What a User Should Know When Selecting an EVACUATION Model

By Erica D. Kuligowski and Steven M. V. Gwynne

In recent years, evacuation models have been increasingly applied in an attempt to understand the outcome of emergency egress scenarios. This has been due to the increased use of performance-based design and the availability of cost-effective, high-performance computer capability. The increase in the use of these types of evacuation tools requires that the important factors involved in the selection of an appropriate evacuation model are better understood. This article provides evacuation model users with the important questions and factors to consider for model selection.

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Evacuation model users are faced with the choice of numerous modeling tools available across a variety of projects, i.e., applications with ships, buildings, and cities, all of which vary in their requirements. The models vary in their background, capabilities/characteristics, and future developmental flexibility, which are all important issues that a user should take into consideration before selecting a model for application to a project or series of projects.

It is important to examine the nature and scope of the project in order to determine whether the model is able to cope with the requirements of that particular application area.

With all of these choices, what help is available to aid model users in the model-selection process? Currently, several evacuation model reviews exist[1,2,3,4,5,6,7,8,9,10,11,12,13] that aid in the categorization of evacuation models developed up until the time of their publication. However, in most instances, the user is left to distinguish which categories are significant for their particular circumstance and why this is the case. The *SFPE Handbook of Fire Protection Engineering*[1] provides a basic list of questions that a user should ask when selecting a model; however, the questions mainly focus on model sophistication and do not necessarily provide explanations as to why those factors are important. This article attempts to aid in the selection process of an appropriate evacuation model by identifying key factors and explanations regarding project requirements, the background of the model, the current capabilities and characteristics of the model for comparison with other models, and the future progress of a model for a specific application. For many of the key factors, associated examples* of evacuation models are presented in the text.

Project Requirements: What Are the Project Objectives?

Before selecting a model, the user should consider the specific project to which he/she is assigned. It is important that the user consider key questions relating to the suitability of the model to the requirements of the project in question. This is not an exhaustive list of the questions that need to be asked, nor are the questions necessarily mutually exclusive; however, by answering these four questions, the user should be able to ascertain whether the model is able to support the project requirements and whether it is appropriate to be used for the project at all.

- What are the nature and scope of the project?
- What are the deliverables of the project?
- What information is available within the project to frame the egress analysis?
- How much time and funding are available to complete the project?

It is important to examine the nature and scope of the project in order to determine whether the model is able to cope with the requirements of that particular application area. For instance, if a user is to model a ship evacuation, he/she may need to simulate mustering. The user should then ask whether the model's representation of mustering is sophisticated enough to answer the questions being posed within the project. Even though a project can be categorized by a specific application type (e.g., it involves a maritime vessel, an office building, an airport terminal, etc.), categorizing evacuation models is more difficult given that the use of the model can change over time.

The completion of any project involving modeling will require the production of a set of deliverables. The user should therefore be aware of both the output that can be produced by the model (and whether this matches up with the project requirements) and the techniques used within the model to generate these results. It may not be feasible to make use of a model when, for instance, a detailed understanding of the experiences of the simulated evacuees is required but only the final arrival time can be produced by the model. In addition, the techniques used within the model (whether artificial intelligence techniques, flow calculations, cognitive models, etc.) may not be capable of producing the output required by the project. For instance, a cognitive model may provide information on the decision-making process; however, it might not be able to provide a quantitative assessment of the overall evacuation time.

The amount of project information available to the user may influence the model selection. For instance, if the information that the user has on the project is limited, e.g., a vague description of the building floor plan or limited information on the occupants, then the user may want to select a less-sophisticated model with a limited number of user inputs.

Lastly, it is important for the user to understand the amount of time and funding allocated to the egress analysis of the project. This may influence the selection of the model, potentially precluding those models from selection that are financially and/or computationally expensive.

* Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

Background Research: What Is the Origin of the Model?

Understanding the origin of the model is important in the selection process because it establishes the constraints under which the model was produced (e.g., the commercial pressures), the expertise available when the model was created (e.g., mathematicians, psychologists, sociologists, etc.), and the extent of the efforts to validate the model. This information is useful because it allows the user to better establish the credibility of the claims made of the model.

