



Technical Report
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Response of Occupants close to Fire

FCRC Project 4
Fire Safety System Design Solutions
Part A – Core Model & Residential Buildings

Fire Code Reform Research Program
March 1998

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Background

The Fire Code Reform Research Program is funded by voluntary contributions from regulatory authorities, research organisations and industry participants.

Project 4 of the Program involved development of a Fundamental Model, incorporating fire-engineering, risk-assessment methodology and study of human behaviour in order to predict the performance of building fire safety system designs in terms of Expected Risk to Life (ERL) and Fire Cost Expectation (FCE). Part 1 of the project relates to Residential Buildings as defined in Classes 2 to 4 of the Building Code of Australia.

This Report was relevant to the project activities in support of the Model's development and it is published in order to disseminate the information it contains more widely to the building fire safety community.

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Comments

Comments on the content or other aspects of this document are always welcome and should be addressed to:- Fire Code Reform Centre Limited, Suite 1201, 66 King Street, Sydney, NSW 2000, Australia. Tel: No:- +61(2) 9262 4358 Fax No:- +61(2) 9262 4255

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PATRICIA BRENNAN
March 1998

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P. BRENNAN March 1998

1.0 Evidence for response in the AFO

As stated in Section 5.3, it is difficult to obtain data from people who have been in apartment fires. However, the model demands that times and probabilities be placed on occupant response in the room of fire origin or in another room in the apartment of fire origin.

At the beginning of 1997, there were only 3 cases involving occupants from the apartment of fire origin on the Response in Fires database. In each situation the individuals were awake and the key cue which resulted in direct evacuation was seeing flames (along with smoke). The time to start evacuation is estimated at 60 seconds for two people (one of whom had moved to investigate unusual sounds first) and 120 seconds for the third person (who made some attempt to control the fire before evacuating).

Since then, only one interview with an occupant who was in *an apartment* when a fire occurred has taken place. The three occupants who were in a living room and not in the room of fire origin were awake (time: 10pm), smelt smoke, and then investigated after the smell persisted and no cause could be found in their immediate location. The time for tolerating the smell of smoke before any action was taken is not known - it could have been up to five minutes but may have been less than a minute. There were three responses when one person (a guest) discovered smoke. The guest was instructed to alert other apartments and left immediately. A woman attempted to extinguish the flames but was forced to leave because of the smoke. It is estimated this took 60 seconds. The third person left later as he called the fire brigade (responding to an instruction) after first having to re-connect the phone and then dialling the wrong number. His response is estimated to take between 60 and 120 seconds.

2.0 Case studies - CESARE

To the end of February 1997, Brennan has interviewed a number of occupants in **houses** where non-fatal fires occurred (primarily in Melbourne, 1998). The following summary of responses of 15 relevant cases (ie. where both occupants and fires were inside the house) distinguishes occupants according to whether they were awake or asleep and to whether they were in the room of fire origin or not. An attempt is made to provide an estimate of time use from the time the first cue was noted by the occupant until the occupant left the house (or telephoned the fire brigade if evacuation did not take place) on the basis of the occupant's account of the incident.

This research was undertaken to identify similarities and differences in response in house and apartment fires. There are two instances of fires in the room of fire origin where at least one occupant was initially awake, 3 where they were asleep, 9 where occupants were in other rooms than the room of fire origin and were awake and 1 instance where a person was asleep in a room not of fire origin.

Awake, RFO n=2

Case 1 (H2) Small farmhouse. Occupant spilt paraffin while filling a small paraffin heater which was on. Applied a fire blanket and then exited to get help from neighbours. Getting no response she reentered the house and used the phone. The occupant was ringing the fire

brigade when the neighbour broke a window and used an extinguisher. When the contents of the extinguisher contacted the metal it produced choking black smoke. The occupant exited, feeling her way and closing doors behind her. She then reentered to look for a puppy neighbour failed when forced to retreat because of the smoke.

