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Selected Literature Reviews on Human Behaviour in Fire

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

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Important Notice

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 prepared as part of 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

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REVIEW OF STATISTICAL STUDIES BY WOOD AND BRYAN OF HUMAN BEHAVIOUR IN FIRE

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Section **1. Introduction**

This paper reviews **two** reports which are two of the earliest large scale studies of behaviour in fire. The reports provide statistical information on human behaviour in fire based on responses to questionnaires. The purpose of this review is to ascertain the extent to which their data can provide support for the Human Behaviour and Evacuation sub-model of the CESARE-RISK model. The statistical information contained in this paper is derived from the reports, albeit with further analyses and summaries of the data therein. The paper is an attempt to extract and present the most pertinent information from the reports. No attempt is made to compare the data in the reports with other findings. In summary, though the studies provide a general picture of behaviour in fires, they lack the detail required by the CESARE-RISK model.

Section 2. **Data required for the CESARE-RISK Human Behaviour Model**

The current version of the Human Behaviour Model requires data on the relationship of occupant characteristics to

- the initiation of actions which may impact on the fire such as contacting the fire brigade
- the initiation of actions which may affect the responses of other people such as the giving of warnings, sounding of alarms
- the initiation of evacuation
- the time taken before the initiation of such actions
- the time taken for the completion (or abandonment) of such actions.

The initiation of the above actions *is* dependent on the recognition of cues from the fire, alarms and warnings, and from other people, and on the perception of them as a potential or real threat. The time to initiate actions requires data on the probabilities of specific reactions by sub-populations to specific cues including those from the fire itself, from alarms and warnings, and from other people.

The six occupant groups specified in the present model are a single person, two unrelated people sharing, family couple and child, disabled person with a caretaker, and an intoxicated/drugged person. The following factors are nominated as affecting response and speed of response: age, mobility, and whether the occupant is awake or asleep, alone or with others, and related or not to others present.

Successful completion of evacuation itself is dependent on fire and smoke spread as well as occupant characteristics. Data on responses to the presence of smoke are particularly relevant *to* evacuation.

It can be assumed that the development of more sophisticated versions of the model will involve additional and more refined versions of occupant characteristics and responses. For example, the probability of and time delay for taking other actions which may impact directly on the fire will be considered. Consequently, this review presents and discusses information which is likely to be relevant to more advanced models as well as to the present model.

Section 3. Overview of the large-scale studies

The research was undertaken in the 1970s and involved the use of questionnaires passed by fire brigade personnel to people who had been involved in a fire incident (Wood, 1972) or completed on the spot by firefighters interviewing occupants (Bryan, p.197). The key researchers were Peter Wood in the **U.K.** who was under contract to the Fire Research Station, Department of the Environment and Fire Offices' Committee Joint Fire Research Organization, and John Bryan in the U.S. working for the National Bureau of Standards (now NIST). This paper refers primarily to Wood P.G. (1972), The behaviour of people in fires (U.K. Fire Research Note 953) and Bryan, J. L.(1977), Smoke as a determinant of human behavior in fire (Project People) NBS-GCR-77-94. The following articles, where they referred to the same data have also been consulted: A survey of behaviour in fires (Wood, 1980), and Human behaviour and fire (Bryan, 1986).

Table 1 outlines the population surveyed in the two studies. It gives immediate indications of the difficulties of making any direct translations to the CESARE-RISK database which has more specific occupancy categories. The incidents are dominated by house fires, apartment fires adding to 10% (U.K.) and 20% (U.S.) of the fires. The large number of factory fires in the U.K. data could have considerable influence on the findings about human behaviour as factories are more **likely** to have established systems for dealing with fire. Wood's population is more broadly based.

TABLE I: Comparison of the populations surveyed by Wood and Bryan

	UK (Wood)	US (Bryan)
No of incidents	952	335
No of storeys		90% 3 or <3
No of subjects	2193	584
Buildings: houses	50%	63.6%
factories	17%	
flats	11%	18.5% (<20 units) 2.4% (>20 units)
shops	7%	
institutions	4% (includes hotels)	
motels, hotels		1.5%
offices		0.9%

Wood's questionnaire sought data on the following variables:

Fire - extent, location, smoke spread, smoke density

Building - category, safety provisions, number of storeys, number of people, number who evacuated, were rescued, were injured

Personal - age, sex, how first aware, seriousness rating, building familiarity, proximity to fire, frequency of prior training, knowledge of emergency exits, who they were with, previous experience of fire

Behaviour - first action, next actions, whether they evacuated, returned into the building, moved through smoke (and how far) and turned back because of smoke.

