A PERFORMANCE-BASED DESIGN OF A HOTEL BUILDING USING TWO EGRESS MODELS: A COMPARISON OF THE RESULTS

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ABSTRACT

With the move toward performance-based design, engineers have been looking to evacuation computer models to assess a building's life safety. Many times, the engineer is tasked with the selection of one evacuation model for a specific project. Currently there are a wide variety of evacuation models for engineers to choose from. However, with each model containing its own unique features and simulation capabilities, confusion may arise as to which model is best for the task at hand. The results gained from this work emphasize the importance for users to choose an egress model for each project with the appropriate input features and simulation capabilities. This report compares results from two similar egress models based on documented evacuation movement data. When EXIT89† and Simulex† (both only partial-behavioral models) are used to 1) simulate the same design scenarios and 2) perform a bounding analysis of the hotel building, differences in egress times were identified. EXIT89's evacuation times were found to be (25 to 40) % shorter than Simulex for the design scenarios, attributed to differences in unimpeded speeds, movement algorithms, methods of simulating slow occupants, density in the stairs, and stair configuration input between the models. For the bounding analysis, EXIT89 produced maximum evacuation times (30 to 40) % shorter than Simulex, primarily due to the simulation of slower-moving occupants.

INTRODUCTION

Evacuation calculations are increasingly becoming a part of performance-based analyses to assess the level of life safety provided in buildings[1]. In some cases, engineers are using back-of-the-envelope (hand) calculations to assess life safety, and in others, evacuation models are being used. Hand calculations usually follow the equations given in the Emergency Movement Chapter of the Society of Fire Protection Engineers (SFPE) Handbook[2] to calculate mass flow evacuation from any height of building. The occupants are assumed to be standing at the doorway to the stair on each floor as soon as the evacuation begins. The calculation focuses mainly on points of constriction throughout the building (commonly the door to the outside) and calculates the time for the occupants to flow past that point and to the outside.

To achieve a more realistic evacuation calculation, engineers have been looking to evacuation computer models to assess a building's life safety. Currently, there are a number of evacuation models to choose from, each with unique characteristics and specialties. A concern with current evacuation models is whether they can accurately simulate the unique

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scenarios that accompany a certain type of building. How would a user know which model to choose for his/her design?

To aid with the difficult task of choosing an appropriate model, a comprehensive model review of 28 past and current egress models has recently been completed at part of graduate work at the University of Maryland, College Park[3]. This model review was completed with large influence from the work done by Gwynne and Galea at the University of Greenwich[4] and Steve Olenick from Combustion Science and Engineering, Inc[5]. The model review provides information on model purpose, availability, modeling method, model structure and perspective, methods for simulating movement and behavior, output, use of fire data, use of visualization and CAD drawings, etc. The model review organizes the evacuation programs into three basic categories that aim to describe the models' level of sophistication in simulating behavior of the occupants. These categories are movement models (no behavioral capabilities), partial-behavioral models (implicit behavior is simulated[4]), and behavioral models (occupant decision-making and behavior is simulated).

The model results and simulation capabilities can be very different among the three categories of models (movement, partial-behavioral and behavioral). Even within the same category, however, differences in evacuation results can vary significantly due to the difference in data used by the model – for instance, data to simulate people movement. Since it is common for engineers to use only one evacuation model for a performance-based design of a structure, a question arises concerning the degree of difference in results from two similar evacuation models for the same building and design scenario.

This paper attempts to use two similar evacuation models, EXIT89[†] and Simulex[†] (both partial-behavioral models) to simulate the same evacuation design scenario for a hotel building. The evacuation results (evacuation time and population split to each exit) will be described for each model and differences between the models will be presented. Lastly, reasons for differences between the models' results will be explained. This work is not meant to be a validation exercise of the models used for this study, but more so as a comparative exercise between model results for the same building.

In addition to the simulation of the evacuation design scenario, the occupant characteristics of the hotel population will be varied using each model, in an attempt to simulate one aspect of a performance-based design of the building. The evacuation results will be described for each model and differences between the models will be presented. This paper provides a summary of work completed for M.S. requirements at the University of Maryland, College Park[3].