Cue: flame

Estimated time to first evacuation: 1-3 minutes

Cue for other occupant: warning (from outsiders, not from other occupants)

Case 2 (H19) A night time fire where one person was asleep and the other awake. Occupant was moving from bed using a cigarette lighter as lighting (normal practice), The lighter burst into flames and then fell under the bed when she dropped it, setting the base of the bed on fire. She woke her husband and both tried to control the fire before ringing the fire brigade. She and a third person (over 80 years, asleep, not woken by smoke detector alarms) evacuated, he fought the fire from outside. They closed the door to the room as they left it (a window was partly open).

Cue: flame

Estimated time to ringfire brigade: 3-5 minutes

Cue for other occupants (sleeping): direct warning

Asleep, RFO n=3

Case 1 (H4) Father asleep in RFO (kitchen), two other family members in another room. Father woke to glass cracking on the rangehood. Parents fought fire while daughter rang fire brigade. They went out when they heard the sirens approaching.

Cue: noise resulting from fire (but not window breaking)

Estimated time till went outside: 5-10 minutes. No evacuation.

Cue for other occupants: warning

Case 2 (H5) Adult male asleep on sofa in lounge room, woke to a smoke detector alarm - mantelpiece in front of him was on fire. The smoke detectors were upstairs. After two attempts to extinguish the flames with pots of water, went upstairs to get sleeping child, was surprised by the amount of smoke there (at waist level), dismantled the smoke alarms and then took the child outside to the planned meeting place (planned as a result of the primary school education programme Fire Ed). **He** then reentered the house alone to ring the fire brigade.

Cue: alarm (Smoke present but in high layer)

Estimated time from waking until first evacuation: 3 to 5 minutes

Cue for child: warning

Case 3 (H1 1) Adult male asleep on sofa in lounge room, probably woken when flames touched his hand - table next to his hand and sofa he was asleep on *were* on fire. After three or four attempts to extinguish the flames with pots of water and an attempt to extinguish them by beating them, he went to sleeping flat mate for help. They then both continued to fight the flames (using water and beating them) before deciding to ring the fire brigade. They went outside when they heard the sirens approaching and as a result of the smoke levels in the room. Occupants thought the **fire** itself was much less by the time fire fighters arrived due to the water and the house design - there was a brick wall behind the sofa.

Cue: flame (Smoke present but in high Layer)

No evacuation. Estimated time from first adult waking until exited house: 5 minutes minimum to possibly 15 minutes

Cue for 2nd adult: warning

Awake, RNFO n=9

Case 1 (H3) *Three* adults and infant downstairs, fire upstairs. One adult smelt smoke. Second adult checked wood fire and returned. Smoke continued and the other two then went to check other rooms and saw a curtain in flames upstairs. Adult evacuated immediately with infant, the other two extinguished the flames.

Cue: smoke

Time to evacuate: unknown because time to respond by investigating is not known. Possibly 1-3 minutes. No evacuation for the two occupants who fought the fire

Case 2 (H6) Family, two children 8 and 10 years. Fuse box fire. Husband investigated noise, wife continued on phone. Husband instructed wife to evacuate self and children. She finished the phone call then got children and evacuated. Husband first rang electrician then, on instruction, the fire brigade.

Cue for adults: flicking lights followed by an explosion

Estimated time to evacuate, wife and children: 1-3 minutes

Time for husband not known

Cue for children: warning?

Case 3 (H7) Two adults present. Both investigated. Fire in wall near operating dishwasher. Rang electricity company then fire brigade. Used fire extinguisher successfully.

Cue: clicking noise. No smoke in room

Estimated time to phoning fire brigade: 4-6 minutes. No evacuation

Case 4 (H8) Two adults present. Workman upstairs started fire while burning paint off window. Warned two adults downstairs. **Two** adult males tried to subdue fire with pots and buckets of water. Wife called fire brigade independently then took protective action and prepared for fire brigade arrival and finally ordered the two males from the house.

