building Engineering, 7 from the Sustainable Built Environment, and 2 from the International Symposium on Automation and Robotics in Construction and Mining (ISARC). A significant majority, more than 80% of the articles, fall under the categories of simulation and social science, while the remainder comprise case studies conducted across diverse scenarios. The investigation into the intersection of Building Information

Modeling (BIM) and fire safety evacuation has exhibited a noticeable growth in BIM adoption capability and heightened awareness regarding fire safety evacuation protocols. Notably, a predominant portion of the articles focus on BIM integration within the context of fire safety evacuation during the construction phase, preceding the project's handover to end-users. This emphasis could be attributed to the potential for BIM's integration in the design phase and on-site implementation of fire egress systems within construction sites.

The year 2022 stands out in our search as having the highest number of included studies, as shown in Figure 2. Our findings reveal a notable rise in the quantity of published studies over the

span of 10 years. BIM and fire safety evacuation have been utilized to enhance various tasks across different stages. During the construction phase, these activities are categorized into four application domains: safety, prediction, construction planning, and on-site guidance. Activities are clustered into maintenance and operational functions within the facilities management phase. In the design phase, the primary focus lies in assessing the feasibility of employing BIM and fire safety evacuation during collaborative review sessions. Among the chosen articles, the topics most frequently addressed are safety, prediction, and design review. In contrast, the least extensively examined subject pertains to utilizing BIM and fire safety evacuation for building operations.

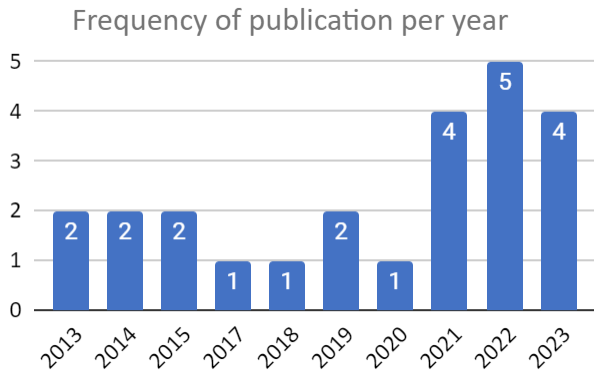

Fig. 2. Frequency of Publication per year

4. Discussion

The integration of Building Information Modeling (BIM) in fire safety evacuation has gained significant attention in recent years. Numerous studies have explored different aspects of this integration, ranging from fire safety analysis and design optimization to risk assessment and evaluation. A systematic literature review provides valuable insights into the current state of research and identifies key challenges, lessons, and opportunities in this field [20]. More papers have been published after the pandemic, which may be related to the increase in the level of awareness of BIM and fire safety evacuation in this industry. A large percentage of the papers also focused on integration, adoption and awareness, while insufficient paper supported the design of the building or construction process.

It is worth noting that systematic reviews, much like other forms of reviews, often entail procedures and interpretive practices that may not necessarily be entirely objective. In light of this, scholars critically analyze the 'discourse of systematic review,' highlighting that reviews not only represent existing knowledge but also contribute to shaping knowledge within distinct political and socio-cultural contexts. Despite this, the concept of employing clear and comprehensive guidelines remains crucial in order to minimize bias and generate reliable (and less subjective) evaluations of the existing knowledge landscape.

The surge in BIM-related research post-pandemic underscores a heightened industry awareness of its potential applications in fire safety evacuation. However, an intriguing observation is the disproportionate emphasis on integration, adoption, and awareness, with a notable gap in supporting the actual design and construction processes. This calls for a reevaluation of research priorities to bridge the divide between theoretical emphasis and practical application. One such guideline is the PRISMA protocol [6], which could be a valuable tool for researchers in the field of

construction. It offers an extensive checklist for evaluating current and future trends in any domain. Regrettably, our study reveals that only a mere five reviews adhered to such a protocol. Additionally, in the majority of reviews published in building technology journals, many of the eligibility criteria outlined by the PRISMA protocol were either overlooked or not explicitly mentioned in the papers. As an example, even essential information underpinning the review, such as the specific keywords used for database searches, often remained unspecified in the published reviews.

