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ORIGINAL ARTICLE

TOWARDS EFFECTIVE EVACUATION PROCEDURES IN DISASTER MANAGEMENT (DM): SIMULATION MODELLING AND GOVERNANCE STRATEGIES

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ABSTRACT – Natural catastrophes and disasters may cause the destruction of infrastructure and personal property. In order to reduce the effects of such tragedies, the effectiveness of the evacuation procedures is essential. Effective evacuation procedures, however, also depend on governance issues in addition to technical aspects like infrastructure and communication. This paper intends to review on how governance, and evacuation protocols relate to emergency preparedness and disaster management (DM). Thus, this study explores the use of agent-based and social force theory in developing evacuation simulation models that incorporate evacuation governance strategies. Practitioners and policymakers can better understand the elements that determine the effectiveness of evacuation procedures and create more efficient methods for disaster management and emergency response by modelling human behaviour in disaster circumstances. The policy is an illustration of how governance elements can be integrated into evacuation procedures and guidelines for effective DM. Thus, the expected result for this study emphasises the significance of governance for policymakers and practitioners in the execution of evacuation procedures.

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INTRODUCTION

Running an algorithm on a computer model is called computer simulation. The simulation also encompasses an extensive collection of models and applications that are used to simulate the behaviour of real-world systems. Simulation has become one of the most popular models in operational research (OR) for providing a closer representation of the real scenarios that happen in the investigated environment. The simulation model implements "what-if" scenarios for examining different possibilities for achieving the best solution at the lowest cost for the investigated cases (Musolino, Ahmadian, & Falconer, 2020).

Other than that, modelling is indeed a problem-solving technique that can be represented by a simple object that describes the real system's behaviour while simulation has become one of the most popular methods in operational research (OR) for providing a closer representation of the actual scenarios that happen in the investigated environment. Research in simulation and modelling of human evacuation has been widely studied in the past two decades, and still, a lot of questions remain unclear. Furthermore, the simulation models have been used in several areas, such as manufacturing, healthcare, transportation, business, banking, and crowd dynamics.

On the other hand, emergency situations are an unexpected event that risks human life. Modelling the emergent movement of evacuees is a critical challenge as the people's movement is unpredictable. Thus, it is impractical in terms of cost, time consumption, and safety to perform various evacuation drills in real time for crowd evacuation. The evacuation simulation model is related to human behaviour governance, which is using the computational tool to simulate and analyse the behaviour of individuals during an evacuation scenario in a given environment. Thus, industries, researchers, academicians, practitioners, and policymakers have attempted to investigate the elements of human behaviour in several domains, such as disaster or emergency management and planning, traffic flow, human evacuation, and other similar applications.

Besides, research in simulation and modelling of evacuation has been widely studied in the past decades. The simulation is used as an instrument for examining the flow of human movement in a closed area or outdoors during both normal and emergency situations. The indoor or closed building evacuation includes schools, malls, office buildings, and stadiums (Zhang, Yu, & Yu, 2018). In buildings, evacuation happens because of many factors, such as earthquakes, floods, electrical short circuits, and fire. Most of the frequent evacuations are due to disasters and were reported every day all over the world. Disasters can happen at any moment and have severe repercussions. In such cases, outdoor evacuation may be required to safeguard the safety of those in the impacted regions. Tornadoes, hurricanes, earthquakes, and floods are a few instances of outdoor calamities. It is important to be prepared for such events by having emergency

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plans in place and knowing what to do in different situations. Thus, these hazardous events threaten people's lives and force an immediate movement of people trying to escape from a dangerous area (Yuan et al., 2019).

Evacuation drills are important to encourage people to practise their evacuation skills and to ensure they are familiar with the environment. Nevertheless, such drills cannot adequately depict emergency situations, and people may injure themselves during practice in some cases. It is impractical in terms of cost, time consumption, and safety to perform various evacuation drills in real time for crowd evacuation. Therefore, modelling human movement in relation to crowd dynamics in evacuation situations has important implications for human safety and evacuation processes (Yang et al., 2022). Moreover, many research problems are still wide open and need to be further investigated to advance the applications and practices of evacuation simulation (Omar & Kamarudin, 2019).

