Adaptive Decision-Making in BuildingEXODUS in Response to Exit Congestion

S. Gwynne, E. R. Galea, P. J. Lawrence, M. Owen and L. Filippidis

Fire Safety Engineering Group, Centre for the Numerical Modelling and Process Analysis,
University of Greenwich, London SE18 6PF. U.K.
http://fseg.gre.ac.uk

ABSTRACT

Given the importance of occupant behaviour on evacuation efficiency, a new behavioural feature has been implemented into buildingEXODUS. This feature concerns the response of occupants to exit selection and re-direction, given that the occupant is queuing at an external exit. This behaviour is not simply pre-determined by the user as part of the initialisation process, but involves the occupant taking decisions based on their previous experiences with the enclosure and the information available to them. This information concerns the occupant's prior knowledge of the enclosure and line-of-sight information concerning queues at neighbouring exits. This new feature is demonstrated and reviewed through several examples.

KEYWORDS: evacuation, fire safety, queuing, adaptive behaviour, familiarity, line-of-sight.

INTRODUCTION

Computer based evacuation models *[1]* offer the potential of overcoming the shortfalls inherent in determining the safety of individual premises. In doing so, they not only address the needs of the designer but also of the legislator in the emerging era of performance based building codes. In order to fully assess the potential evacuation efficiency of an enclosure, it is essential to address the following factors:

- >the configuration of the enclosure, which encompasses the impact of the geography of the structure,
- >the procedures implemented within the structure, which would entail the configuration knowledge of the occupants and the training and activities of the staff,
- >the atmospheric environment within the structure through which the evacuation takes place, describing the effect of heat, toxins and smoke upon the occupant's ability to navigate and make decisions,

>and finally the behaviour of the occupants describing the culmination of all of the above influences on an occupant and their interpretation by the individual, as well as the impact of social affiliation, role adoption and a number of other factors*[2]*.

The last of these factors has attracted the least interest from the computer modelling community. This is arguably due to a number of reasons including the almost complete avoidance of human behavioural considerations in most national building codes, the lack of detailed quantifiable information concerning human behaviour and the difficulty in representing these considerations within computer models. Most of the behavioural representation in current models has to date attributed the occupants with a passive response to the stimulus provided by their environment. For example, it may be assumed in computer models that occupants will join and remain in an exit queue regardless of its length, the speed at which it appears to be moving or the availability of a more viable egress route. However in reality, occupants are not oblivious to their surroundings and take a more pro-active role in these decision-making activities. This may manifest itself in the occupant performing an estimation – however crude – as to the most advantageous route or action to select. The final activity chosen will then be dependent on these determinations.

Recently, at least one model has attempted to address this issue *[3]*. In this paper we attempt to address this issue through the development of an adaptive decision making capability for occupants attempting to select the most viable available exit during an evacuation. This capability is implemented within the buildingEXODUS evacuation model and demonstrated through several evacuation scenarios.

THE EXODUS MODEL

EXODUS is a suite of software tools designed to simulate the evacuation of large numbers of people from a variety of enclosures (aircraft and buildings). It is developed by the Fire Safety Engineering Group of the University of Greenwich. The basis of the model has frequently been described in other publications *[4-7]* and so will only be briefly described here. The version of buildingEXODUS described in this paper is version 2.0 released in late 1998.

The buildingEXODUS model comprises five core interacting sub-models, these are the Occupant, Movement, Behaviour, Toxicity and Hazard sub-models. The software describing these sub-models is rule-based, the progressive motion and behaviour of each individual being determined by a set of heuristics or rules. The spatial and temporal dimensions within buildingEXODUS are spanned by a two-dimensional spatial grid and a simulation clock (SC). The spatial grid maps out the geometry of the building, locating exits, internal compartments, obstacles, etc. Geometries with multiple floors can be made up of multiple grids connected by staircases, with each floor being allocated a separate window. The building layout can be specified using either a DXF file produced by a CAD package, or the interactive tools provided, and may then be stored in a geometry library for later use. The grid is made up of nodes and arcs with each node representing a small region of space and each arc representing the distance between each node. Individuals travel from node to node along the arcs.

