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Human Behaviour in Fires

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HUMAN BEHAVIOUR IN FIRES

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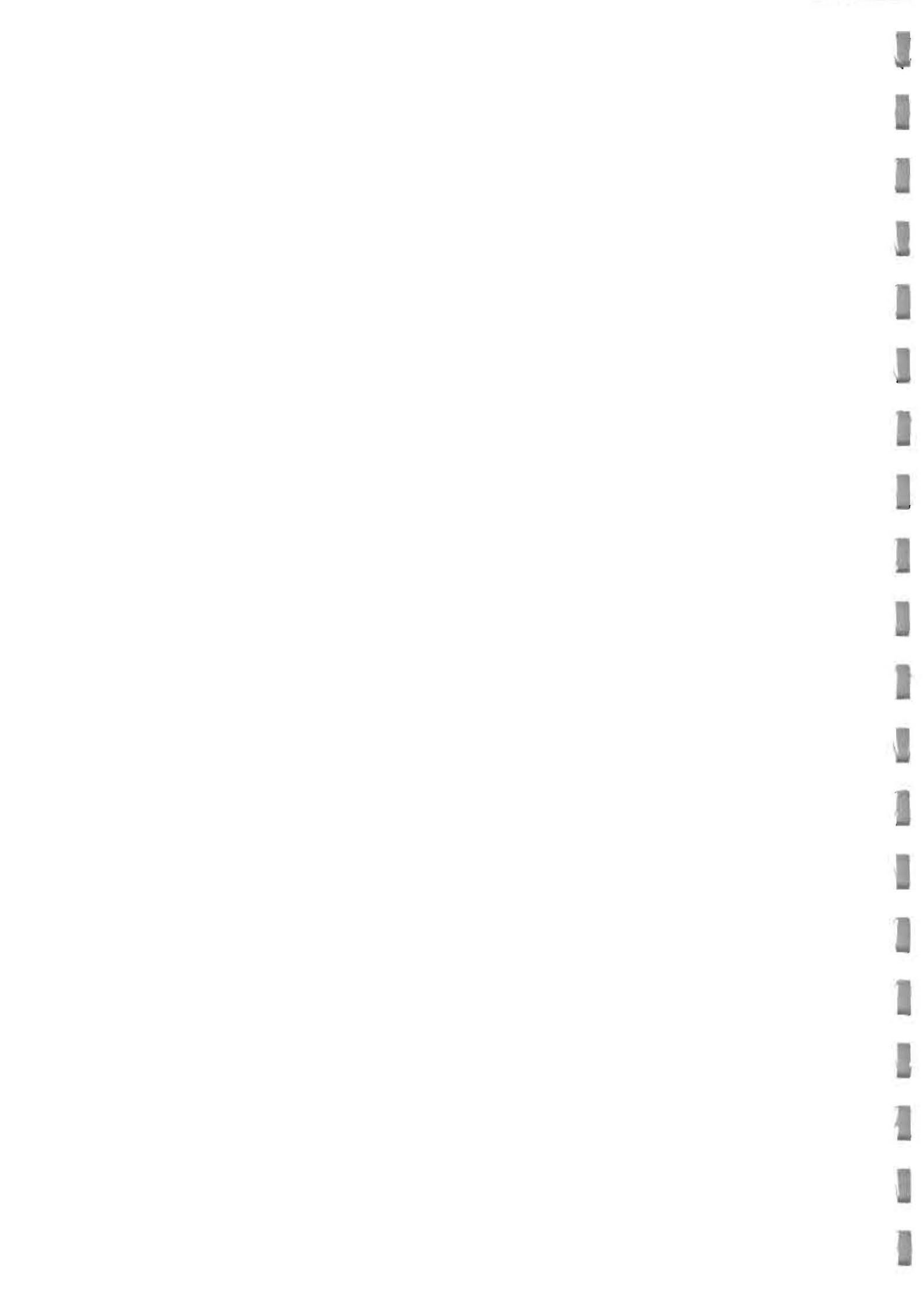
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HUMAN BEHAVIOUR IN FIRES

A three year project commissioned by the Fire and Emergency Planning Department of the Home Office, and monitored by their Scientific Research and Development Branch (SRDB) and the Fire Service Inspectorate: 1985-1988

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INTRODUCTION

This document summarises the findings of a three year research project on escape behaviour in fires conducted between 1985-1988. The findings are reported in greater detail in five research reports which were submitted at regular intervals to the Home Office during the course of the project. As a Management Summary of research findings, and for the sake of clarity, the actual statistical analyses and many of the details of the studies have not been set out in this report. The reader is referred to the actual research reports themselves (See Chapter 11 references 1-5). It should also be emphasised that the research has intentionally focused on a series of highly detailed case studies, rather than attempting to make broad generalisations based on a questionnaire survey of a large number of fires.

The objective of the project was 'to determine what factors may deter people who are escaping from a fire from using internal escape routes, and having established the factors, to assess their importance'. In the project the term 'exit choice behaviour' was adopted to denote people's decision to move one way or another when faced with the choice between two or more exits required by regulations and design standards, in circumstances where one exit may become obstructed by flames or debilitating smoke. The original list of 6 factors set out in the research brief (paragraph 1.1) was revised and increased to 11 factors (paragraph 2.5) following a detailed literature review. These 11 factors, in various combinations and to differing degrees, were found to have influenced exit choice behaviour in a series of studies. In addition, a set of assumptions derived from a review of regulatory and design standards literature (paragraph 2.6) was rejected, and a set of correspondingly different propositions (paragraph 2.7) was supported. In addition, the significance of the 'timing' of escape, or when people start to move towards an exit was identified early on in the project as being of fundamental importance. As a consequence, the timing of escape was included in a revised definition of 'exit choice behaviour' and became a focus of the study.

The research programme concentrated on two types of exit choice defined in terms of building and occupancy type, namely:-

- (a) escape from a single room (as in a hotel or hall of residence); and
- (b) escape from an assembly setting (as in a department store or theatre).

Nine case studies were conducted (listed as A to I in the Contents section.) These case studies fell into three complementary categories of research namely:-

- (a) mapping and statistical analysis of actions and movement in fires (data derived from police witness statement transcripts - A, B, C, D, E;
- (b) monitored evacuations - F, G.); and
- (c) video-disc simulation of a fire - H, I.

The research suggests the importance of the following factors in relation to the escape behaviour by individuals:-

- (a) the importance of building dimensions;
- (b) role of person in building (public or staff);
- (c) floor of location;
- (d) knowledge of the fire;
- (e) familiarity of route; and
- (f) smoke development.

Measuring a statistical relationship between an absolute unit of smoke density proved impossible in the studies of these fires. A review of existing research suggests that it is misleading to expect an absolute relationship between a numerical measure of visibility in smoke and/or travel distance to an exit (See paragraph 2.2).

The most important finding of the research is the fact that the start up time (ie people's reaction to an alarm) is as (if not more) important as the time it takes physically to reach an exit (see paragraph 2.7(c)). In the lecture theatre study 2, on average two-thirds of the time from the onset of the alarm to reaching exits was spent by people not moving at all. On average one-third of the time was spent in moving from seat positions to and through an exit. It is not suggested that this finding is what would be expected in all settings and circumstances. Indeed, inquiries into major fire disasters suggest that delays in staff warning the public and poor alarm systems have meant that the proportion of time spent, from the discovery of a fire to the majority of people moving to an exit, has normally been significantly longer than two-thirds of the time between an alarm and escape. Further research on this subject is needed.

Bearing in mind that data on this subject is limited, the research strongly suggests that there is a disproportionate emphasis on time to move and exit flow rates in design

standards and regulations. For the moment, a two-thirds/one-third division might be taken as a rule of thumb, not for calculating exit widths, but for representing the true nature of the problem. In this respect, a distinction is made between two time phases in 'exit choice' (escape) behaviour:-

- (a) 'time to start to move' from the onset of an alarm or discovery of a fire by someone in a building or a device such as a smoke alarm and
- (b) 'time to move' (and reach a point of relative safety such as a 'protected' staircase or absolute safety, ie outside a building).

It is argued that serious attention should be directed to the apparent assumption that time to escape is exclusively dependent on time to travel to and through exits. It is felt that 'escape time' should take into account 'reaction to alarm time' and the two phases of 'time to start' and 'time to move' should be explicitly addressed in design codes of practice and regulatory literature. In this respect, a delay in time to start is a fundamental problem which characterises large scale fire disasters involving injury, including those at the Bradford City Football Club ground and King's Cross Underground station, which occurred during the period this research was conducted.



CHAPTER 1: OBJECTIVES OF THE PROJECT

1.1 The objectives of the research brief were as follows:-

To determine what factors may deter people who are escaping from a fire from using internal escape routes, and having established the factors, to assess their importance. Factors to be considered to include:-

1. Smoke obscuration
2. Fire characteristics (such as heat and smell)
3. Familiarity with escape routes
4. Characteristics such as age or infirmity
5. Advice provided
6. Light levels

including an appraisal of:

- (a) how reasonable the assumption is 'that an escape route would in general not be used by people if the range of visibility in their intended path were to be reduced to 10 metres or less'; and
- (b) 'what contribution to safety can be expected from an emergency lighting point or an exit sign indicating the safest way out'



CHAPTER 2: LITERATURE REVIEW

2.1 The five research reports (see references 1, 2, 3, 4 and 5) form the basis for this Management Summary. Also produced is a working document on Fire Safety Legislation (reference 6) and a publication outlining the research methods adopted (reference 7). Several conference papers have been subsequently published (references 8, 9 and 10). In commissioning the research by a team of environmental psychologists working within a School of Architecture, a central concern has been to understand the interrelationship between people's pattern of escape behaviour on the one hand, and the physical environment of buildings and changing physical environment of fire and smoke spread on the other. An essential part of the research conducted was the short literature review of research on escape behaviour (report 1) and the extensive review of the international research literature (report 2). The latter is a 40 page review, supported by over 100 references.