Hotel Building

The building selected as a basis for analysis is a 21-story high-rise hotel. The building floor plan is based on a 28-story hotel building located on the west coast of the United States. The hypothetical 21-story hotel building contains 473 guest rooms and one 74 m^2 conference room on the first floor. The gross area of each floor level ranges from 1 168 m^2 to 1 204 m^2. For the purposes of this study (comparing model results), the occupants evacuate their respective guest rooms and once they reach the stair door of the ground floor, they are considered to be "safe." A floor plan of the first floor is shown in Figure 1 and a plan of the ground floor is shown in Figure 2.

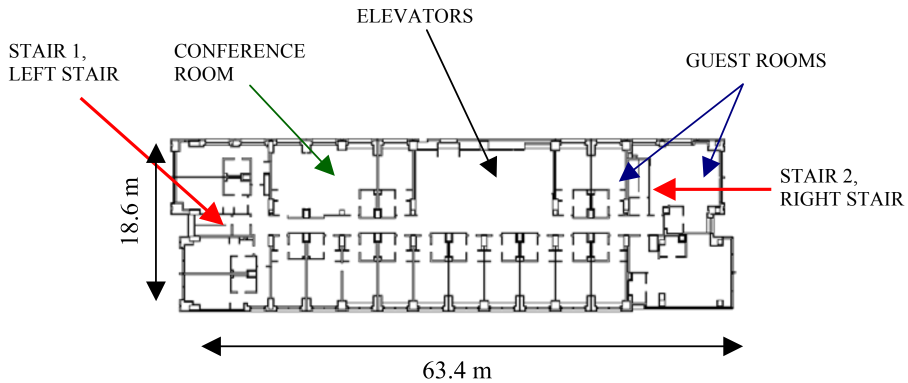

Figure 1: Floor 1 (located above the ground floor/area of safety)

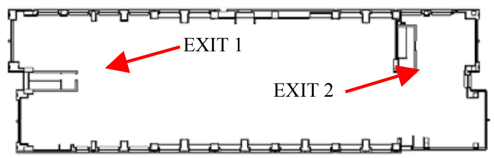

Figure 2: Ground floor/area of safety

All guest rooms are occupied by either 2 or 4 guests (depending upon the size of the room) and the conference room on the first floor is assumed to be empty. Considering all 21 floors, a total of 1044 occupants are present in the building at the time of the evacuation. Both exits, consisting of two stairways (width = 1.13 m) located on the right and left sides of the building, are available to occupants in each simulation.

Design Scenario

The design scenario was selected using the frequency of fire causes and frequency of fire origin for fires involving casualties, injuries, and property damage tabulated in the NFPA U.S. Fire Problem Overview of hotel and motel fire statistics[6]. The evacuation design scenario chosen was one that presents a high risk to occupants residing in a hotel. A hotel fire most frequently begins in the bedroom and results in frequent deaths and injuries to civilian guests. And, from the fire cause data, possible causes of a fire in a guest bedroom could be incendiary or smoking materials. Other conditions to consider in the scenario are the floor of origin, time of day and the season/weather. The floor chosen as the floor of origin is the fifth floor. By choosing the fifth floor, smoke migration presents a risk to occupants throughout the building, especially those who have the farthest distance to travel to evacuate the building. Also, to present the greatest amount of risk to the occupants (or the worst-case scenario), a time of 3 a.m. and the season of winter is chosen for the scenario. A night-time scenario assumes that the occupants of the hotel are sleeping and may take additional time to wake up and prepare to leave the guest room. By choosing a winter scenario, the occupants may take additional time to dress appropriately for time spent outside of the hotel.

Multiple sources[7,8,9,10,11] from hotel and apartment building fires were used to estimate a delay time (the time taken by the occupant before evacuation movement toward a goal begins) for the guest bedroom fire scenario of 0.5 min to 10 min, with a mean of 5 min.

The main evacuation design simulation is labeled as "hotel" simulation. Two additional design simulations are run for comparative purposes, which include disabled occupants in the evacuation. These simulations are included to provide more than one set of simulation results, and since both models have the capability of simulating slower moving occupants, the inclusion of disabled occupants was used in the additional simulations. The additional simulations are labeled as "hotel – 3 % disabled" for the simulation which includes 3 % disabled occupants to the hotel population and "all disabled" for the simulation which includes 100 % disabled occupants.