On the basis of an individual's personal attributes, the Behaviour Sub-model determines the occupant's response to the current situation, and passes its decision on to the Movement Sub-model. buildingEXODUS has the capability of implementing two behavioural regimes:

Normal and Extreme behaviour. Under Normal behaviour, an occupant is prepared to wait until it is possible to make the desired move. Under this regime, occupants will patiently queue until a period of time equal to their Patience has been reached (a user defined occupant attribute) before taking actions which results in them jostling around or possibly recommitting to another course of action.

The Behaviour Sub-model functions on two levels known as Global and Local behaviour. Global behaviour involves implementing an escape strategy that may lead an occupant to exit via their nearest serviceable exit or most familiar exit. There are several ways in which this may be implemented within buildingEXODUS. Exits carry an attribute known as the exit potential. Exit potentials may be biased making them more or less attractive. In this way the catchment area of an exit may be increased, preferentially attracting occupants. Finally, occupants may be specified an exit to use *[7]*. The desired global behaviour is set by the user, but may be modified or overridden through the dictates of local behaviour.

The local behaviour includes such considerations as determining the occupants initial response to the call to evacuate i.e. will the occupant react immediately or after a short period of time or display behavioural inaction, conflict resolution, overtaking and the selection of possible detouring routes. The manner in which an occupant will react to local situations is determined in part by their attributes. As certain behaviour rules, such as conflict resolution, are probabilistic in nature, the model will not produce identical results if a simulation is repeated.

Conflicts occur very frequently in congested spaces. If two or more individuals wish to move onto a particular node at the same time, a conflict arises. This is resolved using the individuals' personal attributes and a hierarchy of rules. First the distance to be travelled and travel speeds of each conflicting occupant is checked to determine the travel time. Given that the travel times associated with each of the conflicting occupants are such that there is no clear winner, the outcome of a conflict depends on the *Drive* of each of the occupants.

THE QUEUING AND FAMILIARITY BEHAVIOURS

The manner in which occupants queue is of fundamental importance to the success of an evacuation. Their ability to ascertain the likelihood of extensive delays and possibly alter their exit route accordingly is essential to the navigation process. Occupants determine their choice of exit through examining a number of factors. Initially, the occupant must be aware of the existence of an exit. Obviously, inherent in this knowledge is the geometric layout of the enclosure surrounding that exit. Occupant familiarity has long been seen as of fundamental importance to the progress of an evacuation. Instead of occupant's heading towards the nearest exit – of which they may have no prior knowledge - as would be assumed by the majority of present building regulations, they instead move towards other more distant exits with which they have had previous experience and with which they feel more confident*[2,8]*. Pauls*[9]* identified the importance of examining regular social and physical movement and behaviour, to predict the actions of occupants in a difficult and possibly unique situation. This correlation was seen during the King's Cross fire, where passengers, when attempting to evacuate, adopted routes which were closely related to those usually used *[2,10]*.

The impact of familiarity upon the behaviour of the occupant is not limited to exit usage. Horiuchi recorded the increased levels of confidence which familiarity bred in occupants, allowing them to perform actions not directly linked with speedy evacuation *[2,11]*. Familiarity with the enclosure may generate a level of confidence that allows the occupant to attempt activities such as fire-fighting, delaying their response or attempting to follow alternative, less direct routes. Although in the short term these routes may not be considered optimal, they will have been adopted through calculation on the occupant's part to guarantee safe egress and to minimise the imminent risk and the evacuation time.

It is unlikely that occupants make decisions concerning redirection in isolation, but instead weigh up the data available to arrive at a final decision. Influential factors which are likely to affect this decision include the length of the queue at any exit, the existence and severity of smoke and the distance to the exit. Except for the final influence, all of the factors require the occupant to be in visual contact to make these determinations. Therefore, the decision to redirect egress movement is not solely based on factors determined prior to the evacuation, such as familiarity, but is likely to be influenced by dynamic factors such as population size and environmental considerations.

