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Conceptual Framework for Intelligent Indoor Evacuation Model Assessment Algorithm Using Integrated Assessment Model

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ABSTRACT

This research aims to describe the adaptation of the Integrated Assessment Model (IAM) in modeling a conceptual framework for an intelligent indoor evacuation model assessment algorithm in a high-rise building. Evacuation defined as moving from a place that gives danger or threat to a safer place and evacuation model used to help evacuees to evacuate safely without any harm. Currently, many evacuation models developed, but each model focused on different evacuation behavior and time; hence the models differ in terms of its features. Moreover, the validation and comparison of each evacuation model have been made independently without using any standard assessment that encapsulates the functions involved in the critical incident during the indoor evacuation and virtual spatial element. Therefore, this proposed conceptual model believed to act as guidance in developing the assessment algorithm that needed for the evacuation models. It is essential to ensure that there is a standard guideline for the researchers to validate and compare with the existing evacuation model in a critical incident.

Key words: Integrated Assessment Model, evacuation, evacuation model, simulation, high-rise building, assessment algorithm, algorithm

1. INTRODUCTION

Evacuation defined as the retreat, dispersal or the withdrawal of people from places of risk or threat or their reception and treatment in safe environments was coordinated, controlled, and monitored [1]. The number of large public buildings increased significantly, with the growth of the economy and the advancement of the population, and many people gathered in significant buildings, such as libraries, shopping centers, stages, and metro stations. The complicated interior design and the large number of people involved make the management of evacuation more difficult, thus making evacuation planning more necessary [2]. Therefore, it is crucial to have the right emergency evacuation in every high-rise building.

Evacuation is not the same with the pre-designed evacuation plan, considering different aspects, including the enclosed layout, environmental change, feature of the evacuee, and likely encounters with evacuees' crowds. Evacuees with a misperception of the building environment may display significant rounding or even be trapped, resulting in an exceptionally longer evacuation time. People generally follow a route of self-estimated rapid escape based on a sense of the current situation. Furthermore, intense hysteria and stamping can contribute to multiple individuals evacuating in emergencies. The layout of escapes from structures, human psychology and behavior, and numerous social, behavioral patterns can profoundly impact evacuation performance, which leads to being trapped [3]. Thus, it is a need for a high-rise building to have an evacuation model to allow evacuees to exit the building without any harm safely.

2. EVACUATION MODELS

There are two main goals for the development of evacuation models (EM). Firstly, to determine whether the building safety efficiency (architectural layout, exit capability) is appropriate. Secondly, to ensure that evacuees may invest the least time in the safety zone in the event of a fire and other accidents, allowing an ideal escape path. Nonetheless, most current EMs either neglect a few human behavior characteristics in crowds or are computationally complicated, making it difficult to fully reflect evacuation outcomes, which are more precise and practical [4]. Therefore, it is essential when it comes to implementing the right EM to the specific high-rise building since it helps better planning, due to it imitates real evacuation situations.

The model seeks to depict a scenario for the evacuation of natural hazards through principles extracted from transport science, risk analysis, sociology, and disaster management [5], understand the effects of rapid flows, and human experiences on the evacuation period [6]. Moreover, an EM concentrates on three main tasks: (1) move towards the nearest exit, (2) move into an area with small crowds, and (3) try to avoid evacuation obstacles. With a bigger size, capability, and architecture of a floor plan of a high-rise building, the three tasks can become complicated [7]. EM divided into three; microscopic models, macroscopic models, and multiscale or known as mesoscopic models [8].

Microscopic models often define everyone's spatial and temporal actions where the individuals considered as an interaction particle, and the individual's activity often characterized by their contact with other individuals [9]. The Helbing method is the best-known social force model that is part of the microscopic model. This model by physically separated by a discrete model and a continuous model [10]. Some example of microscopic models includes social forces, rule-based, time-varying network, integrated network approach, spatial-grid evacuation, fine grid, hybrid space discretization, finite state automata, and cellular automata models [11] and agent-based model [12].