2.2 A detailed appraisal of the origin of the assumption that there is a statistical association between a range of visibility of 10 metres or less in a person's intended path (due to smoke) and their disinclination to move in that direction, suggests that this conclusion should be treated with extreme caution. The origin of a statement that 10% of people are likely to turn back if visibility is reduced to 10m and 20% at 5m, which now appears in research review documents which we have traced in Australia, USA and Britain, is a particular reanalysis (reference 11) conducted in Britain of data originally collected in a questionnaire survey of people's behaviour in fires (reference 12); (for further details see reference 2). Scrutiny by us of the data, confirmed in detailed discussion with the researcher who collected it (reference 12), shows that of the 88% of people in the sample who recalled the presence of smoke, 26% entered it and turned back. Of these, approximately 10% turned back when they reported visibility to be 10 metres or more. The original data has weaknesses. For instance it does not take into account the number of people who did not enter a smoke filled area or the travel distances involved. (see reports (1), paragraphs 3.7-3.15 and (2) 1.9.1-1.9.6 for details and references).

2.3 Implicit in assumptions of a statistical relationship between units of smoke obscurity and distance of visibility is the argument that a physical stimulus, whether it is a fire alarm, travel distance, exit width or smoke actually determines the direction people decide to move. Associated with notions that people react rather like inanimate objects propelled by a physical force to an exit, rather than of their own volition, is the concept of 'panic' which has been widely used to explain deaths in large scale fire disasters and the direction people moved.

2.4 An appraisal of the research and regulatory literature shows that there are serious weaknesses in using the concept of panic, to exclusively explain patterns of escape behaviour in which people appear to have ignored the alternative emergency route to safety (exit choice), dictated as a means of escape in the building design. There is now general agreement amongst social scientists who have studied the subject, that flight behaviour to an exit, often attributed to panic, is accounted for primarily by a serious delay in people becoming and being made aware of a threat. Far from being irrational, the behaviour is very rational from the perspective of people who (a) received a fire warning too late to reach safety easily and (b) are far more familiar with the normal entry route into a building, than an alternative fire emergency route (references 16 and 17).

2.5 Exit Choice Behaviour Factors: Direction, Distance and Timing of Movement

The research review suggested that the original list of six factors and corollaries (a) and (b) in the research objectives (see paragraph 1.1) should be revised to include other factors likely to have as much bearing on escape behaviour as structural design features. The expression, 'Exit choice behaviour' defined not only the direction, but the distance and timing of a person's movement when faced by the choice between different routes. The objectives listed in paragraph 1.1 were therefore extended so that the revised list of factors were as follows:-

1. Smoke obscuration (irritancy and toxicity)
2. Fire characteristics (such as heat and smell)
3. Familiarity with escape routes
4. Characteristics such as age, infirmity, disability
5. Advice provided (existing guidance prior to fire)
6. Light levels and light sources
7. Role in occupancy
8. Group dynamics and attachments
9. Location and proximity to exit
10. Information/communication on fire in progress
11. Fire exit signs

2.6 Common Assumptions

The literature review (reference 2) also outlined common assumptions about exit choice behaviour which it was felt should be examined in the research programme. These were as follows:

- (a) people's safety cannot be guaranteed since in certain circumstances they 'panic' leading to 'inappropriate' escape behaviour;
- (b) individuals start to move as soon as they hear an alarm;

- (c) the time taken for people to evacuate a floor is primarily dependent on the time it takes them to physically move to and through an exit;
- (d) movement in fires is characterised by the aim of escaping;
- (e) people are most likely to move towards the exit they are nearest to;
- (f) people move independently of each other (unless in a dense crowd);
- (g) fire exit signs help to ensure people find a route to safety;
- (h) people are unlikely to use a smoke filled escape route; and
- (i) all the people present are equally capable of physically moving to an exit.

2.7 Research Propositions

The appraisal of recent research findings suggested nine propositions which might prove to have greater validity and should receive attention in the research programme. Propositions (a) to (i) are based on what is felt to be a more accurate 'model' of people's behaviour taking into account not only the objective physical environment, but people's knowledge of a building layout and information available about a fire threat. These propositions (corresponding to (a) to (i) in paragraph 2.6) are as follows:-

- (a) deaths in large scale fires attributed to 'panic' are far more likely to have been caused by delays in people receiving information about a fire;
- (b) fire alarm sirens cannot always be relied upon to prompt people to immediately move to safety;
- (c) the start up time (ie people's reaction to an alarm) is just as important as the time it takes to physically reach an exit;
- (d) much of the movement in the early stages of fires is characterised by investigation not escape;
- (e) as long as an exit is not seriously obstructed, people have a tendency to move in a familiar direction, even if further away, rather than to use a conventional unfamiliar fire escape route;

- (f) individuals often move towards and with group members and maintain proximity as far as possible with individuals to whom they have emotional ties;
- (g) fire exit signs are not always noticed (or recalled) and may not overcome difficulties in orientation and wayfinding imposed on escapees by the architectural layout and design of an escape route;
- (h) people are often prepared, if necessary, to try to move through smoke; and
- (i) people's ability to move towards exits may vary considerably (eg a young fit adult as opposed to a person who is elderly or who has a disability).

CHAPTER 3: RESEARCH METHODOLOGY

3.1 The literature review (reference 2) instanced a number of research strategies which have been adopted to study aspects of escape behaviour in fires. These are as follows:-

- (a) laboratory experiments;
- (b) carrying capacity and evacuation (pedestrian movement) research;
- (c) computer and environmental simulations; and
- (d) field research (questionnaire surveys and case studies based primarily on interviews).

3.2 Weaknesses were highlighted in previous research, in particular the insufficient knowledge available about the relationship between people's behaviour and the architecture of buildings and the time to escape. Weaknesses in a questionnaire survey methodology were identified and the review confirmed the advantages of carefully conducted field studies and field experiments. The rationale was that the very real practical difficulty in observing and timing people's responses directly in fires and exposing people to real danger, could be overcome by a research programme which integrated statistical analyses of behaviour in fires (based on interview transcripts) with monitored evacuation studies and a fire simulation study in which people's exit choice decisions could be explored in depth. The research would be concerned primarily with the horizontal movement on a floor:-

Stage 1 - Travel within rooms.

Stage 2 - Travel from rooms to a stairway or final exit.

Stage 3 - Travel within stairways to a final exit.

3.3 Three research strategies were adopted in the 3 year research programme:-

- (1) mapping and statistical analysis of actions and movement in fires;
- (2) monitored evacuations; and
- (3) video-disc simulation.

3.4 The mapping studies were based on police witness statements collated at a number of major fires involving an extensive smoke spread. These statements were linked up to Fire Investigation Reports collected by particular UK Fire Brigades. Statistical analyses were conducted on the patterns of movement and action. The pattern and direction of movement were traced on architectural plans and the distances travelled

were recorded. Despite the strong emphasis on travel distance in Codes of Practice, the amount of information on the distance people move, in relation to the travel distance available in particular buildings, has, prior to the present research, been minimal. In the larger scale fires we studied, detailed statistical analyses were conducted of sequences of actions using what is technically termed an 'action dictionary' (of 57 actions and in a reduced form 23 actions in fires). Included in the action dictionary were physically situated actions relating to different routes followed (eg main stairway, emergency fire escape, lift). Statistical analyses were conducted on the numbers of individuals moving between particular locations (using a 'location dictionary' tailored to each building).

3.5 As a supplement to this data it had been hoped during Year 3 (Stage 3) to make use of a smoke density index (SDI) in interviews with survivors of a selected fire. The SDI is a set of photographs showing different smoke densities on an experimental corridor used in experiments on behalf of the Home Office by the Fire Research Station (reference 18). With the aim of finding a suitable fire, a fire notification system was set up during a four month period, October 1987 - January 1988. The number of fires BUSRU were notified of was disappointing. While this does not obviate further use of the SDI and application of the research techniques developed for this project in the future, the difficulties in finding a fire suitable for a further case study, albeit within a four month period, strongly confirmed the advantages of the original decision to explore first the extent to which existing fire and police records could be used. While limited, the records proved sufficient for our purposes. Case studies A to E are comprehensive studies in the dynamics of exit choice behaviour.

3.6 During the early part of the research a variety of possibilities for experimentally testing people's pattern of escape movement were explored. One possibility had been an experimental stairway and corridor network at the Building Research Establishment (reference 19). Since this was a single route and an exit choice setting was found with greater advantages, the use of the BRE setting was abandoned.

3.7 The settings chosen for monitored evacuation studies were two lecture theatres of exactly the same design, except for the position of the entrance and emergency fire exit. These proved to be ideal settings for monitoring evacuations in response to an alarm, and establishing the relative effects of different architectural and social factors on paths of movement. The lack of empirical research into the calculations used in means of escape formulae (see paragraph 7.7), which seem to have their origins in a reference to the Empire Palace fire in 1911 (reference 14), suggested that studies of the lecture theatres would be important to conduct. The first case study F, was based on a questionnaire and recording by observers of the time to leave by different

exits. The second case study G, involved a modified experimental design, incorporating a video of the evacuations and interview procedure in which the time to start to move and time to reach exits in response to an alarm were recorded. The advantage of including evacuation studies in the research is that precise measurements could be made of people's times to move.

