Modelling Cue Recognition and Pre-Evacuation Response

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ABSTRACT

In most models of human behaviour in fire, pre-evacuation response receives less attention than the actual process of evacuation. However, delay in responding during this period is strongly associated with injury and fatality. This paper explains the selection, operation and evidence for features of a model of occupant response during the *pre-evacuation* stage in fires in residential buildings. The goal of the pre-evacuation response model is to determine the proportion of occupants leaving apartments (or rooms in non-apartment buildings) at each time step. The model is designed for a wide range of residential occupancies and, as part of a larger risk model, cannot detail all aspects of response. The model is constrained by lack of data, but operates within the limits of available evidence.

KEYWORDS: human behaviour in fire, pre-evacuation, response model

INTRODUCTION

This paper describes key elements in a model of initial occupant response, that is, response prior to starting evacuation, during residential fires. It explains the selection of variables and indicates the main sources of data for pre-evacuation response and for the associated probabilities and times. The model is part of a Human Behaviour model, and predicts the number of persons remaining in or leaving their initial location in a residential building at each time step during a fire. The Human Behaviour model records occupant movement and time spent in each compartment and uses the information to calculate the effect of gases (CO and CO2) and heat on occupants. The Human Behaviour model itself is part of a risk-assessment model (CESARE-Risk) which is designed to calculate expected risk-to-life and fire cost of a building and its fire safety systems [1].

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The Human Behaviour model is a generic model. It is intended to predict response in Class 2 and 3 residential buildings as defined by the Building Code of Australia (BCA) [2]. In brief, these classes cover apartment buildings, hotels, hostels, backpacker accommodation, boarding houses, hostels for the aged and similar but exclude hospitals and nursing homes, single dwellings and accommodation for not more than twelve persons. The model thus concentrates on features of response common to residential occupancies. It is designed for flexibility of input while placing boundaries on the number of variables employed, and many of its features can be modified.

The model relies heavily on the reported experiences of occupants in fire incidents. Published research on human response in actual emergencies has been examined and, as well, interviews conducted with people who had experienced fires in residential settings. The principal interview format, which is based on the work of Keating and Loftus [3], combines narrative and interrogatory methods to obtain a full and sequenced account of response from immediately prior to awareness of something untoward happening until evacuation or an alternative occurs. Less intensive interviews are held with occupants who were not threatened by flames or smoke. A questionnaire has also been used when personal interviews have not been practicable. There is a continuing need for data to support the times and probabilities used.

POPULATION DEFINITION

Occupants are grouped to reflect differences within and across occupancies. From the outset, occupant groups were limited to six in each type of occupancy for economy. Table 1 lists the six occupant groups and their proportions for apartment buildings, which were the first to be modelled. Australian Bureau of Statistics (ABS) data [4,5,6,7] for apartment buildings of 3 or more storeys and other government statistics [8,9] underlie group nomination and group frequency. The most frequently occurring household types (single persons at approximately 43%, 2 persons at 35% and family groups at 20%) are divided further to distinguish elderly people and to include people incapacitated by drugs or alcohol and people with a handicap. ABS data were used to determine the proportions used as default values.

The use of demographic characteristics (age, incapacitation and handicaps) which relate to residential fire injury and fatalities [10] simplifies the application of probabilities and times for human response and makes the model more flexible. Times and probabilities for action, and other components such as smoke susceptibility and walking speed, relate to quantifiable features that can be readily identified and be adjusted for the type of occupancy. The occupant groups can be modified to respond to population changes in occupancies over time.

The relative frequencies are used to distribute groups in the generic building, which is the initial step in the operation of the Human Behaviour model. Users will be able to change occupant groups and their proportions to fit specific building types. Occupancy rate can also be changed. The model runs with each occupant group in the apartment of fire origin (AFO).

