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4th International Symposium on

HUMAN BEHAVIOUR IN FIRE

Conference Proceedings

Robinson College, Cambridge, UK

13-15 July 2009

Proceedings of the 4th International Symposium on Human Behaviour in Fire 2009
held at the Robinson College, Cambridge, UK
13-15 July 2009

A conference organised by:
Interscience Communications Ltd
West Yard House, Guildford Grove,
LONDON SE10 8JT, England

Human Behaviour in Fire 2009

ISBN 978-0-9556548-3-1

p680, 134 tables and 276 illustrations

TABLE OF CONTENTS

Page No

09/11

EXPERIMENTAL STUDY OF THE EFFECTIVENESS OF EMERGENCY SIGNAGE

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ABSTRACT

Signage systems play an important role in aiding occupants during both circulation and evacuation. Despite the fact that signage systems are an important component in building wayfinding systems, there is a lack of relevant data regarding how occupants detect, interpret and use the information conveyed by emergency signage. The effectiveness of signage systems is therefore difficult to assess. In this paper we address this issue through experimentation. The experiment involved measuring the impact of a signage system on a population of 68 test subjects who were instructed to individually vacate a building as quickly as possible via any means they thought appropriate. The evacuation path involved a number of decision points at which emergency signage was available to identify the appropriate path. Through analysis of video footage and data derived from questionnaires, the number of people who saw and utilised the signage information to assist their egress is determined. The results are then incorporated within the buildingEXODUS software and used in a demonstration of agent interaction with signage systems in a hypothetical evacuation scenario.

INTRODUCTION

Wayfinding, within the building evacuation context, describes the process by which an individual located within an unfamiliar and arbitrarily complex enclosure attempts to find a path which takes them to a place of relative safety or to an exit leading them to the exterior of the enclosure. The wayfinding task can be relatively straightforward if the occupant has direct visual access to the desired target (exit) or if the enclosure has a simple or intuitive layout. In most other situations the occupant will require additional information to assist them in locating their target [1]. An important component of building wayfinding systems is the emergency signage system. The information conveyed by signage is intended to reduce the apparent complexity of an enclosure thereby improving wayfinding efficiency under both general circulation and emergency conditions. Building guidelines and standards attempt to increase the effectiveness of signage systems by prescribing signage design and installation criteria, e.g. the size of the sign, nature of sign message, design of the sign, positioning of the sign etc [2, 3]. However, as with most prescriptive building regulations, these standards/guidelines do not provide quantification concerning how effective the "correctly" designed signage system is likely to be in practice. The implied assumption is that if the signage system is compliant it will be effective in conveying the specified information to the occupants and that this will be correctly interpreted and utilised by the occupants.

In reality, the interaction between the occupants and signage is extremely complex and influenced by a number of physical, cognitive and psychological factors. The visibility of signage is influenced by the level of ambient lighting, the presence of smoke and irritant gases etc [4, 5] and the presence of visual clutter within the environment. Even if the sign is physically visible, the likelihood that the occupants will perceive the sign is influenced by their attentiveness and level of familiarity with the building structure. Assuming that the sign is physically visible and the occupants perceive the sign, whether the occupants actually follow the information conveyed by the sign is subject to cognitive factors such as their interpretation of the information and psychological factors such as their desire to believe the information. As a result, the actual effectiveness of wayfinding signage systems may be far from ideal.

Within evacuation and circulation computer models [6] a similar "optimistic" situation prevails regarding wayfinding. In general, the wayfinding method adopted in the majority of models is to simply assume that the agents 'know' the appropriate exit route. One of the few models that attempts to represent signage systems as part of the wayfinding process of agents is the buildingEXODUS egress model [7, 8]. Within this model the visibility of the sign is represented through the concept of the Visibility Catchment Area (VCA) [9, 10]. The VCA of a sign by definition is the floor area from where it is physically possible to discern information from the sign. Once within the VCA of the sign it is physically possible to see the sign, but unless the agent is actually facing the sign they will not see the sign. The model thus takes into account the angle between the agents direction of travel and the direct line of sight to the sign to determine the likelihood that the agent will be physically able to see the sign [11, 12, 13]. Given that the agent is capable of seeing the sign, the model then introduces probabilities to represent uncertainties of detecting the sign and acting upon the information. In the detection phase the model determines whether the agent perceives the sign and correctly interprets the information conveyed by the sign. In the acceptance phase the model determines whether the agent decides to follow the information conveyed by the sign. This process can be summarised in the following three steps:

- Visibility of sign: Is it possible for the agent to physically see the sign? Is agent within VCA of the sign, and if so, is the angle between the direction of travel and the normal to the sign such that the agent is capable of seeing the sign?
- Detection: Given that it is possible for the agent to see the sign, does the agent see the sign and correctly interpret the information.
- Acceptance: Given that the agent sees the sign, does the agent follow the information conveyed by the sign.