3.8 The third research strategy adopted, involved the development of a video-disc simulation of a fire based on a four storey students' hall of residence in Portsmouth Polytechnic, which also doubles up as accommodation for conference delegates outside term time. Possible actions open to a person caught in a fire in a four storey hall of residence were stored on a video-disc linked to a microcomputer program. Each participant in the simulation was offered various action and 'exit choice' options during the course of the fire.

3.9 The simulation shows a participant the view of the route up to the room he or she is staying in on the fourth floor (as if he or she is moving up the stairs). The fire scenario begins with the person in bed asleep. Action options are offered when the video image 'freezes'. Having made his or her choice, the microcomputer program promptly selects the corresponding segment of video images. As in a real fire the aim is to reach safety before being overcome by smoke (or flames).

3.10 If the person delays escape, the smoke conditions outside the room become worse. Different possible paths of movement have been videoed from the perspective of a person able to move around a room and corridor on the fourth floor. The video-disc simulation is based on previous sequential analyses of patterns of behaviour and is itself a means of 'modelling' the factors influencing exit choice behaviour. Through analyses of sequences of action, decisions and interviewing the participants, insight can be gained into patterns of psychological reaction difficult to obtain using the other two research strategies alone. While funded by the Home Office as a research tool, the video-disc simulation has also attracted wide public attention through the media as an educational training aid and has been demonstrated at major exhibitions such as Fire '86, Fire '87, Fire '88, Fire '89 and Fire '90. Two case studies, H and I have been conducted.

3.11 The buildings studied were chosen for their availability with the aim of covering a variety of exit choices. Each case study should be considered as a different example of an exit choice, characteristic of certain building and occupancy types, namely:-

- (a) escape from a single room (as in a hotel or hall of residence); and

(b) escape from an assembly setting (as in a department store or theatre).

3.12 Within the broad framework of the three complementary research strategies, nine case studies have been conducted. The findings of each are summarised in the following paragraphs. The reader is referred to the back-up reports for details.

CHAPTER 4: MAPPING AND STATISTICAL ANALYSIS OF ACTIONS AND MOVEMENT IN FIRES

Case Study A: Hotel/Hostel Fire: (BUSRU Reports references 2 and 3)

4.1 Drawing on reports obtained from East Sussex Fire Brigade and Sussex Police, a detailed set of statistical analyses were carried out on the pattern of escape behaviour during a fire designated as Case Study A. The occupancy, although certificated under the Fire Precautions Act 1971, is most accurately described as a boarding house or hostel (reference 20). The building had a ground and three upper floors, each served by a main staircase at one end of an L shaped corridor with a lift and fire escape at the other end. The fire occurred at night (time of call to the fire brigade: 04.54 hours), while residents were mostly asleep in their rooms. The smoke spread from the ground floor and up the main staircase. Detailed statistical analyses were carried out on the sequences of actions of 60 people out of 62, one of whom was a fatality. The analysis of 862 actions highlighted three main phases of response: reaction to noises or an alarm (recognition), movement to the doorway of the room (investigation) and escape. Those in rooms facing onto the protected route enclosing the main staircase were generally forced to remain in their rooms because of dense smoke and escaped via windows with fire brigade assistance. The majority of others left via the fire escape route. Two people escaped by lift.

4.2 Statistical associations were found between the room location (within the compartment or proximity to fire escape), direction and the distance of escape. Paths and distances of movement, recorded using the architectural plan, showed that the average distance moved (sometimes involving backtracking to rooms) was 19.5m (64 ft) with a range of 1.8-63 metres (6-208 ft.) 28% of people entered smoke, moving an average distance of 16.4m (54 ft).

Case Study B: Teachers Hall of Residence Fire: (BUSRU Report 3)

4.3 This fire began in a room on the upper floor of a ground and first floor building (time of fire brigade call: 22.46 hours). Statistical analyses were based on paths and distances of movement derived from witness statements and architectural plans obtained through the Manchester Fire Service, the Greater Manchester Police and the Field Investigation Section at the Fire Research Station (FRS). This fire, with one fatality (an 83 year old) is referred to in an FRS report on group-residential fires (reference 21).

4.4 The hall of residence was occupied by 11 ordained teachers in a Roman Catholic Boys School. The building had no

protected means of escape and no detection or alarm system. In the fire, the lack of fire doors on the main corridor and inadequate compartmental-station was reflected in the statistical associations found between room proximity to the fire and likelihood of collapsing in smoke (outside the rooms) or being rescued from windows. A statistical association was also found between the distance moved and the age of occupants (those under 65 being less likely to move as far). The paths and distances of movement, like Case Study A, were related to the travel distances in the building. However, the distances were also increased by the greater social cohesion amongst the occupants and consequent altruistic behaviour. The average distance moved was 44.2m (145 ft), range 12.7-93.7m (42-309 ft); 45% entered smoke, moving on average 15.1m (50 ft).

Case Study C: Multiple Occupancy Bedsit Fire:
(BUSRU Report 3)

4.5 The smoke from this fire on the ground floor spread up the single staircase to the first and second floor of a building occupied by eight people in bed in their rooms (time of call to the fire brigade: 03.55 hours). The data source was records from the county of Avon Fire Brigade, and Avon and Somerset Constabulary. All of the occupants were rescued by the fire brigade from bedroom windows, except for the owner and a girl who tried to escape down the staircase through thick smoke. Paths and distances of movement were statistically analysed. Males engaged in a statistically higher number of actions than the females present. The average distance moved was 12.5m (41 ft); 25% entered smoke, moving on average 17.2m. In the three fires A, B and C, distances moved were constrained by the available travel distances, while distances moved through smoke were more constant.

Case Study D: Nurses Home Fire: (BUSRU Report 5)

4.6 This fire began on the second floor of a building with a ground and 5 upper floors (time of call to the fire brigade: 00.57 hours). The primary data source was the witness statement transcripts of the 51 occupants and plans obtained from the Fire Constabulary. This fire has also been the subject of a report by the Field Investigation Section of FRS which concentrated primarily on aspects of smoke and fire development in relation to the building design (references 21 and 22).

4.7 Our study concentrated on a detailed statistical appraisal of the patterns of human movement and psychological reactions in relation to the exit choice. Of the 51 occupants, one died on the second floor and 20 were injured; 8 jumped from the second floor, 7 were rescued by the fire brigade from windows, 28 left via the west 'emergency' route, 7 via the main stairway route and exit (See Table 1).

4.8 Movement was constrained by the pattern of smoke development, which trapped many people in their rooms on the second and fourth floors and eventually blocked the main stairway. A statistical analysis was conducted of sequences of actions (1084 actions) and paths between 17 locations (391 location moves). As in the other fire studies, the most important 'exit choice' decision to be made was at the doorway of rooms after the investigative action of opening the door onto the corridor. Occupants decided either to move towards one or other staircase or remain in the room. People were realistically reluctant to try to move through thick smoke. From the location sequence statistical analysis, four major escape paths of movement were identified: from the fifth and third floors via the emergency stairway; first floor via the main stairway; second floor via windows; fourth floor via windows (See Table 1).

4.9 The strongest statistical relationships were found between the floor a person was on, smoke encountered ('thick', 'thin' or no smoke), exit path followed and subsequent likelihood of injury. The pattern of exit choice behaviour and distances moved were strongly associated with whether people were on the fire floor where there was the least movement: average 15.2m (50 ft), moved; above or below the fire floor: average 56.7m (186 ft) and 63.4m (208 ft) distances moved respectively. The overall average distance moved was 47.5m (156 ft) ; 57% entered smoke, moving on average 27.1m (89 ft).

4.10 The distances moved included some backtracking behaviour away from smoke. No statistical association was found between room distances to exits onto stairway and the direction of movement. Statistical relationships were found between distances moved and both floor level and smoke density. The floor on which people were located in the building was a much more significant influence on exit choice behaviour than room location on floor. Nobody jumped from above the second floor, reflecting jumping as a rational action at the height of the second floor to avoid the very real risk to life from smoke to people trapped at that level. As in fire A, many people were first alerted by an alarm. In fires A, B, C and D peoples ability to move one way or another was constrained by smoke after a delayed warning.

Table 1: Floor level location and numbers of residents escaping by different routes in the nurses home (Case Study D)*

FLOOR LEVEL	ESCAPE ROUTE			
	ESCAPED VIA EMERGENCY STAIRWAY WEST STAIRWAY	ESCAPED VIA ROOM WINDOW	ESCAPED VIA MAIN STAIRWAY EAST STAIRWAY	
5TH FLOOR	9	0	0	9
4TH FLOOR	5	3	0	8
3RD FLOOR	11	0	0	11
2ND FLOOR	0	12	0	12
1ST FLOOR	3	0	7	10
	28 (56%)	15 (30%)	7 (14%)	50*

*Single fatality excluded

Building Dimensions and Distances Moved in Fires A, B, C, D Compared

4.11 Table 2 provides data on the average distances moved in relation to the travel distance dimensions for floors and in relation to smoke for case study fires A, B, C and D. In general, the dimensions of a building (corridor lengths, number of floors), floor a person was located on and consequent exposure to smoke, had more of an influence on the distance and direction of escape behaviour in the hotel/hostel and halls of residence case study fires (A, B, C and D) than proximity of rooms to alternative exits.