The macroscopic model, also known as the continuum model, combines variables and monitors parameters such as bottleneck densities [13]. The model considers the evacuees to be an integer of the same properties, so the performance of an evacuation depends upon crowd flow, crowd density, and physical architectural factors. In other words, it ignores the actions of evacuees during evacuation and use network stream models to address the evacuation issue [14]. As the evacuations research comes from traffic flow research, the perfect and mature method of fluid research is naturally inherited; ready-made results from fluid mechanics research used so that it can easily start. This EM is similar to swarming behavior, but it has several similar evacuees with explicit interactions. The simple overlay of the model's different properties is not a model's property as the model is nonlinear, and therefore limits the use of the results from this approach [15]. It also achieves excellent reliability and productivity in terms of prediction and rate overall, while the drawback of the model is that it retains the lack of detail and precise estimation of individual movement [16].

Lastly, the mesoscopic model uses probability distributions where the location and velocity of the evacuees represented. This model usually focuses on the elements of the human activities in both microscopic and macroscopic models in large crowd densities, and the unit analysis is the individual. Still, the interaction between evacuees is not considered. Each of these models has its advantages and disadvantages when implemented. The microscopic model currently has been much prevalent within the research community compared to the macroscopic and mesoscopic model. In general, macroscopic models have high computational performance but cannot represent interaction and human heterogeneity. In contrast, the compute the output of microscopic models is relatively lower, yet the human movements and activities can be more reliable and generally defined. Thus, microscopic models have been used widely in recent years [17].

3. INTEGRATED ASSESSMENT MODEL

[18] declared integrated assessment as provides relevant information within a decision-making context that brings together a broader set of areas, method, styles of study, or degrees of certainty than would typically characterize a study of the same issue within the bounds of a single research discipline. Thus, in advance, an integrated assessment model (IAM) defines as an analytical approach that brings together knowledge from a variety of disciplinary sources to describe the cause-effect relationships by studying the relevant interactions and cross-linkages. In the beginning, IAMs have become a common tool for assessing strategies to address climate change, including the costs and benefits of such strategies over time and widely used to explore potential strategies to mitigate future climate change [19]. While IAMs, such as simulation and optimization, are applied in a variety of ways, the primary inputs and outputs in different models are still identical [20].

Two groups of IAMs have typically identified, which are inter-temporary optimization models and models of simulation. Inter-temporary optimization models aim at finding the best future path based on global or regional healthcare and cost-efficiency. Opticalities in this category of IAMs defined in conjunction with total foresight and the predicted state of the world of the IAM system. Alternatively, simulation (or assessment) models carry out policy simulations over time without specifying or attempting optimum directly. As explored in two decades, the challenges involved in assessing IAMs include the potentially high rates of system sophistication, the degree to which design elements are implemented and defined, and the uncomplete awareness of the underlying processes and information [21].

Figure 1 shows the ten dimensions of IAM that considered as the integration of components across and within the interrelated dimension. According to [22], the first three dimensions of IAM should be an implementation driver, and the main drivers will comprise: 1) topics of interest to be taken into consideration, 2) governance environments, and 3) shareholders. It can then evolve to requiring multiple integrations, which are 4) natural setting, 5) human setting, 6) spatial scales, and 7) temporal scales. These are the technical issues relating to the convergence of 8) disciplines, 9) methodologies models, other instruments, and data, and 10) sources and forms of vulnerability. An overlap can occur; for instance, shareholders and governance environments are an important part of the human setting. Each of the ten dimensions is, therefore, defined as an aspect of the IAMs.