As no data was available regarding the final two steps, these probabilities were arbitrarily set to 100%, implying that if it was possible for the agent to see the sign, they would detect the sign and correctly follow the information conveyed by the sign. This paper addresses these two deficiencies through experimental trials designed to capture information relating to the effectiveness of emergency signage on individuals attempting to vacate a building. The findings are then incorporated within the buildingEXODUS software [7, 8] and used in a demonstration of agent interaction with signage systems in a hypothetical evacuation scenario.

THE EXPERIMENTAL METHOD

The specific purpose of this experiment is to determine the likelihood that building occupants involved in an evacuation situation and faced with a route decision point and who are located within the VCA of an emergency sign, will; perceive the sign, correctly interpret its information and correctly act upon the information. The types of sign considered in this experiment are the green "running man" emergency exit signs with directional information (see Figure 1). The signs were reflective in nature and the size of the signs located in the corridors and above the target doors are 0.1 x 0.3 m in size. In all cases the design of the signs complied with UK standards. The signs were located in well lit areas which were also illuminated by natural lighting.

The test building consisted of a wing of the Queen Anne building at the University of Greenwich. This building consists of staff offices, lecture halls and smaller lecture classrooms. The test area was located on the first floor of the west side of the building (see Figure 2).

(a) (b)

Figure 1: Signs used in the experiment in the corridor (a) and above the target door (b).

Egress trials were conducted out of term time or out of normal working time so as the trials would not be disturbed by students. The evacuation path involved participants walking down a short corridor running east-west which ends in a "T" intersection with the adjoining corridor running south-north. The participants then went either left (south) or right (north) along the south-north corridor. Both corridors are approximately equal in length and width. At their widest point, both the north and south corridor are 6.8 m wide. The length of the south corridor is 22.9 m while the length of the north corridor is 22.6 m. Both corridors are more aptly described as open circulation spaces than corridors. Although both corridors are viable exit routes eventually leading to two external exits, the left (south) route is more commonly used for circulation as it leads to the main entrance on the south (left) side of the building. On both the left and right side of the east wall of the south-north running corridor are two non-exit doors leading to rooms while at south and north extreme ends of the corridor is a door leading to another corridor running west-east. Each of these corridors runs a short distance and ends with three doors, one door across the corridor and two additional doors to either side (see Figure 2). The door across each corridor simply leads to another stretch of corridor, while in the south (left) wing corridor, the door on the north wall of the corridor is the exit door which has a glass pane and the door on the south wall of the corridor is an office door. In the north (right) wing corridor, the door on the south wall of the corridor is the exit door which is a wooden door while the door on the north wall of the corridor is an office door. The glass pane in the exit door in the south (left) wing corridor was opaque and obscured the sight of the exit staircase. The egress system thus has three decision points; (i) the "T" intersection, (ii) along each stretch of south-west corridor leading from the "T" intersection and (iii) the end of each west-east corridor (see Figure 2). At each of these decision points emergency signage was available to identify the appropriate path. In this paper, due to space constraints, we only present the results from decision points 1 and 2.

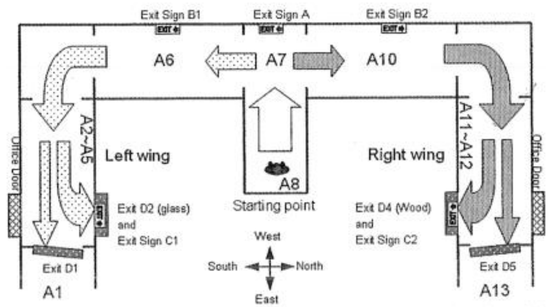

Figure 2: The geometry, exit signs and exit routes used in the trials.

In total 68 test subjects volunteered to take part in the experimental trials. The subject population has a broad distribution of background (students, visitors and residents from local community), age (from 20 to over 70) and gender (36 females and 32 males). Among the test participants, 41 (60.3%) were naïve test subjects, completely unfamiliar with the building layout while the remaining 27 (39.7%) test subjects were familiar or partly familiar with the building layout.