Table 2: Building dimensions and distances moved in four fires: A, B, C, D*.

	1 LENGTH OF BUILDING	2 LENGTH OF LONGEST CORRIDOR ON FLOOR	3 NUMBERS OF PEOPLE FOR WHOM DISTANCES RECORDED	4 AVERAGE DISTANCES MOVED	5 RANGE OR DISTANCES MOVED	6 NUMBERS OF PEOPLE ENTERING SMOKE ZONE	7 AVERAGE DISTANCE MOVED THROUGH SMOKE	8 RANGE OF DISTANCES MOVED THROUGH SMOKE
FIRE A: Hotel/ Hostel	21.4m (70ft)	25.6m (84ft)	60	19.5m (64ft)	1.8-62.4m (6-208ft)	17/60 (28%)	16.4m (54ft)	6-29m (20-90ft)
FIRE B: Hall of Residence	32.6m (107ft)	31.1m (102ft)	11	44.2m (145ft)	12.6-97m (42-309ft)	5/11 (45%)	15.1m (50ft)	6.6-18.9m (22-63ft)
FIRE C: Multiple Occupancy Bedsit	8.5m (28ft)	4.3m (14ft)	8	12.5m (41ft)	0.6-36.3m (2-121ft)	2/8 (25%)	17.2m (57ft)	13.5-20.4m (45-68ft)
FIRE D: Nurses Home (Hall of Residence)	36.9m (121ft)	33.5m (110ft)	50	47.6m (156ft)	7.8-106.8m (26-356ft)	29/51 (57%)	(27.1m) 89 ft	3.6-84.9m (12-283ft)

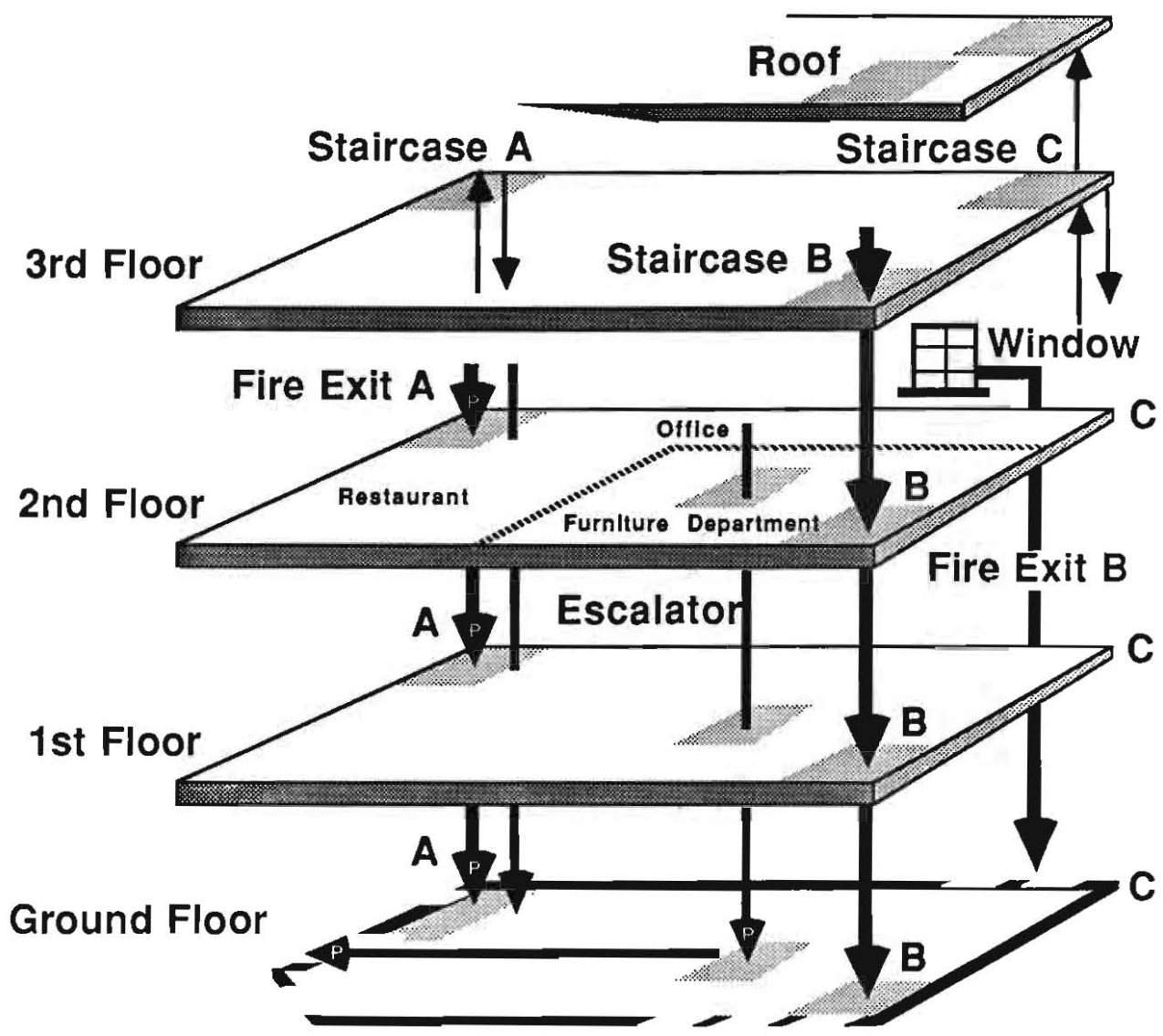
*A note on the measurement of distances moved: straight line (travel distance) distances were recorded using a mapometer. In Fires A, B and D the starting point was taken notionally as the middle of each room as the exact position of each person's bed was not known. In Fire C the starting point was the bed itself as there was a record of the position of furniture in each room, see BUSRU Report (3).

Case Study E: Department Store Fire: (BUSRU Report 4)

4.12 This statistical analysis of the pattern of escape behaviour in the Woolworth's fire, Manchester, used witness statements and records of the fire as a data source. The documents relating to the fire were obtained from the Greater Manchester Police and the Fire Service (references in our report 3 and 23). The location path and action sequence statistical analyses were based on the behaviour of 132 individuals, an estimated 25% of those present. 1110 moves between locations and 2463 actions were analysed for 63 members of the public and 69 staff.

4.13 The building consisted of a ground and 5 upper floors. The fire occurred on the second floor, in a furniture storage area adjacent to a restaurant. The analysis of exit choice behaviour relates primarily to the behaviour of those on the second and third floors, heavily populated by the public and staff. Strong statistical relationships were found between the role of staff or public and the final exit used, and between the floor people were on and the exit used (see Figure 1).

4.14 The public and those on floor 2 were most likely to use staircase A which, in the everyday use of the building, could be used to reach the restaurant directly from the street (independently of the store). 71% of the public used staircase A. The staff (and those on floor 3) were most likely to use staircase B (41% of staff used B and 27% A), often after unsuccessfully trying staircase A where smoke was encountered or C which had an exit locked. Fewer people used the escalator and a number of the public and staff were rescued from windows or the roof (see Figure 1). The availability of an exit choice was constrained by the delay in staff receiving a warning, poor communications amongst staff, between staff and public and a rapid smoke and fire spread (from the furniture which contained polyurethane). This study highlighted the differences between where staff and public were most likely to be in the department store, and the different escape routes many staff used as opposed to the public.



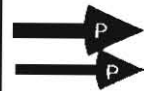
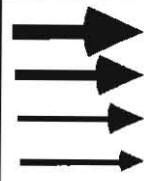
Escape Routes Used	Public		71% Staircase A 22% Escalator 7% Window
	Staff		41% Staircase B 27% Staircase A 14% Window 13% Roof 5% Escalator

Figure 1 Proportions of public and staff using different escape routes from the second and third floors during the Woolworth's department store fire.



CHAPTER 5: MONITORED EVACUATION STUDIES

Case Study F: Front and Rear Lecture Theatres Evacuation: (Study 1) (BUSRU Report 4)

5.1 The aim of the study was to examine the effects of exit position on the exit chosen and the time to evacuate. To do this the simultaneous evacuation of two lecture theatres on the ground floor of a building in Portsmouth Polytechnic was monitored. The 'front' F lecture theatre had its entrance and fire exit in both back corners. The 'rear' (R) lecture theatre had the entrance at one corner at the back and fire exit in a corner at the front (see figures 2a and b). The fire exits from each theatre led directly to the outside of the building. In both theatres the students were attending a lecture which was disrupted by the fire alarm. Except for the exit locations, the room dimensions and seating arrangement in each theatre were identical.

5.2 In the F theatre the lecturer decided not to tell his 'audience' which exit to leave by. A statistical analysis was conducted on the possible relationship between seat position, travel distance moved, exit used and time taken to leave in the F theatre. Observers at each exit recorded frequencies and evacuation times and gave out a questionnaire to each evacuee, which was used to supplement the other data. Of 56 people in the F theatre 55% left by the entrance, 45% by the fire exit; 88% left within 2½ minutes (see Figure 2a). The last person left 3 minutes after the alarm sounded.

