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Representing evacuation behavior in engineering terms

Steven Gwynne
Hughes Associates, UK

Erica Kuligowski
Engineering Laboratory, National Institute of Standards and Technology, MD, USA

Daniel Nilsson
Department of Fire Safety Engineering and Systems Safety, Lund University, Sweden

Abstract

In performance-based analyses, engineers evaluate whether a building design and/or evacuation procedure allows occupants sufficient time to evacuate before fire conditions become untenable. Guidance exists for the calculation of the time until conditions become untenable in areas of the structure (known as the available safe egress time) during fire situations. This article presents a method for determining the amount of time required for building occupants to reach a defined point of safety (known as the required safe egress time) for a particular building design or scenario. The method requires the engineer to identify real-world factors from the building conditions/situations that influence human performance (e.g. evacuation), understand the nature of their impact on human performance and then represent this impact in terms that can be employed within evacuation model calculations. An example is also presented to demonstrate the method described here.

Keywords

Evacuation, human behaviour, performance-based design, evacuation models

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Corresponding author:
Erica Kuligowski, Engineering Laboratory, National Institute of Standards and Technology, MD, USA
Email: erica.kuligowski@nist.gov

Introduction

Performance-based analyses are used more frequently as building designs become more complex and/or fall outside the traditional regulatory scope. In performance-based analyses, engineers evaluate whether a building design and/or evacuation procedure allows occupants sufficient time to evacuate before fire conditions become untenable. Computer-based evacuation simulation tools are increasingly used, along with existing engineering calculations, to evaluate the required safe egress time (RSET), which is the amount of time required for the building occupants to reach a point of safety. RSET is then compared to the available safe egress time (ASET), defined as the time until conditions become untenable in areas of the structure required for evacuation. The simulation tools and engineering calculations are referred to collectively as evacuation models for the rest of this article.

In order to establish RSET, the first step is to identify occupant-related factors from real-world situations that influence human performance (e.g. in this case, during an evacuation). Given the number of possible factors, it is unlikely that all these factors will be included in the analysis. Also, it may not be credible for all these factors to have an impact simultaneously; i.e. some factors may be mutually exclusive. Therefore, the engineer typically selects sub-sets of real-world factors to develop representative occupant scenarios to ultimately determine occupant responses to the fire scenarios of interest. Fire scenarios, as defined in ISO/TS16733, are a qualitative description that characterizes the fire and its development in terms of key events. These key events are determined from initial conditions that allow this fire and its development to be differentiated from other incidents. In other words, once an initiating event, the hazards, the geometric and other environmental conditions and the protection measures are specified, the fire's evolution can largely be determined. Analogously, the term occupant scenario is used here to qualitatively describe the key elements of the occupant response to the incident and the initial conditions that determine this response. In other words, geometric, environmental, procedural and behavioural factors describe the initial conditions that then characterize and shape the occupant response to the incident. This article addresses the design of these occupant scenarios and the process of translating real-world factors/situations into parameters for use in evacuation models. The process described here complements the methods employed to produce fire scenarios, described elsewhere [1].

The proposed method was initiated as a part of the ongoing work in ISO to develop a guidance document for the design of occupant-related scenarios [1]. The method has been presented to experts in an ISO working group (TC92/SC4/WG11) and has been continuously revised based on comments received from the group. In addition, the authors' experience with performance-based analyses has played an important role in the development of the method. The method, as presented, has been extended by the authors beyond the original ISO approach. As such, it will be subject to additional expert review and will be modified accordingly.

When calculating RSET using evacuation models or other calculation techniques (e.g. hand calculations), the engineer must complete the following series of tasks in order to distill real-world factors into representative model scenarios that can be used in the RSET calculation:

- Task 1 identifies real-world conditions associated with the building design in question;
- Task 2 identifies the occupant model scenarios that will eventually be represented;
- Task 3 quantifies these model scenarios by configuring the human performance components that are accounted for by evacuation models;
- Task 4 translates the human performance components into input for the chosen evacuation model(s);
- Task 5 employs the evacuation model(s); and
- Tasks 6 compares these RSET results with that of ASET from fire modelling.