The visibility of the exit determines the level of information that the occupant may use in any calculation of the tenability of any future use *[12]*. For a thorough appraisal to take place, the occupant has to be in visual contact with the exit, to examine the surrounding population, environmental conditions, etc. If the exit is not within visual range, the occupant has to rely solely on his recollection of exit details from memory, such as position and distance, or possibly from information communicated to them from the surrounding population or from a procedural influence such as an intelligent alarm systems *[2]*.

Finally, through examining these factors and their own experience, the occupant must come to a decision on a course of action. This might involve a crude determination of which route would enable the most 'efficient' and safest path of egress. As highlighted previously, this calculation can only be made in respect to the information available to the occupant and any previous experience that he might have. This represents the occupant as being capable of information processing as described in recent psychology literature *[13]*.

Behavioural Features Currently Modelled within buildingEXODUS

Within the current version of buildingEXODUS (and most other evacuation models) *[1]*, the implementation of the occupant's ability to determine their choice of exit, 'redirective' behaviour and the factors highlighted above is somewhat limited. The occupant's familiarity with the enclosure can, at present, be represented using the potential map and target doors *[7]*.

A global/default method can be used which defines the attractiveness of each of the exits within an enclosure according to a potential map system. The occupant is assumed to be ***fully aware*** of the existence of the exits involved, but can be made to be more/less attracted to the exit using a biasing system. This method fulfils the requirements of the building regulations, in that occupants can (if required) be assumed to move to the nearest exit. The manipulation of the biasing attached to individual exits extends/diminishes the catchment area within which that exit appears attractive. Once in this area, an occupant will move towards the exit, unless the user has specifically instructed the occupant to move to another exit through the identification of a target door. This identification specifies the exact destination for the occupant and does not provide for alternative routes. This specification is functional under the

Normal behavioural regime. If the Extreme behavioural regime is selected (at the start of the simulation), once an occupant attains the "extreme condition" the occupant will ignore the user specified target exit and select the nearest available exit. At present the Extreme behavioural regime is also global and therefore applies to all of the occupants involved in the simulation.

Through the use of exit biasing it is possible to make a biased exit globally more or less attractive and thus biasing is a representation of global familiarity i.e. all occupants will be affected equally. Through the use of target exits, it is possible to represent the familiarity of a particular occupant with a single exit. However, the occupant does not have the ability to examine the viability of other potential routes to exit. Thus, with the exception of specifying target exits, it is not possible to provide a comprehensive and *individual* representation of an occupant's familiarity with the structure.

New Behavioural Features Currently Under Development For buildingEXODUS

Each of the components identified as influencing the 'redirective' behaviour of the occupant is addressed in the following section. This includes a more realistic depiction of occupant familiarity, the effect of exit visibility and the occupant's ability to adapt his egress route according to analysis of the situation. While the status of the exits (whether it is available or otherwise) is currently represented in the buildingEXODUS model *[7]* as is the effect that smoke has on occupant travel speeds, the occupant's psychological reaction to the existence of smoke and the effect that this may have on redirection is left for future work.

The features described here are in prototype form for research purposes and do not constitute part of the current general release of buildingEXODUS. It is considered vital not only to represent the initial occupant target, but also to represent the individual occupants familiarity with the structure. This is less important under non-emergency conditions or conditions of low population density, where the occupant may evacuate unhindered to the target of his choice. However, during situations involving redirection (such as queuing or confrontation with environmental barriers), the existence of alternative routes and the occupant's awareness of these routes becomes significant.

To overcome the problem of familiarity the proposed implementation credits each occupant with an individual understanding of the exits available. These are drawn from the complete list of exits within the enclosure, defined prior to the simulation. The probability of the occupant being familiar with a particular exit is dependent on a number of factors including the exit type (e.g. whether or not it is in frequent use, whether it is a non-reversible fire exit, etc), the attractiveness of the exit (identified by a user-defined index) and internal occupant attributes.

Once formed, the exit list (or door vector) is ordered according to preference, which is based on the exit distance, attractiveness and a number of other factors. In this respect, the original target door approach may be considered as a door vector containing only a single candidate door. The biasing of exits is still therefore important, as given the availability of several exits, the familiarity/attractiveness of the exit may be the determining factor between them. However, biasing does not form a catchment area as before, but is a *consideration* in exit familiarity and the adoption of exits. The door vector is intended to be dynamic. The ability of the occupant to receive information through communication is currently under development.

