Enhancing Disaster Management for Human Emergency Evacuation using an Integration of the Social Force Model and Agent-Based Simulations

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Abstract

Purpose: The purpose of this review study is to consolidate and evaluate existing research on flood and disaster evacuation modelling, with a specific focus on human behaviour during emergencies and the effectiveness of various simulation models. By utilizing secondary sources from published documents, the study aims to provide a comprehensive overview of current methodologies and their applications in disaster management. This review seeks to identify common themes, highlight significant findings, and uncover gaps in the literature to inform future research and improve the planning and execution of evacuation procedures. Ultimately, the study aims to enhance the understanding and propose effective evacuation strategies, contributing to increased public safety and more efficient disaster management practices.

Design/methodology/approach: The methodology involves a comprehensive literature review of existing studies on flood and disaster evacuations, focusing on human behaviour during emergencies and the effectiveness of various simulation models. Relevant academic articles, books, and reports were identified through databases such as Google Scholar, PubMed, Scopus, Google Scholar and IEEE Xplore. Keywords used for the search included "flood evacuation", "disaster management", "human evacuation behavior", "human evacuation", "human evacuation movement", "Social Force Model", "Agent-Based Simulation," and "hybrid models".

Findings: Synthesis of findings is from the extracted information to provide an overview of the current state of research on flood and disaster evacuation modelling. Particular attention was given to identifying common themes, gaps in the literature, and areas where further research is needed. The review included a critical analysis of the methodologies and findings of the selected studies. This involved assessing the strengths and limitations of different simulation models (e.g., SFM, ABS, hybrid models) and their applicability to various disaster scenarios.
Research limitations/implications: The primary limitation of this review study is its reliance on secondary data from published documents rather than primary data collection. This approach may lead to the exclusion of recent, unpublished findings or emerging trends that are not yet documented in the literature. Additionally, the quality and comprehensiveness of the review are dependent on the availability and accessibility of relevant publications. While the study aims to provide a thorough overview, it may not capture all nuances and regional variations in human behaviour during evacuations. Future research could address these limitations by incorporating primary data collection and expanding the scope to include a broader range of sources.
Practical implications: The findings of this review have significant practical implications for emergency planners, building designers, and policymakers. By synthesizing current knowledge on flood and disaster evacuation models, the study provides insights into effective strategies for managing evacuations in various scenarios. The critical analysis of different simulation techniques (SFM, ABS, hybrid models) offers guidance on selecting appropriate models for specific applications, enhancing the planning and execution of evacuation procedures. This information can help optimize resource allocation, design safer buildings, and develop more efficient evacuation plans, ultimately improving public safety during emergencies.
Originality/value: This review paper offers a valuable contribution to the field of disaster management by consolidating and critically evaluating existing research on evacuation modelling. The use of secondary data allows for a broad perspective on established methodologies and their effectiveness, providing a comprehensive overview that is not limited by the constraints of primary data collection. The study highlights the strengths and limitations of various simulation models, offering a nuanced understanding of their applicability in different disaster scenarios. This review serves as a resource for researchers and practitioners, fostering informed decision-making and encouraging further research to address identified gaps and emerging challenges in evacuation modelling.

Keywords: Emergency evacuation, simulation models, Social Force Model, Agent-based Simulation, hybrid model, disaster management, operation research

Introduction

The unpredictability of human behavior in emergencies, characterized by panic and the emergent need to follow or avoid others, makes real-time evacuation drills impractical. Therefore, simulation models offer a feasible alternative for planning and training purposes. Simulation models are critical tools used to understand, predict, and analyze the behavior of systems under various conditions. They are particularly useful in scenarios where real-life experimentation is impractical due to cost, time, or safety concerns. Furthermore, modelling is a method of solving problems by creating a simplified representation of a real system. The representation, known as a model, replicates the system's behavior and can be manipulated to observe different outcomes.