Participants were brought to the starting point via a route which did not include the test section. Trial participants were instructed to evacuate the building as quickly as possible without running, via any means they thought appropriate. No specific mention of the signage system was made during the instruction announcement. Participants were put through the test section individually and their progress was recorded using a head mounted mini video camera. In addition, on completion of the trial, each participant completed a detailed questionnaire which identified the stimuli which assisted them in selecting exit paths at each of the decision points.

EXPERIMENTAL RESULTS AND DISCUSSION

Decision point 1: "T" intersection, exit sign A, route selection at A7

The first decision point encountered is A7 and the first sign encountered is sign A, which points to the left (towards the next sign) along corridor A6 (see Figure 3). A7 is a T-junction from which another corridor extends to the left (A6) and the right (A10). The left exit route via A6 and the right exit route via A10 are similar but not identical in structural configuration and dimensions. It is expected that the two exit routes offer similar affordance to unfamiliar participants if additional information in the form of signage is not available. This expectation can be tested by considering the behaviour of the unfamiliar participants who did not detect sign A. Whether participants detected a sign was determined primarily from the questionnaire. Participants were specifically asked in the questionnaire whether they noted a sign at the decision point and whether the sign influenced their decision. In addition, by viewing the video recording of each participant's progress, it is often possible to determine whether a participant noted the presence of the sign. From this analysis, 25 unfamiliar participants failed to detect sign A and therefore did not use signage to make a route choice at junction A7. Of these, 12 (48%) selected the left route and 13 (52%) selected the right route. This result is exactly as would be expected if the route decision was unbiased and down to random choice. This supports the view that the affordance of both routes is almost identical.

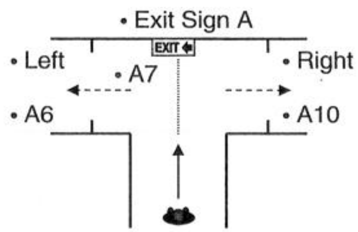

Figure 3: The 1st Decision Point: individual participant approaches Exit Sign A at location A7 with an approach angle of zero degrees to normal of sign.

When a similar analysis is undertaken for the familiar group, we find that 18 familiar participants failed to detect sign A and therefore did not use signage to make a route choice at junction A7. Of these, 12 (66.7%) selected the left route and 6 (33.3%) selected the right route. Thus twice as many of the familiar group elected to go left as went right. This is consistent with the fact that this group represented participants who had partial or total familiarity with the building layout and hence were familiar with the fact that the main entrance is accessed via the left route.

Among the 41 unfamiliar participants who entered the T-junction A7, 16 (39%) claimed that they saw an exit sign. Of these, 12 (29%) confirmed that the exit sign they saw was sign A, while the other 4

could not recall if the sign they saw was sign A (may have been sign B1). However, upon detecting the exit sign, all 16 (100%) participants correctly interpreted the sign and decided to follow the sign.

Among the 27 familiar participants who entered the T-junction A7, 9 (33%) claimed that they saw sign A at A7. Upon detecting the exit sign A, all 9 (100%) participants correctly interpreted the sign and decided to move in the direction of the sign. However, the manner in which the familiar subjects used the sign information is slightly different from that of the unfamiliar participants. Among the 9 familiar participants, 7 claimed that they made a route selection decision solely according to the information gained from the sign, while the other 2 used the signage information to confirm their route choice which was primarily based on their familiarity with the building.

In addition, the video footage was used to determine the amount of time a participant spent in determining which direction they would travel. This was measured from the moment they entered the A7 junction area to the moment they decisively headed in a particular direction. For the unfamiliar participants who detected the sign the average decision time was 2.6 s, while for the unfamiliar participants who did not detect the sign, the average decision time was 5.6 s.

These results can be summarised as follows, for participants who are within the VCA of an emergency exit sign measuring 0.1 x 0.3 m and whose direction of travel makes a 0° angle to the sign's normal (i.e. moving directly towards the sign):

- 39% (16/41) of participants unfamiliar with the building layout are likely to detect the sign
- 100% (16/16) of participants unfamiliar with the building layout who detect the sign correctly interpret and follow the sign.
- 33% (9/27) of participants familiar with the building layout are likely to detect the sign
- 100% (9/9) of participants familiar with the building layout who detect the sign correctly interpret and follow the sign.
- 37% (25/68) of participants with mixed building layout familiarity are likely to detect the sign
- 100% (25/25) of participants who detect the sign correctly interpret and follow the sign.
- Unfamiliar participants who detect the sign require on average 2.6 s to decide which direction to take.
- Unfamiliar participants who fail to detect the sign require on average 5.6 s to decide which direction to take.