The evacuation simulation model is one of the decision support tools that allow evacuee performance to be quantified. Simulation runs or experiments are to be performed to gain insight into the impact of various scenarios on the outcome of an evacuation. The simulation model for evacuation is a virtual representation of reality that was built from various simulation models or approaches as well as it can predict the evacuation pattern and movement of people. Therefore, the evacuation simulation model can be a useful tool for developing and evaluating appropriate evacuation protocols and governance regulations. The model can assist identify possible bottlenecks or regions of congestion in the process of evacuation and evaluate alternative tactics for enhancing the general efficacy and protection of the evacuation by simulating different emergency situations.

Effective management guidelines, such as demanding frequent evacuation practices or financing for emergency preparation training, may assist in ensuring that evacuation processes are in line as well as everyone is prepared to respond promptly and safely in the case of an emergency. The simulation model may be used to assess the efficacy of these procedures and policies while offering recommendations for enhancements. Furthermore, the simulation model could be used to create and test novel evacuation processes, such as alternate evacuation routes or other ways of communication during an emergency. Policymakers may make educated judgements on how to enhance evacuation procedures and governance policies in the real world by examining the impact of these changes in a simulated setting.

"Governance" and "administration" are synonyms. It refers to the methods, practises, and structures that are utilised to manage and direct a company, organisation, or society. In the lens of disaster management (DM), the term "governance" refers to how multiple stakeholders, including government agencies, rescuers, community leaders, and the general public, collaborate and coordinate to develop, carry out, and evaluate disaster response plans. In this environment, effective governance entails open lines for interaction and synchronised decision-making processes. and shared accountability for disaster management and response. It also entails developing rules and procedures to govern disaster management efforts and guarantee that they are carried out in a clear, adequate, and effective manner.

Considering the necessity of prompt and efficient evacuation processes in disaster management, several locales are lacking adequate techniques for recognising and addressing possible disaster concerns. Traditional evacuation planning procedures may be inadequate in the event of progressively complicated and unexpected natural disasters, for example, tsunamis, earthquakes, and floods.

Other than that, identifying possible risks, designing and disseminating emergency strategies, constructing evacuation routes, and offering staff or visitors training and information on what to do in the circumstances of a disaster. Adequate resources and facilities such as rescue organisations, transportation, and temporary shelter, are required. The public was prone to have faith in their government's ability to protect them if evacuation planning are organised and executed. On the contrary, poorly performed evacuations, can lead to public condemnation and decrease confidence in the government's capacity to manage crises efficiently. Thus, governance is needed for the evacuation policies and procedures which refers to the methods and mechanisms that a government uses to take decisions and execute the policies.

RELATED WORK

This section delivers the theoretical foundations for the concept and research study. A review of previous studies provided an understanding of this research work. At the end of this section, the research gap will be revealed. Furthermore, this part describes human behavior and evacuation procedures which relate to governance as well. Next, this section will discuss simulation and modelling (M&S) and the evacuation simulation model. Then, a few approaches and techniques for a simulation model are discussed as well.

Emergency Evacuation Procedures

A source of potential damage, a risk to the environment, and human health are some definitions of hazards. Natural hazards can have both geological and climatic origins, such as floods, windstorms, droughts, and wildfires. Examples of geological causes include landslides, earthquakes, volcanic eruptions, tsunamis, etc. It is reported every day around the world. When a fire emergency happens, human evacuation will follow. The people, or evacuees, started to move while evacuating quickly. For instance, people trying to exit a hazardous area into a safe area Thus, it has vital effects and implications for the safety and evacuation processes as well. Figure 1 depicts the theoretical foundation of human evacuation based on the previous works' discussion. This concept was derived from previous studies that provided future researchers with information about crowd evacuation (Borowska-Stefańska et al., 2023).

The former researcher assumes about the governance that group behaviour is governed by emergent norms formed through social interaction within a gathering. The crowd members adhere to the norms once they have been established and disseminated through rumour or movement. The latter emphasises the convergence of various individual identities

that contribute to the creation of a shared group identity and the establishment of the norms, values, and beliefs guiding the behaviour of the group. Numerous characteristics, including emotionality, suggestibility, and destructiveness, have been connected to human movements (Radianti & Gonzalez, 2013).