Simulation refers to running the model using algorithms to mimic the real system's operations over time (Abu Bakar, N. A., Zakaria, S. A., & Aminuddin, A., 2023). In operational research, simulation models are popular because they provide a closer representation of actual scenarios, enabling the testing of various "what-if" scenarios efficiently and cost-effectively. Emergency evacuation models are essential for planning and managing emergency situations in crowded environments, such as buildings on fire or any disasters happen such as flood or earthquake. These models aim to predict human behavior and movement, identify potential bottlenecks, and optimize evacuation procedures to enhance safety and efficiency.

Evacuation simulation has been applied in Operational Research (OR) to provide closer representation of real scenario that happens in investigated environment. Evacuation simulation is needed in tackling some issues such as to investigate various of human movements (Rozo, Arellana, Santander-Mercado, & Jubiz-Diaz, 2019). An evacuation simulation model with possible scenarios can be investigated and analyzed with the aim of improving the effectiveness and accuracy of one situation. For instance, the purpose is to reduce costs and time during emergency evacuation (Sano, T., et. al, 2017).

Evacuations during emergencies are actions in panic situations of human movements where humans quickly change their directions and move faster from initial to the destinations. On the other hand, evacuation entailed egress. Egress is the act of leaving or going out of one place. Meanwhile, evacuation egress (EE) means the urgent, immediate egress or escape of people from an area that contains an imminent threat, an ongoing threat, or a hazard to their lives (Sawano, T.,et. al, 2023).

Human movements are changes made in relation to places, positions, or postures in certain environments. Prior to evacuations, people often described human movement as walking normally at all times. If emergencies happen, humans tend to evacuate. These hazardous events threaten people's lives and force people who are trying to escape from a dangerous area to immediately move. This scenario demonstrates that the study of human evacuation in close proximity, like an office building, has become a significant field in recent decades, necessitating the resolution of several issues (Yuan et al., 2019).

Consequently, evacuation drills in the building are held to encourage people to practice evacuation skills and to ensure they are familiar with the environment. However, these drills cannot accurately represent real emergencies, and in some cases, people may be injured during real practice. Furthermore, human movement is difficult to model correctly during real evacuation practice or training because such practices are not concerned on how people move, individual emotion and individual differences, obstacles and many more. It is impractical in terms of cost, time-consuming, and safety to perform various evacuation drills in real-time for emergency evacuation (Rozo et al., 2019). Therefore, we need emergency evacuation simulations to effectively address these challenges and ensure the safety and preparedness of individuals without the risks and impracticalities associated with real-life drills (Samsudin, W. N. A. W., & Ghazali, K. H., 2019).

In short, this study is emphasizing the importance of efficient disaster management practices, which are crucial for the stability and continuity of business operations worldwide. Effective evacuation strategies not only protect human lives but also minimize the economic impact of disasters on businesses and communities (Rozo, K. R., et al. al, 20190. By synthesizing current knowledge on evacuation modeling, this research provides valuable insights that can inform policy-making, strategic planning, and resource allocation in the context of global business and management. Additionally, the study highlights the role of innovative simulation technologies in enhancing resilience and sustainability, key priorities for businesses operating in a globalized and interconnected world

Related Work

Floods and other disasters significantly impact human lives, infrastructure, and the environment, necessitating effective evacuation models to mitigate their effects. Simulation models play a crucial role in disaster management by providing insights into human behavior and movement during evacuations, helping to plan, execute, and evaluate evacuation procedures without the risks associated with real-life drills. These models, which include the Social Force Model (SFM), Agent-Based Simulation (ABS), and hybrid models, consider various factors such as population density and building size to optimize evacuation routes. Despite their broad applicability across fields like military simulation, safety science, and city planning, one of the main challenges in developing accurate simulation models for human evacuation is capturing the complexity and diversity of human movement. Researchers have proposed hybrid models that combine multiple simulation techniques to produce more realistic and efficient results. Thus, the literature review emphasizes the importance of utilizing different simulation techniques and addressing their limitations to enhance safety and efficiency during emergencies, particularly for recurrent and rapid-onset events such as floods or disasters 9Fernandez, S. V., et. al, 2019).