5.3 Statistical relationships were found between seat location and the exit used, and the exit used and the time to escape (although a minority of people did not return a questionnaire marking their exact seat location). Generally, people were more likely to leave by the exit they were nearest to. However, the relationship between the exit used and evacuation time was more complex. While those leaving before 1½ minutes was up were seated near the entrance, movement out via the fire exit began later (after 1½ minutes). Those nearest to the fire exit were amongst the last to leave. Of 77 people in the R theatre, 100% left by the fire exit and 70% within 2½ minutes (Figure 2b). It should be noted that because some of the evacuees did not mark their exact seat location or return a questionnaire, not all the seat locations are represented in Figures 2a and b. (See BUSRU report (4) for details.) Exclusive use of one exit in the R theatre pre-empted a full statistical comparison of the location and the exit chosen. The decision by people to use the fire exit in the R theatre, in contrast to the F theatre, was evidently determined primarily by: -

- (a) the location of the R theatre fire exit in full view, near the lecturer;
- (b) the regular use of the R theatre fire exit by which to leave after lectures (the fire exit in the F theatre was rarely used in this way); and

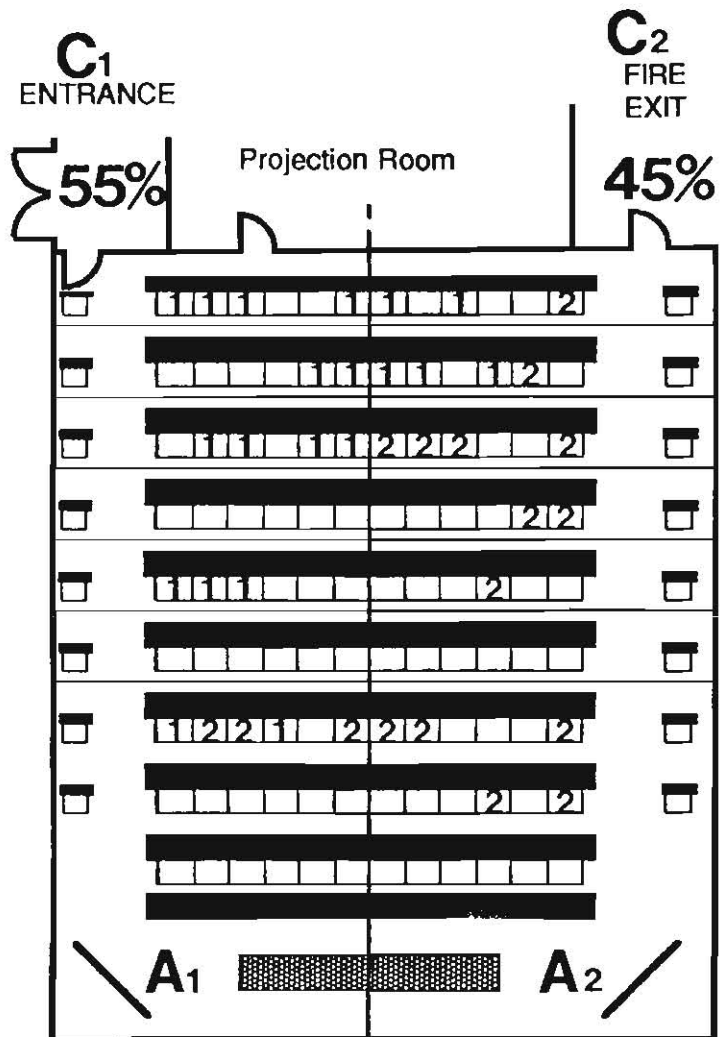


Figure 2a "F" Lecture Theatre Seat Locations for Questionnaire Respondents and Percentages of People Using Each Exit (Study 1)
Code 1 = Used Entrance
Code 2 = Used Fire Exit
(Ent = 0.8m, F Exit = 0.76m wide)

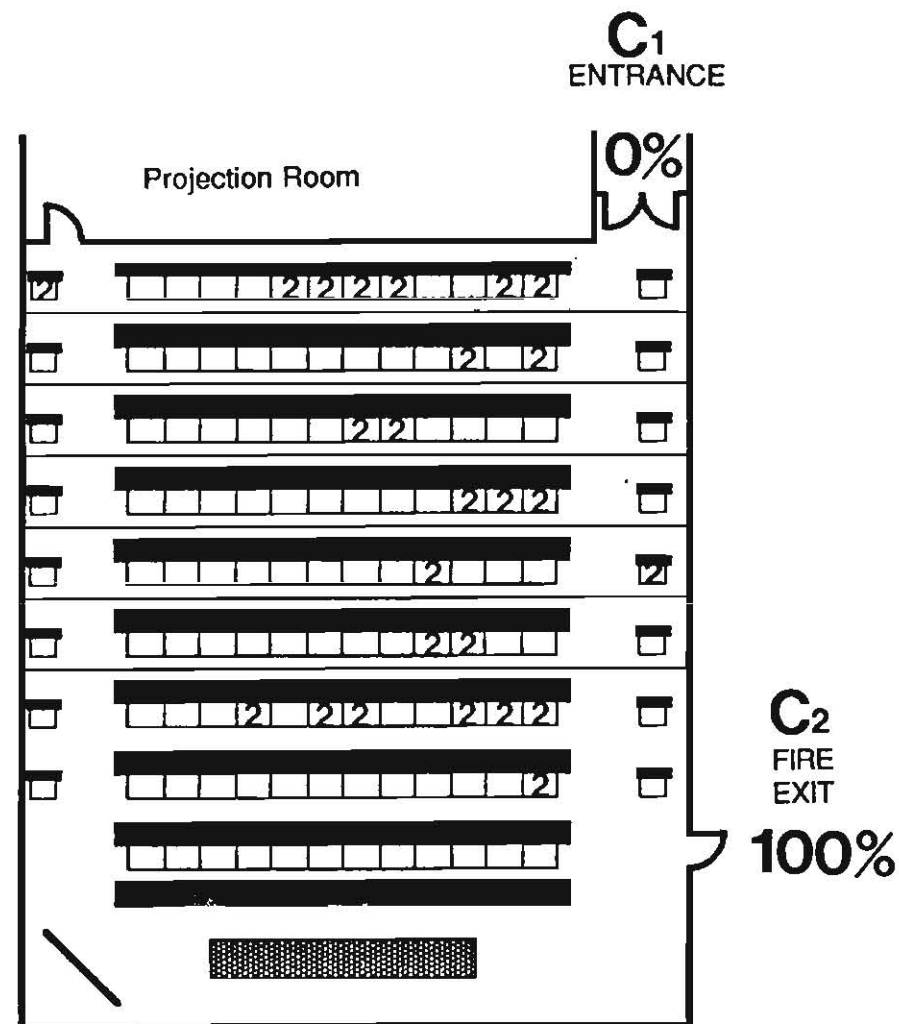


Figure 2b "R" Lecture Theatre Seat Locations for Questionnaire Respondents and Percentages of People Using Each Exit (Study 1)
Code 1 = Used Entrance
Code 2 = Used Fire Exit
(Ent = 1.3m, F Exit = 0.76m wide)

Scale: 1in = 8ft 1in 1cm = 0.97m

- (c) movement to the R theatre exit by the lecturer and his explicit verbal instructions that everyone should leave that way.

Case Study G: Front and Rear lecture theatres Evacuation:
(Study 2) (BUSRU report 5)

5.4 In the follow-up evacuation study (case study G) conducted one year later and with a different intake of first year students there were three changes in the research methodology:-

- (a) both lecturers were informed beforehand of the alarm and were instructed to issue exactly the same instructions (to ask students to leave but not tell them by which exit);
- (b) video cameras recorded the movement (time to start as well as to reach exits); and
- (c) in-depth interviews of a sample of students (21 in each theatre) were conducted.

5.5 On this occasion, of 63 people in the F theatre, 62% left by the entrance and 38% left by the fire exit. Of 74 people in the R theatre, 30% left by the entrance and 70% left by the fire exit (See figures 3a and b).

5.6 Studies 1 and 2 showed a consistent pattern in the proportions of people moving towards the entrance in the F theatre (study 1 = 55%, study 2 = 62%) and fire exit in the R theatre (study 1 = 100%, study 2 = 70%). The research indicated that the instructions by the lecturer in study 1 reinforced the movement towards the fire exit in the R theatre but did not solely determine it. Thus, without a directive to leave by the R theatre fire exit in study 2, the majority of people were still inclined to leave that way.

5.7 Statistical analyses of the relationship between seat location, distance moved, exit used and time to evacuate in the different theatres and case studies F and G, indicated that with the exception of the R theatre (study 1), there was a general tendency to leave by the nearby exit. Familiarity of route, through regular use, and instructions from an authoritative source, are reflected as important influences on exiting behaviour. From the studies it can be concluded that the main factors influencing the direction of movement in the theatre studies were:-

- (a) visibility and location of exits;
- (b) proximity to exits;
- (c) familiarity with escape routes (through use); and
- (d) instructions from lecturer.