According to pertinent research, a person's ability to respond to an emergency scenario may vary noticeably depending on how the environment changes. This means that regulations or governance relating to how people behave during an evacuation must accommodate variables like personal characteristics, flow density, smoke concentration, and building designs if the evacuation happens in a close area. Therefore, spatial analysis and reasoning are required to show how these features relate to one another and to support decision-making in behaviour modelling (Tan & Ren, 2012). The theory and procedure behind emergency evacuation are described as follows: In a real-life situation, during the evacuation, the pedestrians or people were not all able to determine the specific evacuation route. As a result, their actions are based on self-organization to sudden non-linear engagement with many objects or subjects, but other persons could influence them (Ahmadi, Karampourian, & Samarghandi, 2022; Fekete & Rufat, 2023). For instance, the actions demonstrate that the public's actions affect them based on their behaviour and judgements (H. Zhang, Liu, Qin, & Liu, 2018). Some people are shifting on their own (Yang et al., 2022). Some people prefer to interact with others, specifically with relatives or close companions. For instance, the term "evacuation" describes the preference of the people to evacuate in a group. The group of people prefers guided emergency evacuation.

Figure 1 depicts the theoretical foundation of human evacuation processes which is important to be considered. In order to create efficient evacuation protocols and governance measures, it is imperative to understand the theoretical underpinnings of human evacuation processes. Simulation models are essential for investigating different scenarios and forecasting people's reactions in emergency situations. These models offer important insights for enhancing evacuation procedures.

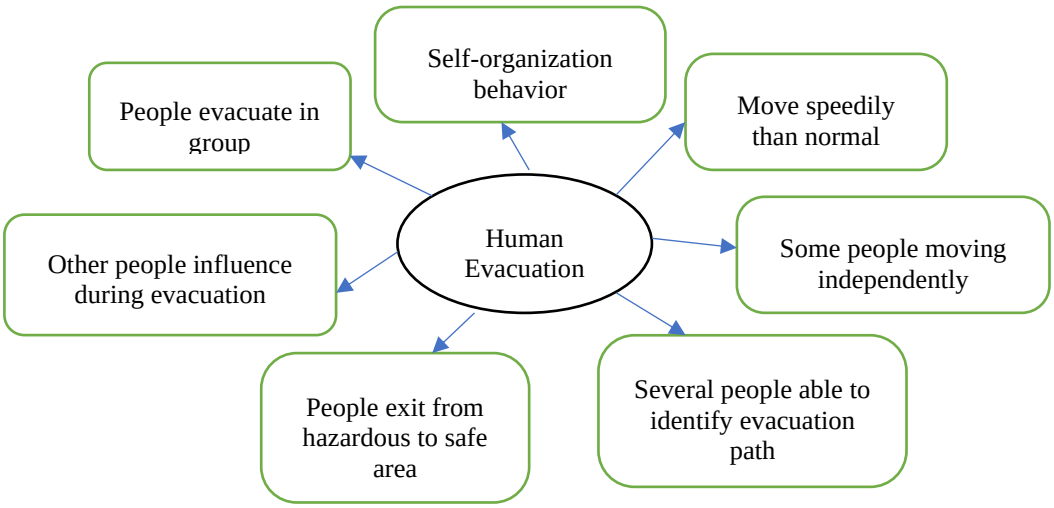

Figure 1. The theoretical foundation of human evacuation processes

In addition, group simulations are becoming increasingly important in emergency simulation. Studying human behaviour is difficult in emergency cases because it frequently involves exposing actual people to a real, potentially dangerous situation. For instance, people are always looking for the shortest and simplest route from their initial location to their desired location. They avoid alternate routes whenever possible, regardless of whether the shortest route is congested. The fundamental aspect is the "least effort principle," which states that everybody strives to achieve their goal as quickly as possible while spending the smallest amount of effort and time (Yari et al., 2021). Observations of people or evacuees in emergency cases usually show the same patterns. As people try to flee the building as quickly as possible, the desired velocity rises, resulting in some distinctive formations. As nervousness goes up, there is less consideration for a comfort zone and learning and discovering the easiest and quickest route. Nevertheless, examining group dynamics in emergency situations is difficult because it frequently necessitates exposing actual people to a potentially hazardous situation (Rozo et al., 2019).

Furthermore, the study on human evacuation related to how evacuees move to the exit during an emergency in a building or interact with the surroundings and environment for outdoor evacuation. Therefore, doing the evacuation drills frequently and a real evacuation is impractical, time-consuming, costly, and would not verify the evacuation in the building for safety purposes. The alternative solution is to develop a simulation model to investigate evacuation. However, to model safe human evacuation with the processes and procedures, the variety of human movement makes it difficult (Hamza et al., 2019). A few techniques for simulation will be explored as they are described in the sections that follow for the purpose to have a simulation model related to human evacuation with the evacuation processes and procedures.