Floods and Disasters

Floods and other disasters significantly impact human lives, infrastructure, and the environment, necessitating effective evacuation models to mitigate their effects. Floods, in particular, are recurrent events that demand comprehensive evacuation planning due to their rapid onset and widespread impact. Moreover, these kinds of disasters, such as floods, earthquakes, and fires, pose significant threats, requiring immediate and efficient evacuation strategies. Therefore, effective disaster management necessitates a thorough understanding of human behavior and movement during evacuations. Various models help in planning, executing, and evaluating evacuation procedures without the risks associated with real-life drills 9Fernandez, S. V., et. al, 2019).

Recent advancements highlight the broad applicability of simulation and modeling across fields like military, architectural design, safety science, entertainment, psychology, training systems, robotics, sociology, city planning, and traffic engineering (Burghout, W., & Koutsopoulos, H. N., 2019). These models are categorized into continuous and discrete models, each providing different perspectives on system dynamics. Continuous models use equations with variables representing real values to calculate the state of the system at any point, while discrete simulations model state changes over time or events (Chao, Q.,et. al, 2019).

Human Behavior during Evacuation

Human movement is the motion and flow of people from the first place to another. The movement or motion involves the changes of a person in a place, position or posture relative to some point in the environment. The sociological, environmental, psychological, mechanical, physiological and anatomical are all factors that must be built into one's concept of movement. The maximum linear densities (persons/distance) of the crowd along the flow path and in the side direction, above which people are assumed not to be able to move due to their proximity, care, respectively, the critical (minimum) linear densities of the crowd along the flow path and in the side direction for free movement (Ahmadi, C., Karampourian, A., & Samarghandi, M. R., 2022).

The complexity of human movement during evacuations, such as the tendency to follow familiar routes and the influence of social behaviors, poses challenges for accurate modeling. Historical data and fire reports indicate that most fire-related incidents occur in commercial buildings, which underscores the need for realistic simulation models that account for the specific dynamics of such an environment (Borowska-Stefańska, M., Kowalski, Michałand Wiśniewski, S., & Dulebenets, M. A., 2023).

Human evacuation during emergencies, such as fires, floods, and earthquakes, is a critical area of research due to the significant threat these events pose to human life and infrastructure. Emergency evacuation involves two or more humans communicating and interacting with each other in the same period, at the same location and for the same purpose, which is to egress. Then, for evacuation related to crowds can estimate traffic needs and increase safety elements and efficiency. Many research problems regarding human movement and evacuation have arisen. On the other hand, effective disaster management relies on a thorough understanding of human behavior and movement during evacuations. This understanding is often developed through the use of simulation models, which help in planning, executing, and evaluating evacuation procedures without the risks associated with real-life drills (Bi, H. & Gelenbe, E., 2019).

Simulation models are particularly valuable in operational research for representing real conditions and studying system characteristics. These models involve general rules and algorithms, often resembling real-time applications. They are crucial in scenarios where real-life experiments are impractical due to technical difficulties, ethical concerns, or high risks. Simulation models for flood evacuations consider various factors, including population density, terrain, water flow, and infrastructure. These models help in designing evacuation routes and determining safe zones.

Besides, simulation models for human evacuation take into account a variety of factors, such as population density, building layout, exit availability, and human behavioral patterns. These factors are critical for designing efficient evacuation routes, determining safe zones, and optimizing resource allocation during emergencies. Research has shown that the proximity of exits and bottlenecks created by high-density populations has a significant impact on evacuation efficiency.

Furthermore, the literature highlights the importance of incorporating real-world data into simulation models to improve their accuracy and reliability. This includes data on human behavior during past evacuations, building layouts, and environmental conditions. Such data-driven models can better predict human flows and inform the development of more effective evacuation strategies. Overall, the literature review underscores the critical need for advanced simulation models to understand and improve human evacuation processes.