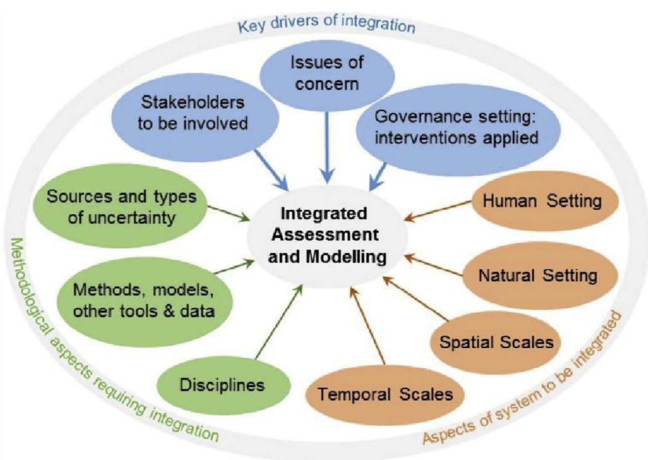

Figure 1: Ten Dimensions of IAM

By considering the system (including the human system components), IAM improves understanding of the problem and may help elucidate underlying causes and point to potential longer-term. Some of the models that implement IAMs include Dynamic Integrated model of Climate and the Economy DICE, FAIR-DICE, GEM-E3, REMIND 1.6, POLES MILES, and many more. The next sub-section will explain more on the proposed evacuation assessment model using IAM for the evacuation model.1 IA is not a new idea; the recent usage of the term applies to activities over the last decade arising from new requirements of society in resolving increasingly complicated and intrinsically complex issues. IAM's scale is not limited to the global level as in climate change models but includes local and national environmental issues models. Due to that, we have proposed a conceptual framework in the progress to develop the evacuation model assessment algorithm. The conceptual framework depicts the key relationships among the elements involved in the system and gives a better understanding of the network's ideas.
Several factors from the dimensions of IAM considered to applied from each of the categories; critical drivers of integration, methodological aspects requiring integration, and aspects of the system to integrate.

1) Key Drivers of Integration

- *Issues of concern:* Two issues identified, which are, many evacuation models developed, but each model focused on different evacuation behavior, and time, hence the models differ in terms of its features. Moreover, the validation and comparison of each evacuation model have been made independently without using any standard assessment that encapsulates the features involved in the critical incident during the indoor evacuation and virtual spatial element. Thus, such a conceptual model with the help of IAM is needed to create such an assessment algorithm.
- *Stakeholders to be involved:* Involving the owner of the building in deciding the best evacuation model and scenario analysis.
- *Governance setting-interventions applied:* Each of the buildings must have an evacuation procedure and follow guidelines by fire safety management such as security, fire detection, life safety systems, and corresponding safety systems in a building. It involved the instruments of command and control to narrow the spectrum of a target group's behavior inclusive of the administrative, licensing, and management areas.

2) Methodological Aspects Requiring Integration

- *Sources and types of uncertainty:* Decision on which model is the best and uncertainty on the attributes of the evacuation model.
- *Methods, models, other tools & data:* Identify the relevant tools, data, and using clustering K-mean algorithm.
- *Disciplines:* Integration with information technologies and computer science.

3) Aspects of System to be Integrated

- *Human setting:* The human setting relates to all human elements relevant to the problem, behavior, population factors, culture, organizations, economic and technology sectors. It is essential to understand the underlying human forces, for example, obstacles to implementing possible solutions, to understand environmental issues, and help formulate successful policies.
- *Natural setting:* The scope identified is fire evacuation in a high-rise building and the evacuation model that have different variables and behavior by defining natural behaviors and indicators.

After considering the several factors from the dimensions of IAM as the pillar to develop the conceptual framework for evacuation model assessment, we come out with the proposed conceptual framework, as in Figure 2. Few steps and flows identified as below:

4.1 Knowledge Acquisition and Background Study

- In the first step, any kind of existing indoor evacuation system and evacuation models gathered and the sources to find these are taken directly from journals and researches conducted by researchers.

- From the gathering, seven evacuation techniques have been found and discussed earlier. These include the very popular and will be more focused on microscopic evacuation models, which are Social Force Model (SFM), Agent-Based Model (ABM) and, Cellular Automata (CA) [23]. Other model includes NOMAD, Gas-Kinetic Model (GKM), Lattice-Gas Model (LGM), and Fluid-Density Model (FDM).
- Next, it followed by the exploration of IAM, the function, aim, and ten dimensions of IAM and relates it with the current case study for evacuation model assessment. Lastly, the knowledge acquisition on the K-mean clustering algorithm, the steps involved, and how it works for clustering.