This article presents a method for translating real-world considerations or situations into model scenarios (Tasks 1–3 shown in Figure 1) that describe human response for use in a performance-based assessment. A description of Tasks 1, 2 and 3 will be presented and followed by the presentation of an example of this

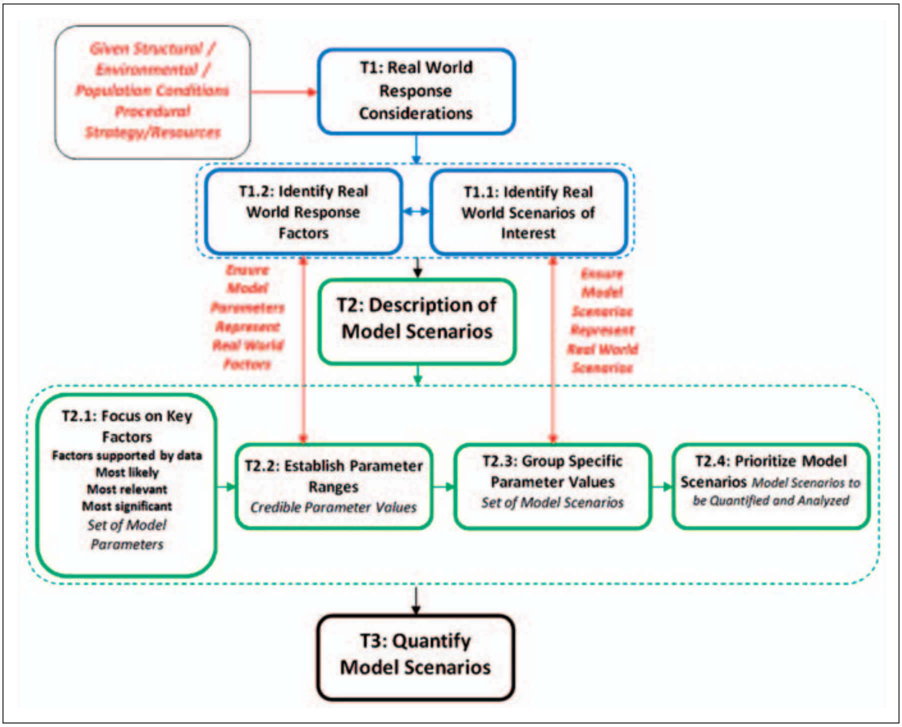

Figure 1. Process described in this article (T = Task).

methodology using a hypothetical arena. The approach will be based on general engineering practice, research related to fires and human behaviour, such as Kuligowski [2] and Gwynne [3], and the actions required to employ engineering models to meet regulatory objectives. At present, little guidance, if any, is available for translating real-world scenarios into evacuation model input parameters needed to run a model. This article presents a simple method to support the engineering process.

Although only the process of performing Tasks 1 through 3 is discussed here, the engineer should be better able to do Tasks 4–6 after following the process outlined herein.

Real-world scenarios and response factors

The case for guidance

One of the key issues with the RSET calculation is the ability of the engineer to reliably and credibly represent occupant response given the scenario(s) examined. Oftentimes, the engineer is familiar with the modelling process, i.e. the simplification of real-world entities into a form that can then be used in calculations. However, engineers tend to be more familiar with these processes when the subject matter is physical/mathematical-based as opposed to the sociological/psychological-based. A lack of understanding of the subject matter can lead to inappropriate assumptions of human behavior during given emergency scenarios and in turn, inaccurate evacuation modelling results. The guidance provided here parallels the methods of developing modelling scenarios for other areas of the engineering process. By doing so, the engineer's existing understanding of the modelling process can be used to support the method described in this article of developing occupant scenarios for RSET calculations.

Methods for development of model scenarios

Task 1 – real-world response considerations. In any performance-based assessment of a building, there are real-world scenarios and/or factors that influence occupant response during an emergency [4]. In Task 1.1 (Figure 1), engineers assess the building, occupants and emergency procedure to develop real-world scenarios of interest to include in the performance-based assessment. Information on the structure, population and procedure may be provided by or be generated in discussion with the client. Alternatively, the engineer may be responsible for generating design variants him/herself. In addition, environmental information (e.g. fire conditions) may be provided, or credible design fires may have to be generated. Irrespective of the manner in which it is provided, this information is critical in establishing the initial conditions typical of real-world scenarios. From these real-world scenarios, specific occupant factors can be identified (in Task 1.2) that form these scenarios.