Modelling and Simulation (M&S)

A model is a system that describes an operation, such as pedestrian traffic and its movements, with several mechanisms. Modelling is defined as replacing a simple object and duplicating a situation in order to designate an actual situation and the behaviour. It is important to realize that modelling is a method of abstracting a real-world problem into modelling tools that contain a set of rules (i.e., equations, flows, and charts). Simulation is a technique for explaining a model's development and operation (Bakar, Lim, & Majid, 2022). The model is described as being closer to a real system and supporting the system analyst in order to predict the changes in a system. The term "model is considered an abstract and simplified representation" of a particular reality, whether it is a plan or an existing case. The model that is related to the research work is the analytical model. This analytical model is defined as an equation system with the relationships of the variables to predict the behaviour of the system. Normally, a model is considered along with simulation and can be performed with computer code or programs to represent a complex structure or system (Yang et al., 2022).

A simulation denotes a huge collection of models to imitate, predict, and present virtually the behaviour of real systems. Meanwhile, a simulation is described as a representation of the operation, such as human movement, using a computational and graphical tool. Over the past year, a significant amount of attention from different research fields has been focused on simulation and modelling (Chanthakhot & Ransikarbum, 2021). As simulation refers to the test and experiment that will perform and that derives from a model, different scenarios and the results obtained for evaluation. The simulation model enables the real-time application of evacuation procedures, ultimately aiming for effective and improved governance during emergency situations. Furthermore, the significance of the simulation model was identified, which in some cases cannot run the real experiments in actual because of technical difficulties. Then, the reasons for ethical behaviour and risk as well would require a simulation model. A research study described how M&S with visualization have been commonly used during the planning phase to enhance effectiveness. Aside from that, a simulation model is essential to utilize in addressing issues in modelling real-world human behaviour and specifically their movements, which saves time, cost, and effectiveness over an actual, real-life simulation (Rozo et al., 2019).

For instance, the model may pinpoint possible bottlenecks and areas for improvement in the current evacuation protocols by simulating various evacuation situations, resulting in a more effective and optimized evacuation process. As a result, it makes it easier for policymakers and disaster planners to apply appropriate governance policies and make decisions that will protect people during emergencies (Borowska-Stefańska et al., 2023). The establishment of efficient evacuation protocols may be facilitated by the development of a model for simulation, improving governance in emergency scenarios. The processes can then be tested and improved for maximum efficacy using the simulation approach. As a result, the following section will examine the different alternatives and their possible uses in enhancing the efficacy of evacuation processes and governance techniques in order to choose the best appropriate simulation methodology for a specific situation.

Agent-based Model

A well-known technique in operational research (OR) for a simulation model is called "agent-based" (AB), which emerged around the 1990s. It has been recommended that agent-based (AB) simulation technology is a good choice since it instantly models human behaviour and movement. This makes it possible to depict real-world circumstances more accurately, making it easier to establish efficient evacuation protocols and improve governance in emergency situations. Although the agent-based (AB) approach has its supporters, it also has critics who either overstate or underestimate the likelihood of related difficulties. Although the above is true, AB has the benefit of being able to accurately represent a complicated system with a variety of agent properties, such as size, behaviour, and mobility, defined in detail. AB is modelled in consequence, which can present specific individual movements.

Other than that, there are a few advantages of the AB technique when compared to other modelling techniques (Yang et al., 2022). AB provides a natural representation of a system, and AB is a flexible simulation model technique. A basic simulation model using AB contains three elements, which are summarised below; a set of agents with similar characteristics and behaviours is referred to as an agent. The agents then formed an agent relationship and interacted with one another. In AB, the interaction of agents demonstrated proactive behaviour. The third component is the agents' environment, which includes the link between the environment and the agents. Furthermore, the interactions between various individual and global behaviours are covered in AB (Edrisi, Lahoorpoor, & Lovreglio, 2021).

A previous study reported that AB produced results with high reliability in simulation runs. However, there are a few limitations in AB on the level of detail. The model developed should have the exact level of explanation and precise quantity of detail to deliver its aim. Hence, it shows the complexity and difficulties in developing the simulation model using the technique of AB (Li et al., 2020). For instance, the existing work on the crowd evacuation simulation models compared several simulation models with different techniques. Thus, this work aims to reduce the number of deaths in public spaces in the building for the evacuation simulation model using the AB technique. Nevertheless, AB delivers the results at a computationally expensive cost. It also involves high skills in computation, particularly for large systems (Na & Banerjee, 2019).