The numbers and proportions of occupant groups are adjusted for seven types of occupancy other than apartment buildings. These are extensions of five BCA Class 3 categories. In hotels, for example, there are no couples over 70 years and the number of single adults and

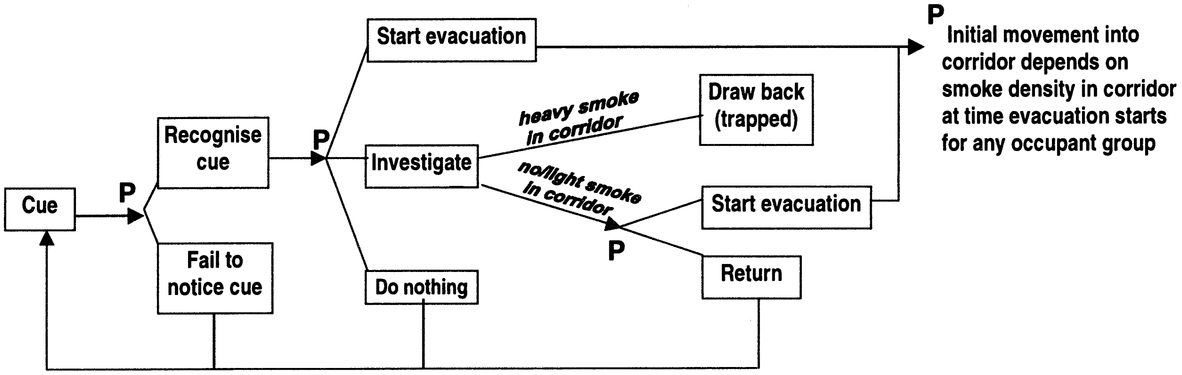

Figure 1. Model of initial (pre-evacuation) response in apartments of non-fire origin
Note: ***P** indicates application of probabilities.*

couples under 70 is increased, based on ABS and other statistics on age distribution in these dwellings and discussion with industry representatives. In some cases occupant group membership is redefined. Two examples of this are:

a. Elderly and family groups are excluded and the number of people in a room is adjusted in backpacker accommodation that is primarily used by young travellers
b. Staff form an occupant group in some residential buildings e.g. hotels and hostels for the aged. Staff action differs from that of other occupants (see Initial Action Selection below).

TABLE 1. Occupant Groups (apartment buildings)

Occupant Group	Composition	No. households, Australia (ABS)	% (day) households	% (night) households
OG1	1 person =<70 years	110 708	35.2	33.2
OG2	1 person >70 years	25 732	8.2	6.2
OG3	2 adults and child	62 984	20.0	20.0
OG4	2 persons <70 years	96 831	30.8	30.8
OG5	1 person incapacitated	3 144	1.0	5.0
OG6	2 persons >70 years, 1 with handicap	14 994	4.8	4.8
	Total	**314 393**	**100.0**	**100.0**

Occupant groups in hostels or accommodation offering some form of supportive care are defined by response capability rather than by age or group membership. In these occupancies more people are likely to be dependent during a fire incident (some physically dependent, some needing guidance). These occupants are defined by mobility, with those predicted to need individual assistance to evacuate being classified as 'non-mobile' (Table 2). They are categorised as not recognising cues whether or not they would do so in reality as the outcome is always the same. (A preferred version, not yet programmed, is to separate mobile occupants into those who would be likely to make an independent decision to evacuate and those who would respond to an instruction but not need further assistance.) Dependent numbers are increased for a night condition to make allowance for sleeping medication.

TABLE 2. Occupant group representation in special accommodation

Occupant Group	Hostel for the aged		Boarding house offering support		Accommodation for disabled	
	Day	Night	Day	Night	Day	Night
Mobile, single room	20%	13%	35%	10%		
Mobile, shared room	5%	2%	20%	5%		
Non-mobile, single	65%	72%	35%	60%	60%	60%
Non-mobile, shared room	10%	13%	10%	25%	40%	40%
Staff	2 staff to 30 residents (day) 1 to 30 (night)					

Information sources for establishing the numbers of mobile and non-mobile occupants included a comprehensive survey, prepared by the Centre for International Economics for the

Minister for Family Services, of over 46 000 residents in hostels for the aged and nursing homes [11], and other reports on hostel and boarding house residents. As well, advice was received from people working in these areas and direct evidence on the response of occupants during fire incidents was considered.