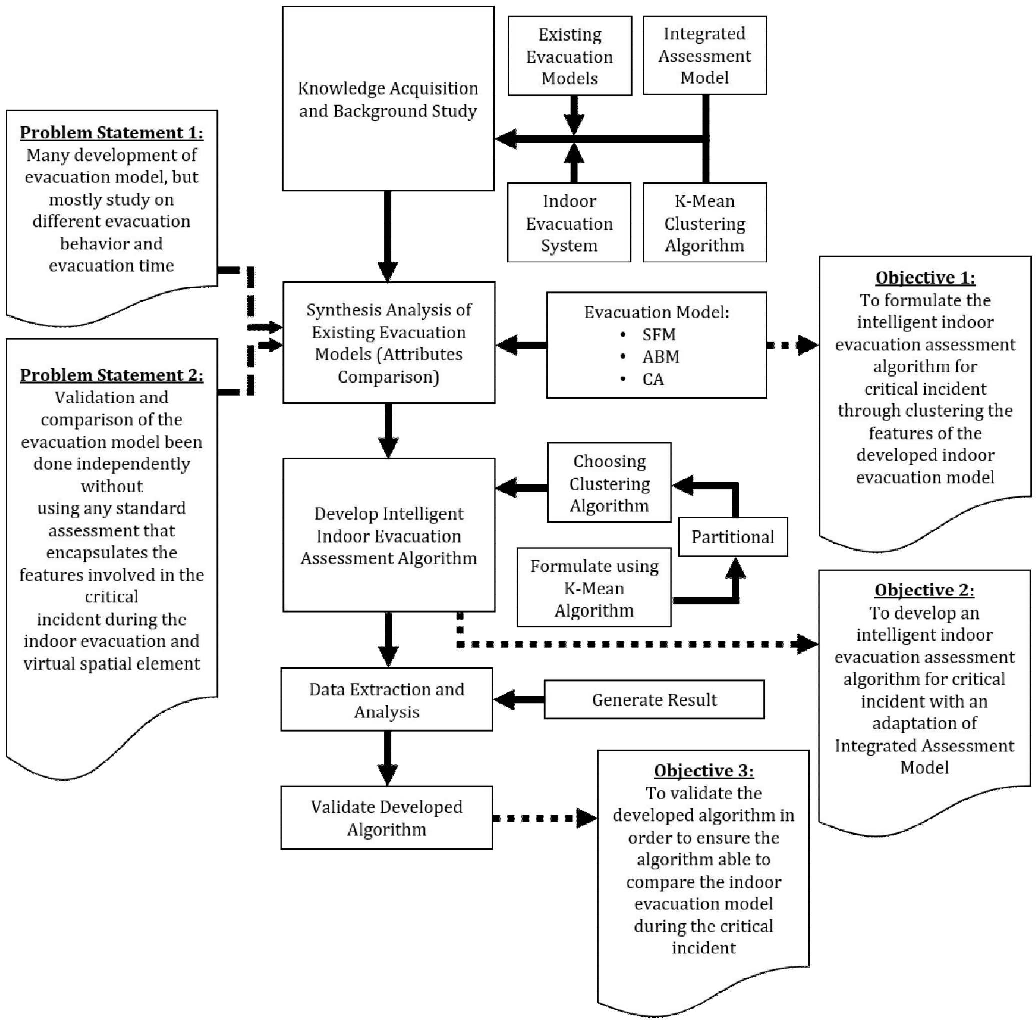

Figure 2: Conceptual Framework for Intelligent Indoor Evacuation Assessment Algorithm