Utilising this feature, the exit list may expand according to new information, allowing for new exits to become available through occupant communication, observation or procedural instruction.

Occupants are also provided with 'line-of-sight' information concerning neighbouring exits. A complete 'line-of-sight' system would be computationally expensive and complex to implement. An alternative method has been developed to represent the ability of occupants to examine exits within their line-of-sight and reflect upon the information gleaned. In this simplified system, the user supplies the visibility status of exits. This is achieved through grouping the exits according to which of them can be seen simultaneously (see **Figure 1**). Therefore, if information becomes available on a particular exit, those exits that share an identifying marker will also be visible and could be interrogated for information to a similar degree. This information is supplied by the user who is expected to have the appropriate knowledge to accurately describe the enclosure. This introduction is based on examining the occupants *present target*, which it compares against the other exits in the enclosure list to extract relevant information. This rule is fired only when the occupant is required to queue. Therefore the rules are based on the assumption that those doors identified are visible from anywhere in the occupant's present queue.

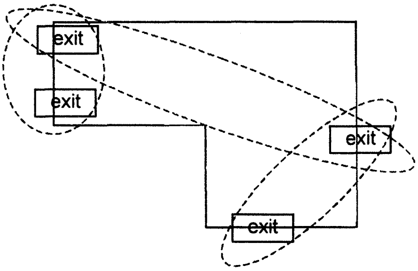

Figure 1: Possible lines of sight in a small geometry

The type of information that can currently be extracted from examining visible exits includes the queue size around the exit. In future developments, an ability to consider smoke density in the decision making process is planned. It is recognised that this system is simplistic in that the occupant's perspective may alter during their movement and that occupants will differ in their capabilities and their attention to detail. These considerations are currently beyond the scope of the current work.

The proposed adaptive queuing behaviour is reliant upon the introduction of the door vector and the exit line-of-sight feature. Initially, the occupants situation is examined to determine whether he desires (i.e. estimated exit time is reduced) and whether it is possible for him to alter his target. This involves examining the extent of the time he has spent waiting, his patience, whether he is completely surrounded by other occupants, the estimated time of arrival at the proposed exit, the estimated time of arrival at the current exit etc. This decision-making process is currently deterministic in nature i.e. if the occupants estimate that redirection provides an advantage, they will do so. A stochastic element to the decision making process is planned for future developments.

Once the decision to redirect has been made, the occupants door vector is interrogated. Initially, those exits that are *visible* are examined. The visible exit that is seen as most viable is then stored. This viability is dependent upon the time the occupant estimates it will take him to arrive at that exit, given its distance and the crowding around the exit. The non-visible exits are then interrogated. In this case the viability is determined according to distance and familiarity only as crowding information is not available. The introduction of the line-of-sight therefore determines the manner in which exits are treated. If a visible exit is stored it will be adopted as a new target otherwise the most viable non-visible exit will be adopted. This is based on the assumption that an occupant would prefer to reduce their queuing time through movement towards visibly preferable exits rather than taking the more risky option of moving towards unseen exits. If neither exists, the occupant will remain queuing. By allowing the occupant to move to an unseen exit, it is possible for the occupant to make the wrong or sub-optimal decision. This is due to the fact that the unseen exit may in-fact not be viable due to the extent of crowding around the exit. As the exit is unseen, the occupant is deprived of this information and essentially takes a chance.

Once adopted, the new exit will be adhered to irrespective of the new queuing considerations with which the occupant is faced. If the new exit is visible, it is assumed that the conditions are favourable so as to have encouraged redirection. Otherwise, the occupant, once redirected, is assumed to have committed himself to the new target. This is to prevent the occupant rebounding continually between target exits. In future planned developments, the ability of the occupant to redirect several times will be examined along with the ability of the occupant to analyse crowd formations prior to joining them, the occupant's commitment to maintaining their present course of action, the ability to communicate, the existence of group behaviour, and the occupant's reaction to smoke.

DEMONSTRATION OF PROTOTYPE BEHAVIOURAL FEATURES.