Evacuation Models

The models used in this analysis, EXIT89[12] and Simulex[13], are both partial-behavioral models, as categorized by the review cited as reference 3. Partial-behavioral models primarily calculate occupant movement, however they begin to simulate behavior in an implicit way[4]. These models simulate behavior implicitly by considering pre-evacuation time distributions among the occupants, unique occupant characteristics, overtaking behavior, and the introduction of smoke or smoke effects to the occupant. The occupant characteristics can be simulated by assigning simulated individuals or groups of individuals a certain body size, unimpeded speed, and pre-evacuation time delay.

Occupants' movements throughout the model are based on research of observed human behavior data, however, there are no standard data specified for use in evacuation models. It is up to the discretion of the model developer to implement human data on behavior and movement from past research, his/her own research, or a mixture of the two. As is stated in the following sections, EXIT89 and Simulex use occupant movement data (density vs. speed) from two different sources. It is of interest to understand how the models use this type of occupant movement data and how the movement data influences differences in model results between EXIT89 and Simulex.

EXIT89

EXIT89 is a model capable of simulating large populations occupying high-rise structures. The model requires the user to represent the structure as a series of nodes and arcs and contains a variety of input features, such as:

- Shortest travel route or user-defined route for occupants
- The use of CFAST[14] smoke data, user-defined blockages, or none
- The choice of a body size for occupants which applies to entire population of the building - Large (0.1458 m^2), Medium (0.113 m^2), or Small (0.0906 m^2)
- The choice of speed for the entire population of the building – Emergency (horizontal unimpeded speed = 1.36 m/s) or Normal (horizontal unimpeded speed = 0.9145 m/s)
- A random delay time (uniform distribution in tested version)
- The modeling of disabled occupants, including the percentage of decrease in travel speed for these occupants compared with the rest of the population

EXIT89 uses a series of nodes and arcs to represent any type of structure. In this type of model, known as a network model, the floor plan is entered as a series of nodes (rooms, corridor, stair sections, etc) and arcs (distance between nodes). The occupants move from the center of each node, through the opening between nodes, to the center of the next node. The node/arc network can provide a more realistic configuration for compartmented buildings, such as hotels, where the floor plan is already segmented into rooms, hallways, and stairs. However, for more open floor plans, the user determines how to segment and link the building space, and then needs to check to make sure that occupants are traveling in realistic patterns to the exits. If the segments are too large, occupant movement patterns may be unrealistic, and if the segments are too small, the user is faced with a larger and more time-consuming input file.

EXIT89 was used to model the evacuation design scenario that was described earlier. Table 1 outlines the inputs chosen to model the evacuation design, categorized using the Four Factors of Egress outlined by Gwynne and Galea[4]. In summary, the shortest route was chosen for the occupants, and the entire population of 1044 occupants was given the medium body size and the emergency speed movement (related to the density of the space). The emergency speed option was chosen to speculate what a user may chose when modeling this type of scenario, however it should be stated that occupants do not always move in an emergency mode when evacuating a building. Also, delay times ranging from 30 s to 10 min were randomly distributed to 100 % of the population.

Table 1: Inputs for the evacuation design scenario using EXIT89

Input Type	User choices/input		
Building Configuration	Node and arc positions	Area each node (usable space)	Distance from node to node (arc)
Evacuation Route	Shortest route chosen for all occupants		
Environment	No smoke blockages		
Behavior – Body size	All 0.113 m^2 (Medium)		
Behavior – Speed	Emergency speed = 1.36 m/s unimpeded horizontal		
Randomly distributed response time	Minimum delay time = 0.5 min	Maximum delay time = 10 min	100 % of population to delay
Occupants with disabilities	None		
Stair Travel	Down		

In addition to this evacuation design scenario, two additional scenarios were simulated that included disabled occupants. One simulation (hotel – 3 % disabled) included 97 % medium body, emergency speed with 3 % disabled occupants (medium body, moving at an average of 45 % of the calculated able-bodied speed). The other simulation (all disabled) included 100 % medium body, moving at 45 % of able-bodied speed. The results for these simulations (with and without the delay time) are provided in Table 2.