Modelling and Simulation

Simulation models play a crucial role in disaster management, providing insights into human behavior and movement during evacuations. These models help in planning, executing, and evaluating evacuation procedures without the risks associated with real-life drills. A comprehensive review of previous works is presented to understand the simulation and modelling techniques, especially in the context of human evacuation during emergencies such as fire, flood or earthquake. According to Bianco and Musse (2019) and Yuan et al. (2019), simulation is defined as the act of representational a system by a symbolic model that can easily be manipulated and produces numerical results. Thus, it is not only an imitation process of a real system over time but also a simplified mimicking of an operational system to consider and enhance the system behaviour (Majid et al., 2019). They also stated that simulation indicates a large gathering of models and applications to mimic, predict and present virtually the behavior of real systems. In addition, simulation was also described as a representation of the operation, such as the human movement using a computational and graphical tool. Over the years, a significant amount of attention from different research fields has been brought to simulation and modelling. Few simulation approaches or modelling techniques have been reviewed, such as Cellular Automata (CA), Agent-based Simulation (ABS), and Social Force Model (SFM).

CA is a discrete, decentralized, and spatially extended system consisting large numbers of simple, identical components with local connectivity. Cellular automata (CA) is a random technique to simulate occupant evacuation considering the gathering behaviour. Datta and Behzadan (2019) used CA to model the large crowd evacuation in hazard-impacted environments. The study simulated different hazard types using the CA technique and investigated the different types of people, intervention systems, human attackers, obstacles, and distance from the exit to the obstacle. However, their study did not compare with other simulation techniques. The different evacuation factors had been investigated, but performance measures were not focused on velocity and simulation time. D. Zhao et al. (2015) proposed CA to simulate gathering behaviour and the evacuation process with more than 2 points. Their study used random distribution and comparison of gathering random distribution. CA was enhanced with two 2D random models based on position repulsive force with the simulation result of visual radius (VR). The factors of density had been emphasized, but their work did not consider other significant factors. The simulation technique applied was CA only, and there was no comparison with other techniques. Overall, CA lacks in term of realism, such as it restricts the agent's motion to grid-based movement (Eliyan et al., 2018). Then, CA also underestimates the evacuation conditions, such as congestion and interaction between the agents that will restrict the motion. It was also found to focus less towards the independent decisions of movement, where the inability of the group movements cannot be independent.

Among the popular simulation techniques are the Social Force Model (SFM), Agent-Based Simulation (ABS). SFM is particularly useful for modeling the aggregate behavior of crowds, especially in high-density scenarios, while ABS focuses on individual agents' behaviors and interactions, capturing complex human movements and decision-making processes. The characteristics of ABS are the size, behaviour, and movement of an agent. There are three advantages of ABS compared to other modelling techniques (Bi & Gelenbe, 2019). Firstly, ABS is able to model the emergent phenomena, using deductive and inductive reasoning. Then, ABS offer an accurate depiction of a system, and lastly, it is flexible for a simulation model. A prior study reported the basic elements of a simulation model using ABS. He stated that agent refers to a set of agents with the characteristics (attributes) and behaviour. Then, an agent's relationship and interaction among agents is presented as proactive behaviour. The third element is agents' environment, which comprises the connection between the environment and agents. Furthermore, interactions between various behaviours of people and global behaviour are also covered in ABS.

For instance, a previous work on the crowd evacuation simulation models compared several simulation models with different techniques, include ABS. The work aimed to reduce the number of deaths in public spaces in the building for the evacuation simulation model using the ABS technique. Nevertheless, ABS deliver the results computationally expensive. It also involves high skills in computation, particularly for the large systems. Other than that, ABS reported the inconsistent repeatable results and consisted of communication with many costs. Therefore, ABS show the difficulties in development and simulation runs. However, it may not be without any troubles if using a different simulation tool or software, such as the AnyLogic simulator. Conclusively, ABS allow people or agents to make decisions due to their discrete and autonomous behaviours. However, ABS do not support certain activities based on the discrete event or process flow, such as in a queue system where the queue system should be applied in the simulation model related to the crowd evacuation, as there is a process of waiting in front of the emergency exit while egressing.