A list of factors, or occupant characteristics, found to influence occupant decision-making and/or movement are discussed in the SFPE Engineering Guide on Human Behavior in Fire [4].

In reality, the interaction between the client and the engineer may initially produce scenarios of interest, which then require the engineer to establish the occupant factors of interest. On the other hand, the interaction may initially produce occupant factors of interest, which then requires the engineer to produce credible scenarios of interest. Either way, this process may be informal (e.g. being dependent upon key scenarios emerging from client–engineer discussions), or from a more formal analysis (e.g. a formal risk analysis pairing the probability of an event occurring with the consequence of the event). In any case, factors and scenarios need to be established and the relationship between them understood in order to proceed.

For example, the engineer may be asked to assess the performance of occupants evacuating from a nursing home. In discussion with the client, the engineer attains an understanding of the structural design, existing and viable procedural responses and expected population distributions. Credible fire scenarios for the nursing home may arise at this stage or later. The engineer may then begin generating real-world scenarios of interest. One example is a scenario containing an older-aged population, possibly sleeping at the time of an emergency, possibly unable to evacuate without assistance and the 24 h presence of nursing home staff in the building. Just in this scenario alone, certain factors arise as potentially influencing human response or performance, including age, physical ability of the occupant, level of familiarity with the building and/or procedure, the occupant's engagement in an activity and the emergency procedural design.

There are a large number of scenarios/factors of interest that the engineer may consider in this task. It is important for the engineer to identify the types of situations in which the occupants may find themselves at the start of an emergency. The full set of real-world factors and scenarios will not be employed during the engineering analysis; however, it is important to establish the range of potential factors and scenarios of interest in order to understand their significance and potential impact.

Task 2 – description of model scenarios. The purpose of Task 2 is to develop the evacuation model scenarios that will eventually be employed in the performance-based assessment. Task 2 has four subtasks that lead the engineer from the real-world scenarios to the development of model scenarios. The subtasks are labelled as Tasks 2.1 through 2.4 and each will be described below.

The purpose of the first subtask, Task 2.1, is to reduce the real-world factors into a manageable set of model parameters. This should be done by selecting the real-world factors that have been shown to affect evacuation results and that are supported by data and theory of human behaviour and movement in fires and other emergencies. There are several studies and reviews that have been published on the factors that influence evacuation response (including [2, 5–15]). These works contain original work or review previous studies on building evacuations from both real events and trials and in turn, identify model parameters that influence evacuation response based on data and theory. A select group of model parameters that have been found in previous studies to affect evacuation response are included here:

- occupant age/gender;
- event state (e.g. asleep, intoxicated);
- social role;
- training/experience;
- familiarity;
- social affiliation;
- disability;
- building layout and the occupants' visual access of the floor;
- alarm system design; and
- environmental cues from the event (including cues from the incident and cues from others in the building).

Inevitably, there will be real-world factors that are of particular interest (either for the client or because of perceived importance), but which lack supporting data to quantify the effects. Examples of the latter would be specific cultural factors, local social relationships, etc. In such circumstances, engineering judgement will need to be applied. It is critical that this is clearly identified, so that the reviewer of the assessment is aware of all engineering assumptions and judgements made.

In the second subtask, Task 2.2, the engineer should establish the viable range or distribution of values for each model parameter identified in Task 2.1. For some factors of interest, the range/distribution is fairly straightforward; e.g. an occupant will either be awake or asleep in the model scenario. However, for other factors, the range/distribution may be more difficult to identify and may require more information about expected building use and population; e.g. age. It requires the engineer to understand the type of people expected to use the building for each scenario. The engineer should also be aware of the level of uncertainty associated with the value ranges or distributions of the data used. This process is critical in being able to quantify the parameters and also generating credible model scenarios.

In the third subtask, Task 2.3, the engineer should cluster the model parameters and their values together to produce representative model scenarios. Again, this may involve informal methods to produce representative scenarios, or a more formal risk analysis approach may be employed. The outcome of this subtask is the development of model scenarios that will eventually be examined by engineering/computational evacuation models. An example from the nursing home assessment is as follows: one scenario might assume that all older adults (ages 60–95) are awake, ambulatory and located in one room of the nursing home watching a television show. Another scenario might assume that all older adults (ages 60–95) are asleep, non-ambulatory and located in their separate living spaces with only tone-based alarms to alert them of an incident. Here, the engineer is simply listing the different types of scenarios that he/she will evaluate in later stages of the performance-based process.[1]

The model scenarios produced in Task 2.3 should be compared with the real-world scenarios of interest in Task 1.1 in order to confirm that they are representative and comprehensive, enabling robust solutions.