Bryan adopted the same method of data collection (also relying on fire brigade personnel who attended the scene of a fire incident either at the time of the incident or later) and analysed similar variables. In contrast to Wood's questionnaire, Bryan's questions did not have prepared responses from which subjects could choose.

Section 4. Limitations of the findings as support for the CESARE-RISK model

Methodological aspects of the studies cast doubt on their usefulness in providing any reliable statistical backing. The population sampled, the reliance on univariate and bivariate analysis, and the failure to distinguish among occupancy types are restricting factors.

- Bias in the population. Sampling was neither random nor representative. Fire brigade personnel questioned people on the spot. Wood does say that the sample is weighted towards people who discovered the fire (p.25). Both samples are dominated by single family residential buildings.

- Most of Wood's tables are bivariate (eg. comparing age or gender in relation to a specific action). Bryan does some analyses to compare US findings with those of Wood, this being one of the objectives of his research. Most of his tables are univariate. They describe the demographic characteristics of the population responding to the questionnaire (but do not distinguish the people most immediately concerned with a fire from other occupants, which might be of interest to us) and give details of fires and buildings. The statistics as presented are not directly transferable to the CESARE-RISK database.

- Aggregation of data. The data are summaries of responses covering different building categories and do not distinguish individuals in close proximity to the fire from others. Some differences in responses according to occupancy are noted occasionally, usually to explain a particular finding, but occupancy-type was not of primary interest. Table 2 is based on Wood's table on First Action & Building type (Table 13, p. 60) which refers to 29 actions. Wood notes that warnings occur significantly more often in the first three occupancy types than **in** the 'Other occupancy' group, that evacuating immediately does not appear to be a function of occupancy type, and that work and retail groups are more likely to fight a fire than the residential groups. However, comparison across occupancy types in this general way does not provide data relevant to the CESARE Risk-Cost model. Table 2 indicates the close similarity in behaviour between dwellings and flats, with the exception of *Protective action* which is more frequent in a dwelling. None of the differences between dwellings and flats **is** statistically significant. (*Protective action* in Table 2 combines three of Wood's *categories: Something to minimise risk, Switch off utilities, Shut doors.) This* provides some support for using statistical data from house fires if there is insufficient from the required occupancies. Note though that the table refers only to actions, not perceptions, and gives no indication of times.

  It is unfortunate that information on second and third actions in relation to occupancy type is not available because this would provide a clearer picture of the probability of specific behaviours required by the model occurring. However, as will be seen later (Section 7, Tables 8 and 9) the proportional frequency of the above actions remains fairly constant except for certain logically predictable changes (eg. reduction in investigation, increase in inaction).

  The table indicates that for apartment occupants (presumably occupants of the apartment of fire origin) the probability of contacting the fire brigade *is* 12:100, of evacuating immediately is 9:100 and warning others is 9:100. The statistics do not take into account the cue(s) contributing to these actions eg. size of the fire, occurrence of alarms, presence of smoke, warnings from others. The probability figures are based on first actions. Contacting the fire brigade and warning others have different probabilities if three nominated actions are taken into account (see Section 7, p.9).

TABLE 2: Relationship between building type and the ten most frequently reported first actions (Percentages of respondents)

		Dwelling	Flat	Multiple occupancy	Other occupancy*
	Investigate	12	12	17	12
	Fight fire	IO	12	6	21
	Contact fire brigade	9	12	12	9
	Move to exit or leave	9	9	9	9
Action	**Protective action**	13	7	5	9
	Warn others	a	9	20	6
	Evacuate family	11	10	2	1
	Move towards fire	5	4	a	6
	Get dressed	3	4	4	I
	Ask if fh was contacted	3	3	2	2

*Other occupancy = factory, shop, pub, cafe, ‘institutional’ -hospital, school, hotel, hostel

- There is some uncertainty about the accuracy of the statistics presented. Often, for example, a translation of a percentage figure using the stated number in the set does not produce an expected whole number. This may be because the authors have not mentioned changes in the population base due to people *not* answering or partly answering questions - a major problem with questionnaires. Significant differences quoted in this review are taken directly from the research reports and are not based on reanalysis. The term ‘significant’ refers to statistical significance which is usually p>0.05 or p>0.001.