Human modelling is used to simulate either a single person's behaviour or the entire action by a group of people (Samsudin & Ghazali, 2019; Stuart et al., 2019). This action relates to human behavior and movement and is found important to be considered for an evacuation model. One of the well-known techniques in the evacuation model is social force-based and known as the Social Force Model (SFM) or Social Force Simulation (SFS). SFS was founded by Helbing and Molnar and has been developed since 1991, which relates to human motions. Other than that, the simulation technique of SFS used is to accomplish this by describing numerous observed collective scenarios, such as bottleneck and clogging, as reported by Yuan et al. (2019). Helbing et al. (2002) summarized the characteristics of escape behavior and presented an evacuation model in the self-driven many-particle system (Omar, C. N., & Kamarudin, K. H., 2019). Thus, SFS shows the appropriateness technique for a simulation model which consists of the level of details for a human movement during evacuation.

For instance, Song et al. (2018) applied SFM to enhance the unrealistic observed phenomenon in a few simulation' software. They considered the time and strategy of exit assignment characteristic for the SFS-simulation model to overcome the issue of different desired speed in tangential direction and normal movement (avoiding the wall). This study aimed to improve the algorithm in the existing simulation model using SFM to ensure that pedestrians to avoid hitting the wall and to compute queue time accurately. However, this study did not precisely consider other significant evacuation factors which are required for the simulation model. This study also failed to compare this SFM-simulation model with other related simulation techniques. Conclusively, SFM was found as one technique which can capture the people's movement and evacuation characteristics as discussed previously. However, SFM do have its limitation if been modelled individually. This issue motivates the researcher to investigate the performance of SFM and compare it to other simulation techniques. In addition, the explorations of the related works found that there are some gaps to be filled. This research work proposes to investigate and compare all chosen simulation techniques, including the significant evacuation factors and identified performance measures related to the simulation model (Bakar, N.A.A et. al, 2018).

Previously, there have been few individual simulation techniques reviewed. The existing works reported that the hybrid technique can be used to overcome the limitations of individual techniques. Then, recent research was reported that hybrid techniques in simulation and modelling are getting famous as well. This technique is a combination of two or more techniques to be a simulation model or system. As discussed previously, different techniques have advantages in different areas and features. Thus, several kinds of the research proposed the combination of two different techniques for a simulation model in order to perform better based on simulation results. Hybrid models leverage the strengths of both SFM and ABS, offering a more comprehensive simulation. Challenges in developing accurate simulation models for crowd evacuation include capturing the complexity and diversity of human movement. Thus, the hybrid models have been proposed to overcome these challenges, providing more realistic and efficient simulation results. The literature underscores the importance of utilizing different simulation techniques and addressing their limitations to enhance safety and efficiency during emergencies (Wang, X. et. al, 2019).

For instance, a previous work aims to design an evacuation plan and considered the pedestrian behavior and multiple routing strategies (Rozo et al., 2019). They emphasized on the variables those influence pedestrians' movement in evacuation simulation model. This study proposed hybrid technique. Hence this study focused on the new evacuation plan and compare with the current and new plan with few evacuation factors. However, this study does not compare the hybrid technique with another simulation techniques.

Consequently, simulation models frequently utilize the concept of distribution variables to simulate the behaviors and movements of people during the evacuation. Therefore, it is essential to adopt and implement a model that not only illustrates the explored scenario but also serves as a tool for predicting future incidents. However, we found that the model itself was not suitable for simulating any actual system or real scenario. Therefore, we must adopt both a model and a simulation to create a comprehensive simulation model that addresses the human movement issue during evacuation (Zhang, S. et. al, 2023).