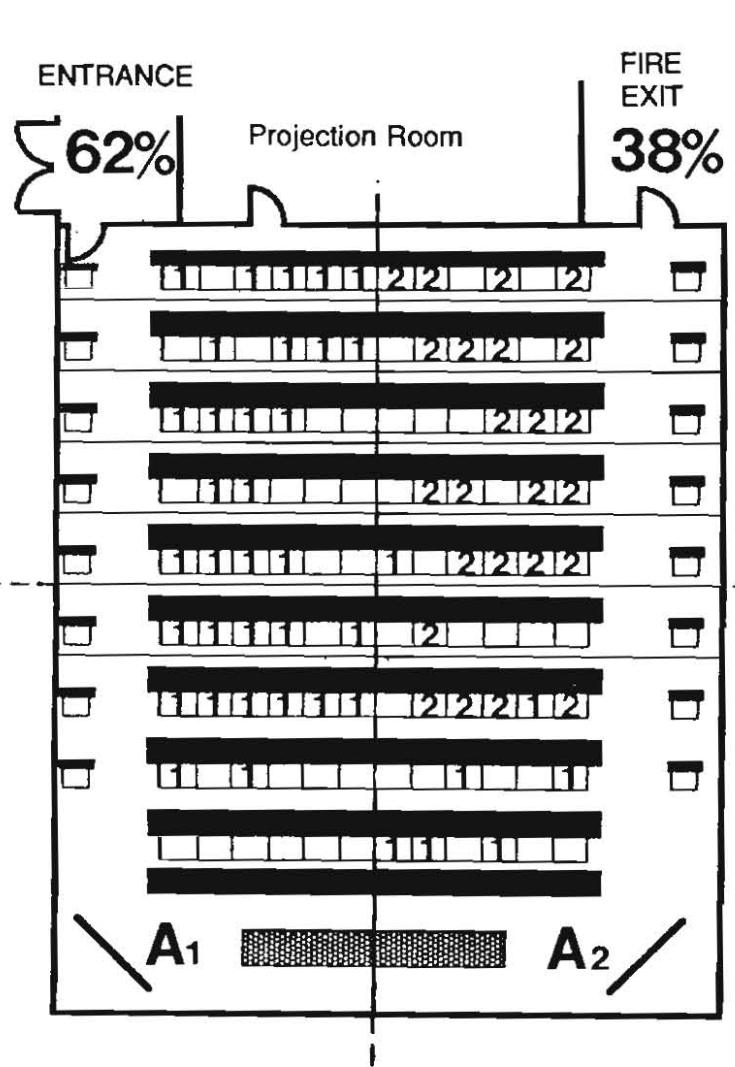


Figure 3 (a) "F" Lecture Theatre Seat Locations of People Using Each Exit (Study 2).

Code 1 = Used Entrance
Code 2 = Used Fire Exit

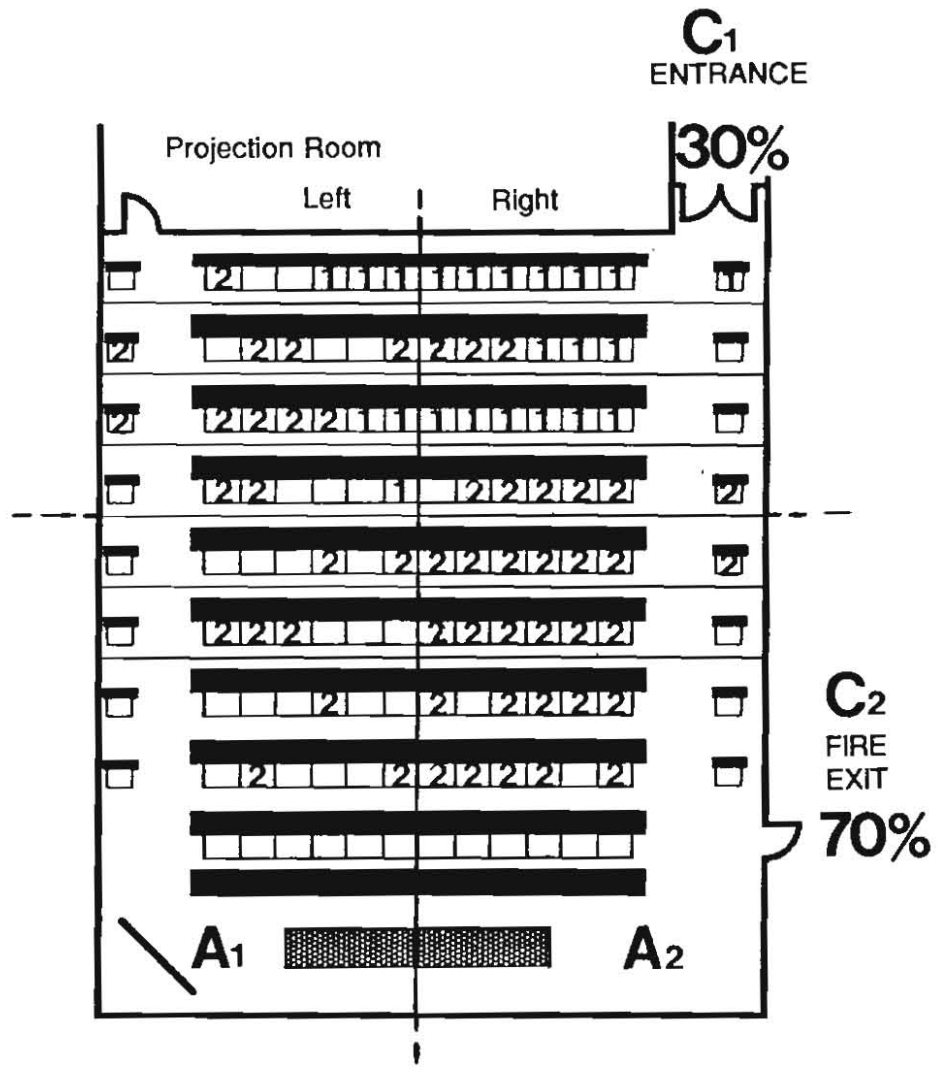


Figure 3 (b) "R" Lecture Theatre Seat Locations of People Using Each Exit (Study 2).

Code 1 = Used Entrance
Code 2 = Used Fire Exit

Scale: 1 in = 8 ft 1 in
1 cm = 0.97m

5.8 Detailed analyses were conducted on the time spent by people in different time phases t1 to t6 from the onset of the alarm. These time phases, defined primarily in terms of movement and physical locations, were aggregated into two phases of 'time to start' (ts) and 'time to move' (tm). In the F theatre the average times were ts = 31.7 seconds, tm = 13.9 seconds, ts + tm = 45.6 seconds. In the R theatre ts 33.2 seconds, tm = 15.8 seconds, ts + tm = 48.9 seconds. In summary, it was found that:-

- (a) the evacuation time for similar numbers of people in the same physical settings took half the time in study 1 (approximately 1½ minutes) as opposed to study 2 (approximately 3 minutes);
- (b) on average, two thirds of the evacuation time for individuals in both theatres, from the alarm to exiting was taken up by 'time to start' (from the onset of the alarm to starting to move). One third of the time was expended in actually moving the travel distance from a seat to the outside; and
- (c) the time for movement out via each exit to begin was earlier in study 2 (see Table 3) and the flow rate through the exits (see below) was more concentrated.

Table 3: Range of times (mins : secs) to leave by the (C1) Entrance (ENT) and (C2) (FIRE EXIT) in the front and rear lecture theatres
N = Number of people

	ENT First	ENT Last Person	TIME SPAN	N	FIRE EXIT	FIRE EXIT First Person	TIME SPAN Last Person	N
FRONT Theatre Study 1	0:47	2:54	2:07	31	1:35	3:01	1:26	25
REAR Theatre Study 1	ENTRANCE NOT USED				0:50	3:00 Approx	2:10 Approx	
FRONT Theatre Study 2	0:17	1:28	1:11	39	0:21	1:15	0:54	24
REAR Theatre Study 2	0:27	0:57	0:30	22	0:14	1:26	1:12	52

5.9 It was also found that the time to evacuate via different exits was variable. In this respect the patterns of movement to exits were influenced by the seating arrangements and degree of access to the alternative aisles for people in different seat positions. In addition, the evacuation flow rates were variable and markedly lower than the standard 40 persons per minute per unit exit width. The most important influence on the evacuation times in the theatres (study 2) was not travel distance and exit widths (or time to move) but time to start.

5.10 The variability in times between studies 1 and 2 suggests the powerful effect of social factors in contrast to travel distance. The interviews revealed that most people assumed that the alarm indicated a drill and not an emergency and would still have considered so in a real fire situation unless there was additional information. It is also worth noting that people regularly sat in the same locations in the theatres and this influenced the degree to which they were aware of the fire exit in the F theatre. People were not aware of the fire exit signs having particularly influenced exit choice decisions.

5.11 In another evacuation study of the same building, BUSRU statistically analysed the numbers of people leaving via an emergency exit near the R theatre in evacuations conducted before and after the introduction of a sign saying 'fire exit only' and restrictions on being able to open the door from the outside. This study revealed a statistical reduction in the numbers leaving that way in the second evacuation drill (reference 5). Evidently the restriction on regular use of the exit, reduced the likelihood of it being used in an evacuation.

CHAPTER 6: VIDEO-DISC SIMULATION STUDIES

Case Study H: Pilot Hall of Residence Video-Disc Fire Simulation: (BUSRU Report 4)

6.1 The purpose of this case study was primarily to test and validate the operation of the prototype video-disc simulation. Validation took two forms: in terms of face validity (ease of operation, by participants) and through statistical analysis of the sequence of actions followed in the simulation compared with that found in actual fires. Seventy-two young adults (16-18 years old, 37 females and 35 males) participated individually in simulation runs. While a statistical difference found between an alarm on and alarm off condition was attributed to an operational problem in the clarity of the sound, which was rectified in the second refined video-disc simulation, the finding that males were more likely to 'die' than females was noted. It was also found that children were more likely to read the fire notice when tests with 22, 10-11 year olds, were compared with the young adult sample. An action sequence analysis conducted on the adult sample revealed a similar pattern of response as in case studies A to D.