Cue for two occupants downstairs: warning (Workman not interviewed)

Estimated time for two males to evacuate: 5-7 minutes

Time for wife to exit house for first time: 2-3 minutes

Case 5 (H9) Electrical fire in t.v. set. Going for unknown time before occupant noticed smell on moving upstairs. She assumed it was from construction work outside and shut the windows. Completed various activities before returning upstairs and finally noticing a 50 cm layer of smoke in the room of fire origin.

Cue: smell of smoke

Estimated time to call fire brigade: 30-60 minutes. No evacuation

Case 6 (H10)

Only occupant was eating, watching t.v. and using phone when noticed a strange smell. Rang fire brigade after he opened door to room and saw flames. Then attempted to douse flames.

Cue: Smell of smoke

Estimated time to call fb: 1-3 minutes

Case 7 (H13)

Four occupants at breakfast and preparing for the day heard a 'bump' followed by another '10 minutes' later. Later still, heard knocking and shortly after the power failed. One went to check the fuse box and one found the fire in a back room. Called fire brigade after alerting neighbour.

Cue: noise from fire

Estimated time to call fb: 12-25 minutes

Estimated time to evacuate: 1 minute after calling fire brigade

Case 8 (H17) Four adults present. Smoke first noticed by occupant one room to mother. Fire was in a gas meter under the house. One adult occupant fought fire and issued directions, one helped with protective activities, one phoned fire brigade. All exited house but one returned and was directed out again.

Cue: smelling smoke

Estimated time to phoning fire brigade: less than 30 seconds.

Estimated time to evacuate: 10 seconds for two occupants, 1-2 minutes for the other two.

Cue for other occupants: warning

Case 9 (H19) Adult male watching t.v. Heard a 'crack' in next room. Immediately went to investigate and saw flames in centre of a bed. A number of attempts at extinguishment (water, hose, blankets) were followed by flashover, whence he notified the fire brigade from another dwelling.

Cue: noises from the fire (unlikely to be window breaking)

Estimated time to phone fire brigade: 2-5 minutes

Asleep RNFO n=1

Also note response of other parties in Asleep RFO Cases above.

Case 1 (H1) Two adults, two children 5 and 7 years. Adult female woke to noises, got up after about 15 seconds to check on the children, saw smoke and a glow from the other end of house. Alerted husband, woke and evacuated children (no dressing). Husband rang fire brigade and then collected some items from the RFO before evacuating and returned for other items. Final exit as fire brigade approaching.

Cue: noises of fire (but not window breaking)

Estimated time to evacuate (wife and children): 60 seconds

Estimated time to first evacuation by adult male: 4-7 minutes

Cue for adult male and children: warning

3.0 Case studies - external sources

The following 12 summaries of occupant response in situations when the occupants are close to the fire are taken from the literature and from one coronial case - the source for the summary is noted. Only the first four refer to fires in apartment buildings. The selections are made on the basis of finding fires in which sufficient information is given to make any supposition about cues and times. Such information is often very limited: only six of the 14 domestic fires reported by Sime, Breaux and Canter (1994) have sufficient information on occupants, their behaviour and the fire cues to warrant being included; only three from Tremblay (1995). A very real problem exists with interpreting a report which says someone 'woke to smoke' as there is no indication of whether this means 'because of the smoke' or whether other cues woke the person.

The majority are house fires. Reports with sufficient details of occupant response in fires in apartments are rare. Fires in apartments or in rooms in hotels are dealt with first and cases where an occupant was in the room of fire origin are given precedence. The location of occupants is interpreted according to the Response Model (ie. whether they are in the RFO or RNFO). The cues nominated are derived from the descriptions presented. The times or time ranges are estimates based on consideration of what an occupant does and of the fire cues recorded as being present. They represent the time from recognising the initial cue until the person leaves the room/apartment/house.

Incident 1 RFO

Fatal **fire** on 9th floor of **an apartment** building. Time: 12.00h. Occupant (male, 75 years, heavily intoxicated - .26mg/l) is understood to have been awake and possibly playing with matches. He was severely burned but left the apartment and collapsed in the corridor outside.