The new behavioural features are demonstrated through a series of scenarios based on the geometry depicted in Figure 2. The geometry is relatively complex and enables us to demonstrate the differences introduced through the line-of-sight calculation as well as the possibility of the occupants being unaware of certain exits (see Figure 2 and TABLE 1). The size of the crowds initially located around each exit varies in order to demonstrate the importance of the tenability calculations made by the occupants in their decisions to re-commit to another exit.

In each case the populations are randomly generated using the buildingEXODUS random generate function *[7]*. For these scenarios, it is assumed that the evacuation has been underway for some time and has resulted in crowding around two of the four exits available (see Figure 2). Initially, populations 1 and 2 are zero while populations 3 and 4 consist of 108 and 126 people respectively. The size of the exits are 1.5m for exits 1 and 2 and 1.0m for exits 3 and 4. Four scenarios are investigated, the first scenario is the base case which utilises the existing software features while the remaining three scenarios test the new features (see TABLE 1). Scenario 2 affords the occupant complete access to all of the information available, irrespective of any other considerations.

This is not intended to represent a realistic scenario, but is included to allow comparison with Scenarios 3 and 4 where the occupant access is varied according to familiarity and visibility.

In TABLE 1, 'fully aware' indicates that all the occupants have a complete knowledge of the exits within the enclosure (i.e. their door vectors contain the complete listing of available exits). 'All visible' indicates that all of the exits are within line-of-sight (hence occupants have full knowledge of exit status). 'Non-visible' indicates that these exits are not within line-of-sight of the other exits. 'Variable awareness' indicates that not all of the occupants will be aware of the two non-visible exits (i.e. these do not appear in their door vector).

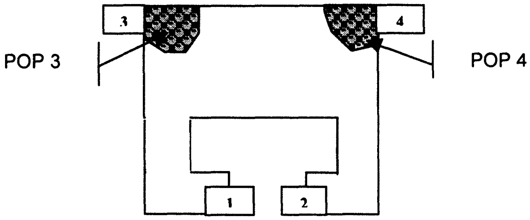

Figure 2: Representation of the geometry used in Scenarios 1-4.

On average, 4% of the occupants are only aware of door 1, 5% of the occupants are only aware of door 2 and 32% of the occupants are aware of both doors 1 and 2. The remaining occupants are unaware of both exits 1 and 2. Each scenario was repeated five times to establish a level of consistency within the results. The simulations were conducted on a Pentium 100MHz PC with 32 MB of RAM, with simulations taking approximately 2-5 minutes each to complete.

TABLE 1: Details of the scenarios examined

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Queuing Status	Existing	New	New	New
Exit status	N/A	All Visible, fully aware	2-Visible, 2-non-visible, fully aware	2-visible, 2-non-visible variable awareness
bias	0	0	0	Non-visible exits have reduced attractiveness

During this discussion reference will be made to several statistics generated by the buildingEXODUS model *[7]*, namely the PET and the CWT. The PET (Personal Elapsed Time) is a measure of the time spent by the occupant in the evacuation *[7]*. The CWT attribute is a dynamic attribute calculated by buildingEXODUS and is a measure of the total time (in seconds) that an occupant remains stationary after he/she has started to evacuate *[7]*.

RESULTS/DISCUSSION

The introduction of an adaptive decision-making capability, where the occupant is able to redirect according to a crude predictive capacity in response to the information available, is incrementally compared against the present buildingEXODUS capabilities. The results will be provided in terms of an average figure and the distribution of results generated. Those averages without distribution figures indicate static/negligible variation in the results.

Examining the results for Scenarios 1-4 (see TABLE 2) we note that the introduction of the new behavioural features significantly impacts upon the evacuation results. However, these results are complicated due to the introduction of familiarity as a significant factor. Scenario 1 represents the behaviour exhibited in the current buildingEXODUS implementation. It produces the longest evacuation time (58 seconds), the longest average evacuation time (25.8 seconds) and the longest average CWT (2.7 seconds). In this case there is no migration between exits, and therefore the occupants spend the entire simulation waiting for access to their initial target. This is reflected in the extensive evacuation times generated and the time spent waiting by each occupant (see TABLE 2 and Figure 1).