Finally, in the fourth subtask, Task 2.4, the engineer will need to prioritize the scenarios developed in Task 2.3 based on a number of factors including their likelihood, similarity, potential impact and whether there is the potential for these scenarios to be addressed through engineering means. The selected model scenarios from Task 2.4 can represent clusters of more detailed or even similar scenarios ensuring that all major model parameters and conditions are accounted for in the performance-based design. If the engineer has developed too large a number of model scenarios in Task 2.3, prioritization and selection of model scenarios should be performed based on the likelihood of the particular scenario occurring and/or the consequence of each scenario.

Task 3 – quantifying model scenarios. Core performance components represent the initial conditions of evacuation models used to evaluate evacuation time. These core components need to be addressed (and can be addressed) irrespective of the engineering approach adopted, representing the minimum when establishing RSET. The purpose of Task 3 is to quantitatively represent the chosen scenarios from Task 2 for use by evacuation models. This is done by configuring the five core performance components to account for the factors in each chosen model scenario. These five core components that represent evacuee performance are:

a. pre-evacuation time – the time for evacuees to initiate response;
b. travel speeds – the speed at which evacuees move;
c. route usage/choice – the routes selected by the evacuees from those available;
d. route availability – the routes available to the evacuees; and
e. flow conditions/constraints – the relationship between speed, flow, population density and population size.

Table 1 presents the five core performance components that engineers can configure to represent the model scenarios, ultimately calculating egress times for the performance-based assessment of the building. How this is achieved will differ according to the model and the performance component in question. It may be that new data are provided to the model, model settings are chosen and/or default data-sets embedded are selected/modified to reflect the desired conditions.

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[1] The engineer may also be interested in testing various aspects of the emergency procedure in order to establish a level of robustness. To do so, the engineer may produce scenarios that are not ‘realistic’ (i.e. not representative of a real-world scenario) in order test a specific aspect of the emergency procedure. For instance, it may be assumed that the evacuating population begins evacuation immediately (without delay), in order to produce the highest levels of congestion possible.

Table 1. Description of performance components.

Core performance component	Example component setting	Considerations for evacuee response given a component setting
Pre-evacuation times	Instantaneous (hypothetical)	No delay
	Distributed (hypothetical)	Evacuation begins over a period of time
	Estimated	Estimated response from comparable empirical data
	According to procedure	Evacuation starts according to the procedure assumed during the scenario
	According to external conditions	Start time derived from the external environmental/structural/social conditions faced
Travel speeds	Homogenous (hypothetical)	Everyone has the same speed
	Heterogeneous (hypothetical)	A range/distribution of speeds are employed
	Heterogeneous (representative)	A range/distribution of representative speeds are employed
	Affected by external conditions	Speeds are modified given environmental/structural/social conditions
	Affected by procedural actions	Speeds are modified according to the procedure employed
	Affected by innate attributes	Specific evacuee attributes that impact speed are represented
Route usage	Proximity based	Evacuees use nearest exit
	Design based	Exits are used in the numbers specified by the design
	Familiarity based	Evacuees use exits through which they routinely enter/leave the structure
	Procedure based	Exits are used according to procedural instruction
Route availability	Environment based	Routes limited through environmental conditions
	Regulation based	Routes limited according to regulatory requirement
Flow constraints	Model predicted	Model is allowed to predict the flow levels produced
	Regulation based	Flow levels derived from code
	Data based	Flow levels derived from literature

Some more sophisticated models will allow (or require) a greater number of parameters to be considered that address factors beyond these five core components. However, the core components need to be addressed, in some way, in all the models employed. These five components are configured to reflect evacuee performance in response to and constrained by the initial conditions provided in Task 1 (e.g. structural design, procedural measures employed, population distribution and fire conditions).

It is important that the quantification of the model scenarios is transparent and well documented in the performance-based analysis. Lack of transparency may result in repeatability issues, since it will not be obvious why certain component settings were chosen based on specific model parameter values.