Table 2: Results (evacuation times) from the evacuation design scenarios using EXIT89

Evacuation times (s)	NO DELAY	DELAY – 0.5 to 10 min
Hotel simulation	445	809
Hotel – 3 % disabled	633	969
All disabled	990	1226

In order to compare results between EXIT89 and Simulex and explain why such differences occur between models, it is important to understand the inner workings of both models. Therefore, the results from these partial-behavioral models will be compared by identifying the initial conditions of the population as well as the output from the evacuation design simulations. In the case of EXIT89, the areas of interest are the following:

- Unimpeded speeds of the occupants on horizontal components and stairs
- The body sizes of the population
- The movement algorithm that decreases speed due to density
- The number of occupants in a stairwell section throughout the simulation
- The method used by the model to simulate slower moving occupants

In EXIT89, the areas of interest were obtained by reviewing the input parameters or by studying the output text files. For the unimpeded speeds for the "hotel" population, EXIT89 uses the data provided by Predtechenskii and Milinskii, in which occupants have an unimpeded speed of 1.36 m/s on horizontal components and 0.99 m/s on stairs. And, since the entire population was assigned the medium body size, each individual measured 0.113 m^2.

The movement algorithm of the occupants in EXIT89 is based on the formulas from Predtechenskii and Milinskii[15] to determine walking speeds as a function of the density of the occupants in each space. Density is first obtained by multiplying the number of people in the space by the horizontal projection of the person (related to the body size) and dividing that value by the area of the space or movement stream, resulting in a density in units of m^2/m^2. EXIT89 uses tables of velocities (based on occupant density) for normal and emergency movement along horizontal paths, openings, and stairways. Predtechenskii and Milinskii obtained this data from observations of people in different circumstances and perception of risk, which is the reason for the choice of emergency or normal speed data. More information on the data used by EXIT89 can be found in references 3 and 12.

To determine the number of occupants occupying a stair section, the output text file from the "hotel" simulation was analyzed. The stair section, the stair area in between floors 2 and 3 (measuring 9.93 m^2 of horizontal space), was monitored for occupant numbers at different times throughout the simulation. Analysis shows that EXIT89 predicts a maximum of 45 occupants (in different states of transition from this stair node to the next stair node) in the stair section at a specific point in time.

Finally, because EXIT89 gives the option to simulate slower moving occupants, it was of interest to examine whether or not these slower moving occupants impacted other occupants' movement throughout the building. For instance, if an occupant is slow moving down a flight of stairs, will others be affected? Analysis from the "hotel – 3 % disabled" output file shows that EXIT89 does not simulate the slower moving occupants interfering with the able occupants in the simulations. Instead, those slower moving occupants just take longer than the rest to leave the building, without interfering with other occupants' evacuation.

EXIT89 was used, in addition to simulating the evacuation design scenarios, to simulate a variety of occupant characteristics in an attempt to bound the evacuation times for the hotel building. It is recognized that a performance-based design often varies other factors, such as population number, location, and egress route; however in this study, only occupant characteristics were varied. Since EXIT89 has three body sizes to choose from and two occupant speed vs. density correlations (normal and emergency), the occupant characteristics were varied by pairing each body size with each speed. This created six different simulations (i.e., small normal, small emergency, large normal, etc.). When these simulations were run, keeping all other inputs the same, the evacuation results ranged from 384 s to 679 s for no delay and 809 s to 862 s for a (0.5 to 10) min delay.