As expected, Scenario 2, where the population is fully aware of all of the exits and are able to determine the extent of the queue at each exit, produces the most effective evacuation (see Figure 3 and TABLE 2). This case may be considered somewhat unrealistic as all the occupants are fully aware of all the exits, even the ones that are not actually in line-of-sight. It produces the smallest average PET and overall evacuation times and causes the occupants to wait for the least amount of time. It also more evenly distributes the occupants between the exits, reducing possible queuing time (see TABLE 3).

TABLE 2: Evacuation Times for Scenarios 1-4

	Avg cwt (secs)	Evac times(secs)	Avg pet(secs)
scenario 1	2.7 [2.5-3.3]	58.0 [56.0-64.0]	25.8 [23.0-27.0]
scenario 2	1.7 [1.5-2.2]	37.7 [35.3-43.0]	17.7 [16.0-20.8]
scenario 3	1.7 [1.5-2.3]	38.5 [37.5-43.0]	19.0 [18.6-22.0]
scenario 4	1.9 [1.7-2.4]	46.9 [45.6-48.8]	21.2 [20.1-22.7]

Indeed, the behaviour introduced into Scenario 2 reduces the evacuation times generated in Scenario 1 by 35% (see TABLE 2). In general, occupants chose to migrate towards the initially underused exits. As the simulation progressed and congestion appeared at all of the exits less migration to these exits was evident. However, the migration that was evident was more evenly distributed between the exits, as these became equivalently populated.

Scenario 3, where visibility was introduced as a factor, demonstrates the subtlety of the occupants adaptation to their surroundings. In this case, while occupants are aware of all the exits they do not have *line-of-sight* with exits 1 and 2 and so cannot ascertain the full potential advantage of diverting to these exits.

TABLE 3: Exit usage (number of occupants) for Scenarios 1-4

Scenario	**Exit 1**	**Exit 2**	**Exit 3**	**Exit 4**
scenario 1	0	0	108	126
scenario 2	49 [45-52]	63 [58-65]	58[56-63]	64 [60-70]
scenario 3	54 [46-57]	42 [40-48]	80 [79-95]	58 [54-67]
scenario 4	26 [24-31]	34 [26-35]	94 [89-97]	80 [79-93]

Due to the initial inequalities in the population distributions, large numbers of occupants migrated towards the unseen exits. Therefore, due to the queuing at the visible exits, unseen exits become more attractive. This migration was based upon the distance that had to be covered, as no other information was available to the occupants. After this initial wave of migration, the populations around exit 3 and exit 4 had diminished dramatically. Due to the slight inequalities in the initial populations around these exits, exit 3 eventually became a viable exit for redirection for some of the occupants queuing at exit 4. Therefore, as priority is given to visible exits, occupants began to migrate between exit 4 and exit 3. It should be noted that these occupants were not able to interrogate the two unseen exits, therefore the build up of occupants around these exits went unnoticed and was not a factor in the movement to the visible exit. This behaviour is responsible for the eventual discrepancy between the two exit (exit 3 and exit 4) populations (see TABLE 3). The overall evacuation times produced are on average only 2% slower than those of Scenario 2.

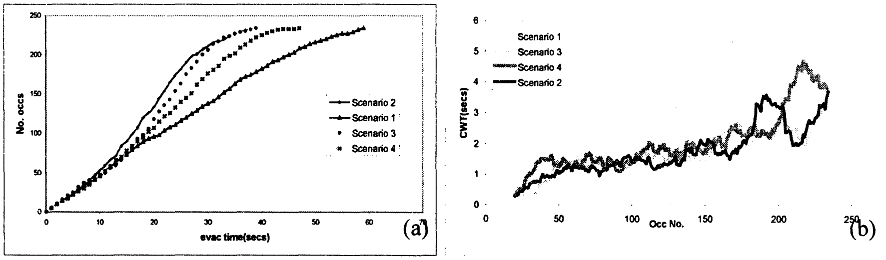

Figure 3: Cumulative arrival times (a) and Cumulative wait times (b) for Scenarios 1-4.