In the case of pre-evacuation times, in Table 1, research has shown that certain factors (occupant characteristics, environmental factors and even building design) influence how long occupants will take to respond to cues or to begin evacuation. The engineer is almost always tasked with providing data on pre-evacuation times, e.g. a pre-evacuation time distribution, as input to the evacuation model. Often, these data are based on the type of building; however, some data identify factors that increase or decrease pre-evacuation time (e.g. intoxication of occupants causes pre-evacuation time to increase [16]) and it is up to the engineer to quantify this factor using engineering judgement.

Similarly, the engineer may be required to provide travel speeds for occupants or groups of occupants in each scenario. However, there are some models that are equipped with rules that allow travel speeds to change based on occupant characteristics, such as gender and age. In cases where the engineer must provide travel speeds as input to the model, these speeds should be based on the factors of interest identified in the scenario (e.g. in the nursing home, older, ambulatory adults are expected to walk slower than younger adults).

Route usage/choice and route availability are normally required as input by the evacuation model as well. There are certain parameters (e.g. familiarity and proximity) that affect the routes that occupants choose during an evacuation. The engineer is required to assess whether any of the model parameters in the scenarios of interest influence route usage/choice and in what ways. Route availability, on the other hand, can be influenced by the fire design scenarios (i.e. the ASET calculation), code requirements (e.g. that a route needs to be discounted) or could be an input that the engineer is interested in altering in certain occupant model scenarios. Either way, route usage/choice and availability are provided as input to evacuation models.

It becomes necessary to provide initial conditions on flow conditions or constraints mainly when the engineer is using a hand calculation or a flow-based evacuation model. To achieve this, the engineer will need to understand the types of crowding expected in the building during evacuation in each model scenario. For example, in a scenario where all occupants are highly trained to respond to the alarm and a well-constructed emergency message is provided, the engineer may assign low or even no delay times to the population. In this example scenario, the engineer might expect optimal (or crowded) flow conditions/performance.

Thus, there are certain factors from the scenario (e.g. familiarity and alarm system) and even other inputs for the model (e.g. low delay times) that influence expected flow conditions. For certain evacuation modelling methods, the engineer will need to account for flow as an input variable.

In addition to these model parameters that represent human response, information is also required on the initial conditions from which the scenario unfolds: the population size and initial starting position, the structure and the environmental conditions. Population size and initial starting position are always the initial inputs required by the engineer for the configuration of the evacuation model. Sometimes, population size is provided by the client and other times, it can be found by performing calculations based on the plan area in the building and the occupancy load factors in the building codes. Population starting position (i.e. the location of occupants throughout the building) may also be provided by the client; however, other times this is dictated by the model scenario (e.g. older adults located in their rooms were sleeping). Similarly, several structural designs (e.g. layout configurations) and procedural designs (e.g. human and technological resources) may be considered, either through early discussions with the client in Task 1 or through subsequent analysis. The fire conditions present in the scenario may be provided by the client, by regulation or *through parallel analysis*. In all instances, they may have a direct impact on evacuee performance and so should be represented in the five performance components.

During this phase, similar sets of model input parameters may be produced when representing different model scenarios. For example, although the model scenarios represent different real-world scenarios, they are represented by the same numerical performance components within the model scenarios and can, therefore, be deemed equivalent. This quantitative comparison represents another opportunity for reducing the number of scenarios finally modelled. Therefore, as in Task 2.4, it may be possible to reduce the number of model scenarios being examined.

Now that Tasks 1–3 have been described, an example will be provided to demonstrate this method using a hypothetical arena, namely a multi-purpose stadium and events center.

Example – multi-purpose arena and events centre

The arena is a one-storey building with a floor that accommodates a wide range of sports, such as basketball (four courts), volleyball (four courts) and badminton (six courts). In addition, the floor can be modified to accommodate individual sports, such as fencing, boxing and wrestling.