4.1 BIM in Fire Safety

The inconsistencies arising from the comparison of various systematic reviews can be attributed to the multi/interdisciplinary nature of fire safety and the integration of new technology in construction. Notably, Building Information Modeling (BIM) has emerged as a promising tool for fire safety analysis in complex buildings. BIM empowers designers and engineers to visualize and simulate fire scenarios, evaluate potential risks, and optimize fire safety designs [21]. BIM-based frameworks have been developed to streamline fire safety analysis by incorporating pertinent information, including building geometry, material properties, and occupant behavior [22]. The visualization and simulation capabilities of BIM enable designers and engineers to assess fire hazards, evaluate evacuation routes, and refine emergency response strategies. However, to gain a comprehensive understanding, it is essential to consider the scope of regulations and rules applied in the research and inquire about any specific case studies, such as the type of building involved in the analysis.

Consider the case of the Petronas Towers in Kuala Lumpur, Malaysia, an iconic pair of skyscrapers that exemplify the complexities associated with tall building designs and the need for robust fire safety measures (Wajdi et al., 2020). In the context of the Petronas Towers, compliance with UBBL regulations is crucial, and the case study could delve into how these regulations influenced the design of fire-rated compartments, placement of exits, sizing of stairwells, and the implementation of emergency lighting and signage (Fu, 2018). This real-world example would serve to highlight the practical implications and implementation challenges associated with adhering to fire safety evacuation provisions. This additional information would contribute to a more nuanced assessment of the effectiveness of BIM in fire safety within specific regulatory frameworks and building contexts.

4.2 Benefits of BIM Integration

The reviewed studies consistently highlighted the potential benefits of integrating BIM in fire safety evacuation processes. The overarching goal of these studies is to seamlessly incorporate BIM into evacuation processes, thereby refining planning, response mechanisms, and the overall safety of buildings. The developed frameworks are intended to provide real-time visualization of escape routes, facilitate decision-making for occupants and emergency responders, and enable the simulation of evacuation scenarios. The output of these frameworks often includes evacuation route recommendations, hazard identification, and optimized exit designs. One of the key advantages is improved accuracy and reliability. BIM allows for the creation of a detailed 3D model that accurately represents the building and its components, enabling more precise analysis of fire safety measures [23; 24]. This level of accuracy helps identify potential fire hazards and design flaws early in the process, leading to improved fire safety outcomes. For instance, Wang, Li, Pan, and Wang (2020) conducted a case study on the BIM-based fire safety analysis of underground rail transit stations, considering factors such as smoke movement, evacuation time, and emergency response [25]. Such simulations allow stakeholders to identify potential fire hazards, optimize evacuation routes, and evaluate the effectiveness of fire safety measures.

4.3 Diverse Approaches in BIM Integration

The reviewed studies exhibit a diverse range of approaches in developing BIM-integrated fire evacuation systems. Notably, data fusion techniques play a crucial role, involving the amalgamation of BIM data with real-time fire and smoke data. This integration enhances the accuracy and relevance of simulations, providing a more realistic representation of emergency scenarios. Additionally, several studies adopt agent-based simulations to model occupant behavior during evacuations, offering valuable insights into the dynamic human element of emergency situations.

Machine learning algorithms are also prominently featured in these studies, contributing a predictive dimension to evacuation planning. These algorithms are employed to forecast evacuation times, adding a valuable tool for optimizing emergency response strategies. It's important to note that the methods used are not rigidly confined to qualitative or quantitative approaches; they encompass a spectrum of techniques, including machine learning, to cater to the diverse aspects of fire safety analysis.

Furthermore, the studies highlight the utilization of platforms like Autodesk Revit, Bentley MicroStation, and Trimble SketchUp, along with the integration of custom-developed plugins and modules. These plugins play a pivotal role in extending the functionality of BIM tools, offering tailored solutions to address specific fire safety concerns. While the specific details of the machine learning techniques employed may vary, they generally involve algorithms capable of learning patterns and making predictions based on the integrated data.