During Scenario 4 a lesser degree of redirection amongst the occupants is noted because of the distribution of awareness levels of the unseen exits (see TABLE 3). Recall that in this scenario not all of the occupants around exits 3 and 4 are aware of the unseen exits. The redirection included the movement between the large populations around exits 3 and 4 observed in previous scenarios, but was most notable for the decrease in occupant movement to the less crowded unseen exits (due to the lack of awareness). In addition, a contra-flow or cross-over movement was produced by a minority of the migrating occupants who were aware of a more distant unseen exit as opposed to the closer of the unseen exits (see Figure 4). This demonstrates the significant qualitative differences that can be generated through a subtle change in the implementation of this behaviour.

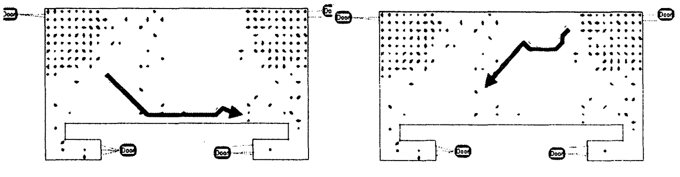

Figure 4: Example occupant paths from Scenario 4 occupants can be seen heading to the furthest unseen door. This is due to the incomplete occupant knowledge of the enclosure.

The comparison of the cumulative wait times between the scenarios is complicated through the introduction of the awareness factor, and is therefore more difficult to interpret (see TABLE 2). The exit efficiency is affected through the increased time spent in transit by the occupants, producing more non-optimal use of the exits. This is especially apparent in Scenario 2. Examining the average time spent waiting by occupants during the simulation we can see the impact that the adaptive queuing behaviour had upon the individual experience. Scenario 1 incurred a 59% increase in the average time spent waiting by each occupant over Scenario 2. This is obviously because of the enforced queuing.

From examining the average evacuation time for each occupant the individual experience of occupants differs between the scenarios, according to our expectations, with differences in the time spent in the enclosure, along with the differences in the occupant waiting times already identified. Finally, it is important to note that considerable variation was achieved in the results generated through repetition of the simulations (see TABLE 3). The occupants may make different decisions depending on their immediate environment which is likely to change from simulation to simulation.

The introduction of an adaptive capability into the occupant decision-making process has significantly affected the outcome of the simulation. This effect is not uniform across the evacuating population, nor is it limited to either qualitative or quantitative factors, but is instead localised and specific to the individual experience. It is important to note that this introduction is not guaranteed to increase the optimality of either the individual or the overall evacuation. The influence is scenario specific, so that in a more densely populated environment, occupants redirecting to unseen exits may be faced with similar or worsening queuing conditions, reducing the overall optimality of their performance.

As identified earlier, the occupants are adapting their behaviour according to the information available to them. If circumstances are changing beyond their scope of awareness, then their decisions may be unsuitable as described above. This level of awareness may be extended through communication (either with other occupants, staff members or through information provided by intelligent alarm systems; a form of behaviour presently under development).

CONCLUSIONS

This paper has demonstrated the potential advantages associated with the introduction of an adaptive behavioural capability within evacuation models. This was demonstrated through enabling occupants to make decisions concerning the selection of the most viable available exit during an evacuation. These decisions were based on considerations such as prior experience, structural familiarity, line-of-sight, and the extent of the crowding around the available exits. The implementation was shown to provide a more complex and arguably more realistic representation of this behaviour than that provided by the existing model. The implementation demonstrated the significance to both the evacuation as a whole and the occupant as individuals of the inclusion of such behaviour. The incremental introduction of the factors identified discernible quantitative and qualitative differences.

If the occupant is able to utilise his ability to determine a more effective route through the analysis of exit crowding, then the optimality of the evacuation is increased. However, the capability of the occupant to switch between available exits does not guarantee the reduction of individual and total evacuation times. The introduction of this behaviour increases the functionality of the buildingEXODUS, model whilst possibly reducing computational overheads. It is intended that the adaptive capabilities of the occupant will be extended to include the reaction to hazardous environment, communication, affiliative behaviour, occupant motivation and a stochastic element to the queuing recommitment behaviour. For this development to occur and to establish an acceptable level of confidence in the results produced, more data is required concerning the decision-making process.

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