Psychological attributes have not been used directly to define populations or response. This avoids the problem of attribute selection. The use of occupant groups and of times and probabilities for response from data on behaviour in real fires is the preferred means for dealing with social and psychological influences. Familiarity is acknowledged to be an important feature in response, but most of the evidence on familiarity refers to the process of evacuation (e.g. route selection) rather than to cue interpretation. Clearly, the experience of false alarms affects interpretation, but this model, which covers all types of buildings in an occupancy, can only recognise this through times and probabilities.

Use of occupant groups allows the differentiation of actions, times and probabilities during different stages in the total response and evacuation period. In the present version of the model only options that can be supported by evidence are activated. For example, in the pre-evacuation period, the family group is only distinguished by the number of members (groups stay together) and by the fact that sleeping children do not respond to alarms.

OUTLINE OF INITIAL RESPONSE

Figure 1 depicts the initial responses for the majority of residents, that is, those from apartments or rooms other than that of fire origin, and indicates where probabilities are applied. Recognition of a cue is treated separately from reaction to the cue. Times to start evacuation begin from the time the cue is recognised and refer either to direct evacuation or to evacuation after investigation. Times cover all actions that might occur before evacuation starts. More detail on times is given below. Response in the apartment of fire origin follows a similar pattern except that all occupants who recognise a cue will evacuate, although not all within the same time period.

CUES AND CUE RECOGNITION

A cue is defined as any indication of a fire, direct or indirect, which has the potential for being recognized or for affecting behaviour. Cues may come from the fire itself (flames, smoke, sounds), from detection and warning systems and from other people (occupants, outsiders, fire fighters). Cues can be specific to place and time and may or may not be physically sensed ('recognized') by an occupant.

The selection of cues in the model is governed by research into behaviour in fires and the availability or potential availability of quantitative evidence for their effect and by the practical need to reduce the potentially large number of cues. Cues used are those

- which are available to most occupants in a building
- which are known from the literature to motivate action

- which are compatible with data collected through interviewing building occupants who have experienced a fire
- for which times of occurrence are available from the Fire Growth and Smoke Spread sub-model (with the exception of warnings).

Human behaviour in fires is not always or even usually a direct response to fire cues like flames, smoke, or alarms. Other variables impact on the *interpretation* of the degree of threat from perceived cues (one's own awareness, presence of others, role, understanding of escape routes, knowledge of fire growth, training). This model avoids using a level of interpretation 'black box' by defining the occupancy, building population and occupant status and associating them with incident-based probabilities and times for starting evacuation.

Cues used for probabilities of recognition and initial response are alarms, smoke, the sound of glass breaking and warnings. The time for recognizing a cue is the time of occurrence of the cue if the occupant is awake and 30 seconds later for sleeping occupants. The delay for sleeping occupants is based on findings of Bruck and Pisani [12] that subjects showed a 42% decrement in ability to complete a cognitive task in the first three minutes after waking to an alarm.

An awake/asleep condition affects probability for cue recognition for all occupant groups. Probabilities for recognizing cues are derived from experimental evidence, journal and other reports on particular incidents, and evidence from Coroners' investigations. They are typically estimated for Occupant Group 1 (lone person of 70 years or less) and adjusted for other groups. Occupants who do not recognize a cue may respond to later cues (unless they have been defined as non-mobile). A limitation of the present version is that no allowance is made for the effect of recognising more than one cue because available quantitative data from any source are insufficient to provide reliable estimates for the effect of cumulative cues.

Alarms. Any of nine types of alarms may be nominated in the CESARE-Risk model. Loudness of an alarm is important in recognition but variability from any cause other than whether the alarm sounds within the apartment/room or outside it is not considered. This is because these default probabilities (Table 3) are taken to apply to all occupant groups in an apartment building and data on variability are not available.