Case Study I: Main Hall of Residence Video-Disc Fire Simulation: (BUSRU Report 5)

6.2 The tests with the prototype video-disc simulation and less formal tests with other participants and fire experts contributed to the additional filming, editing and computer programming in the production of this simulation. A statistical comparison was conducted on the frequencies of actions engaged in by two samples: Sample 1, video-disc simulation 1, case study H and sample 2, video-disc simulation 2, case study I. The younger age group (Sample 1) were statistically more likely to read the fire notice, turn to the right outside the room and be overcome by smoke after attempting to leave by the entrance door to the corridor. The older age group were more likely to leave by the fire exit. The results are suggestive of differences between the age groups, but not definitive without a further study comparing both age groups using video-disc simulation 2. This was beyond the time and resources available for the current study. The greater inclination of the older age group to move to the left and escape safely via the fire exit could have been a function of the greater possibility in video-disc simulation 2 to explore and become familiarised with the layout of the floor (including the position of the fire exit) after first arriving in the room. The overall analysis, however, indicated no clear difference in the likelihood of individuals moving to the right or left, after leaving the room.

Numbers of people using different escape routes in case studies A, B, D, H, I

6.3 A comparison was made of escape routes used in the video-disc simulation; compared with other studies. Table 4 illustrates the

difficulty people had in using the main staircases in fires A and D, since the fire conditions made them impossible. Very few people used the lift. A far lower proportion of people remained in or returned to their rooms in the video-disc simulations. (Simulation 1: Case Study H and Simulation 2 Case Study I). This may be predominantly because people were heavily penalised for opening the corridor entrance door (unless early on in the fire scenario). It is also important to note that the movement in fires A, B and D is based on individuals in different rooms on different floors, as opposed to one room on one floor in H and I. (Further discussion is provided in BUSRU report 5).

TABLE 4: Frequencies and Percentages of people using different escape routes in fires A, B, D, and the Video-Disc Simulation.

	FIRE ESCAPE	RESCUED FROM WINDOW (or dead in room)	MAIN STAIRCASE (or collapsed in corridor)	LIFT	
FIRE A	38 (61.3%)	19 (32.3%)	2 (3.2%)	2 (3.2%)	62
FIRE B	2 (18.2%)	4 (36.4%)	5 (45.4%)	NO LIFT	11
FIRE D	28 (54.9%)	16 (31.4%)	7 (13.7%)	0	51
VIDEO DISC (SIM 1) H	48 (51.1%)	6 (6.4%)	40 (42.6%)	NO LIFT	94
(SIM 2) I	100 (70.9%)	6 (4.3%)	35 (24.8%)	NO LIFT	142

6.4 The results of the video-disc simulation studies have not proved definitive, but the simulation offers considerable scope for further studies such as testing reaction to different types of fire instruction notice. In addition, the manner in which exit choice decisions in a fire are based initially on investigative behaviour, the ambiguity of fires, the consequences for exit choice of early actions and the crucial question of the conditions under which people should be expected to leave the temporary refuge of a hotel room and make their way to a designated emergency escape route, or await rescue by the Fire Brigade from a room on an upper floor, are highlighted. Because the simulation has been derived from research of behaviour in fires and produced patterns of behaviour comparable with the studies of fires, it is considered valid as a training aid as well as a research tool. (See references 5, 9, 24, 25).



CHAPTER 7: APPRAISAL OF FINDINGS

7.1 The aim of this part of the Management Summary is briefly to appraise the original research brief, the revised list of factors, the assumptions in paragraph 2.6 and the propositions in paragraph 2.7 in the light of the research findings. Within this Management Summary, no attempt has been made specifically to re-word paragraphs in the codes. Indeed, the implications are felt to be as much at the level of a reappraisal of the broad nature of assumptions about psychological response in fire emergencies, as in terms of specific amendments to the Codes and Guides. (References 15, 26-31). In this respect, there has already been discussion of weaknesses in assumptions about escape behaviour and the studies conducted have strongly supported the argument put forward in this respect in the Literature Review (paragraphs 2.3 and 2.4). The original research brief listed 6 factors which were to be considered in terms of their relative importance in deterring the use of internal escape routes (paragraph 1.1). The research has generally confirmed the revised list of factors set out in paragraph 2.5. The findings are, in general, inconsistent with the assumptions in paragraph 2.6 and support the propositions in paragraph 2.7.

7.2 The literature review indicates that the assumption of a strict relationship between a range of visibility of 10 metres or less and a disinclination to move through smoke cited in the Home Office brief (paragraph 1.1) is very questionable. The general indication is that visibility through smoke has to be reduced to a minimum of up to a few metres before people begin to be strongly deterred. The case studies of fires indicated that the floor a person is located on and thick smoke conditions do have a major influence on the likelihood of a person using a room as a refuge and waiting for fire brigade rescue. However, there is unlikely to be a strict relationship between a specific smoke density, (range of visibility) and movement, without factors such as the type of building and occupancy, familiarity of route and goal of movement being taken into account. Expressed in another way, travel distance and smoke density, while very important, are not absolute or exclusive determinants of the pattern of escape behaviour. For example, it is unlikely to make a significant difference to human behaviour if visibility through smoke or travel distance is 8m, 10m or 12m. The 10m visibility criteria is easy to apply in relation to optical density smoke measures but not substantiated by research of psychological reactions (see Reports 1 and 2 for details).

7.3 The majority of people become less inclined to move through smoke when it is described by them as 'thick' or 'black', an estimated visibility in smoke of approximately 0-5m. While descriptions of smoke such as 'thin' or 'thick' are not totally satisfactory and it may be possible in future to compare subjective and objective evaluations of smoke density, at the moment it is most valid to refer to reactions to smoke in terms of descriptive categories rather than precise measures. There are ethical constraints on conducting research in which people are exposed to real smoke, although some Japanese research has been conducted in this area (Reference 32). Use of a Smoke Density Index (SDI) as we have proposed, could provide more precise information in the future.

7.4 The statistical analyses of fires A to E suggest that the floor of location (and therefore degree of exposure to smoke) had more of a bearing on direction of movement than travel distance per se. By inference, a delay in people becoming aware of the risk and starting to move increased the chances of encountering debilitating smoke conditions and as a consequence influenced the direction of movement. The research studies confirm that the revised list of factors (paragraph 2.5) is a more comprehensive representation of the factors influencing escape behaviour. Generally, the case studies demonstrate that different combinations of factors in paragraph 2.5 influenced the direction of movement in a particular fire. For example, role (staff or public) which does not appear in the original list (paragraph 1.1) had a crucial influence on movement in the Woolworth's department store fire E, partly because it influenced the likelihood of people being on a particular floor and staff members were more familiar with certain escape routes. Since there was not a strict division between staff and public, or few staff were on duty in the other fires studied, 'role' was not significant.

7.5 The lecture theatre evacuation studies are important in demonstrating that proximity to one exit, as opposed to another, can have a strong bearing on the direction of movement within an assembly setting. In this respect the statistical pattern of movement was different from that in the field studies of fires in halls of residence or the hotel, in which the exits were not directly visible to people located in their rooms. The general impression from the lecture theatre studies is that a fire exit sign is less important than the regularity with which a route is used. In this respect, people nearest to the familiar entrance route normally left by the entrance and the regular use of a fire exit route, as in the R theatre, had a strong influence on people's inclination to leave by that fire exit. There is no evidence from the research that a fire exit sign necessarily encourages people to automatically head towards it in an emergency, unless the route is familiar.

7.6 The conclusion in paragraph 7.5 was reinforced by the supplementary study which was carried out on evacuation behaviour before and after the introduction of design changes to a fire exit sign. This study is not considered definitive. Coupled with the theatre evacuation studies, however, the study suggests that a sign proclaiming 'Emergency Exit Only', far from encouraging use of an exit in an emergency could have the opposite effect to that intended, as it reduces people's inclination to move towards it in an emergency. In this respect, fire exit signs do have a very important function, but are unlikely to overcome problems of unfamiliarity with a route inherent in the design and normal circulation problems in a building. The different pattern of movement in the F and R theatres suggests that in assembly settings factors such as the seat layout, regularity of seat position with closer proximity to the fire exit, visibility of a fire exit, regularity with which it is used, proximity of a fire exit to the outside and orientation of a building in relation to destinations in the neighbourhood, as well as normal ingress and egress patterns, will have an influence on the likelihood of a fire exit being used.

7.7 The Home Office Guide to Fire Precautions in Existing Places of Entertainment and Like Premises (reference 26) referring to exits from a building, states that the factors governing the technical requirements for means of escape from buildings 'are largely interdependent and include evacuation time, the distance to exits and the number, width and siting of exits' (paragraph 5.7, Reference 15). The maximum evacuation time varies according to three classes of building construction, A, B, and C, between 3 minutes, 2½ minutes and 2 minutes respectively (Reference 27). The times for evacuation are calculated on the basis of a rate of discharge of 40 people per minute per unit of exit width (525mm). This formula forms the basis of determining exit and occupant capacity in relation to the maximum permitted evacuation time (maximum number of occupants any given exit or exit route can serve in a building).