- **Findings** on responses are mainly concerned with actions and the order of actions rather than with the effect of specific cues. The information on cues is discussed in the next section. In Section 6, data on actions over all occupancy types is considered.

Section 5. Cues

Apart from questions on smoke (discussed below), information on cues is derived from one question asking people how they first became aware that there was a fire. This does not tell us why people evacuated. Table 10 (Wood, p.54) links first cue with first actions and this includes evacuation as a response (see Section 6 Evacuation below). Bryan does not provide this information.

.Wood (1972) lists alarms, noises, shouts and being told as ambiguous cues. Heat, flames & smoke are unambiguous. Table 3 is based on data extracted from Table 10 Initial Awareness of Fire by First Action which contains 29 actions.

As numbers in the categories above were not sufficient for statistical tests the categories were combined. A significantly greater proportion of the ambiguous cue group as against the unambiguous cue group evacuated (Wood, p.53). Wood offers as explanation that responding to the alarm by evacuating probably reflects the required response in a work setting and is responsible for the significant difference. Most houses would not have an alarm. Perhaps the bifurcate simplification is too coarse.

TABLE 3: Percentage of people taking particular actions in relation to first cue
(Table is based on Table 10, Wood, p. 54. The remaining 23 actions have frequencies of <8%)

		First cue						
		Heat	Flames	Smoke	Noise	Shouts	Told	Alarm
Action	Evacuation	7	6	6	11	9	8	19
	Contact FB	14	10	10	13	7	11	6
	Warn others	11	13	9	7	11	4	1
	Fire-fighting	18	24	1.5	10	14	12	9
	Investigate	4	3	13	12	13	15	24
	Move to fire	0	1	5	3	12	7	10

No distinctions are made in types of alarms. The CESARE-RISK model distinguishes local alarms (eg. smoke detectors) from general building alarms. As response to different sorts of building alarms can vary, later versions of the model may incorporate more than two categories.

No numbers are given on how people first became aware of the fire but Wood (1972) notes (without stated probabilities) that men more frequently become aware by seeing flames, hearing shouts and hearing the fire alarm and women more frequently become aware by seeing or smelling smoke and being told. One graph (p.38) presents the cues leading to first awareness in the following order of frequency (figures are approximate): smoke 35%, told 25%, see flame 15%, hear shouts 12%, noises 9%, alarm 7%, other 2%, heat 1%.

Table 4 gives a simplified version of the initial cues alerting U.K. and U.S. populations as presented by Bryan (Table lvib, p.243). Bryan gives slightly different percentage figures from Wood. The isolation of the variables in this table from any other variables and its very general information makes it of little value. It confirms the important role of smoke and shouted warnings in alerting people. The difference in *Seeing flames* is significant at the .01 level but could well reflect some simple cultural difference such as culinary style - perhaps more people in the seventies in the U.K. cooked their own chips!

TABLE 4: Comparison of cues alerting people in the UK and US
(Table is based on Table lvib, Bryan, p. 243)

		UK%	US%
Cue	Flame	15.0	08.1
	Smoke	34.0	35.1
	Noises	09.0	11.2
	Shouts & told	33.0	34.7
	Alarm	07.0	07.4
	Other	02.0	02.8

Table 5 lists the first cues reported by occupants in order of frequency according to Bryan (p. 85). The role of others in passing on information is demonstrated clearly, with 34.7% of respondents alerted by being told either by family members or other people. In fact this is the most frequent category. Such figures are not directly transferable to a database which uses finer coding and is more sensitive to other variables such as those from alarms.