According to previous research, AB has the characteristics of a decentralized control system. In comparison to a centralized control system, a decentralized is more realistic and trustworthy. Individual autonomy and free will in making decisions are natural to many social scenarios or phenomena, so AB thought it was appropriate to model human movement in the evacuation because AB also covers the individual-centric approach. Individual-centric places individuals (or agents

in a simulation model) in such a specific environment (Wang & Jia, 2021). Using AB, the simulator will define the active entities. Then, the simulator determines the agents, such as the people, companies, etc. AB required the simulator to identify the behaviour of the agents. Among the agents, they have relationships through which they can interact with each other. Then, all the agents establish themselves in the environment and running the simulations or experiments will be started. So, these processes for modelling and simulating are important to be used for the proposed work, as AB in one of the simulation techniques will be used.

The summary of features of AB described is as follows. Autonomous: the most important feature for each agent is that they present their own behaviours. Every agent is an independent entity, and everyone makes their own decisions. Other than that, an agent with self-contained capability has the function to show the individual's behaviour. This autonomous element for each agent is one of the strengths of the AB technique (Yang et al., 2022). The second element in AB is interactive: the agent connects to the surroundings and communicates with others. The information can be shared with each other and influence other pedestrians as well. Thirdly, intelligence: in various situations and conditions, the decision-making can be made by the agent. Individualized: each agent has a set of attributes that determine the independent person (individual) and differentiate him or her from others.

The assortments in personalities and capabilities of each agent produce different behaviours and decisions. An agent is able to learn and adapt his or her behaviour from his experiences. The dynamic agents attribute and store in the memory for the adaptation and learning processes of each agent. All these features presented the benefit of AB. In addition, AB shows that appropriate to be used to model human behaviour and movement (Hassanpour et al., 2022). Furthermore, AB presented the rules, algorithms, and simple probabilities. The simple rules of behaviour can be implemented with if-then statements, nested if-then statements for complex behaviour, or advanced techniques for the sophisticated behaviour modelled (for example, the statistical methods with multinomial logit, etc.). Each individual agent has classes with rules for the interaction. The probability distribution concept was used during the development of a simulation model using AB.

Conclusively, AB was found to be one of the appropriate techniques for this proposed work to model human movement in evacuation. While the diversified characteristics and advantages of AB received extra consideration from the researchers, it is still too early in the research process to draw any firm conclusions. Even though AB is an appropriate technique to model human movement, however, it had less concern with the queue system. It required the waiting process for the queue in a human evacuation simulation model. The agent-based (AB) method has a disadvantage in that it could downplay the significance of the queuing system, which is essential for creating a realistic egress or evacuation model. The social force concept, which considers the interactions between people and their physical surroundings, including impediments and congestion, can be utilized to get around this constraint. The simulation model may replicate real-world circumstances more accurately by including social factors, allowing the creation of efficient evacuation protocols and governance plans that take the queuing system into account.

Social Force Concept

Human behaviour modelling is suitable to simulate either a single person’s behaviour or the entire action of a group of people. In addition to the evacuation simulation model, human behaviour and movement must be taken into account. One popular technique in the evacuation model is known as social force (SF). SF was proposed by Helbing and Molnar and has been developed since 1991. SF follows the Newton movement algorithm. SF was exposed to humans to motivate and interact with people and is called a social force (Huang et al., 2018). In SF, there are three forces: the desired force, and the push actions between people. As a result, such three types of influences can be utilized in the suggested task as essential for simulating human movement during an evacuation (Zheng et al., 2020).

Furthermore, the concept using SF simulated several important scenarios in the escape panic, such as the clogging effect and transition, the ‘faster is slower’ effect because of the impatience of pedestrians, and lastly, the mass behaviour of ignoring the alternative emergency exit. All these scenarios happened in real crowd evacuations. Hence, SF shows a good representation of the real system for a simulation model of human movement during crowd evacuation. The "Headed Social Force Model" proposed a modified SF for the human motion model. The algorithm aims to improve the classical SF for pedestrian motion through the generation of realistic trajectories. However, this algorithm was found not to be appropriate for the proposed work. The algorithm focused on the heads of evacuees during the evacuation (Hassan, Zainuddin, & Abu-sulyman, 2017).

