# Representing Egress Behaviour in Engineering Terms

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## Abstract

When using engineering tools to calculate the required safe egress time (RSET), the engineer must identify actual human factors that will influence the outcome of an evacuation in a particular situation. The engineer must then represent these factors in the engineering method selected to determine the RSET value. This paper presents a method for translating real-world conditions or situations into model scenarios that describe human response for use in a performance-based assessment. The translation will require identifying real world factors that influence human performance, understanding the nature of their impact on human performance, and then representing this impact in fundamental terms that can be employed within engineering scenarios. An example is also presented to demonstrate the method described in this paper.

## Introduction

Performance-based analyses are used more frequently as building designs become more complex and/or fall outside of the traditional regulatory scope. In performance-based analyses, engineers attempt to 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 the existing engineering calculations already employed to evaluate the required safe egress time (RSET), i.e., the amount of time required for the building occupants to reach a user-defined 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. 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 real-world factors that influence human performance need to be identified along with the nature and extent of this effect. Given the number of possible factors, it is unlikely that all of these factors will be included in the analysis. Also, it may not be credible for all of these factors to have an impact simultaneously; i.e., some factors may be mutually exclusive. Therefore, the engineer typically selects representative scenarios constructed from sub-sets of real-world factors to determine possible occupant responses to the fire scenarios of interest. This paper addresses the design of these scenarios and the process of translating real-world considerations into parameters for use in evacuation models. The process described here complements the methods employed to produce human response and model fire scenarios described elsewhere [1].

When calculating RSET using evacuation models, the engineer must complete a series of tasks in order to distill real world factors into a representative form that can be used in the RSET calculation:

- Task 1) identify real-world conditions associated with the building design in question,
- Task 2) identify the evacuation model scenarios that will eventually be represented,
- Task 3) quantify these model scenarios by setting the performance components that are accounted for by evacuation models,
- Task 4) translate the quantified scenarios into input for evacuation models,
- Task 5) employ the evacuation models,
- Task 6) compare these RSET results with ASET results from fire modelling.

This paper presents a method for translating real-world conditions or situations into model scenarios (Tasks 1-3) 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 methodology using a hypothetical arena. The approach will be based on general engineering practice, research related to fires and human behaviour (e.g., [2,3]), and the actions required to employ engineering models to meet regulatory objectives. At present, little guidance, if any, is available on translating design scenarios into evacuation model input parameters needed to run a model. This paper presents a simple method to support the engineering process – translating real world situations or scenarios into modelling parameters.

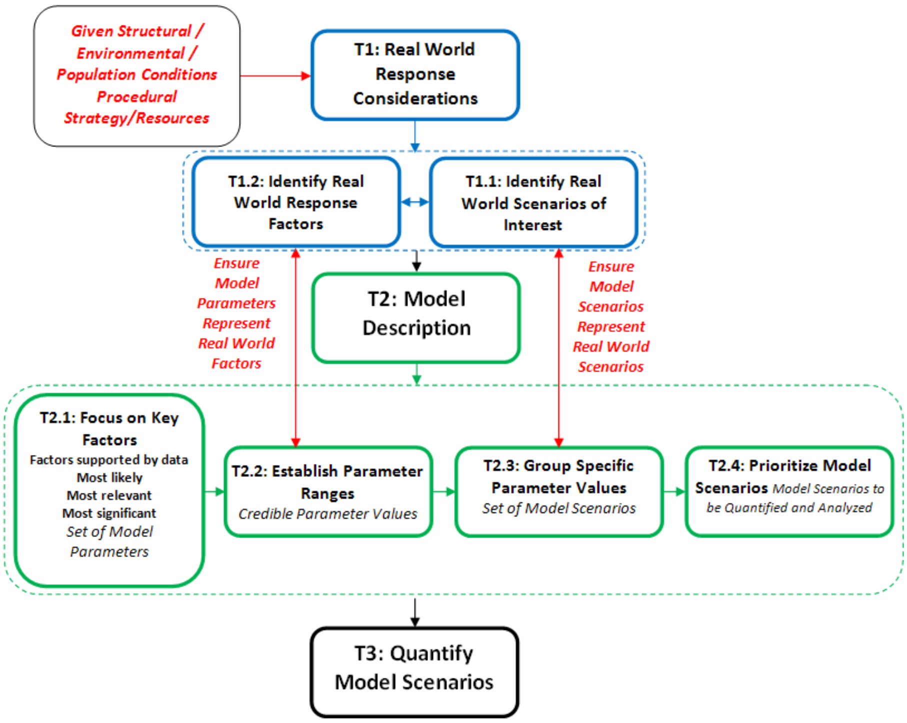



Figure 1: Process described in this article.