Proposed Hybrid ABS and SFM

Modelling is defined as creating a simplified representation of a real system to describe its behavior. Simulation, on the other hand, involves mimicking, predicting, and virtually presenting the behavior of real systems. This is achieved through a wide range of approaches and applications, which are commonly used in operational research (OR) to study real conditions within a system (Yuan, Z. et. al, 2019). Over recent years, significant attention has been given to simulation and modelling across various fields. This broad applicability highlights the versatility and importance of simulation models in addressing complex problems in different domains. Simulation models are particularly valuable in operational research for representing real conditions and studying system characteristics. These models involve general rules and algorithms, often resembling real-time applications. They are crucial in scenarios where real-life experiments are impractical due to technical difficulties, ethical concerns, or high risks. In conclusion, various simulation techniques are employed to model evacuations, each with its strengths and limitations:

- Social Force Model (SFM): Utilized for modeling the aggregate behavior of crowds, particularly useful in high-density scenarios.
- Agent-Based Simulation (ABS): Focuses on individual agents' behaviors and interactions, suitable for capturing complex human movements and decision-making processes.
- Hybrid Models: Combine elements of SFM and ABS to leverage the strengths of both techniques, providing a more comprehensive simulation

Research Gaps

One of the main challenges in developing accurate simulation models for crowd evacuation is capturing the complexity and diversity of human movement. Hybrid models, which combine multiple simulation techniques, have been proposed to overcome these challenges, providing more realistic and efficient simulation results. The literature review highlights the importance of simulation and modelling in understanding and improving crowd evacuation processes. By leveraging different simulation techniques and addressing their limitations, researchers can develop more accurate and reliable models to enhance safety and efficiency during emergencies.

Methodology

The approach entails a thorough assessment of the body of research on flood or disaster evacuation studies that has already been done, with an emphasis on how people behave in emergency situations and how well different simulation models work. Academic publications, books, and reports that were pertinent were found using databases including IEEE Xplore, Google Scholar, PubMed, and Scopus. “Flood evacuation”, “disaster management”, “human evacuation behaviour”, “human evacuation”, “human evacuation movement”, “Social Force Model”, “Agent-Based Simulation”, and “hybrid models” were among the search terms or keywords utilised.

Findings and Discussion

Effective evacuation strategies not only protect human lives but also minimize the economic impact of disasters on businesses and communities. By synthesizing current knowledge on evacuation modeling, this research provides valuable insights that can inform policy-making, strategic planning, and resource allocation in the context of global business and management. Additionally, the study highlights the role of innovative simulation technologies in enhancing resilience and sustainability, key priorities for businesses operating in a globalized and interconnected world.

The literature review underscores the significant advancements made in the field of disaster evacuation modeling, particularly in understanding human behavior during emergencies such as floods, earthquakes, and fires. The review highlights the effectiveness of various simulation models, including the Social Force Model (SFM), Agent-Based Simulation (ABS), and hybrid models that integrate both techniques. Each of these models has distinct advantages: SFM is effective in high-density scenarios by modeling the aggregate behavior of crowds, while ABS provides detailed insights into individual behaviors and interactions. Hybrid models, combining SFM and ABS, leverage the strengths of both techniques to offer a more comprehensive and realistic simulation of human evacuation dynamics. This integration is particularly crucial in addressing the complexity and diversity of human movement, which is often influenced by factors such as population density, building layout, exit availability, and social behaviors. The review emphasizes that incorporating real-world data into these models enhances their accuracy and reliability, making them valuable tools for disaster management (Srinivasan, A. R. et. al, 2018).

Despite the broad applicability and advancements in simulation techniques, the review identifies several challenges and research gaps that need to be addressed. One of the main challenges is capturing the few and varied human behaviors during evacuations, which can significantly impact the efficiency and effectiveness of evacuation procedures. Hybrid models have been proposed as a solution to this challenge, but their development and implementation require further refinement to improve computational efficiency and real-time application. Additionally, there is a need for more comparative studies that evaluate the performance of different simulation models under various disaster scenarios to identify the most effective approaches. Future research should focus on enhancing the hybrid models by integrating additional behavioral and environmental factors, conducting large-scale simulations to validate the models, and exploring their applicability in different types of buildings and emergency situations. By addressing these gaps, researchers can develop more robust and reliable evacuation models that enhance public safety and disaster preparedness.

Conclusively, the research aims to evaluate the performance of three different simulation models: Social Force Model (SFM), Agent-Based Simulation (ABS), and a hybrid SFM/ABS model, in the context of crowd evacuation during fire emergencies. The findings are summarized as follows. Performance Comparison: The hybrid SFM/ABS model predicted to be the superior performance in accurately simulating crowd evacuations compared to using SFM or ABS alone. This hybrid approach leverages the strengths of both individual models, providing a more comprehensive simulation of human behavior and movement during evacuations.