Participants unfamiliar with the building layout had a slightly higher probability of detecting the emergency exit signs. This is probably due to these participants being more actively involved with searching for signage information due to their unfamiliarity with the layout. Furthermore, in situations where the participant had some knowledge of the building layout, while they primarily used their knowledge of the layout, emergency signage served to positively reinforce the wayfinding decisions of the participant.

Decision point 2: Corridor exit signs B1/B2, route selection at A6/A10

The second decision point encountered is A6/A10 and the second sign encountered is sign B1/B2, which points to the door at the end of the south-north running corridor (see Figure 4). The two doors located on the east wall of the corridor (leading to rooms) complicate the wayfinding as participants may mistake these as being part of the exit route. Sign B1/B2, placed on the wall opposite to the non-exit doors, is intended to direct the participants to move towards the door at the far end of the corridor. However unlike sign A, which participants approach with a 0° angle to the signs normal (i.e. moving directly towards the sign), participants approach the B1/B2 sign at angle making this sign potentially more difficult to detect. In essence, there are two reasons for the increased difficulty in detection. Firstly, participants must be closer to the B1/B2 sign compared to the A sign, before they are within the VCA of the sign. Secondly, as the trajectory of the participants is at an angle to the direct line of sight to the sign, there is a smaller probability that the sign will be detected compared to the situation where participants head directly towards the sign. As both sections of the south-north corridor are similar, the analysis of the participant behaviour in both corridor sections will be combined.

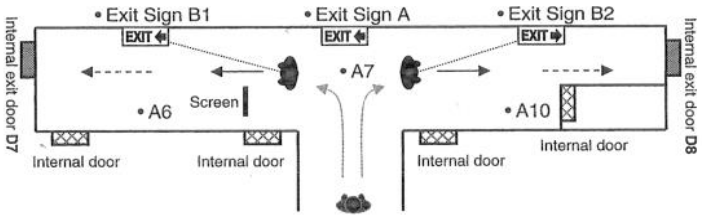

Figure 4: The 2nd Decision Point: individual participant approaches Exit Sign B1/B2 at location A6/A10 with a non-zero approach angle.

Among the 41 unfamiliar participants, 15 (37%) claimed that they detected exit sign B1/B2 at A6/A10. Upon detecting the exit sign, 14 (93%) participants confirmed that the sign had a direct impact on their exit route decision. On detecting the sign they either made a decision to follow the sign and head directly towards the door at the end of the corridor or they were encouraged by the sign to continue their journey towards the door at the end of the corridor. One participant stated that noticing the sign had no effect on his route decision and he simply decided to keep on going in the direction he was travelling in.

Among the 27 familiar participants, 7 (26%) claimed that they detected exit sign B1/B2 at A6/A10. Upon detecting the exit sign, 6 (86%) participants confirmed that the sign had a direct impact on their exit route decision i.e. either they based their decision according to the sign or they were encouraged to continue their journey towards the door at the end of the corridor. One participant stated that noticing the sign had no effect on his route decision and he simply decided to keep on going in the direction he was travelling in.

These results can be summarised as follows, for participants who are within the VCA of an emergency exit sign measuring 0.1 x 0.3 m and who approach the sign at an angle:

- 37% (15/41) of participants unfamiliar with the building layout are likely to detect the sign
- 93% (14/15) of participants unfamiliar with the building layout who detect the sign correctly interpret and follow the sign.
- 26% (7/27) of participants familiar with the building layout are likely to detect the sign
- 86% (6/7) of participants familiar with the building layout who detect the sign correctly interpret and follow the sign.
- 32% (22/68) of participants with mixed building layout familiarity are likely to detect the sign
- 91% (20/22) of participants who detect the sign correctly interpret and follow the sign.

Furthermore, in situations where the participant had some knowledge of the building layout, while the participant primarily used their knowledge of the building layout, emergency signage served to positively reinforce their wayfinding decisions.