This paper describes the process by which the engineer develops model scenarios from real-world conditions and represents them in terms of the five basic performance components. Numerating these components and employing the performance models (i.e., Tasks 4-6) is beyond the scope of this article. However, the engineer should be better able to do this should they have followed the process outlined herein.

## *Method to Develop Real World Scenarios and Response Factors*

### *Task 1 – Real World Response Considerations*

In any performance-based assessment of a building, there are real-world response scenarios and/or factors that influence occupant response during an emergency. The list of factors, or occupant characteristics, found to influence occupant decision-making and/or movement are discussed in the Society of Fire Protection Engineers (SFPE) Engineering Guide on Human Behavior in Fire [4]. In Task 1.1, 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 themselves. 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 this information is provided, it will influence the anticipated evacuee performance and therefore is critical in establishing the initial conditions of the real world scenarios. From these real world scenarios, specific response factors can be identified (in Task 1.2) that form these scenarios.

In reality, the interaction between the client and the engineer may initially produce scenarios of interest (which then require the engineer to establish the constituent factors), or factors of interest (which then requires the engineer to produce credible scenarios of interest). 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 the event). In any event, factors and scenarios need to be established and the relationship between them understood. 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 may arise at this stage or later, leading to the projected fire conditions to be established. The engineer may then begin generating real world response scenarios of interest; e.g., a scenario containing an older-aged population, possibly sleeping at the time of an emergency, possibly unable to evacuate without assistance, and the 24 hour presence of nursing home staff in the building. Just in this scenario alone, certain factors arise as potentially influencing response 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 him/her 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 1 Objective: To develop a set of real world scenarios and response factors.*

### *Task 2 – Model Description*

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 identification of real world scenarios to the development of model scenarios. The subtasks are labelled as Task 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 behavior 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 [5-15]). These works 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 lack supporting data; i.e., even though the factor is considered to be important and needed as a model parameter, it cannot directly be quantified. In such circumstances, engineering judgment 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 judgments made.

*Task 2.1 Objective: To prioritize real-world factors and produce a reduced set of model parameters.*

In subtask 2.2, the engineer should establish the credible range or distribution of values for each model parameter identified in subtask 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.

*Task 2.2 Objective: To produce viable ranges/distributions for model parameters.*

In subtask 2.3, the engineer should cluster the model parameters and their values together to produce credible model scenarios. Again, this may involve ad hoc methods to produce representative scenarios, or more a 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 to 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 to 95) are asleep, non-ambulatory, and located in their separate living spaces with only bedroom, 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.
*Task 2.3 Objective: To produce representative model scenarios.*

Finally, in subtask 2.4, the engineer will need to prioritize the scenarios developed in subtask 2.3 based on their likelihood, similarity, potential impact, credibility, representativeness 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. And, 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 (i.e., the engineer should consider including high-consequence events, especially if they are high-likelihood).
*Task 2.4 Objective: To produce a manageable number of model scenarios.*

*Task 3 – Quantifying Model Scenarios*

The purpose of Task 3 is to represent the chosen scenarios from Task 2 quantitatively for assessment by evacuation models. This is done by configuring the five fundamental performance components to account for the factors in each chosen model scenario. Fundamental performance components are the initial conditions of evacuation models used to evaluate evacuation time.

Table 1 shows the five fundamental 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 is provided to the model, model settings are chosen, and/or default data-sets embedded are selected/modified to reflect the desired conditions. Some more sophisticated models will allow (or require) a greater number of parameters to be considered. However, these basic components need to be addressed, in some way, in all of 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).

These five components that represent evacuee performance are:

1) pre-response or pre-evacuation time – the time for evacuees to initiate response,
2) travel speeds – the speed at which evacuees move,
3) route availability – the routes available to the evacuees,
4) route usage/choice – the routes selected by the evacuees from those available,

[1] The engineer may also be interested in testing various aspects of the emergency procedure in order to establish the level of robustness. In order to do so, he/she 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 begin evacuation immediately (without delay), in order to produce the highest levels of congestion possible.

5) flow conditions / constraints – the relationship between speed, flow, population density and population size.