TABLE 3. Occupant Group probabilities for recognising alarms

Occupant Group	**Local alarm (sounding in apartment)**		**Corridor alarm (outside apartment)**	
	Awake	**Asleep**	**Awake**	**Asleep**
OG 1, 4 (adults)	0.99	0.98	0.78	0.73
OG 2, 6 (elderly)	0.95	0.91	0.72	0.67
OG 3 (family)	0.99	0.66	0.78	0.49
OG 5 (incapacitated)	0.00	0.00	0.00	0.00

The main factor other than being awake or asleep in establishing the probability for recognizing an apartment alarm is the extent of hearing disabilities in the community. ABS data [7] indicate that 2% of people less than 70 years and 9.2% of those 70 years and above have a hearing impairment disability without other disabilities. Experimental work by Bruck [13] has shown that sleeping children and adolescents are unlikely to respond to alarms, so the probability for Occupant Group 3 (family) hearing an alarm is reduced accordingly. The group deemed incapacitated through the use of drugs or alcohol is assumed not to hear the alarm (or to recognize any other cue) – a conservative stance, but one based on the importance of alcohol as a contributing factor in fire fatalities. The probabilities for groups hearing an alarm sounding within an apartment thus vary from 0.00 to 0.99. With further evidence, these (and all other probability figures) can be re-assessed.

For corridor alarms, whether they derive from smoke or thermal detectors or activated break-glass alarms, the probabilities are based primarily on evacuation drills reported by Proulx [14] in four multi-storey apartment buildings. Corridor alarms were not heard by 17-25% of apartment occupants mainly because of sound attenuation. Brennan [15] found that 9 of 30 people from 20 apartments who were interviewed after an apartment building fire and were asleep when the alarm sounded did not wake to the building alarm i.e. 30%. The occupants included people over 70 years.

Smoke. Only one level of smoke is used for recognition and *initial* response in the present version of the model. It is set to be equivalent to a visibility of about 12-15 metres [16]. All people awake are assumed to notice smoke (p=1.00), while 10% of sleeping occupants are predicted to wake to smoke. For the family group (OG3) this figure is reduced to 7% on the assumption that if sleeping children do not hear alarms they will not recognise other cues.

There has been little research into the response of sleeping people to any odours, let alone smoke. We know, however, that many victims fail to wake to smoke or respond too late to permit a safe escape. The 0.10 probability is derived from limited information. This includes experimental research from Kahn [17] (3 of 12 subjects woke to the smell of burning from paint-coated 150 watt bulbs), and from Lynch [18] (2 of 10 subjects attending a sleep clinic woke to an odour from smoke flavouring used for food; 4 others showed signs of arousal but did not wake). Irritants in smoke may increase the likelihood of waking, just as CO and CO2 may work in the opposite direction. Strauch et al [19] demonstrated that people are more likely to wake to stimuli deemed unpleasant and 40% of subjects woke to an unpleasant odour (pyridine) in a study by Carkasdon et al [20]. A slow increase in level of smoke may not be noticed whereas rapid change may be. It is likely that many of the people who report waking to smoke have been first aroused by noises produced by the fire but the experience of smoke dominates their recollection. Other than the cracking of glass, noises from a fire are not included in this model as they are unpredictable. If they could be associated with the presence of smoke, the probability for waking to smoke could be made with more confidence (and would probably increase).

Glass breaking. The sound of glass breaking from window breakage due to heat is included more for the interest of fire engineers than for its actual effect on outcome. It is the only sound immediately linked to the fire for which a time and probability can be established. This cue is taken to be available only to people from the apartment of fire origin but not to those in the room of fire origin as it is assumed that they would be unable to respond by this stage. As the sound is not persistent, 50% of people awake and 25% of those asleep are assumed to hear it. Exceptions to this probability are a sleeping child and an incapacitated person. The figures are not supported by quantitative evidence but have some anecdotal support – house occupants and neighbours often report being awoken by the noise of cracking or shattering glass.

Warnings. While research has shown the importance of person-to-person warnings and communication and indirect warnings from people movement and shouting during a fire, these are not easily incorporated into a probability model. Such warnings might occur from the moment a fire is detected until a building is evacuated.

Occupants issue warnings if they are responding to other cues and if they have started evacuating. Warnings are not issued to occupants of the apartment of fire origin. Occupants evacuating from an apartment can issue one warning only on their level. In addition, people who are descending open internal stairs issue indirect warnings (i.e. alert people through their noise) as they reach lower floors but this can occur once only on any one floor.