RECOMMENDED DATASET FOR OCCUPANT INTERACTION WITH EMERGENCY SIGNAGE

Comparing the signage interaction behaviour at decision point 1 (approaching the sign with zero degree angle to sign normal) with decision point 2 (approaching sign at an angle to the sign normal) we find similar trends for both familiar and unfamiliar participants. For unfamiliar participants, at decision point 1, 39% of participants detected the sign while 37% detected the sign at decision point 2. Thus both signs had a very low detection rate, with the sign at decision point 2 having a slightly lower detection rate. For the sign at decision point 1, 100% of participants who detected the sign followed the sign while at decision point 2, 93% followed the sign. This indicates that if the sign is detected almost all unfamiliar participants will correctly perceive and follow the information provided. For familiar participants, at decision point 1, 33% of participants detected the sign while 26% detected the sign at decision point 2. Thus as with the unfamiliar participants, both signs had a very low detection rate, with the sign at decision point 2 having a lower detection rate. We also note that the detection rate for unfamiliar participants is higher than that for familiar participants. This is likely due to the familiar participants feeling that they did not need to look for signage to assist them in exiting the building. For the sign at decision point 1, 100% of participants who detected the sign followed the sign while at decision point 2, 86% followed the sign. While these percentages appear to be significantly different, the number of participants at decision point 2 who were familiar and detected the sign were quite small (seven people) and while six of the seven followed the sign, this resulted in the relatively small percentage. This again is similar to trend found for the familiar indicates that if the sign is detected almost all unfamiliar participants will correctly perceive and follow the information provided.

Thus we find that the detection probability is slightly less when approaching the sign at an angle compared with approaching the sign head on for both familiar and unfamiliar participants however, this difference is not statistically (chi squared test) significant. We also find that the interpretation and acceptance rates are very high in both cases for both familiar and unfamiliar participants, again the differences between both signs not being statistically significant. This suggests that it is appropriate to combine both data sets to produce a single data set.

Combining both data sets we find that for reflective signs measuring 0.1 x 0.3 m when observed under well light lighting conditions:

- 38% (31/82) of participants unfamiliar with the building layout are likely to detect the sign
- 97% (30/31) of participants unfamiliar with the building layout who detect the sign correctly interpret and follow the sign.
- 28% (16/58) of participants familiar with the building layout are likely to detect the sign
- 94% (15/16) of participants familiar with the building layout who detect the sign correctly interpret and follow the sign.
- 35% (47/136) of participants with mixed building layout familiarity are likely to detect the sign
- 96% (45/47) of participants who detect the sign correctly interpret and follow the sign.

These results provide guidance on the likely uptake of wayfinding information provided by signage. While on average only 38% of people unfamiliar with a building layout are likely to detect regulatory standard signs, on average 97% of people are likely to follow the guidance provided by signs once they are detected. These results also suggest that current emergency guidance signs are less effective as an aid to wayfinding than they potentially can be. If they can be made to be more obvious while maintaining the simplicity and strength of the guidance information they provide, they are likely to become very effective due to high acceptance of signage information. To address this problem it is necessary to increase the affordance of the sign. This can be done in a number of ways such as increasing the size of the sign, making the sign standout more from the background, or introducing additional sensory stimuli such as flashing lights and auditory signals. However, it is essential that the simplicity and strength of the information conveyed by the sign is not decreased through enhancing the affordance of the sign.

DEMONSTRATION EVACUATION SIMULATION

The signage interaction data presented above was implemented within the buildingEXODUS evacuation software [9-13]. Effectively the experimental data replaced the idealised 100% probabilities of Detection and Acceptance (see discussion in introduction). A demonstration case based on a hypothetical supermarket has been designed to examine the impact of signage upon the evacuation behaviour. The geometry has been discussed in detail in other publications [11, 12] and so it will only be briefly described here.

The Geometry and the Test Population

The layout of the supermarket is a complex, single layer geometry of 79 metres in width and 55 metres in depth (see Figure 5). Inside the supermarket there are a number of shelving units and a row of cash tills (check-outs). The shelving units are evenly positioned throughout the floor space and cover the most part of the internal area with the exception of the circulation aisles. The cash tills are placed in line at the front of the geometry. Around the supermarket there are eight exits. Four exits are main entrances/exits which are all located at the front of the geometry (Exits 3-6 in Figure 5). The other exits are emergency exits which are located symmetrically at the left and right side (Exits 1, 2, 7 and 8 in Figure 5). The width of each door is assumed to be 2.5 m.

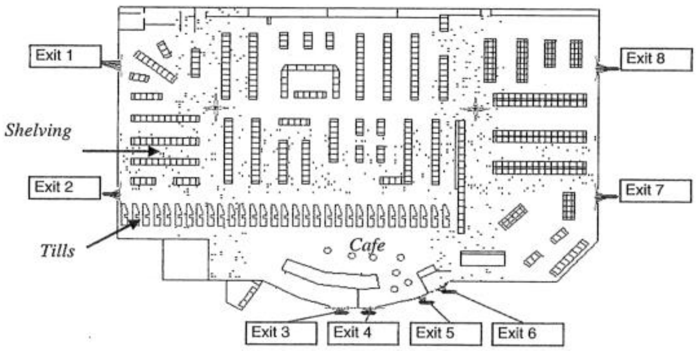

Figure 5: The geometry of hypothetical supermarket.