By understanding the constraints under which the model was developed, the user may be better able to assess whether developments were driven by a need to improve the model or more driven by constraints, such as funding or time.

The user should be aware of the expertise involved in the development of the model. For example, some models may have been developed by an individual, whereas other models may have been developed by a team of people from diverse backgrounds, such as psychology, sociology, and engineering. The background of the development team may affect the abilities of the model to capture some of the more complex behaviors or actions of the occupants during an evacuation.

An important aspect of model selection is the level to which the model has been subjected to validation/verification. It is vital that the user obtain documentation from the developer and other agencies that have performed any type of validation to make his/her own judgments on the validity of the results produced and whether the validation is sufficiently detailed, reliable, and in an area comparable to that involved in the project. For instance, if the model has been validated using scenarios and/or data extracted from the built environment, would the validation performed be sufficient to warrant the use of the model in an aviation application? Validation studies help to identify the capabilities of the model as well as its limitations. These validation studies can investigate a number of different aspects of the model: quantitative performance,[14,15] qualitative performance, functional performance, component-based performance,[16,17] efficiency, speed, and scope. The availability of the supporting data required to perform such comparisons can limit these vital evaluations. The user should develop a verification suite of tests to provide a level of confidence in the validation process and in their understanding of the use of the model.

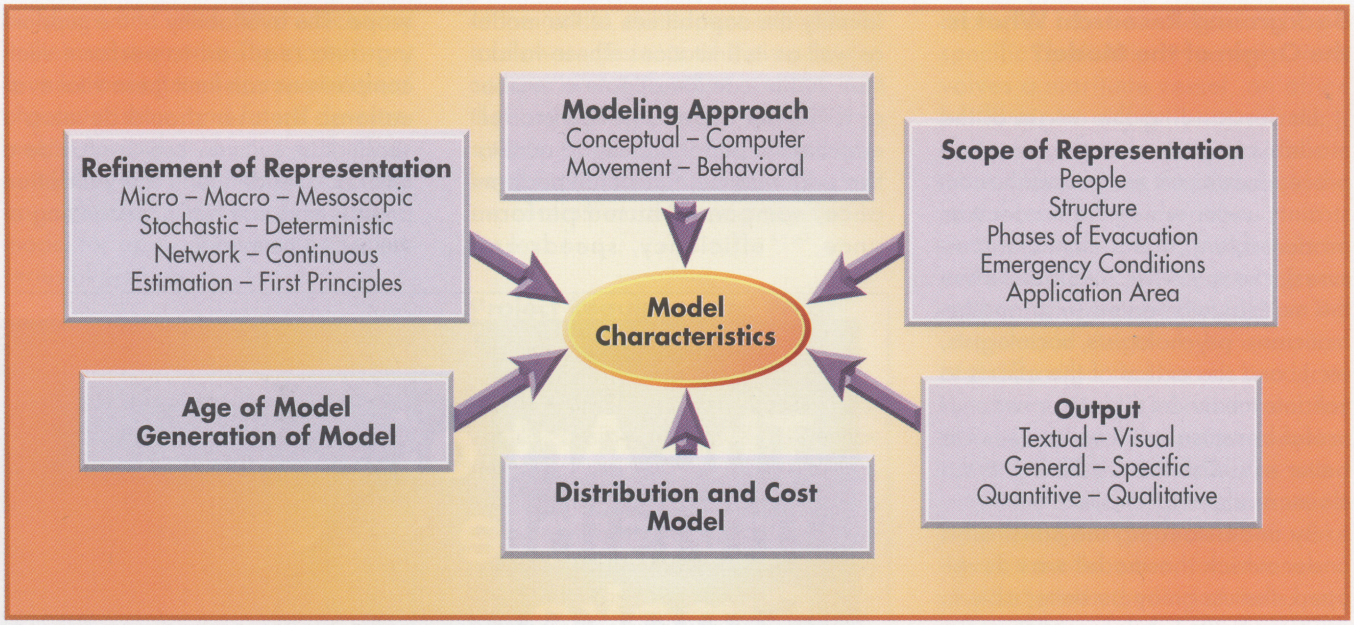

Figure 1. Current characteristics of evacuation models

Model Characteristics: Where "Is" the Model in Relation to the Others?