4.2 Synthesis Analysis of Existing Evacuation Models (Attributes Comparison)

- There are some similarities and differences between the evacuation simulation models. The models divided by macroscopic, microscopic, and mesoscopic models. SFM, ABM, CA, LGM, and NOMAD fall under the microscopic model. The GKM and FDM fall under the macroscopic model. Despite some are under the same type, each of the simulation models has unique attributes that differentiate from each other.
- This study relies on one type of evacuation model, which is a microscopic model. The microscopic model currently has been much popular within the research community compared to the macroscopic and mesoscopic model. In general, macroscopic models have high computational performance but cannot represent interaction and human heterogeneity. In contrast, computing the output of microscopic models is relatively lower, yet the human movements and activities can be more reliable and generally defined;

thus, the microscopic models have been used widely in recent years.

- Thus, from the listed existing evacuation model, only three models have been selected for this study, which is SFM, ABM, and CA. At the same time, at this phase, we can link it with two problem statements of this study and able to fulfill the first objective.

4.3 Develop Intelligent Indoor Evacuation Assessment Algorithm

- The next step of the conceptual model is to formulate the assessment algorithm, which will act as a tool to solve the issues—this include-on deciding which algorithm is the best to use to assess the attributes. The algorithm is generally defined where it uses a value or set of values to construct a value or set of values as an output [24]. It also noted that the algorithm could be defined as recursive, while algorithms implemented in machine models are a special kind of algorithms. Several type algorithms are gathered and analyzed to make sure that the algorithm will be able to assess the attributes of the evacuation technique easily and successfully.
- Clusteringmethod is the classification by a given similarity measure of homogeneous groups of data[25]. Clustering is useful in many applications such as decision-making, data mining, text mining, deep learning, sorting, and intrusion detection and pattern classification. Clusters must be carried out because they help to identify contours and to analyze clusters of small sizes[26].Thus, the next step is to determine which clustering algorithm is the easiest, simplest, and best to use to assess the attributes. There are several types of clustering algorithm can also be found, and that includes hierarchical, partitional, density-based, graph-based, grid-based, and model-based.
- Next, the K-Mean algorithm, which is under the partitional clustering algorithm, is chosen to be used for assessing the evacuation model.K-mean is a basic iterative process by which a particular data set partitioned into a given user number of clusters, k[27]. Equation (1) shows the formula used in K-Mean for clustering.

$$f = \sum_{i=1}^{K} \sum_{j=1}^{N} \|x_j - C_i\|^2 \quad j \in G_i \tag{1}$$

whereK is the number of clusters, N is the number of objects, x_j is the coordinate of object j, C_i is the coordinate of the cluster i and G_i is the group of objects belong to cluster i. The algorithm shifts the cluster in space to reduce the square distances within the cluster [28].

- All the steps involved will be the catalyst and ensure the second objective of the study achieved.

4.4 Data Extraction and Analysis

- The attributes of the evacuation techniques integratedinto the K-Mean formula and result generated. Then, we start the process of data extraction and analyze the output.

4.5 Validate Developed Algorithm

- Once the result produced, the result must be confirmed to be the best one. Thus, this step will determine if the result is the best by validating it using any existing evacuation model based on the existing evacuation technique. Finally, indirectly, we can ensure that we can achieve the third objective.

5.CONCLUSION

In this research, the main objective was to model a conceptual framework with the adaptation of IAM for intelligent indoor evacuation model assessment algorithm, While IAMs implemented in myriad ways, including simulation and optimization, the core inputs and outputs are similar across different models. In terms of the evacuation simulation model, IAM can consider a wide range of environmental characteristics and management activities that impact building safety. IAMs generally represent the influence of policy drivers, such as changes in evacuation rules or regulations restricting building codes, on resource use, and decisions of the management. Both existing and potentially new models can be analyzed using specific assessment guidelines and criteria when considering an evacuation model. Therefore, with this model, we able to have standard evacuation assessments as a guideline in comparing the best microscopic evacuation model. It can be implemented using the same concepts, ideas for all types of buildings, and also other types of microscopic and mesoscopic evacuation models.

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