Simulex

Simulex, version 4.0, is an evacuation model that has the ability to analyze the egress of a large number of people from a large, geometrically complex building. Simulex generates a 2-dimensional building network from CAD drawings of each floor level. Unlike EXIT89, Simulex does not require node/arc configuration. Instead, Simulex uses a fine grid network, which divides the floor plan into 0.2 m x 0.2 m spatial blocks that are used to identify movement paths of the occupants. The input required for this model includes the following:

- Floor plans in the form of CAD drawings

- Connections of floor levels by stairways or ramps (involving user input on stair width and length)
- Distance maps that can be created to block certain exits or paths from groups of occupants
- Occupant movement characteristics for each individual or a group of individuals with a corresponding body size, initial horizontal speed, and percentage decrease of speed on stairs (the user can use default values provided by Simulex or create his own)
- Mean delay time to be randomly, triangularly, or normally distributed throughout the occupants of the building

Simulex allows the user to create a population of many different occupant types (i.e. males, females, children, median, etc.). For instance, a population for a shopping mall may consist of a certain percentage of women, children, men, and older adults. Each occupant type is associated with a specific body size (radius of torso circle and radius of shoulder circles, in meters) and initial horizontal walking speed (m/s). This Simulex capability allows the user to choose a range of occupant sizes for specific occupants in the population as well as an associated range of walking speeds that are distributed among the population.

Although this model allows more sophisticated occupant movement throughout a structure, there are certain limitations to its use. During a simulation, occupants can get "stuck" at a transition point (or link) in between floor plans. If this occurs, the simulation has to be re-run after a slight adjustment of link position. Another limitation involves the use of the global shortest distance map for complex buildings and the fact that Simulex has only an implicit method of guiding occupants to the closest "local exit" (stair door, for instance) on the floor of a multi-level building. It is up to the user to render certain links unavailable to specific groups of occupants in order to avoid unrealistic behavior, such as occupants leaving their initial stair at a lower floor in the building and taking another stair because it involves an overall shorter distance to safety.

As was the case with EXIT89, Simulex was used to simulate the evacuation design scenario. Table 3 provides the inputs used in the model to simulate the scenario, categorized using the Four Factors of Egress outlined by Gwynne and Galea[4]. Similar to EXIT89, the shortest route was chosen for all of the occupants and no exits were blocked from the population (a way to simulate smoke movement). Since Simulex has the capability of simulating a variety of occupant types, the occupant distribution for a hotel building was researched and calculated using D.K. Shifflet's DIRECTIONS Travel Information System[16] and the American Hotel and Lodging Association[17]. The distribution is shown in Table 3 as well as the response delay.

Table 3: Inputs for evacuation design scenario using Simulex

Input Type	**User choices/Input**			
Building configuration	Import CAD files	Stair distance = 7.2 m	Stair width = 1.13 m	
Evacuation route	Shortest route			
Environment	No exits blocked from certain occupants			
Behavior – body size (m^2)	49 % Males = 0.131 m^2	35 % Female = 0.101 m^2	11 % Older adults = 0.113 m^2	5 % Children = 0.072 m^2
Behavior – unimpeded speeds (m/s)	Males = (1.35 ± 0.2) m/s	Females = (1.15 ± 0.2) m/s	Older adults = (0.9 ± 0.3) m/s	Children = (0.8 ± 0.3) m/s
Response delay	Mean delay time (s) = 300 s	(+ or -) 300 s of time for delay	Random distribution	

Similar to EXIT89, two additional scenarios were simulated using Simulex that included disabled occupants. One simulation (hotel – 3 % disabled) included 97% of the hotel occupant distribution (size and speed) shown in Table 3, with 3 % disabled occupants (median body moving at (0.8 ± 0.37) m/s unimpeded). The other simulation (all disabled) included 100 % median body, moving at (0.8 ± 0.37) m/s unimpeded. The results for these simulations (with and without the delay time) are provided in Table 4.

Table 4: Results (evacuation times) from the evacuation design scenarios using Simulex

Evacuation times (s)	NO DELAY	DELAY – 0.5 to 10 min
Hotel simulation	735	1168
Hotel – 3 % disabled	1029	1378
All disabled	1319	1592

The areas of interest to research with the Simulex model are the same as with EXIT89, with one addition to the list. The addition involves the method of inputting the stair configuration into the Simulex model. The results given in Table 4 were simulated using the "separated stair input method." In the separated stair input method, a separate stair is created to connect each floor to the next and the occupants travel 180° around the landing at each floor plan connecting the two stairs. However, after discussion with the developer on how Simulex is commonly used, a new Simulex file is created in which a single continuous staircase is simulated into which all floors enter (without changing direction at each landing). The results of this change are shown in Table 5. Although the changes in Table 5 seem small, the continuous stair configuration makes more of a difference for the simulations without larger-sized bodies or without slower moving occupants.