The total available area where the agents can manoeuvre within the supermarket has been calculated to be approximately 2927 m^2 after the shelving and other furnishings have been taken into account. The majority of the shelving is at a height of 2.5 m. However, there are some with a height of 1.8 m and the tills and tables in the café area have a height of 1.2 m. There are two sets of exit signs installed within the geometry. The first set is located directly above each of the main and emergency exits, one sign above each exit. The second set consists of two groups of four signs positioned above the main central aisle that runs from left to right across the geometry, one group located to the left and the other group located to the right of centre (see Figure 6). These eight signs indicate the location of the four emergency exits. All of the 16 signs are placed at a height of 2.2 m above the floor of the geometry. The lettering on each sign is assumed to be 15.2 cm in height producing a maximum visibility distance of 30 m [14] and the VCA of each sign is circular in shape as determined in [10].

A total of 1000 agents are used in the demonstration simulations to represent a general population of patrons. For the purpose of these demonstrations the population is assumed to be fully mobile (no movement disabilities) and are assumed to react instantly to the evacuation alarm. The population is randomly generated using the standard buildingEXODUS default options (travel speeds ranging from 1.2 m/s to 1.5 m/s). The entire population is assumed to be unfamiliar with the geometry and so only know of the main entrance/exit to the supermarket. The average agent height is assumed to be 1.75 m.

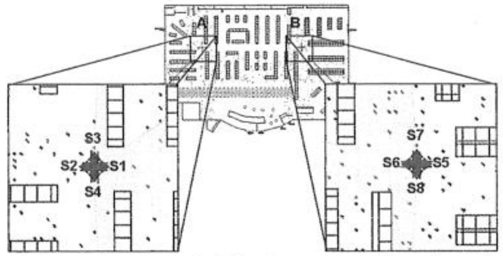

Figure 6: The eight exit signs located within the geometry above the main central aisle.

The Simulation Scenarios

Four scenarios are examined:

Scenario 1: The entire population utilise the four main exits only. All signage information is ignored. This is intended to represent a base case situation which is a plausible worst case egress scenario. It is the type of scenario that most egress models would be capable of simulating.

Scenario 2: The entire population utilise every available exit. All signage information is ignored. This is intended to represent a best case situation or optimal case in which every agent has complete knowledge of the layout of the building. Once again, most egress models would be capable of running this scenario. The likely results of a real evacuation are expected to fall between the results of Scenario 1 and Scenario 2.

Scenario 3: The population have the same level of exit knowledge as in Scenario 1 but are now able to use signage information to wayfind to one of the emergency exits. This will only occur if the agent falls within the VCA of a sign and are moving in an appropriate direction to be likely to see the sign. In this case, the agent is then given a 100% detection probability and a 100% acceptance probability (at each step within the signs VCA) and will follow the sign to the identified emergency exit if it is closer than the main exits. This scenario represents the current capabilities of the buildingEXODUS software and its signage model.

Scenario 4: This scenario is similar to Scenario 3 but the data derived from the signage experiment is used to represent the detection probability and the acceptance probability. This means that even when agents are within the signs VCA and are moving in an appropriate direction relative to the sign, they will have a 38% chance of detecting the sign and if detected, a 97% chance of accepting the directional information and following the sign to the emergency exit. The 38% detection probability represents the probability of detection while in the VCA of the sign, and so the detection probability at each step while within the VCA is considerably smaller. Also, while the signs used in the simulation are larger than the signs used in the detection experiment, the detection probabilities of the smaller signs will be used in the simulations.

Simulation Results

Each scenario was run 10 times to produce a range of result. During each repeat simulation the starting location of the individuals was kept constant so that the influence of the signage system could be better assessed. The VCA of the entire signage system covers 1914.5 m^2 of floor space and so an emergency exit sign or an exit can be seen from 65.4% of the floor space (see Figure 7). We note that amongst the shelving units it is not possible to see an exit sign or an exit.

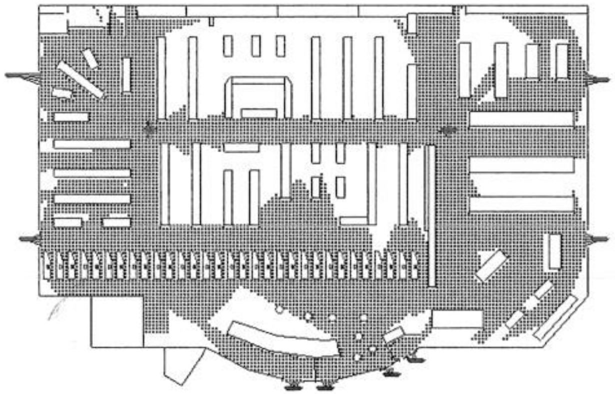

Figure 7: VCA coverage of entire signage system.