The probability for recognizing a warning if given is 1.00. However, receipt of a warning is restricted. On evidence from interviews with apartment dwellers and from considering the wide range of possible scenarios, it was decided to restrict the number of apartments that could receive a warning. Occupants leaving the apartment of fire origin thus warn 2 apartments on their floor, occupants leaving other apartments warn 1 apartment on their floor and people descending warn 0.05 of an apartment. The algorithm applied to calculate the probability of an apartment receiving a warning takes into account the number of apartments on each floor.

Other cues. Other cues for initial recognition and pre-evacuation response were considered but are not applied in this version of the model. A summary of the main ones and the reason(s) for their omission follows.
Flames. The location of occupant groups in the CESARE-Risk model is not done in the same way as a simulation model and it is not feasible to establish whether or which occupants in other locations than the apartment of fire origin would be likely to see flames. While flames are likely to be seen in the latter location, the smoke density selected for a first cue is a more frequent and more reliable cue. Occupants in the apartment of fire origin are deemed to see flames on investigating (a later stage than is currently being described).
Other types of smoke. While it is economical to use one level of smoke as a first cue, different types of smoke would be a desirable development. (Differentiation in smoke density is used in later stages of the Human Behaviour model).
Other types of alarms. Adoption of other types of alarms (particularly EWIS or early warning systems which have the capability of voice communication) is planned but requires reliable evidence to identify patterns in how these systems are set up and used in various occupancies. The significance of these alarms is more relevant to accurately assessing situations and making decisions about action than to recognition aspects.
Arrival of the fire brigade. Evidence on the effect of the arrival of fire trucks outside a building is inconclusive. Proulx [21] suggests that it encourages evacuation but interviews by the author with residents in Australia indicate that for some occupants it is a precipitating cue for evacuating, but for others it delays movement as occupants decide to wait for instructions from fire fighters. Such instructions are a part of the Search and Rescue Model. The cues used in the model are most likely to occur well before the arrival of the fire brigade.

INITIAL ACTION SELECTION

As can be seen in Figure 1, there are three actions that can be initiated in the pre-evacuation period once a cue has been recognized: to wait/do nothing, to investigate, or to start to evacuate. Occupants do not contact the fire brigade but they may activate a warning device (break glass alarm) or warn others. These actions occur during the evacuation stage. Staff members do not respond like other occupants. A proportion of staff is designated to instruct and rescue occupants (depending on fire conditions) while the remainder is assumed to be involved with organizational matters. Staff action also occurs later in the program.

As modelling is concerned with movement from one compartment to another, time spent in any one compartment is more important than activity associated with being in that location. Thus the actions have been selected for their importance in occupant movement. Any activity that might take place within the first compartment is represented only by time use.

Occupants who do not respond to a recognized cue by deciding to evacuate or by seeking more information are recorded as being awake (a change of status for those formerly asleep which is important for the application of recognition probabilities).

'Investigation' for occupants from the apartment of fire origin is only available to those not in the room of fire origin and means movement towards the fire. Every occupant who has recognized a cue will complete this activity. For all other occupants in a building, investigation means moving to check smoke conditions in the corridor. In both cases it involves a time component.

Probabilities for response for AFO occupants are fixed. All who recognise a cue will evacuate at some time (non-mobile occupants are excluded from recognising cues).

Probabilities for initial response for occupants outside the apartment of fire origin (or room in other residential buildings) are not based on 'rules' but are derived from the Response in Fires database developed from interviews with occupants. Key features of the fire, the building and its safety systems, occupant characteristics (e.g. ages, gender, numbers, disabilities, knowledge of safety systems, experience of alarms) and occupant response are recorded on the database. Occupant response categories include cues and the sequence of cues for different stages (locations) during the incident, and response to them as reported by the interviewee.

The probability for starting evacuation on receiving a cue is lower than that for investigating (Table 4). Reported behaviour in other fire incidents provides external validity for these probabilities [14]. Evacuation in many fires in multi-storey buildings is often a response to fire fighter instruction. Instructions from firefighters are not part of the pre-evacuation response model but occur later.

The probability for response to alarms does not in the present version distinguish among types of alarms although experimental evidence has demonstrated the improved effectiveness of two-tone alarms and announcements in encouraging evacuation [22,23,24,25]. As stated earlier, one problem lies with identifying a 'standard' for human intervention with these systems. A second problem is that the database cannot provide figures for response and appropriate probabilities need to be validated.