Cue: Flame

Time range estimate: 30-60 seconds

Source: State Coroner's Office, Case 19922573

Incident 2 RNFO

Fire on fifth floor of a high-rise **apartment** building. Time 0500h. Occupant (male, 49 years) was awake.

Sees smoke coming from the couch **in** the adjacent living room. Tries to extinguish with water. Opens patio door to vent smoke. Quickly sees action is ineffective as couch burst into flames. Flees, leaving the door open (and the patio door open).

Cue: Light smoke

Time range estimate: 120 - 240 seconds

Source: Proulx, G., Pineau, J., Latour, J.C. and Stewart, L. 1995. Study of occupants' behaviour during the 2 Forest Laneway fire in North York, Ontario, January 6, 1995 NRC-CNRC Internal Report No. 705.

Incident 3 RFO

Fatal fire on ninth floor of a high-rise **apartment** building (fatalities not from apartment of fire origin). Time 19.00h. Occupants were 'a number of people attending a drinking party' ie. awake. They left by elevator, leaving the apartment door open. The fire is alleged to have been deliberately set in the living **room**.

Cue: Flame?

Time estimate: <60 seconds

Source: Fire Investigation Report, High Rise Apartment Building, 250 Davenport Rd, Toronto, Ontario, March 7 1992. Office of the Fire Marshal, Ontario.

Incident 4 RFO and RNFO

Fatal **fire** started by children in cupboard in main bedroom of an **apartment** in 9 unit 2 storey building. Level not stated. Time: 08.19h. There were five occupants - a 21 year old who was asleep and four children under 6 years. The 21 year old did not respond and an infant died in the same room. Two children were found in the hallway and one in a living room.

Cue: Flame? for children, no cue for person asleep

No evacuation

Source: Tremblay, K.J. "Catastrophic fires of 1994" NFPA Journal Sept/Oct 1995 p.59

Incident 5 RNFO

Fatal fire on 3rd floor in a 3 bedroom **unit**. The seven occupants (including five children 8 months to 11 years) were asleep. Fire started in the kitchen. Time: 04.30h Parents woke to smoke and heat. Alarms known to have operated, time unknown. Father jumped from the window, mother rescued by fire brigade, children died.

Cue: Alarm? Smoke?

Time estimate for father: <30 seconds

Source: Tremblay, K.J., Catastrophic fires of 1994. NFPA Journal Sept/Oct 1995 p. 59.

Incident 6 RNFO

Fire in kitchen of two-storey **house**. Time: 23.44h. Two adult occupants (one frail) upstairs in bedroom, awake. Wife investigates *persistent* strange noises ie. noises continue for unknown time before action is taken. On locating fire, she informs husband who is still in bed. He comes down. They phone fire brigade and then he attempts to fight fire while she goes to

neighbours for help. One extinguisher is collected from the car. Husband is helped by neighbours from a smoke-filled kitchen.

Cue: noises from fire {but not window breaking}

Time estimates: Wife: 2-5 minutes? Husband: 5+ minutes?

Source: Sime, J., Breaux, J. & Canter, D. 1994 Human behaviour patterns in domestic and hospital fires, BRE Occasional Paper (Fire 3).

Incident 7 RNFO

Fire in kitchen of a two storey semi-detached house. Time: 03.30h

Father and 4 children under 10 years were asleep. Mother awake, moving from toilet to kitchen where she was boiling milk. Hears faint crackling. Enters kitchen and is forced out by heat and flames. Calls to husband who is upstairs. He enters kitchen and tries to extinguish fire. Fails and leaves room. They ring fire brigade and then wait in hall for fire brigade to arrive.

Cue: Smoke and heat (Noise of fire heard just prior)

Time estimate: No evacuation.