A modified SF named the social attribute-aware force model (SAFM) was proposed for the detection of abnormal crowd events. This technique was found to be a simple evacuation model to represent the realistic interaction of crowd behaviours. In this work, the interactions among the people or pedestrians are using the particles to compute the effect force. However, the abnormal behaviour is found to be not important enough to be considered for the evacuation simulation model, which uses three different techniques in order to evaluate the performance (Zhang et al., 2014). Then, an evacuation simulation model using the technique of modified SF has been proposed with three components for the earthquake evacuation. This simulation model optimises and calibrates the parameters of SF to attain the evacuation speed of a desired non-linear that is reliable for real-life video data. The trained evacuation leaders provided the benefit of maintaining calmness and avoiding the panic of the evacuees (Huang et al., 2018).

This work, on the other hand, emphasised the psychological element of the pedestrian's panic and feelings during evacuation. The other study emphasises the combined algorithm called the rule-based social force model for the human movement simulation model. However, the authors have not focused on crowd evacuation, but the work is suitable for

simulating vehicular traffic flow (the movement of the vehicles)(Yuan et al., 2019). Previous research proposed walking ahead with the algorithm of headed SF and provided the advantages of high versatility and high-density scenarios. The research aims for the same traditional SF as well, which is navigating overcrowded environments. The other aim is to avoid unexpected obstacles. However, it involves many equations, including the force input and the torque input. It may impact the simulation time and computational complexity. Science fiction works and fundamental concepts in SF have been discussed. Therefore, how SF works in a simulation model is based on several rules and algorithms. The basic elements in SF are described as force-desire interactions among the people or pedestrians and the avoidance of obstacles such as walls, etc. The queue system included in the SF as well as the clogging effect at the exit such as the emergency exit door (Bakar et al., 2018).

Evacuation Procedures, Simulation Model and Governance Strategies

Governance is the set of rules, practises, and processes that guide and regulate an organization. Governance in relation to evacuation procedures would entail setting clear norms and processes to obtain the process of evacuation, such as who is accountable to make decisions, where these decisions are taken, and how the procedure is conveyed to the community. It would also entail building accountability measures to guarantee that the process runs smoothly and efficiently. Policies and procedures are about creating explicit policies and procedures that explain the roles, duties, and processes associated with the evacuation. This contains standards for decision-making, interaction, and the allocation of resources. Policies and procedures are the most essential elements of governance in evacuation processes. Setting up clear policies and procedures outlining the roles, duties, and processes related to the evacuation (Handayani et al., 2019).

Furthermore, governance consists of planning as well which describes creating a detailed evacuation plan that examines multiple situations, determines possible dangers and hazards, and explains the processes required to provide for a successful evacuation. The next element of governance is leadership. It determines important individuals who can be responsible for the task of deciding actions, allocating resources, and interacting with all parties involved throughout the evacuation process. Other than that, communication is about creating efficient channels of communication and protocols for delivering details to evacuated people, rescuers, and various stakeholders (Bakkour et al., 2015).

Providing clear directions, updates, and notifications during the evacuation process is part of this governance. In order to assure that necessities such as transportation, food, shelter, and healthcare aid are available and distributed in an equitable and reasonable manner, good governance for evacuation procedures is needed. Regular training sessions and evacuation drills are held to assist stakeholders, rescuers, and volunteers in the evacuation procedure. Evaluating and improving the evacuation process on a regular basis helps find areas for enhancement and make required adjustments to regulations, processes, and supplies (Raikes et al., 2019).

The rules and practices put in place to guarantee successful and efficient emergency management are referred to as governance plans. Creating emergency response plans, allocating resources, and coordinating response activities across many agencies and organizations are all included in the plan. Other than that, the efficiency of evacuation protocols along with other emergency response tactics may be tested using simulation models, which are computerized models which can be used to replicate emergency events. These models may be used to find possible flaws in evacuation strategies and to create more efficient emergency response plans (Izumi et al., 2019).

For the simulation techniques, throughout the reviewed process, AB provided a list of strengths that they deemed most appropriate for modelling human behaviour and movement. However, AB is not explicitly modelled but emerges from the interaction of the many individual entities that make up the system. AB also found it suitable to model human movement; however, the main limitation is that when modelled individually, the elements of queuing and egressing are not covered (Siyam, Alqaryouti, & Abdallah, 2019; Haq Amir, Rosyidah, & Lee, 2020). SF was able to model the evacuation, however, the limitation is that modelling with a crowded group does not cover proactive agent behaviour. SF was found to be the most popular model for crowd evacuation. However, AB and SF are not suitable for modelling themselves only. The combination of simulation techniques found suitable to overcome this issue Throughout the literature, also stated that various techniques should be combined to study evacuation to get simulation and experiment results that are efficient and realistic (Noor Akma et al., 2019).