Table 5: Results from the evacuation design scenarios using Simulex comparing stair configuration

Evacuation times	NO DELAY		DELAY – 0.5 to 10 min	
Simulation	Separated Stair	Continuous Stair	Separated Stair	Continuous Stair
Hotel	735	698	1168	1091
Hotel with disabled	1029	1079	1378	1264
All disabled	1319	1230	1592	1647

For the design scenarios using Simulex, individual speeds of the "hotel" population range from 0.5 m/s to 1.55 m/s on horizontal components and 0.3 m/s to 0.93 m/s on stairs, depending upon the occupant type. The body sizes range from 0.072 to 0.131 m^2, with an average size of 0.115 m^2.

The movement of the occupants in Simulex involves the relationship between speed of the occupant and their proximity to other occupants, walls, and obstacles. Simulex uses a correlation of walking speed vs. inter-person distance, which is defined as the distance between centers of the bodies of two individuals. According to the developer, the movement algorithms in Simulex are based on a combination of the results of many video-based analyses of individual movement and results from various academic researchers[15,18,19].

The Simulex output was also analyzed to determine the number of occupants in a stair section and how the model simulates slow moving occupants. The visual display of the "hotel" simulation was used to find the number of occupants in a stair section at different points throughout the simulation, similar to EXIT89. Analysis shows that Simulex predicts from 0 to 29 occupants in the stair section at a specific point in time. Lastly, Simulex allows the slower moving occupant to act as an "obstacle" in the stair that either causes a queue or a slight delay for other occupants, as shown in Figure 3 (2-dimension overhead display of occupants in the stair).

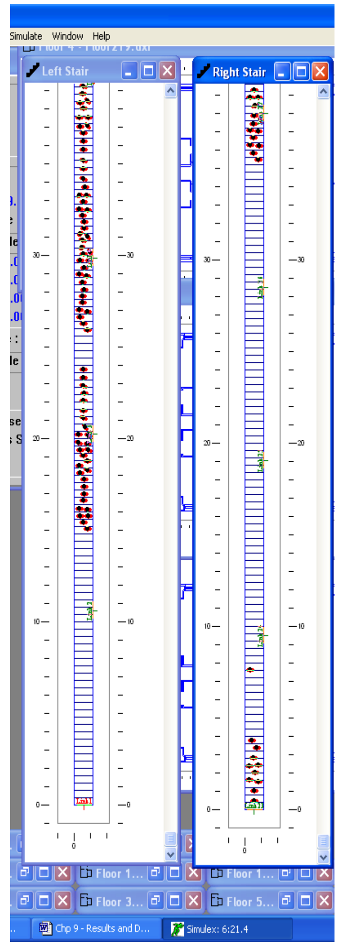

Figure 3: Continuous stair showing queues in stair

Simulex was also used to simulate variations in occupant characteristics for the performance-based design. Simulex allows the user to create any occupant type with an associated body size and unimpeded horizontal speed. For the performance-based design, occupants were varied in the following ways:

- Speed variation – all median body size with varying speeds from 1.0 m/s to 1.4 m/s; including a body size simulating winter jackets at 1.2 m/s
- Occupant type variation – the entire population consisting of a Simulex default occupant type including "all older adult" (slowest) and "all males" (fastest)
- Hotel use variation – population distribution of occupant types reflecting a business hotel, a leisure hotel, and a hotel used for summer camps

When these simulations were run, keeping all other inputs the same, the evacuation results ranged from 420 s to 856 s for no delay and 869 s to 1269 s for a (0.5 to 10) min delay (all using the continuous stair configuration).

Comparison of Model Results

Evacuation Design Scenarios

When comparing model output from the evacuation design scenarios (evacuation time), differences were found between the models. Figure 4 shows the results from the evacuation design scenarios and indicates EXIT89 evacuation times are 40 % (eg. $(735s - 445s)/735s$) shorter in the two hotel scenarios and 25 % shorter in the "all disabled" scenario for the simulations with no delay time when compared with Simulex evacuation times. For the simulations including a delay time with a 5 minute mean (± 5 minutes), EXIT89 provides an evacuation time that is 30 % shorter than Simulex for the two hotel simulations and approximately 25 % shorter for the "all disabled" simulation.