Source: Sime, J., Breaux, J. & Canter, D. 1994 (Fire 6)

Incident 8 RFO and RNFO

Fatal fire starting in bedroom of a 2-storey semi-detached house from clothes drying over a gas fire. Time: 22.30. Mother watching TV in lounge on 1st floor was awake, two children were asleep in bedrooms on 1st floor, grandfather (the deceased - 68, had been drinking) asleep downstairs. Grandfather does not apparently respond, dies from smoke and flames in **RFO**. Mother smells smoke and goes downstairs to investigate, sees smoke under bedroom door, runs to neighbour's, returns and goes upstairs to ring fire brigade. The call is interrupted when she tries but fails to stop neighbour moving to room of fire origin and opening door (not clear whether she moves downstairs to do this). Her exit from upstairs is blocked and she escapes with children via an upstairs window before fire brigade arrive.

Time estimate: Note: 'Approximate' times are given for this incident but their derivation is not explained:

Time until wife goes to neighbour: 3 minutes

Time, until wife rings fire brigade: 5 minutes

Source: Sime, J., Breaux, J. & Canter, D. 1994 (Fire 7)

Incident 9 RNFO

Fire in unoccupied upstairs bedroom of two-storey semidetached house with attic. Time 01.30h.

Parents in lounge downstairs, awake. Three children 9 upstairs asleep.

Mother smells 'something' and responds after unestimated time. She and then husband go upstairs to investigate, see smoke from main bedroom where door was ajar. They take the children downstairs. She then phones fire brigade while he fights fire with pans of water. Brigade arrives after the fire is out.

Cue: Light Smoke

Time: No evacuation

Source: Sime, J., Breaux, J. & Canter, D. 1994 (Fire 9)

Incident 10 RFO

Fire in waste-paper bin in living room of a two storey house. Time 19.27.

A couple in their 60s were absorbed in watching a TV film ie. awake. Husband restrained wife from investigating. When fire was discovered in bin behind their settee, the husband extinguished it before the fire brigade (called by neighbours) arrived.

Cue: Smell of smoke

Time estimate: The report claims fire was smouldering for 20 minutes before occupants moved.

Source: Sime, J., Breaux, J. & Canter, D. 1994 (Fire 10)

Incident 11 RNFO

Fire in mattress in unoccupied bedroom of three storey house with basement, **rented rooms**. Time: 02.00h. The occupants, three males and one female, were all awake. The female had just gone to bed (1st floor), two males were in kitchen (ground floor), one preparing for bed (no information on location). First noticed by female who smelt burning and saw smoke. She went down and warned the others, two of whom then put the fire out. The fire brigade was not called.

Cue: Smell of smoke

Time: No evacuation

Source: Sime, J., Breaux, J. & Canter, D. 1994 (Fire 12)

Incident 12 RNFO

Fatal fire started in kitchen and spread internally via open stairs and through a window on level 1 in a 3 level **house** with basement. Time: 04.49h.

There were 12 occupants, ages 6-37, all of whom were asleep. All were found on or near their beds on all four floors.

Cues: Smoke

Time: No response

Source: Tremblay, K.J. Catastrophic fires of 1994 NFPA Journal Sept/Oct p.53

Table 1 provides a summary of the above crude estimates of time.

TABLE 1. ESTIMATED TIME IN MINUTES FOR OCCUPANT(S) TO EITHER RING FIRE BRIGADE OR EVACUATE, NUMBER OF PEOPLE AND LOCATION AND CONDITION OF OCCUPANT

	Brennan		Other incidents	
	Minutes	Incidences	Minutes	Incidences
RFO awake	1-3	1	<1	1
	3-5	1	2-4	1
			20	2
RFO asleep	3-5	1		
	5-10	1		
	5-15	1		
RNFO awake	<1	1		
	1-3	5		
	2-3	1		
	2-5	2		
	4-6	1		
	5-7	2		
	12-25	1		
30-60	1			
RNFO asleep			<1	1
			2-5	2
			5+	1

Table 1 focuses on the time to an active response of either evacuating or calling the fire brigade. Where the response of more than one person is described in an incident more than one response is included. Cases where time could not be estimated are excluded. The table indicates the location and condition of the occupant (eg. RFO, awake), the time estimate in minutes from noticing the first cue until action is taken by either ringing the fire brigade or

evacuating. Such time includes any investigating, fire fighting or other activity which takes place if such actions occurred before the final action. The wide variation and the uncertainty actual time make it evident that a valid and reliable, statistically-based time for response is not available.