TABLE 4. Probabilities for initial action in response to cue recognition (from database)

		Cue		
		Smoke	**Local alarm**	**Corridor alarm**
Action	**Start evacuation**	0.00	0.25	0.12
	'Investigate'	0.50	0.55	0.28
	Wait/do nothing	0.50	0.20	0.60

TIMES FOR INITIAL ACTIONS

Times for when people start evacuation are also calculated from the database. Time to complete egress is calculated separately. A method for checking the validity of times as reported by interviewees has been described previously [15]. The database distinguishes between those who investigate before evacuating and those who start evacuation without investigating and stores the times separately. Both are calculated from the time of the cue that resulted in the initial action.

Table 5 shows the range of times established from the first seventy cases on the database for fire incidents in apartment buildings. Even for those who decide to evacuate on receipt of a cue the time to actually reach the apartment door can be quite long as occupants engage in preparatory activities. These times include delays occurring for any reason. Times for response in fires are skewed. In the actual operation of the model the mean value presented here is not applied. Three data points with associated probabilities are used to represent the time distribution.

TABLE 5. Times to start evacuation from database (apartment dwellers)

	Range (secs)	**Mean (secs)**
Time to start direct evacuation (all)	10 -1020	199
" " " " **(awake)**	10 - 120	62
" " " " **(asleep)**	30 -1020	267
Time to start evacuation after investigating (all)	40 -1260	282
" " " " **(awake)**	40 - 330	165
" " " " **(asleep)**	120 -1260	356

Times are based at present only on whether people were initially awake or asleep, not on the type of cue. This limitation is due to having insufficient case numbers on the database to provide time calculations that are reliable and to a lack of quantitative evidence from other sources which could be applied directly to the times recorded. Preliminary analysis of the limited number of relevant cases available indicates that the difference in alertness (being awake or asleep) weighs more heavily on time use than a difference in cues.

The times for alerted occupants in the apartment of fire origin (AFO) to start evacuation are taken from the database. The time is taken from when occupants reach the room of fire origin. While the time for starting evacuation from this location is more reasonably related to fire size, there is no interaction between the Human Behaviour sub-model and the Fire Growth model and this information is not available to the former. The time to investigate (reach the room of fire origin) is fixed at 30 seconds (45 seconds if initially asleep), a time that may well fall short of the real time used in fire incidents. The time to evacuate the AFO once occupants are aware of the fire includes the time to fight the fire, to protect, to warn others, to prepare to leave and so on. With this in mind, it was decided to use the times to start direct evacuation determined for occupants in apartments removed from the fire. Thus times for evacuating the apartment of fire origin are conservative.

CONCLUSION

The key mediators of response in the early stages of the evacuation process in this model are occupancy type, occupant group, occupant status, and the type of cue. This initial stage refers to behaviour up to the time when an occupant leaves an apartment intending to evacuate the building, a stage of marked diversity and complexity in real incidents. Recognition of a cue and initial action in response to a cue are predicted separately. Cues available vary according to whether occupants are in the apartment of fire origin or not, and occur at different times in different locations. The model applies probabilities and times for occupant response according to occupant group and status. The primary source for the calculation of probabilities and times is a database developed from interviews with occupants who have been in fire emergencies. The model predicts the numbers leaving apartments and the related times, and records time spent by occupants in their initial location. These data are used in the calculation of incapacitation and fatalities in later stages of the CESARE-Risk model.

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REFERENCES

1. Beck, V., "Performance-based Fire Engineering Design and its Application in Australia", International Association for Fire Safety Science, Proceedings of the 5th Symposium, Melbourne, Australia, ed. Y. Hasemi, 23-40, 1997.
2. Building Code of Australia, Canberra: Australian Building Codes Board, 1996.
3. Keating, J. & Loftus, E., Post-fire Interviews: Development and Field Validation of the Behavioral Sequence Interview Technique, Report No. NBS-GCR-84-477, National Bureau of Standards, Center for Fire Research, 1984.
4. 1991 Census Directory of Classifications: Census of Population and Housing, Australian Bureau of Statistics Catalogue No. 2904.0, Canberra.