The sports floor is surrounded by bleachers (tiered seating), and the maximum capacity of the arena for a sport event (a basketball match) is 4500 (Figure 2). Some of the bleachers are retractable or removable, which means that a large floor area can be cleared for other uses of the building. Toilets are located under the mezzanines (Figure 2). Other expected uses include concerts/entertainment,

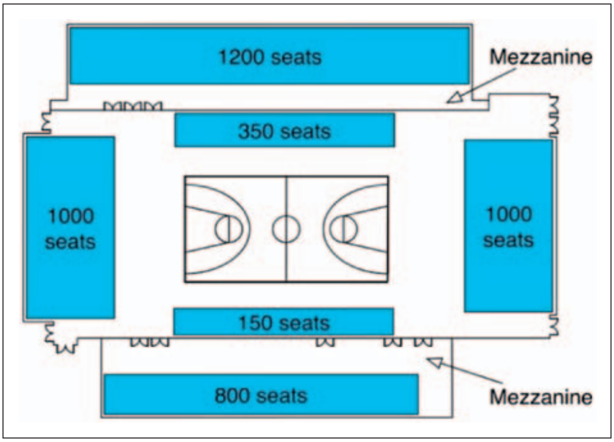

Figure 2. The example arena for a basketball event.

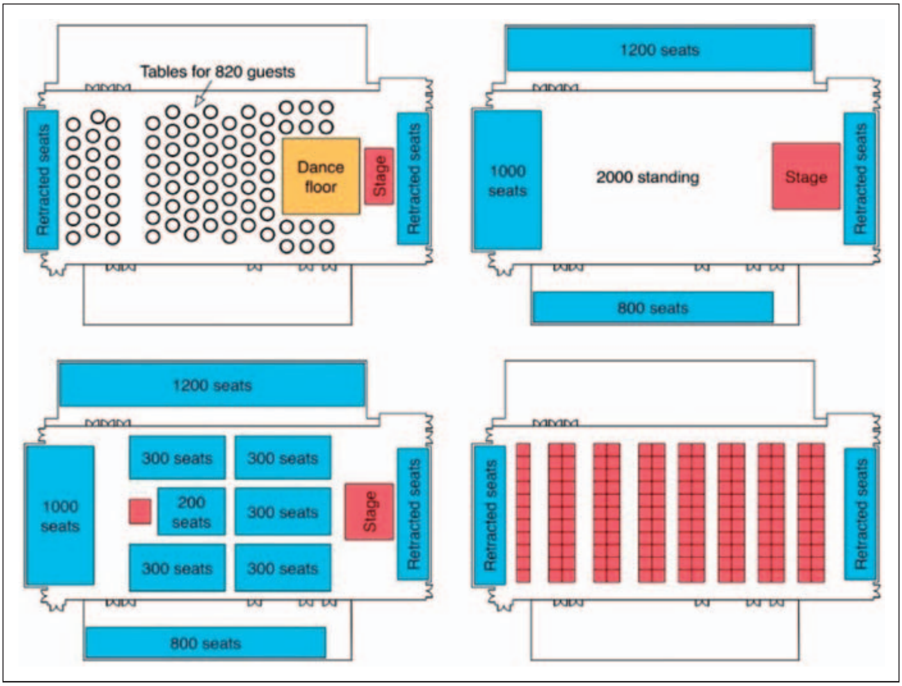

Figure 3. The example arena – banquets (top left), concerts/entertainment (top right), seminars (bottom left) and expositions (bottom right).

banquets, seminars and expositions (Figure 3). The maximum allowed capacity of the building is 5000 occupants. This capacity is relevant mainly for concerts/entertainment.

The arena is equipped with a fire detection and alarm system. A voice alarm will inform people about the cause of the alarm (e.g. that a fire has been detected) and appropriate action to take.

Example implementation of Task 1 – real-world scenarios and response factors

The first task of the proposed method is to identify real-world scenarios (Task 1.1) and factors (Task 1.2) for the arena. Based on the description of the building, the arena can be used in a number of different ways. The relevant real-world scenarios include different types of sport events, concerts/entertainment, banquettes, seminars and expositions. For each of these uses, there are factors (building, population and procedural) that are important for the design process and hence need to be identified.

The arena can be used for concerts and other types of entertainment. This particular use may include a wide set of real-world scenarios, ranging from entertainment events for children to rock concerts. People will be awake during these events, although for some, their alertness, awareness and ability to comprehend available cues may be affected by alcohol or the use of recreational drugs. Concerts typically also involve high sound levels that may cause hearing loss and tinnitus (ringing in the ears that interferes with normal hearing), either temporarily from the concert itself or permanently due to chronic exposure.