7.8 The variability in evacuation times in the theatre studies 1 (F) and 2 (G) is difficult to explain with any degree of certainty, since measures of behaviour within the theatres in study 1 were not made in the same detail as in study 2. However the fact that the evacuation times varied so much for the same theatres on different occasions strongly suggests that time to evacuate was not a strict function of travel distance, exit width and numbers of people. While all of these factors are very important and form the basis for establishing design yardsticks in codes and standards, the finding that time to start to move was markedly longer than time to move in study 2, suggests that the nature of the warning system and communications at the beginning of the evacuation are likely to be crucial in predicting evacuation times from an assembly setting. The theatre studies suggest that the 'non-moving' time should receive greater attention.

7.9 The research suggests that it is likely to make little difference in terms of improving life safety if one were to change the absolute travel distances specified in the codes of public buildings by minimal amounts. The UK Codes and Guides currently recommend maximum travel distances of 6m to 12m for rooms with a single exit, depending on the degree of fire risk, and 30m to 45m within compartments such as in office spaces and department stores, providing that there are fire-resisting doors and adequate provision of alternative escape route directions in the event of one exit being blocked by smoke or flames. It should be emphasised that the average time to react to the alarm (ie start to move) of approximately 30 seconds in study 2(F) is likely to be much faster than in other types of setting and circumstances (for example a hotel where people are asleep). To reflect the reality of how time is expended in escaping in an emergency, one should, at least notionally, allow a minimum of 2½ minutes for time to start plus 2½ minutes for time to move and leave through an exit. Research and Inquiries on disasters such as the Summerland Fire, Beverly Hills Supper Club Fire, Woolworth's Fire, King's Cross Fire (references 16, 17, 23 and 33) indicate that time to start in these incidences was far longer. These conclusions suggest the crucial importance of early and informative warning of the public and building evacuation management in which emphasis is put on efficient communications between staff and public and guidance by staff to exits.

7.10 The principle of limiting travel distance to exits is not questioned. However, recent critiques of assumptions about occupancy loads, movement times in relation to exit widths, in the design codes of different countries, suggest weaknesses in predicted building evacuation times and that too much emphasis may be put on the significance of travel distances (Reference 34). Even more important than pedestrian movement times is the fact that the reduced time to escape caused by a delay in starting escape movement is not included in either travel distance formulae or more comprehensive egress time equations. In terms of exit used, any delay in time to start to move has inevitable consequences for the smoke conditions, making movement in a particular direction difficult. Thus, direction of movement cannot be considered independently of the timing of movement. The research studies conducted reinforce the conclusions of our literature survey (reference 2) which had begun to suggest the important bearing social factors, such as role and consequent location and familiarity with particular escape routes, have on movement. For example, if an emergency escape route is not part of the normal circulation in a building this may well have greater consequences for people's ability to reach safety than the travel distances. The research suggests that while proximity to an exit has an important bearing on the exit route used, travel distance does not determine in an absolute sense (a) how long it takes people to leave and (b) by which exit they will leave. Fire warning communications during an emergency and the familiarity of a route through regularity of use are at least as, if not more important than, travel distance. It is quite likely that people would often be more inclined to move to a familiar exit which is further away than an unfamiliar exit nearby. It is also worth noting that familiarity with a route may not only increase the likelihood of it being used, but speed of reaction: ie decreasing the time to start to move towards an exit (reference 8).

7.11 It is felt that reference should be made to several UK studies conducted, published or begun during the present project. The studies by the Field Investigation Section of the Fire Research Station (FRS) (references 20 and 21) suggest that the use of rooms in hotels and halls of residence as fire resistant 'refuge' compartments, should receive serious consideration in terms of design specifications, building evacuation communications and instructions. The FRS studies also indicate that exit width and travel distance may be less important in terms of life safety than fire doors.

7.12 Also, the work at the Building Research Station on lighting levels (reference 19), is instructive in terms of suggesting the potential advantages of photoluminescent materials used as escape route direction markers in subdued lighting.

7.13 Similarly there is some indication in unpublished research that directional lighting could contribute to people's decision to leave in one direction as opposed to another (reference 35). Finally, the indication from recent work commissioned by the Fire Research Section (reference 36) that informative fire warning systems are more effective than a conventional fire tone alarm in encouraging a prompt evacuation, is consistent with our research.

7.14 While Item 4: 'Characteristics such as age or infirmity' (paragraph 1.1) was examined, the safety of disabled people, many of whom are elderly, was felt to be a pressing issue on its own, worthy of a separate research project. In this respect, BUSRU became involved in discussions during the project with the British Standards Committee drawing up drafts of the British Standard BS5588 part 8 Code of Practice Means of Escape for Disabled People (Published 1988). A further special pilot study on 'Assisted Escape' (not commissioned directly by the Home Office) contributed to a research proposal submitted to the Home Office in 1986 (references 37 and 38) and has led to other BUSRU Publications (references 39, 40 and 41). It is felt that the relationship between access and egress design and evacuation management procedures (embodied in the concept of 'assisted escape') remains a pressing issue (see paragraph 10.1).



CHAPTER 8: CONCLUSIONS

8.1 Familiarity with escape route seems to be at least as important as travel distance as a determinant of people's direction of movement. There also appears to be a strong relationship between the normal routes of circulation in a building and those used predominantly in evacuations. These conclusions suggest there may be inherent problems with emergency escape routes which are designed only to be used in an emergency. Far from encouraging a fire exit to be used in an emergency, restrictions on the regular use of a route make it less likely it will be readily used in a fire. These observations suggest that Codes and Guides need to encourage, rather than discourage regular use of all routes as far as possible through design and evacuation training. An appraisal is needed of the problems for life safety imposed by conflicting demands of building security, which reinforce restrictions on the use of particular routes dictated by a building design and building management policy.

8.2 The greatest problem in serious need of attention is the relationship between the design codes and building evacuation training and management in particular buildings. This is the focus of a three year research programme proposed to the Home Office by BUSRU (references 44 and 45). An objective would be to:-

- (a) improve the planning and internal monitoring of evacuation drills by organisations;
- (b) produce more explicit guidance on recommended building evacuation procedures in the Codes, and produce a separate Guide to Fire Precautions exclusively directed to building evacuation management;
- (c) establish stricter criteria and methods by which to evaluate evacuation plans and communications (including Public Address messages), training and drills in public buildings; and
- (d) provide a sounder basis through research for predicting evacuation travel times to exits in different types of occupancy and physical settings.



CHAPTER 9: RECOMMENDATIONS

In the light of the research carried out the following recommendations are made:-

- (a) references to 'time to escape' in technical codes should emphasise that a period of time to start to move following an alarm is as significant as time physically to move once people have decided to evacuate;
- (b) improve information warning systems and appropriate messages for all building users, particularly the public, addressing the two time phases of 'time to start' and 'time to move' and taking into account the location, progress of the fire, (where possible) any disorienting features of the building layout and unfamiliarity with alternative routes to safety;
- (c) consider circumstances (such as where there is a predominance of disabled people/parents and children separated/people sleeping could be present) in which there should be greater fire protection and an ample provision of appropriate fire instruction notices in public areas/activity rooms/guest rooms (eg halls of residence/hotels/leisure centres);
- (d) consider circumstances where it might be possible to relax travel distances within strictly defined limits as a trade-off where there is an effective information warning system, a structured and well rehearsed evacuation system and other active and passive fire precaution measures;
- (e) improve the monitoring and requirements for employers etc to be trained in evacuation management including the use of regular safety audits; and
- (f) ensure that there is adequate communications technology and a sound building evacuation management strategy all being directed towards effective warning of the public and prompt communications between staff and public.

Note:

Research indicates that there is a consistent problem of delayed warning and poor communications between staff and public in fire disasters (references 46, 47). The stress on staged alarm systems in buildings such as department stores, shopping complexes and theatres (reference 15, 26-31) should be qualified by emphasis on the importance of informing the public immediately there is any indication of a potential danger to their lives.



CHAPTER 10: FURTHER RESEARCH

10.1 The findings of this project are directly pertinent to major crowd disasters such as Bradford, King's Cross and Hillsborough which occurred during the research or shortly afterwards. The most pressing issue of all is how to reduce delays in people starting to move in a safe direction when there is a potential or actual threat from a fire and/or crowd congestion. In this respect it is our firm conviction that there are four interrelated areas where further research is essential:-

- (a) Informative Fire Warning Systems and human responses with particular attention to public address announcements in settings such as heavily populated shopping complexes, places of entertainment, football stadia and underground pedestrian areas (extending earlier research on IFW systems conducted on behalf of the Fire Research Station) (references 36 and 47);
- (b) Wayfinding and disorientation in relation to the design of architectural spaces and sign systems linked to information warning systems in complex building settings such as in (a) above, (extending research on wayfinding' in non-emergency situations) (references 48, 49 and 50);
- (c) Assisted escape procedures for people with mobility difficulties such as those with disabilities (Research proposal submitted by BUSRU to the Home Office) (references 37 and 38); and
- (d) Building Evacuation Management. (Research proposal submitted by BUSRU to the Home Office) (references 44, 45 and 46).

Footnote: Since the preparation of this report BUSRU has ceased to exist. Any further enquiries in relation to these research proposals should be made to Dr Jonathan Sime, Jonathan Sime Associates (JSA), (see inside title page of report), or the Home Office, Fire Research and Development Group.



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