Presented in Table 1 are the mean values, along with the variation (two standard deviations $\pm 2\sigma$) for some of the key parameters generated from the simulations. In Scenario 1, all the agents attempt to exit the store from the four main exits located in the front of the supermarket. The average travel distance in this case is 42.5 m. The large number of arrivals at the four main exits in the early stages of the evacuation soon exceed the exit flow capacity and large crowds develop. As a result, on average agents spend 38.3 s in congestion (cumulative wait time), which accounts for 53.0% of their average individual evacuation time (72.2 s).

Table 1: Average evacuation performance for the four scenarios.

Scenario No.	Total Evacuation Time (s)	Average Individual Evacuation Time (s)	Average Congestion Time (s)	Average Distance Travelled (m)
1	183.7 ± 9.1	72.2 ± 1.2	38.3 ± 1.2	42.5 ± 0.1
2	81.6 ± 1.3	31.2 ± 0.4	12.4 ± 0.4	22.9 ± 0.1
3	97.9 ± 6.5	35.9 ± 0.8	12.9 ± 0.8	28.3 ± 0.2
4	147.3 ± 14.2	53.4 ± 2.6	24.3 ± 2.2	36.2 ± 0.8

In Scenario 2, the agents are aware of all eight exits and use their nearest exit. In this case average travel distance is greatly reduced to 22.9 m, showing that the agents are making use of their nearest exits. Also, the total evacuation time is more than halved to 81.6 s. The amount of time wasted in congestion is also greatly reduced to just 12.4 s and represents some 39.7% of the average personal evacuation time. In reality, some of the occupants are expected to utilise the emergency exits, so an actual evacuation of the supermarket is expected to require a total evacuation time between the results of Scenario 1 and 2 i.e. between 81.6 s and 183.7 s.

In Scenario 3, agents who are within the VCA and are able to see the sign have a 100% probability that they will detect the sign and a 100% probability that these agents will actually follow the directions of the sign. For Scenario 3 we find that the total evacuation time is 97.9 s. The result for Scenario 3 is only 17% larger than the evacuation time in Scenario 2 (all agents utilise their nearest

exit) while the result is some 88% smaller than the result for Scenario 1 (agents only utilise the main exits). The 100% probability of detection and compliance results in a large number of agents utilising the emergency exits. As a result, in Scenario 3 we also note that the average travel distance, average cumulative wait time and average individual evacuation time are slightly higher than those values found in Scenario 2.

In Scenario 4, the average signage detection probability is reduced to 38%. Thus while an agent is within the VCA and is travelling in a direction in which it is physically possible to see the sign, there is only a 38% chance that the sign will be detected. Again, it must be emphasised that this represents the total probability that the sign will be detected while the agent is within the VCA of the sign and not the probability per step while within the VCA of the sign. If detected, there is a 97% chance that the agent will follow the sign. This detection probability is very low and as a result, considerably fewer agents utilise the emergency exits compared with Scenarios 2 and 3. The average total evacuation time for Scenario 4 is 147.4 s, a considerable increase compared to Scenarios 2 and 3. However, the average egress time for Scenario 4 is still 25% lower than for Scenario 1 (all agents utilise only the main exits).

The results from Scenario 3 and 4 indicate that signs can be useful in directing people to emergency exits and hence reducing egress times for large structures with complex interior layouts (against Scenario 1). In the ideal situation (i.e. Scenario 3), where signs have a 100% detection (and compliance) rate, evacuation times could be reduced to a level comparable to the situation in which all the occupants had perfect knowledge of the exit positions (i.e. Scenario 2). However, in the more realistic situation (i.e. Scenario 4), the low detection rate associated with signs greatly constrains the possible improvements in egress times that may be achieved.

Finally, when considering the range of scenarios that need to be investigated to determine the likely performance of a building, engineers will typically run at least two cases. One case would be the situation in which the occupants use all the exits in the building (best time) and another in which the occupants utilise only the main exits (worst time). This can produce a very wide range of possible egress times. In reality, the occupants unfamiliar with the structure may be expected to utilise the signage system to assist in wayfinding. Using the buildingEXODUS signage model with the detection (and compliance) data derived from these signage trials will produce a more realistic upper limit to the egress time.