4.0 Comments

The about response in the apartment of fire origin as it relates to the Human Behaviour Model are made in consideration of the above cases and understanding of response in other situations.

Cues in house fires

In cases where the occupant is awake and in the same room as the fire the first cue is typically seeing flames. This is not a cue in the Response Model which conservatively waits for the Light Smoke criteria to be reached.

In addition to smoke, a common cue for people outside the room of fire origin is noises created by the fire. This cue was excluded as a cue in the Response Model because it is not possible for fire models to predict it (except for the sound of a window breaking). Noises may occur well before Light Smoke reaches the RNFO, so the Response Model is again timing response conservatively.

The time before a cue is recognised is a most critical time but cannot be established from interviews which at most can only indicate the level of the cue. A fire can be well established by the time recognition occurs.

An alarm as a cue is present in only one, possibly two, of the above cases so they do not provide evidence of response to alarms.

The nature of response in house fires

The evacuation response and the speed of starting evacuation is governed by the size of the fire as and when perceived by the occupant. This sort of interaction with the fire is not permitted in the Human Behaviour Model. People who smell smoke from the RNFO may face a fully developed fire on opening a door to the RFO but the model does not deal with this either. The cues used however do allow some consideration of fire severity by distinguishing levels of smoke.

In houses, people often have not evacuated before the arrival of the fire brigade. Furthermore, there appears to be much more movement in and out of houses during a fire. One major consideration is that there are a number of alternative exits available to most occupants in house fires and that this strongly influences responses. In single room accommodation (eg. hotels) or in accommodation where the number of exits is limited (eg. apartments in multi-storey buildings) an occupant alerted to the actual existence of a fire is unlikely to attempt to find and fight the fire. As well, the very compactness of the accommodation can be assumed to reduce the time to prepare to evacuate.

Making some attempt to control the fire is a frequent response. This is not an action option in the Response Model because the CESARE-Risk Model does not allow an occupant to have an impact on the fire. However the application of three times for the occupant to investigate and evacuate or to evacuate allows for time to fight the fire.

Most people do not appear to contact the fire brigade until they have left the room, apartment or house. The Human Behaviour Model does not deal with time to contact the fire brigade - this is part of the Fire Brigade Model.

Times for recognition and response

It is difficult to estimate times even after closely questioning occupants; estimating times from second hand reports of an incident is even more unreliable. Fire brigade times are not of use for timing response in the AFO.

Delay in recognising cues has a big impact on the time to respond. In some of the cases above, recognition occurs when a fire is well developed, in others much earlier. It is known from fatal fires in houses that many fatalities where occupants have been close to the fire are associated with no or very late response. This is particularly so where fatalities occur in the room of fire origin. The 27 cases summarised above show that response and the time for response vary considerably.

In house fires the time to leave once evacuation starts is very brief. This would contrast with fires in apartments, hotels and the like.

AFO times and probabilities in the Response Model

The cases above, the summary in Table 1 and the above comments indicate the impossibility of providing one accurate time for response. The range must be dealt with. In the Response Model, this comes through using three times to start evacuation (T_{evac}). A fixed time is used for actions prior to this period.

The Response Model uses the same probabilities for cue recognition for the AFO and the ANFO (refer to Tables 5.2-5.5). Actions are also pre-determined (Figure 5.1). A time of 30 seconds is given for an ANFO occupant to locate the room of fire origin once recognition occurs if the occupant was awake and 15 seconds longer if the occupant was asleep. The times to start evacuation and to evacuate are the same for AFO as for ANFO ie. based in three time points. Applying a time to start evacuation which is based on ANFO as well as AFO occupant response in apartments means that the time for response of occupants in the AFO is likely to be slower than in reality. While it allows for the “tail” in the times above, it may be too conservative. It does not take into account the proximity of the occupant to the fire.