In the context of plugins, they serve as additional software components that enhance the capabilities of existing BIM platforms. These plugins can be custom-developed to meet the unique requirements of fire safety analysis within BIM frameworks. For instance, they may facilitate the integration of real-time data sources, enhance simulation engines, or provide specialized visualization features.

In summary, the development methods utilized in these studies are versatile and encompass a combination of data fusion techniques, agent-based simulations, machine learning algorithms, and the integration of custom-developed plugins. This flexibility allows researchers to tailor their approach to the specific challenges posed by fire safety in complex building environments.

4.4 Opportunities and Challenges

Successful implementations of BIM-integrated fire evacuation systems, creating digital twins linked with sensors and simulation engines, highlight practical applications. Despite the potential benefits, integrating BIM in fire safety compliance checking also faces several challenges. One major challenge is the issue of data interoperability. BIM's different software platforms and data formats can hinder seamless data exchange and integration. Additionally, the lack of standardized fire safety codes and regulations poses challenges in aligning BIM models with regulatory requirements. Collaboration among stakeholders, including architects, engineers, fire safety consultants, and authorities, is crucial to address these challenges [22, 23]. This interoperability challenge hampers the seamless integration of fire safety analysis tools with the BIM model. The complexity of BIM technology was another challenge identified in the literature. BIM requires specialized skills and knowledge to effectively utilize its capabilities for the fire safety evacuation process [22, 24]. The complexity of BIM tools and workflows can pose a barrier to adoption, particularly for smaller organizations with limited resources and expertise. Cost implications associated with BIM adoption were also highlighted as a challenge. Implementing BIM technologies and training personnel can incur significant upfront costs [22, 23]. Due to cost constraints, small- and medium-sized fire safety

consulting firms or organizations with limited resources may face challenges in adopting BIM. The required financial investment may deter some organizations from fully embracing BIM for fire safety compliance checking, especially if the benefits outweigh the costs. Addressing these challenges requires collaboration among stakeholders, including fire safety professionals, architects, engineers, software developers, and regulatory authorities. Standardization efforts, knowledge sharing, and industry-wide initiatives can play a vital role in overcoming these challenges and promoting the effective integration of BIM in the fire safety evacuation process.

The discussion prompts reflection on how the findings shape current fire safety evacuation practices. BIM's potential in optimizing evacuation routes, improving decision-making, and early hazard detection emphasizes its role in enhancing overall safety. The challenges identified highlight areas for improvement, emphasizing the need for collaborative efforts and standardization to overcome obstacles to BIM adoption. The tangible outcomes of BIM integration, such as real-time visualizations and optimized designs, suggest a transformative impact on fire safety practices. The discussion serves as a call to action for industry stakeholders, urging them to leverage the benefits of BIM while actively addressing challenges to foster widespread adoption and ensure continuous advancements in fire safety evacuation practices. The nuanced understanding gained from the findings offers a roadmap for refining existing practices, emphasizing the need for adaptability, collaboration, and a commitment to technological integration for enhanced safety outcomes in fire emergencies.

Table 1
Article classifications and findings

ID	AUTHOR	CASE STUDY USED	APPROACH USED	KEYWORDS RELATED	YEAR OF PUBLICATION	DOCUMENT TYPE	SOURCE
1	Rüppel U.; Schatz K.	BIM-Based serious game for fire safety evacuation	Simulation	BIM, Fire Safety Evacuation	2013	Article	Scopus
2	Wang B.; Li H.; Rezgui Y.; Ong H.N.	Virtual building system for building performance	Simulation	BIM Stimulation	2013	Conference paper	Scopus
3	Wang B.; Li H.; Rezgui Y.; Bradley A.; Ong H.N.	BIM-based virtual environment for fire emergency evacuation	Simulation	BIM, Fire Evacuation	2014	Article	Scopus
4	Wang K.-C.; Shih S.-Y.; Chan W.-S.; Wang W.-C.; Wang S.-H.; Gansonre A.-A.; Liu J.-J.; Lee M.-T.; Cheng Y.-Y.; Yeh M.-F.	Application of BIM in designing fire evacuation	Case study	BIM, Designing Fire	2014	Conference paper	Scopus
5	Wu C.; Zarrinmehr S.;	Facilitating fire and smoke	Simulation	Fire Evacuation, BIM	2015	Conference paper	Scopus