In addition, the hybrid SFM/ABS model effectively addresses the limitations of using SFM and ABS independently. SFM is known for accurately modeling crowd dynamics, while ABS excels in representing individual behaviors and interactions. The combination of these models provides a robust framework for simulating complex evacuation scenarios. This research underscores the importance of using advanced simulation techniques to improve preparedness for fire emergencies in buildings. The research is limited by its focus on office buildings during fire emergencies. Future studies could explore the applicability of the hybrid model in different types of buildings and emergency scenarios, such as earthquakes or floods. Additionally, efforts to improve the computational efficiency of the hybrid model could make it more practical for real-time applications.
Agent-Based Simulation (ABS); This model focuses on individual agents (people) and their interactions. Each agent follows a set of rules and can adapt to changes in the environment, making ABS suitable for modeling complex behaviors and interactions within a crowd. While, Social Force Model (SFM) uses physical forces to represent the movement and interactions of individuals within a crowd. It is effective in simulating scenarios where physical interactions, such as pushing and crowding, are significant factors. Hybrid Models is the combination and integration of two techniques or approach namely ABS and SFS. The hybrid models leverage the strengths of both approaches to provide a more comprehensive simulation (Yahaya, C. A. C., et. al, 2022). These models aim to simulate both individual behaviors and the collective dynamics of crowds, offering a more accurate representation of evacuation scenarios (Yahaya, C. A. C., et al., 2023).

Conclusion

Simulation models are invaluable tools in disaster management, offering insights that can save lives and minimize damage. By continuously improving these models and incorporating real-world data, researchers can enhance their accuracy and reliability, ultimately contributing to better-prepared communities and more effective disaster response strategies. The findings have significant implications for emergency planners and building designers. One of the main challenges in evacuation modeling is the accurate representation of human behavior under stress. Realistic modeling requires comprehensive data on human responses, which is often difficult to obtain.
This research has reviewed different simulation techniques for modeling human behavior or movement during evacuation such as during fire emergencies, earthquake or flood specifically comparing the Social Force Model (SFM), Agent-Based Simulation (ABS), and proposed an enhanced approach for improving the disaster management by proposing a hybrid SFM/ABS model. The study aimed to identify significant factors influencing evacuation efficiency and to evaluate the effectiveness of these simulation techniques as the future works. Combining ABS and SFS, hybrid models intend to utilize the strengths of both approaches to provide a more comprehensive simulation (Yang, Y., et. al, 2022).
In conclusion, this review study has successfully consolidated and evaluated existing research on flood and disaster evacuation modeling, emphasizing human behavior during emergencies and the effectiveness of various simulation models. By utilizing secondary sources from a range of published documents, the study provides a comprehensive overview of current methodologies and their practical applications in disaster management. The synthesis of findings highlights the common themes across studies, identifies significant gaps in the literature, and suggests areas for future research. The critical analysis of different simulation techniques, including the Social Force Model (SFM), Agent-Based Simulation (ABS), and hybrid models, reveals their respective strengths and limitations, offering valuable insights into their applicability for various disaster scenarios.

The implications of this study are profound for emergency planners, building designers, and policymakers. The review underscores the importance of selecting appropriate simulation models tailored to specific applications to enhance the planning and execution of evacuation procedures. The insights gained from this comprehensive evaluation can help optimize resource allocation, design safer buildings, and develop more efficient evacuation plans, thereby improving public safety during emergencies (Nursal, A. T., Omar, M. F., & Mohd Nawi, M. N., 2015).. Moreover, by highlighting the need for further research and addressing the limitations of existing studies, this review serves as a catalyst for advancing the field of disaster management (Nursal, A.T.,et. al, 2019). Future research should incorporate primary data collection and explore emerging trends to build on the findings presented here, ultimately contributing to more robust and effective evacuation strategies (Adam, K. et. al, 2018).

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