In addition to assessing the project's requirements and model's background information, it is important to understand the current modeling characteristics enabling a comparison between the models currently available. By identifying and understanding the important characteristics of the current evacuation models, the user will be able to make a more informed decision to choose the model that is most appropriate for the specific project. Key evacuation models characteristics are displayed in Figure 1.

The modeling approach describes the overall sophistication that the model is attempting to simulate. A user might choose a conceptual model to attempt to capture the relationship between processes at a theoretical level (e.g., the decision-making process, likely activities performed during an evacuation from a home, etc.).[18,19,20] It is often the case that these "abstract" models become incorporated into evacuation computer models through the development of dedicated algorithms. Alternatively, the user might choose a computer model to quantify human movement and (occasionally) behavior during fire emergencies. A principal objective of these models is to produce an evacuation time for a structure; however, these models have progressively been able to provide information such as flow rates, congested areas, etc. On another level of sophistication, these computer models may be subdivided according to whether they concentrate on the optimal movement of the evacuees, exclude a number of expected behaviors, or include a comparatively wide range of behaviors. The user would then have to determine whether their requirements warranted the inclusion or exclusion of these behaviors.

An evacuation model user should be familiar with the differences in the flexibility or scope of how the models represent aspects of the evacuation, including the occupants, the structure, emergency conditions, etc. Examples of the scope of representation include the simulation of the impact of occupants with disabilities,[21] the inclusion of certain aspects the structure (i.e., doorways, signage) via engineering plans,[14] the number of phases of the event simulated,[22] and the simulation of fire conditions and their impact on evacuees[21,23] against their performance under nonemergency conditions.[24] It is important to understand how a particular model represents/simulates certain aspects of an evacuation, especially if they are key components of the scenarios required for the project in question. For example, if the project requires the simulation of a population that includes people with differences in age, gender, mobility impairments, and size, the user should ensure that the model has this capability.

In addition to understanding whether certain aspects of the evacuation are simulated, the model user should understand to what level of detail these aspects are simulated. The user should be familiar with the refinement (or fine-tuning) of the evacuation aspects available among current models. The user should be aware that an increase in refinement may require an increase in the effort needed of the user and an increase in the computer time needed to run the simulation. Examples of methods of refined representation follow: representing the population as individuals[25] as opposed to representing them as a homogeneous population,[26] representing the structure as a continuous space on a vector grid[14] or dividing the structure into larger spaces (rooms, corridors, and staircases),[15] and representing certain actions performed during an evacuation as deterministic (defined)[27] or probabilistic (based on probabilities provided by the user).[28] For example, if the project requires the simulation of a primarily open structure with the presence of obstacles or several pieces of furniture (e.g., large theater), then it may be more appropriate to choose a model that represents individuals in a continuous or finely segregated space.

It is important for the model user to be aware of the age of the model and the developments/advancements since its release. In some cases, older models become dated, cease to advance in accordance with technology progress, and therefore can no longer be used[29] or become obsolete. On the other hand, if it is seen that the developing organization of an older model continually updates and maintains the software, the user may be interested in using a more "established" model that has been continuously developed and has been involved in a variety of projects over the years;[23,28] it has a proven track record of application. In the case of newly developed models,[12,16,30] the user should be cognizant of its validation efforts, specifically because the model may not have been used for practical purposes/projects since its release.

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The output produced is an important characteristic to consider when selecting a model. Many times, the interested parties will require more information from the simulation than simply the total evacuation time. Current models can provide a variety of output, including textual output,[15] two-dimensional graphical output,[26,31,32] descriptive interpretation and graphs,[23,24] and three-dimensional/virtual reality interface.[25] In addition, several models are able to have the nature of their output modified in order to fit the project requirements.[30]

Another important characteristic involved in model choice is the user's access to the models, i.e., the model availability. Some models are distributed for local application, whereas other models are employed by their developers centrally, with the results then distributed.[28] In the former case, the model user actually develops the input, runs the simulations, and then analyzes the output; and in the latter, the user works with the developing company and will have access to the output only. In reality, the model may be distributed in a number of different ways: the software is free of charge;[33] available on a consultative basis;[32] available via a flat-rate fee;[21] available under license control; or some combination of these methods.[23]

Future Considerations: What Should the User Be Aware of in Evacuation Modeling to Plan for the Future?