	Asl M.R.; Clayton M.J.	simulation using BIM					
6	Zhang J.; Issa R.R.A.	Performance-based fire safety design	Data Collection	Fire Safety	2015	Conference paper	Scopus
7	Yan F.; Hu Y.; Guo Q.; Tang K.; Jia J.; Zhu H.	Virtual training for fire evacuation	Simulation	Fire Evacuation	2017	Conference paper	Scopus
8	Eftekharirad R.; Nik-Bakht M.; Hammad A.	Linking sensory data to BIM by extending IFC (fire evacuation)	Case study	BIM, Fire Safety Evacuation	2018	Conference paper	Scopus
9	Yan F.-T.; Hu Y.-H.; Jia J.-Y.; Guo Q.-H.; Zhu H.-H.; Pan Z.-G.	Fire evacuation system using software	Simulation	Fire Evacuation System	2019	Article	Scopus
10	Ai Z.; Hu Y.; Yan F.; Zhang H.; Wang D.; Qing S.; Zhu H.; Jia J.	Fire escape using Web3D planning	Simulation	Fire Escape, Fire Evacuation	2019	Article	Scopus
11	Liu Z.; Zhang A.; Wang W.; Wang J.	Fire evacuation method based on digital twin model	Simulation	BIM-Based, Fire Evacuation	2020	Review Paper	Scopus
12	Wehbe R.; Shahrour I.	Bim-based system for fire evacuation	Simulation	BIM-Based, Fire Evacuation	2021	Article	Scopus
13	Liu J.; Zhang R.; Yan W.; Sun L.	Evacuation of building based on BIM & GIS	Review	Fire Evacuation	2021	Conference paper	Scopus
14	Beyaz C.; Ozgener E.D.; Bagcl Y.G.; Akln O.; Demirel H.	Integration of BIM for fire evacuation	Simulation	BIM, Evacuation Stimulation	2021	Conference paper	Scopus
15	Jiang S.; Zhang B.; Cui Q.	Risk Assessment for Fire Evacuation supported by BIM	Quantitative assessment	Fire Evacuation, BIM	2021	Conference paper	Scopus
16	Gao R.-J.; Wang K.-C.; Lai X.-H.; Hung W.-H.	Fire Evacuation based on BIM and VR	Case Study	Fire Evacuation, BIM	2022	Conference paper	Scopus
17	Yu X.; Yu P.; Wang C.; Wang D.; Shi W.; Shou	Integrating VR and BIM for Improving	Simulation	BIM, Emergency Response	2022	Article	Scopus

	W.; Wang J.; Wang X.	Emergency Response Training					
18	Jiang A.; Mo Y.; Kalasapudi V.S.	Challenges of Fire Emergency Evacuation	Review	Fire Emergency Evacuation	2022	Review	Scopus
19	Yakhou N.; Thompson P.; Siddiqui A.; Abualdenien J.; Ronchi E.	Integration of BIM and Fire Evacuation Model	Simulation	BIM, Fire Evacuation Models	2022	Article	Scopus
20	Kanangkaew S.; Jokkaw N.; Tongthong T.	Integration of BIM and AR in Fire Evacuation System	Simulation	Fire Evacuation System, BIM	2022	Article	Scopus
21	Soltaninejad M.; Noorzai E.; Faraji A.	Enhance Fire Evacuation operation using BIM	Simulation	Fire Evacuation, BIM	2023	Article	Scopus
22	Zhang, N; Liang, Y; Zhou, CF; Niu, MM; Wan, F	Study on Fire Smoke Distribution and Safety Evacuation Based on BIM	Simulation	Fire Safety Evacuation, BIM	2023	Review Paper	WOS
23	Gerges, M; Demian, P; Khalafallah, A; Salamak, M	Evacuation Simulation using Smartphones	Simulation	Fire Evacuation	2023	Journal	WOS
24	Mohammadiounotikandi, A; Fakhruldeen, HF; Meqdad, MN; Ibrahim, BF; Navimipour, NJ; Unal, M	Fire Evacuation in Smart Building on the IoT	Simulation	Fire Evacuation	2023	Journal	WOS