Conclusively, throughout the exploration, SF has proven to be a suitable method to model and simulate human behaviour that has been used in almost recent research related to evacuation. The authors have investigated various techniques, such as Lattice Gas (LG), Fluid Dynamic (FD), and Cellular Automata (CA). These strategies may be used to create better evacuation policies and governance, which will increase the effectiveness and safety of evacuations during emergencies. The agent-based (AB) and social force (SF) strategies are the most suitable for modelling human evacuation movements, both in close places and outdoors. The significant strengths of SF, such as making it the superior technique for the evacuation simulation model. Despite the excellent performance of SF, there are indications that the attention of SF is crucial to the quality of modelling human movement. The same matters apply to the AB technique. From the previous explorations of AB, there are some limitations and issues to be solved instead of the strengths of AB itself. However, all problems that arise in SF and AB can be solved by combining several simulation techniques into a simulation model called a hybrid technique.

In brief, simulation models, evacuation protocols, and governance methods are all crucial elements of disaster management planning. Emergency management teams may enhance their capacity to respond to emergencies when they happen by creating efficient rules and procedures, designating paths for evacuation and assembly sites, and testing

response plans using simulation models. In conclusion, planning for emergency management must include governance methods, evacuation protocols, and simulation models, which are among the crucial elements (Canton, 2019).

FINDINGS AND DISCUSSION

In this paper, we illuminate the research on evacuation and human evacuation related to procedures and governance as well as the simulation model. In an evacuation, emergency evacuation consists of human movements such as clogging, force elements, and the queuing of people from one place to a safe destination. AB and SF were found as appropriate techniques for modelling human evacuation which intends for a closer and more realistic representation. Throughout the literature, each of them is preferred by various researchers for the evacuation model. AB is a popular method to be used for complex systems due to its characteristics. However, due to the decentralized or individual elements inside the AB structure, it is found difficult to model people's movements that relate to egress movement in evacuation (Li et al., 2015). While, in the SF model, a few limitations and advantages have been reviewed. However, because of the limitations in SF features like walking speed and reaction time are treated as being shared by all pedestrians as identical entities. In fact, people's behaviour during an evacuation might vary according to their physical capabilities, health statuses, and degrees of worry. Therefore, researchers propose to combine both techniques of AB and SF to model the evacuation movements with considerations of improved evacuation procedures with the intention of improvising the governance of evacuation which benefits all stakeholders including the communities.

The proposed methods involve the combination of SF concepts and the AB model for an evacuation simulation model. Due to the limitations of AB and SF, can the combination of AB and SF models produce better results in modelling human movement in evacuation? Thus, this research will investigate hybrid SF and AB versus single models to review the differences between them. Nevertheless, to simulate something as close to reality as possible, several components are required. For instance, factors and processes related to human movement while evacuating, such as evacuation procedures, evacuation times, obstacles, the number of exits, and many more, are vital elements to consider during the development of a simulation model. Such elements are essential as the simulation inputs that will affect the crowd evacuation result analysis. Figure 2 shows an example of the evacuation procedure for a simulation model which is appropriate to be adopted for this study (Zhang et al., 2012).