Table 1. Description of Performance Components

| Performance Component | Example Component Setting | Evacuee Response |
|---|---|---|
| *Pre-Response Times* | Instantaneous (Hypothetical) | Immediate response |
| | Distributed (Hypothetical) | Response over a period of time |
| | Estimated | Predicted Response |
| | According to Procedure | Response according to the procedure assumed during the scenario |
| *Route Availability* | Environment-Based | Routes limited through environmental conditions |
| | Regulation-Based | Routes limited according to regulatory requirement |
| *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 |
| *Attainable 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 |
| *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 |

The model parameters that are included in each model scenario will be used to understand how to configure each of these components in the evacuation model. During this phase, similar sets of model parameters may be produced when representing different model scenarios; i.e., the final numerical representation of different real world situations may eventually be equivalent. This quantitative comparison represents another opportunity for reducing the number of scenarios finally modelled.

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 is always an initial input 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 square footage 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.

In the case of pre-response 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. The engineer is almost always tasked with providing data on pre-response times, e.g., a pre-response time distribution, as input to the evacuation model. Many times, these data are based on the type of building; however, some data identify factors that increase or decrease pre-response time (e.g., intoxication of occupants causes pre-response time to increase [16]) and it is up to the engineer to quantify this factor using engineering judgment. 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 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 pre-response 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 the other inputs for the model (e.g., low pre-response times) that influence expected flow conditions. For certain evacuation modelling methods, the engineer will need to account for flow as an input variable.

As in Task 2.4, it may be possible to reduce the number of model scenarios being examined. Although the model scenarios may represent different real world scenarios, they are represented using equivalent performance component values.

Now that Tasks 1, 2, and 3 have been described, an example will be provided to demonstrate this method. The following section outlines how to apply the method described above using a multi-purpose arena.

## Example – Multi-purpose arena and events centre

An example is given in the following sections to illustrate the application of the proposed engineering approach. In the example, the method is applied to the design of a hypothetical arena, namely a multi-purpose stadium and events centre. The arena is a one story building with a sports floor that accommodates a wide range of sports, such as basketball (4 courts), volleyball (4 courts) and badminton (6 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 (see 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. Other expected uses include concerts/entertainment, banquets, seminars and expositions (see Figure 3). The maximum allowed capacity of the building is 5000 occupants. This capacity is relevant mainly for concerts/entertainment.

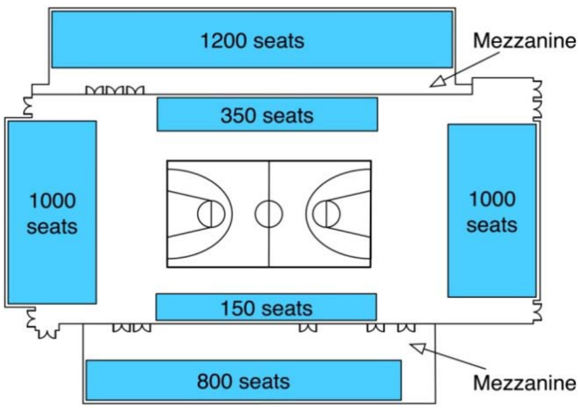
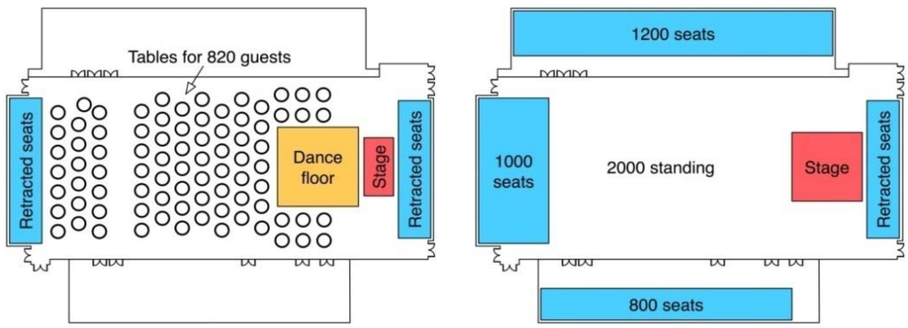



Figure 2. The example arena for a basketball event.

The arena is equipped with a fire detection and alarm system. A voice alarm that informs people about the cause of the alarm (i.e., that a fire has been detected), and appropriate action to take is used. Toilets are located under the mezzanines (see Figure 2).