Overall, Simulex provides a (25 to 40) % higher evacuation time when compared to EXIT89 for these three evacuation scenarios. However, for both models in each design scenario, the same number of occupants is recorded using the left and right stairs. This shows that even though the same number of occupants is using the available exits, Simulex still produces longer evacuation times than EXIT89.

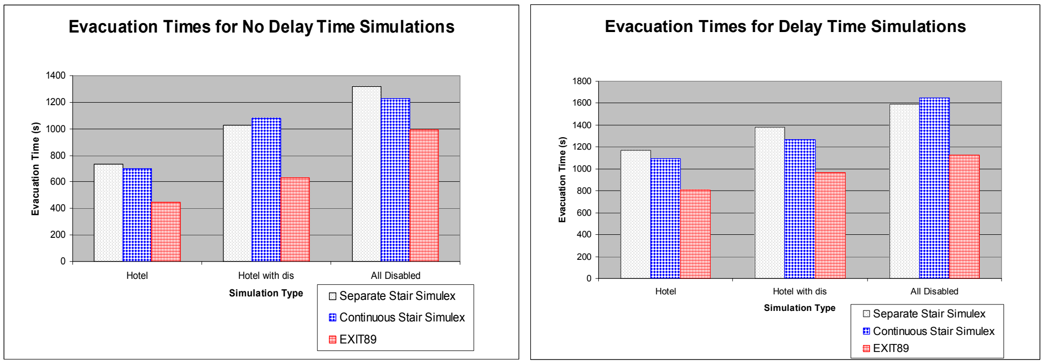

Figure 4: Comparison of evacuation results (times) from EXIT89 and Simulex

The main reason for the differences between model results is the difference in movement algorithms used by EXIT89 and Simulex. The movement algorithms for each model incorporate body sizes and slowing due to distance from others/density of the space. From analysis of the "hotel" simulation, similar overall body sizes were chosen for each model, however EXIT89 simulates occupant movement at a higher unimpeded speed on horizontal components and stairs as compared to Simulex. For analysis purposes, both models' movement algorithms are equated to inter-person distance vs. velocity using an equation relating density to inter-person distance[20]. When velocity vs. inter-person distance is graphed for each model for the "hotel" simulation, Figure 5 shows that movement in the stair is much faster using the EXIT89 model. Occupants' stair velocity using EXIT89 is, at times, larger than the maximum speed of the fastest group of occupants using the Simulex model.

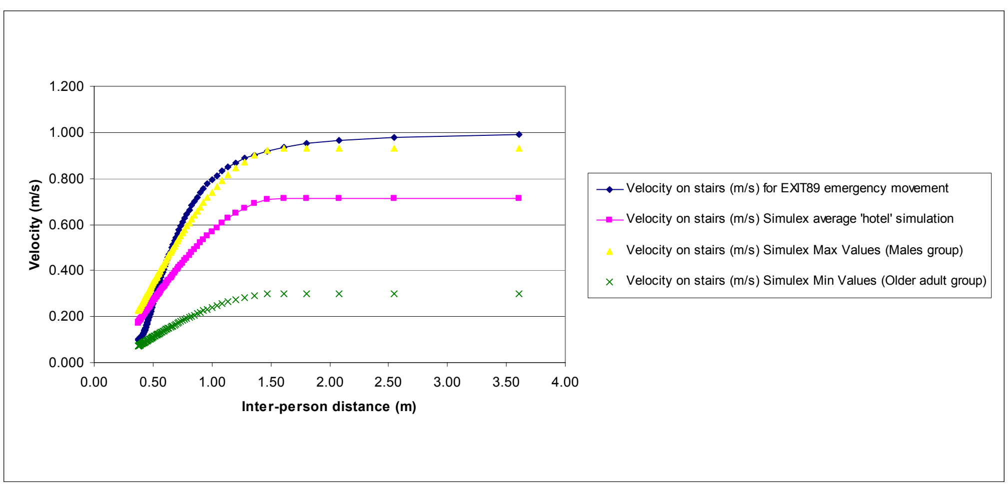

Figure 5: Comparison of velocity vs. inter-person distance on stairs using EXIT89 and Simulex for "hotel" simulation