The age of the visitors can vary significantly depending on the type of concert or entertainment event. Age is therefore an important factor. Another important aspect is that concerts and other types of entertainment are social events. This means that there will be many families at the entertainment events for children or partners and groups of friends can be among the visitors at a concert.

Further investigation of other potential uses of the arena, i.e. real-world scenarios, can reveal additional factors that are important for design of the arena. However, in this article, only the concert/entertainment case will be used to illustrate the different tasks. Based on the sections above, a number of important (potential) real-world factors can be identified (Table 2, column 1). Obviously, these may change from situation to situation, and are used here to demonstrate the considerations that are required. The list in the first column of Table 2 should only be seen as an example, as a more thorough analysis can potentially reveal additional important factors.

Example implementation of Task 2 – description of model scenarios

The second task of the proposed method begins with the reduction of real-world factors into a manageable set of model parameters (see Task 2.1 and Table 2).

Table 2. Examples of real-world factors for the hypothetical arena (concert/entertainment case), the corresponding engineering parameters and the extent of supporting evidence.

Real-world factor	Model parameter	Supporting evidence
Awake	Status	Data/theory
Consumption of alcohol Use of narcotic substances Use of prescription drugs	Intoxication	Data/theory/engineering. judgement[a]
Permanent hearing loss Permanent tinnitus Temporary tinnitus	Hearing impairment	Data/theory
Age	Age	Data/theory
Family groups Partners Groups of friends	Social affiliation	Theory/engineering judgement[a]

[a] It is important to note all assumptions and supporting evidence when engineering judgement is used.

The idea behind this reduction is to identify parameters that are supported by data and theory that have a significant impact on performance. Where data are not available, but a factor is deemed to be important, engineering judgement may be needed. The reduced set of factors is then used in the rest of the design process (Table 2).

Table 2 presents the real-world factors for the concert/entertainment case deemed to be significant and supportable, together with corresponding model parameters. Three of the first four factors, namely *consumption of alcohol*, *use of narcotic substances* and *use of prescription drugs*, can all be reduced to one parameter called *intoxication*. This is because all three factors have an intoxicating effect. From a design perspective, the cause of this effect is of less importance and they can, therefore, be grouped together. Another example is that hearing loss and tinnitus (permanent and temporary) can be reduced to one model parameter called *hearing impairment*. Other real-world factors can be grouped together in a similar fashion (Table 2).

In the next step (Task 2.2), the range/distribution of values for each of the identified model parameters is established. The impact of intoxication will vary significantly for the concert/entertainment case. In some situations, such as entertainment events for children, intoxication may be less of a factor. In this case, the intoxication model parameter may be set to ‘none.’ The impact of intoxication may, on the other hand, be significant for many concerts, i.e. more people may be intoxicated or intoxicated to a higher degree. In this case, the intoxication model parameter may be set to ‘major.’ Therefore, the setting for the intoxication parameter will likely range from none to major. Suggested ranges of the identified model parameters for the concert/entertainment case are presented in Table 3.

Table 3. Model parameters settings produced during Task 2.2.

Model parameter	Parameter settings
Status	[Awake | Drowsy]
Intoxication	[None | Minor | Medium | Major]
Hearing impairment	[None | Minor | Medium | Major]
Age	[Children | Adolescents | Adults | Elderly]
Social affiliation	[Loose | Medium | Strong]

Table 4. A selection of model scenarios for the arena (concert/entertainment case).

		Model parameter				
Scenario	Description	State	Intoxication	Hearing impairment	Age	Social affiliation
A	Entertainment event for children	Awake, drowsy	None	None	Children, adults	Strong
B	Rock concert	Awake	Minor, medium, major	Medium, major	Adolescents, adults	Medium
C	Pop concert	Awake	Minor, medium, major	Medium, major	Adolescents	Medium
D	Folk music concert	Awake	None, minor, medium	None minor	Adults, elderly	Medium, strong
E	Jazz concert	Awake	None, minor, medium	None, minor	Adults, elderly	Medium, strong
F	Religious event	Awake	None	Minor, medium	Children, adults, elderly	Strong
G	Play/drama	Awake	None, minor	None	Adults, elderly	Medium, strong

Once the settings have been established, the model parameters are grouped to produce a set of model scenarios (Task 2.3). These model scenarios should be compared to the previously identified real-world scenarios (Task 1.1) to ensure that they are representative of the initial conditions and information provided. In effect, the model parameters influencing evacuee performance are varied

Table 5. Example component levels.