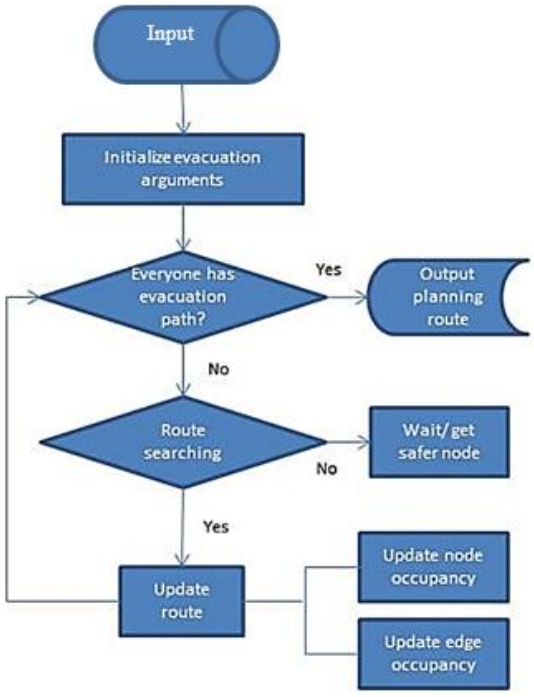

Figure 2. Evacuation procedure for a simulation model

When it comes to ensuring the safety and protection of communities during emergency evacuations, governance and evacuation procedures are crucial components. On the other hand, the integration of agent-based models and social force ideas into evacuation simulation models can aid emergency managers and policymakers in comprehending and forecasting evacuation-related human behaviour. As a result, they will be better able to create evacuation strategies that will reduce risks and guarantee public safety. The integration of agent-based and social force concepts into evacuation simulation models can also aid in the promotion of openness and accountability in government. Policymakers and emergency personnel can assess the strengths and shortcomings of their evacuation strategies by simulating various

evacuation scenarios and analyzing the outcomes. This element can help them make better judgements and enhance their strategies in a more open and responsible manner. Policymakers and disaster planners can objectively examine the efficiency of their evacuation plans using simulation models.

Besides, the protection of individuals during crises like earthquakes, and the protection of individuals during emergency scenarios like fires, natural disasters, or other dangerous occurrences depends on effective evacuation methods and governance measures (Dandoulaki et al., 2022). The following are some essential processes and factors to take into account while creating efficient evacuation protocols and governance strategies. Determine potential risks and their implications for the community by conducting a risk assessment. Then, take into account the likelihood that a hazard may materialize, the population's susceptibility, and any potential repercussions. Second, by creating a plan, governance strategies can be improved by including assembly areas, communication routes, and emergency services and considering the requirements of poor populations, including the elderly, disabled, and children. Other than that, discuss the plan and share it with every relevant organization and stakeholder, such as local authorities, emergency services, and citizens and note to review and update it frequently in order to keep the strategy functional and current. On the other hand, staff training should be performed as well (Bakkour et al., 2015). This training is significant to carry out the evacuation strategy. This covers all parties such as the personnel, volunteers, and emergency services. Collaboration and teamwork together with other agencies are also found to one of the effective governance strategies. This collaboration method is vital to guarantee a well-coordinated response during emergencies and collaborate with other agencies, such as nearby municipalities. The other strategy is establishing a strong emergency management governance structure with distinct roles and responsibilities. A governing framework, procedures for making decisions, and procedures for communicating with the general public should all be part of this strategy. Then, assess and find out after every emergency, evaluate the response and look for areas that may be improved and utilize this input to improve the governance strategy and evacuation plan (Mullins, Holland, & Cunneen, 2021).

CONCLUSION

This paper aims to discover the issues and simulation techniques for an evacuation simulation model: 1) if there are any implemented simulation models based on a few research domains and fields; 2) issues regarding evacuation simulation techniques; 3) evacuation process and procedures; and 4) evacuation governance. The proposed work intends to overcome the problems that have already been discussed in this paper. The limitations of the techniques of SF and AB and the work on the combination of two simulation techniques in order to develop an evacuation simulation model. This paper proposes to investigate the performance of each simulation technique using the simulation results and experimentation as the future work together with other important components to be considered, such as the important factors as simulation input. In addition, as for future work, simulations will be conducted, and a few rules for evacuations in buildings are required, including regulations governing the impact of the moment of entering a staircase, the number of evacuees in the building, the evacuation strategy, the layout of the building, and the total evacuation duration (Fernandez *et al.*, 2021; Rahman *et al.*, 2023).

Furthermore, critical elements of disaster management include simulation techniques, evacuation protocols, and governance. In conclusion, simulation methods, including computer simulations and actual drills, are crucial for anticipating crises and evaluating the efficacy of evacuation plans. The protection of individuals during crises like earthquakes, natural disasters, fires, and depends on evacuation methods. All parties involved should be informed of these processes, which should be carefully prepared and evaluated often. The protection of individuals during crises like earthquakes, and in emergency management, effective governance is crucial. This entails effective management, cooperation between many organizations and stakeholders, and transparent public relations. Effective resource allocation and transparent, accountable decision-making are ensured by good governance. In conclusion, a mix of simulation strategies, evacuation protocols, and sound governance are needed for effective emergency management. Communities may better prepare for calamities and respond to them when they arise by making investments in these areas (Farazmand, 2023)

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CONFLICT OF INTEREST

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