5. Conclusions and recommendation

The systematic literature review underscores the growing interest in integrating Building Information Modeling (BIM) into fire safety evacuation processes. Despite the numerous advantages associated with BIM adoption in this context, there are challenges that need addressing to fully exploit its potential for ensuring fire safety. The review emphasizes both the potential benefits and challenges linked to BIM integration in fire safety and contribute valuable insights to the existing body of knowledge while highlighting avenues for future research.

In terms of techniques used, the review reveals a variety of approaches employed in the development of BIM-integrated fire safety evacuation systems. These include data fusion techniques,

agent-based simulations, and the application of machine learning algorithms for predictive modeling. Additionally, the integration of BIM tools such as Autodesk Revit, Bentley MicroStation, and Trimble SketchUp, alongside the use of custom-developed plugins, is a common trend among the reviewed studies.

The adoption of Autodesk Revit or similar software is particularly noteworthy as it aligns with the preference for tools that designers are already familiar with. This choice streamlines the integration process, ensuring that designers can readily incorporate BIM into their existing workflows. Familiarity with the software enhances efficiency, reduces learning curves, and facilitates a smoother transition towards incorporating BIM for fire safety analysis.

The adoption of BIM is shown to benefit designers by providing them with a visual representation of the building, enabling better understanding and communication of fire safety strategies. The 3D models created in BIM offer a comprehensive view, aiding in the assessment of fire hazards, evaluation of evacuation routes, and optimization of emergency response strategies. This enhanced analysis capability helps identify potential risks and allows for the development of more effective fire safety designs.

In summary, the systematic literature review highlights the diverse techniques employed in BIM integration for fire safety, emphasizes the preference for familiar tools like Autodesk Revit, and underscores how the adoption of BIM benefits designers by enhancing visualization, communication, and overall analysis of fire safety strategies in buildings.

Acknowledgement
We would like to thank Ministry of Higher Education under Fundamental Research Grant Scheme, UTM, FRGS/1/2022/SSI02/UTM/02/33 for supporting this research.

References

[1] Paul, Shimonti. "BIM Adoption around the World: How Good Are We?" Geospatial World, *Geospatial Media & Communications*, December 14, 2018. https://www.geospatialworld.net/article/bim-adoption-around-the-world-how-good-are-we/.
[2] Wang, Shih-Hsu, et al. "Applying Building Information Modeling to Support Fire Safety Management." *Automation in Construction*, vol. 59, 2015, pp. 158–167. https://doi.org/10.1016/j.autcon.2015.02.001.
[3] Department of Standards Malaysia. Uniform Building By-Laws (UBBL) 1984. Ministry of Works Malaysia, 2020.
[4] Ronchi, Enrico. "Developing and Validating Evacuation Models for Fire Safety Engineering." *Fire Safety Journal*, vol. 120, no. 103020, 2021, p. 103020. https://doi.org/10.1016/j.firesaf.2020.103020.
[5] Ronchi, Enrico, and Daniel Nilsson. "Basic Concepts and Modelling Methods." *Evacuation Modeling Trends, Springer International Publishing*, 2016, pp. 1–23.
[6] Liberati, Alessandro, et al. "The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration." *PLoS Medicine*, vol. 6, no. 7, 2009, p. e1000100. https://doi.org/10.1371/journal.pmed.1000100.
[7] Durán-Sánchez, Amador, et al. "Religious Tourism and Pilgrimage: Bibliometric Overview." *Religions*, vol. 9, no. 9, 2018, p. 249. https://doi.org/10.3390/rel9090249.
[8] Booth, Andrew. "Searching for Qualitative Research for Inclusion in Systematic Reviews: A Structured Methodological Review." *Systematic Reviews*, vol. 5, no. 1, 2016, p. 74. https://doi.org/10.1186/s13643-016-0249-x.
[9] Petticrew, M., and H. Roberts. Systematic Reviews in the Social Sciences: A Practical Guide. Blackwell Publishing Ltd, 2006.
[10] Pickering, C., and J. Bryne. "The Benefits of Publishing Systematic Quantitative Literature Reviews for PhD Candidates and Other Early Career Researchers." *Higher Education Research and Development*, vol. 33, 2014, pp. 534–548.
[11] Bardin, L. Análise de Conteúdo. Edições 70: São Paulo, Brazil, 2011; ISBN 978-85-62938-04-7.
[12] Cruzes, D.S., Dybå, T. "Synthesizing evidence in software engineering research." *ACM*, 2010. https://doi.org/10.1145/1852786.1852788.