Scenario	Example pre-evacuation component	Example travel speed component
A	Distributed (moderate–low intoxication)↑	Heterogeneous (wide range reflecting ages) ↑↑
B	Distributed (significant intoxication and hearing impediment) ↑↑	Heterogeneous (moderate range reflecting potential intoxication) ↑
C		Heterogeneous (wide range reflecting potential for severe intoxication) ↑↑
D/E	Distributed (moderate–no intoxication, some hearing impediment) ↑	Heterogeneous (wide range reflecting potential for elderly) ↑↑
G	Distributed (moderate–low intoxication, no impediment) ↑	Heterogeneous (wide range reflecting potential for elderly) ↑↑

↑, moderate increase in component setting (e.g. 0–25%) and ↑↑, significant increase in component setting (e.g. 25–100%).

within the stated ranges given the structural (e.g. design variations), population (e.g. location distributions, sizes, etc.), environmental (e.g. fire location, severity, etc.) and procedural information provided (e.g. alarm type, staff activities, etc.). Some of the relevant model scenarios and their impact on performance for the concert/event case are presented in Table 4. (For simplicity, it is assumed that the set of structural designs, fire scenarios and population distributions are comparable across the stated scenarios given that the example only addresses concert/entertainment use.)

For example, a rock concert is one possible model scenario (scenario B in Table 4). For this particular scenario, the occupants can be expected to be awake, but it is also possible that they will be intoxicated. The level of intoxication can, however, vary significantly from one occupant to another (minor to major). Because the event involves loud music, hearing impairment will also be an important parameter (medium to major). At a rock concert, the occupants can be expected to be both adolescents and adults. In addition, most visitors are expected to attend the concert either in groups or in pairs, which makes social affiliation relatively important (medium).

In this example, Scenario F can be excluded given that (in this hypothetical case) it is considered relatively infrequent and has a reduced population. In addition, Scenarios D and E are qualitatively similar and can be grouped together into one scenario. The seven original scenarios (A–G) have now been reduced (through high level qualitative comparison and according to crude risk analysis) to a more manageable number of model scenarios (Task 2.4).

Example implementation of Task 3 – quantify model scenarios

In Task 3, the model scenarios are represented using the five core performance components. Effectively, the performance components are quantified to adequately represent the scenario in question within the evacuation model. Various options available during this process were presented in Table 1. Here, descriptions of the component settings are shown. These settings would then need to be quantified and represented in a form that could be implemented directly within a model. For instance, the *Instantaneous* setting for *Pre-Evacuation Times* indicates that the modelled occupants commence their response at 0 s; where *Route Usage* is set to *Proximity-Based*, then the population uses their nearest available exit; where *Attainable Travel Speeds* are set to *Homogenous*, the population is able to travel at the same speed, etc.

Given the scenarios described earlier and the associated model parameter settings, component settings can then be selected. These provide sufficient detail for the components such that the engineer can now quantify them according to the available information. An example of hypothetical pre-evacuation and travel speed values is presented in Table 5. It is apparent that Scenarios D/E and G are quantitatively similar in nature and may potentially be represented using the same calculations.

It may be possible to skip labelling the component settings (shown in Table 1) and therefore go from the description of the model parameters associated with the scenarios (Table 4) to the qualification of the component levels (shown in Table 5). However, the intermediate step given in Table 1 can help to identify scenarios that, although based on different real-world assumptions, lead to similar model scenarios.

Conclusions

Producing viable response scenarios is a critical component in performance-based design, enabling the engineer to establish the RSET. However, it is not simply a case of being able to generate values that can then be used in the ASET/RSET comparison. Rather, the engineer needs to understand the real-world factors that are being represented and the manner in which these factors are simplified and represented in a modelled form. Although the proposed approach represents a significant simplification of reality and will certainly not guarantee that engineers will employ accurate figures in their calculations, it should allow engineers to better characterize the impact of certain factors and then develop engineering input in a more credible and reliable manner.

The suggested approach will be subjected to 'beta-testing' by engineers in the field and those involved in the ISO guidance development process. As such, the suggested approach is only in preliminary form. However, it is felt that this is a useful initial step in guiding the analysis of human egress and subsequently establishing RSET in a more credible and reliable manner.

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