Any user or potential user should be aware that there are important factors regarding future projects and advances in the field that can influence the selection of models. Future considerations are especially important when a user intends to invest significant resources into using a model, possibly for multiple projects over several years, and therefore has a vested interest in the ability of the model to cope with future demands. This might not be the case if a user is only interested in short-term projects or if he/she has access to a number of models.

Although the future of evacuation modeling is uncertain, it is possible to extrapolate from the current situation to establish what issues future developments will be sensitive of and therefore what capabilities the user should expect from future models. It is anticipated that the user will need to address the following questions relating to the future development of evacuation models and their suitability to the needs of the user:

Will the user attempt to model designs of a larger scale in the future?

The user may require that future projects involve larger and more complicated structural configurations inhabited by more diverse populations. The user should be aware that as the complexity of the scenario increases, so evacuation models will have to cater for the computational expense of simulating them. If the scale of future projects will be a factor, the user should select models that are flexible to this issue, for instance, models that are only constrained by the user's computing technology.

Is the evacuation model able to incorporate new data?

With future research projects developing in the area of human behavior in fire, the understanding of egress behavior will increase, providing additional datasets for application with evacuation models. The user should be aware of this potential increase in people movement and behavioral data, and choose a model that allows for flexibility of scope. For instance, the user may be interested in the impact of the performance of staff in their execution of a procedure during an emergency scenario, requiring that the evacuation model be extended to reliably reflect this aspect of an evacuation.

What type of scenarios might the user model in the future?

Given the potential for a variety of different emergency scenarios, the user may expect that the evacuation model in question should be flexible enough to cope with the set of scenarios in which they are interested. This may include the occurrence of a fire; an earthquake; an explosion; the involvement of biological, chemical, or nuclear material (accidental or intentional); as well as structural collapse. In determining the safety of a structure in the future, the user may wish to investigate a number of these scenarios, possibly examining multiple-event scenarios, requiring that the evacuation model being used is capable of reflecting these incidents and their impact upon the evacuating population. These scenarios should also take into consideration the procedural response of the evacuation. This might include a phased or controlled evacuation procedure and may also involve the use of vertical egress systems, e.g., elevators.

Will the user require that the evacuation model be better coupled with other modeling technology and allow for real-time manipulation?

In future applications, the user may wish to analyze the evacuation in conjunction with the evolution of the incident, the performance of the rescue services, the integrity of the structure, the activity of the suppression systems, etc. The user may therefore require that either the model is able to interact with other existing technologies or that it has the capacity to be modified in order to do so. In addition, the user may wish to adopt a more active role with the scenario development within the model; i.e., the user may require that the model have the capability to be manipulated in real time in order to investigate the consequences of these interventions or to establish a worst-case

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scenario more effectively. For instance, the interaction between the user and the model may reflect simulated staff intervention (e.g., what happens if a member of staff closes an exit).

Is the model able to produce output flexible enough to cope with future demands?

It is important that the user establish whether the model is able to produce output that is sufficient for future applications. The requirements of future applications may differ from those currently addressed by the user as: 1) the application area of the user may expand to include new areas; 2) the regulations governing an application area may change; and 3) the expectations of the target audience may increase in light of technological developments. For instance, a user may take on a maritime project, where previously their application area involved buildings; the requirements of the regulations determining compliance for ships may be different from those controlling buildings; and the future audience for these results may expect that they be presented in a variety of different forms, e.g., numerical output, two- and three-dimensional graphics, interactive output, etc.

If a user (or potential user) intends to invest significant resources into selecting a model, acquiring support, licenses, documentation, and training staff to utilize the model, then the flexibility and long-term capabilities of the model would be of great interest.

Erica Kuligowski is with the National Institute of Standards and Technology, and Steven Gwynne is with the Fire Safety Engineering Group, University of Greenwich, UK.

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