In addition to faster movement in the stairs, EXIT89's faster evacuation times can be attributed to the number of occupants in the stair at one time and its method for simulating slow occupants. EXIT89 predicts a larger number of occupants in the stair section at one time during the simulation than Simulex. Simulex predicts the slower moving occupants will cause slight queues or blockages in the stair, while EXIT89 does not model occupant interference. These three reasons, including the movement algorithm, may explain why EXIT89 produces faster evacuation times than Simulex.

Performance-based design

It is clear to see that Simulex offers more input choices for occupant characteristics, than EXIT89. When comparing the results for the basic performance-based design of the hotel building, Simulex (continuous stair simulations) still contains evacuation times larger than EXIT89's times for each minimum and maximum value, as shown in Figure 6. This is especially apparent with Simulex's maximum value simulations with and without delay times. The larger evacuation times produced by Simulex are mainly due to the introduction of the slower populations, a known capability of the model. EXIT89 produces maximum results in the bounding simulations that are approximately 40 % shorter than that of Simulex for no delay. In the case of simulated delay times, EXIT89 produces maximum results that are approximately 30 % shorter than Simulex. In both cases of delay and no delay, EXIT89 produces a faster minimum result, but only by approximately 10 %.

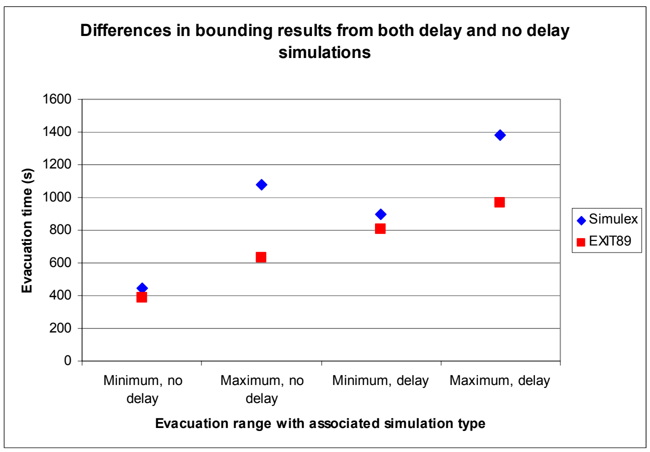

Figure 6: Comparison of evacuation results (times) using EXIT89 and Simulex for the performance-based design simulations

Even though Figure 6 shows the evacuation time for the minimum, no delay simulations, caution should be used when relying on this data point for a hazard calculation. The minimum, no delay value is displayed in Figure 6 for comparison purposes, however it has been established in previous research that an appropriate delay time before evacuation should be assigned to each building.

Conclusions

Differences were found in the comparison of evacuation results from EXIT89 and Simulex for both the evacuation design scenarios and the performance-based design analysis. The models in this comparison produced different results due to the difference in capabilities between the models. Simulex has the capability to simulate a variety of occupant types and more realistically incorporate the interaction of different body types and speeds throughout the stairwell. EXIT89, on the other hand, does not have the capability of simulating occupant interaction, and therefore slower occupants do not affect the evacuation times of other occupants in the building.

Another difference found between the models was the data used to move occupants throughout the stairwell in the hotel. In this study, Simulex produced slower movement on the staircase than EXIT89, even compared with the fastest occupant group (males) for the "hotel" simulation. This is most likely due to the data used by each model to simulate movement throughout the building. The problem with this difference is that there is no correct answer as to which set of data, those used by EXIT89 or Simulex, is the more accurate set to account for occupant movement in an emergency.

It is recommended that the user fully understand the inner workings of the model in order to assess whether or not the movement algorithm and methods are realistic. For the hotel scenario, Simulex produced results that were more representative of the occupant movement throughout a building. However, it should be stated that limitations of the Simulex model inhibited progress at times, specifically due to the fact that occupants would remain at a link indefinitely, necessitating a restart of the simulation. No such problems were found with EXIT89, which produced results of each simulation in seconds.

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