5. 1989-1990 National Health Survey: Alcohol Consumption, Australia, Australian Bureau of Statistics Catalogue No. 4381.0, Canberra.

6. Disability, Ageing and Carers in Australia, 1993: Summary of Findings, Australian Bureau of Statistics Catalogue No. 4430.0, Canberra.

7. Disability, Ageing and Carers Australia, 1993: Hearing Impairment, Australian Bureau of Statistics Catalogue No. 4433.0, Canberra.

8. Statistics on Drug Abuse in Australia, 1994, Department of Human Services and Health, Canberra, 1994.

9. Victorian Drug Strategy Statistics Handbook: Statistical Indicators and Trends on Alcohol, Tobacco and Other Drug Use and Related Harms in Victoria, Public Health Division, Melbourne.

10. Brennan, P. "Victims and Survivors in Fatal Residential Building Fires", Human Behaviour in Fire Proceedings of the 1st International Symposium, Belfast, ed. T.J. Shields, pp. 157-166, 1998.

11. Review of the Resident Classification Scale, Exposure Draft, Centre for International Economics, Canberra, 1998.

12. Bruck, D and Pisani, D. "Sleep Inertia and Decision Making Performance", Australian Journal of Psychology (50), 1998 Supplement: Combined Abstracts of 1998 Australian Psychology Conferences, 1998.

13. Bruck, D. "Arousal from Sleep with a Smoke Detector Alarm in Children and Adults", Department of Psychology, Victoria University of Technology, Melbourne, 1997.

14. Proulx, G. and Fahy, R. F. "The Time Delay to Start Evacuation: Review of Five Case Studies", International Association for Fire Safety Science, Proceedings of the 5th International Symposium on Fire Safety Science, Y. Hasemi (Ed.) Melbourne, 783-794, 1997.

15. Brennan, P. "Timing human response in real fires", International Association for Fire Safety Science, Proceedings of the 5th International Symposium on Fire Safety Science, ed. Y. Hasemi, pp. 807-818, Melbourne, 1997.

16. He, Y and Brennan, P. "On Quantifying Perceptions of Smoke", Human Behaviour in Fire Proceedings of the 1st International Symposium, Belfast, ed. T.J. Shields, pp. 611-621, 1998.

17. Kahn, M.S., Human awakening and subsequent identification of fire cues, Fire Technology, 20:1, 20-26, 1984.

18. Lynch, J. "Nocturnal Olfactory Response to Smoke Odor", Human Behaviour in Fire Proceedings of the 1st International Symposium, Belfast, ed. T.J. Shields, pp. 231-242, 1998.

19. Strauch, I., Schneider-Duker, M., Zayer, H., Heine, H.W., Heine, I., Lang, R & Muller, N. "The influence of meaningful auditory stimuli on sleep behaviour", Sleep Research, 4, 178, 1975.

20. Carskadon, M.A., Bigler, P.J., Carr, J., Gelin, J., Etgen, G., Davis, S.S. and Herman, K.B., "Olfactory arousal thresholds during sleep", Sleep Research, 19, 147, 1990.

21. Proulx, G. "Evacuation Time and Movement in Apartment Buildings", Fire Safety Journal, 24, 229-246, 1995.

22. Keating J. & Loftus E. "Evaluation of the effectiveness of the vocal alarm system of the Seattle building", in Emergencies in Tall Buildings: the Designers Respond to the Human Response, Proceedings of the Conference on Human Response to Tall Buildings, Chicago, ILL., ed. W.A. Meisen & R.E. Reinsel,. 302-309, Stroudsburg, Pa: Dowden, Hutchison & Ross Inc., 1977.

23. Keating, J. & Loftus, E. "Vocal Alarm Systems for High-rise Buildings: A case study", Mass Emergencies, 2:1, 25-34, 1977.

24. Canter, D., Powell, J. & Booker, K. Psychological Aspects of Informative Fire Warning Systems, BRE Report. Borehamwood, U.K., Building Research Establishment, 1998.

25. Bellamy, L.L., & Geyer, T.A.W., Experimental Programme to Investigate Informative Fire Warning Characteristics for Motivating Fast Evacuation, BRE Report, Borehamwood, U.K., Fire Research Station, 1990.