CONCLUSION

This paper has described an experimental approach to study the interaction between occupants and signage systems within the built environment. The experimental findings were then implemented within the buildingEXODUS evacuation model to investigate the impact signs may have on egress situations involving complex structures.

The experimental findings suggest that for reflective signs measuring 0.1 x 0.3 m when observed under well light lighting conditions that 38% of occupants who are unfamiliar with the building layout and who are within the VCA of a sign will actually detect the sign. Of those who detect the sign, some 97% will use the information to assist them in wayfinding. For those occupants who are familiar or partially familiar with the building layout both these probabilities are slightly reduced. These results suggest that current emergency guidance signs are less effective as an aid to wayfinding than they potentially can be. It has been suggested that to address this problem it is necessary to increase the affordance of the sign. However, it is essential that the simplicity and strength of the information conveyed by the sign is not decreased through enhancing the affordance of the sign.

When the signage data was implemented within the buildingEXODUS signage model, the simulation results confirm that while some agents are likely to detect the emergency signs and thereby be lead to a nearby emergency exit, the number doing so are small and hence the signage system has a small impact on the overall evacuation times. However, in the ideal situation where signs had a 100% detection rate, evacuation times could be reduced to a level comparable to the situation in which all the occupants had perfect knowledge of the exit positions. This result provides strong support for the improved design of emergency signage through enhancement of the signs affordance.

REFERENCES

1. Paul Arthur and Romedi Passini, *Wayfinding: people, signs and architecture*, pp76-81, ISBN 0-07-551016-2, 1992

2. BS 5499-1:2002 Graphical symbols and signs - Safety signs, including fire safety signs – Part 1: Specification for geometric shapes, colours and layout, ISBN 0 580 38258 3, UK, 2002

3. BS 5499-4:2000 Safety signs, including fire safety signs – Part 4: Code of practice for escape route signing, ISBN 0 580 33205 5, UK, 2000

4. Jin, T., "*Visibility Through Fire Smoke*", Journal of FIRE & FLAMMABILITY, Vol. 9, pp135-155, April 1978

5. Jin, T and Yamada, T., "*Irritating Effects From Fire Smoke On Visibility*", Fire Science And Technology, Vol. 5, No.1, pp79-90, 1985.

6. Erica D.K., Computer Evacuation Models for Buildings, SFPE Handbook of Fire Protection Engineering, 4th ed, 2008, pp 3-456 to pp 3-478. National Fire Protection Association: Quincy.

7. Owen, M., Galea, E.R., Lawrence, P. J., "*The Exodus Evacuation Model Applied To Building Evacuation Scenarios*", J. Of Fire Protection Engr. 8(2) pp65-86, 1996.

8. Gwynne S, Galea E R, Owen M, Lawrence P J and Filippidis L, "*Adaptive decision-making in buildingEXODUS in response to exit congestion*", Proc 6th IAFSS Symp, pp 1041-52, France, 2000.

9. Filippidis L, Galea E R, Lawrence P and Gwynne S, "*Visibility Catchment Area of Exits and Signs*", INTERFLAM 2001, Proceedings of the Ninth International Conference, Vol. 2, p1529-1534, ISBN 0 9532312 9 1 (Vol 2)

10. Xie H, Filippidis L, Gwynne S, Galea E, Blackshields D, Lawrence P., "Signage Legibility Distances as a Function of Observation Angle", Journal of Fire Protection Engineering, Vol. 17, No. 1, pages 41-64, 2007 DOI: 10.1177/1042391507064025

11. Filippidis L., Gwynne S., Galea E.R., and Lawrence P., "*Simulating the Interaction of Pedestrians with Wayfinding Systems*". Proc 2nd Int Pedestrian and Evacuation Dynamics Conference, Ed: E.R.Galea, CMS Press, Greenwich, UK, ISBN 1904521088, pp39-50, 2003.

12. Filippidis L, Galea E, Gwynne S, Lawrence P., "*Representing the Influence of Signage on Evacuation Behaviour within an Evacuation Model*", Journal of Fire Protection Engineering, Vol 16, No1, pages 37-73, 2006. DOI: 10.1177/1042391506054298.

13. Filippidis, L., Lawrence, P., Galea E.R., Blackshields, D., Simulating the Interaction of Occupants with Signage systems. Proceedings of 9th IAFSS Symposium Karlsruhe, Germany, ISNN 1817-4299, pp 389-400. DOI:10.3801/IAFSS.FSS.9-389, 2008.

14. NFPA, *Life Safety Code Handbook*, National Fire Protection Association, Quincy, MA, 1997