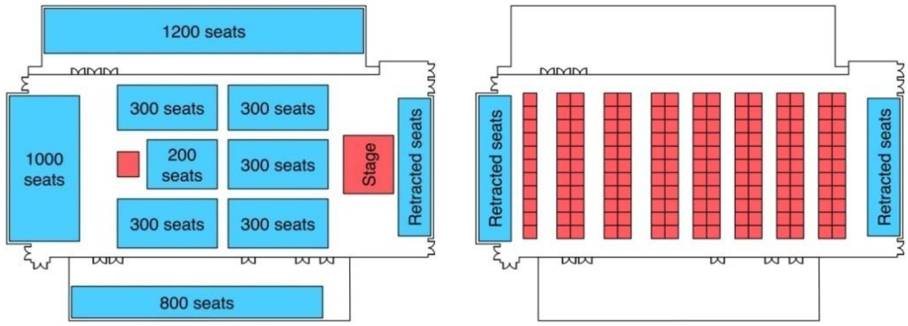



Figure 3. The example arena – banquets (top left), concerts/entertainment (top right), seminars (bottom left) and expositions (bottom right)

*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, it is clear that 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 the cues available may be affected by alcohol or the use of recreational drugs. For some of these scenarios, e.g., punk or rock concerts, it is likely that some visitors have consumed alcoholic beverages and some may also use narcotic substances and/or prescription 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, and age is therefore an important factor. Another important aspect is that concerts and other types of entertainment are social events. This means that different groups will be common for real world scenarios involving concerts/entertainment. For example, there will be many families at entertainment events for children. Partners and groups of friends can also 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 the present paper only the concert/entertainment case will be used to illustrate the different tasks. Based on the sections above, a number of important real world factors can be identified (see Table 2, column 1). The list in the first column of Table 2 should only be seen as an example, as a more thorough analysis can potentially reveal more important factors.

Table 2. Examples of real world factors for the 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 | Intoxication | Data/Theory / Eng. Judg.* |
| Use of narcotic substances | | |
| Use of prescription drugs | | |
| Permanent hearing loss | Hearing Impairment | Data / Theory |
| Permanent tinnitus | | |
| Temporary tinnitus | | |
| Age | Age | Data / Theory |
| Family groups | Social Affiliation | Theory / Eng. Judg.* |
| Partners | | |
| Groups of friends | | |

**It is important to note all assumptions and supporting evidence when engineering judgment is used.*

*Task 2 – Model description*

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

Table 2 shows the real world factors for the concert/entertainment case deemed to be significant and supportable, together with corresponding model parameters. The first three factors, namely *consumption of alcohol*, *use of narcotic substances* and *use of prescription drug*, 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 hearing loss and tinnitus (permanent and temporary) that can be reduced to one model parameter called *hearing impairment*. Other real world factors can be grouped together in a similar fashion (see 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 shown 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 \| Partial(existing) \| Partial(temp.) \| Deafness (permanent) \| Deafness (temp.)] |
| Age | [Children \| Adolescents \| Adults \| Elderly] |
| Social affiliation | [Loose \| 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 information provided or compiled regarding the population distribution, relevant fire scenarios, and structural design (i.e., the information that describes the initial conditions, rather than the response itself). In effect, the model parameters influencing evacuee performance are varied 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 shown 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.)

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

| Scenario | Description | Model parameter | | | | |
|---|---|---|---|---|---|---|
| | | **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 |
| etc | | | | | | |

In this example, Scenario F is now 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 very similar and can be grouped together into one scenario. The seven original scenarios (A to F) 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).

*Task 3 – Quantify model scenarios*

In Task 3, the model scenarios are represented using the five basic performance components. Effectively, the performance components are quantified in order to adequately represent the scenario in question within the evacuation model. Various options available during this process were shown 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-Response Times* indicates that the modelled occupants commence their response at zero seconds; 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, and so on.

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-Response and Travel Speed values is shown in Table 5. It is apparent that Scenarios D and E 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 (see Table 4) to the qualification of the component levels (shown in Table 5). However, the intermediate step shown in Table 1 can help to identify scenarios that, although based on different real world assumptions, lead to similar model scenarios.

Table 5. Example Components Levels

| Scenario | Example Pre-Response Component | Example Travel Speed Component |
|---|---|---|
| A | Distributed (Moderate – low intoxication)↑ | Heterogeneous (wide range reflecting ages) ↑↑ |
| B | Distributed (Extended – intoxication and hearing impediment) ↑↑ | Heterogeneous (moderate range reflecting potential intoxication) ↑ |
| C | | Heterogeneous (wide range reflecting potential for severe intoxication) ↑↑ |
| D and 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%)
↑↑ significant increase in component setting (e.g., 25-100%)

## *Conclusion*

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: 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.

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