[13] Clarke, M., Devereaux, P.J., Kleijnen, J., Moher, D. "The PRISMA statement for reporting systematic reviews and Meta-analyses of studies that evaluate health care interventions: explanation and elaboration." *PLoS Med*. 6 (7) (2009), e1000100. https://doi.org/10.1371/journal.pmed.1000100.
[14] Gokhale, Angelina, et al. "A Bibliometric Analysis of Digital Image Forensics." *Science & Technology Libraries*, vol. 39, no. 1, 2020, pp. 96–113. https://doi.org/10.1080/0194262x.2020.1714529.
[15] Roemer, R. C., and R. Borchardt. Meaningful Metrics: A 21st Century Librarian's Guide to Bibliometrics, Altmetrics, and Research Impact. *Association of College and Research Libraries*. 2015.
[16] Milian, Eduardo Z., et al. "Fintechs: A Literature Review and Research Agenda." *Electronic Commerce Research and Applications*, vol. 34, no. 100833, 2019, p. 100833. https://doi.org/10.1016/j.elerap.2019.100833.
[17] Blanco-Mesa, Fabio, et al. "Fuzzy Decision Making: A Bibliometric-Based Review." *Journal of Intelligent & Fuzzy Systems*, vol. 32, no. 3, 2017, pp. 2033–2050. https://doi.org/10.3233/jifs-161640.
[18] Martínez-López, F. J., et al. "Fifty Years of the European Journal of Marketing: A Bibliometric Analysis." *European Journal of Marketing*, vol. 52, no. 1/2, 2018, pp. 439–468.
[19] Mas-Tur, Alicia, et al. "Half a Century of Quality & Quantity: A Bibliometric Review." *Quality & Quantity*, vol. 53, no. 2, 2019, pp. 981–1020. https://doi.org/10.1007/s11135-018-0799-1.
[20] Deuble, M., et al. "A Review on Integrating Fire Safety Design with BIM: Challenges, Lessons, and Opportunities." *Automation in Construction*, vol. 122, 2021.
[21] Hu, Y., et al. "A Review of BIM-Based Fire Safety Analysis for Complex Buildings." *Journal of Building Engineering*, 2021.
[22] Chen, Y., et al. "A BIM-Based Framework for Fire Safety Analysis of Buildings." *Journal of Information Technology in Construction (ITcon)*, vol. 24, 2019, pp. 477–497.
[23] Smith, D., et al. "BIM for Fire Safety Design of Complex Building Environments." *International Journal of Construction Management*, vol. 18, no. 3, 2018, pp. 218–227.
[24] Wang, Y., et al. "BIM-Based Fire Safety Analysis of Underground Rail Transit Stations: A Case Study of Shanghai Metro." *Automation in Construction*, vol. 119, 2020.
[25] Wang, Y., et al. "BIM-Based Fire Safety Analysis of Underground Rail Transit Stations: A Case Study of Shanghai Metro." *Automation in Construction*, vol. 119, 2020.
[26] Kim, J. Y., and J. Lee. "Integrating BIM and Fire Simulation for Fire Safety Analysis of Complex Underground Spaces." *International Journal of Architectural Computing*, vol. 15, no. 2, 2017, pp. 112–127