TABLE 5: First Cues of 569 respondents (97.4 % of respondents)
From Bryan (p. 85)

First cues	%
Smell smoke	26.0
Told by others	21.3
Noise	18.6
Told by family	13.4
See smoke	9.1
See tire	8.1
Explosion	1.1
Feel heat	0.7
FB seen or heard	0.7
Electricity cut	0.7
Pet	0.3

Bryan (ch. vi) and Wood (pp. 79-85) present data on response to smoke, but more in terms of whether people would move through it or turn back and what personal characteristics (gender) this is related to. It does not discriminate smoke as a cue for deciding to evacuate or taking any other action but refers to smoke at any time in any location. Table 6 below presents relevant findings on responses to smoke. It lists the questions asked and gives the percentages of responses. These data have some value in determining probabilities of whether people will initiate or continue evacuation in the presence of smoke. Unfortunately, however, they do not provide information on other intervening variables which could well be highly significant in determining the responses, such as being aware that an exit is available, being with others, or knowing the location of the fire.

Bryan treats the visibility issue differently. He presents a table comparing the percentages who moved through smoke for a distance of more, equal to or less than they could see. 46% moved for a distance greater than the visibility distance. Bryan also compares first actions under two smoke spread conditions - a. room and one floor and b. two to seven floors - using similar categories for actions as in Section 7 below. The main difference is in Got *dressed,* with significantly more people getting dressed where the smoke spread is more extensive (13.7% to 2.4%). Bryan puts this down to smoke spreading further at night (p.187), presumably because the fire is detected later.

Bryan found statistically significant (.05 level) gender differences for seeing smoke and hearing noise. Males were more likely to be alerted by seeing smoke (12% males cf.. 6% females) and by hearing noise (22% cf. 15%).

TABLE 6: Responses to smoke
(Based on Bryan, ch. VI and Wood)

		Bryan	Wood
1. Was there any smoke?	Yes	Not clear - 99%?	88%
2. Did you move through it?	Yes	62.7% n=366	60% of the 88%
3. How far?	>17 yards	15.4%	
	20 yards or more		20%
4. How far could you see?	10 yards or less		75%
	20 yards or more		20%
5. Did you turn back?	Yes	29.2% of 62.7%	26% of 60%
6. How far could you see then?	2 yards or less	54.1%	66%
	10 yards or less	94.0%	88%

Section 6. Evacuation

Some data are available on numbers who evacuated. Bryan's measures of times and distances (Table 7 below) involved may have some value although is still subject to the aforementioned methodological problems.

Only half (54.5%) of Wood's subjects (but from 70% of incidents) evacuated. No figures are given on the occupancy or building types. As previously discussed (Section 5) people with ambiguous cues were **more** likely to evacuate where they had ambiguous cues (Wood, p.53). Additionally, they were **more** likely to evacuate *if* they *did* not *know* of an emergency escape route (>0.001 level of significance) (Wood, p. 70). They were fess likely to evacuate if they have been involved previously in a fire incident (>0.001) (p.70).

Nearly half (43%) went back in again for various reasons:

- 36% to fight fire
- 19% to observe fire
- 13% to save personal effects
- 10% to shut doors
- 9% to wait for the fire brigade
- 5% because the fire wasn't severe
- *2%* to rescue pets

These figures are of interest because they highlight a response that is not at present included in the Evacuation model which takes egress as an end action.

Bryan (pp. 70,72) reports that evacuation occurred before the arrival of the fire brigade in 264 of the 335 incidents (79%), after the arrival of the fire brigade in 76 and that in 83 incidents no-one evacuated, figures which do not compute. Bryan obtained estimates of distances (calculated by fire brigade personnel after people reported their movements) and times (nominated by the respondents). The distance measures would have a greater (but unknown) degree of reliability on the assumption that firefighters have more experience than the general public at making such estimations.

Of the *463* people who reported an evacuation distance, the mean distance was 41.7 feet. Of 431 reporting estimated evacuation time the mean was 1.92 minutes. 26.2% (153 people) did not report time and/or distance. Table 7 is derived from two tables (Bryan, pp. 191, 193) which present variations of the same information.

Some gender differences are indicated in relation to evacuation. Women are significantly (p>0.0001) more likely to evacuate over the course of the incident (Wood, p. 69) and more likely to evacuate as first action (7% as against 9%). Gender differences are discussed further in Section 6.

TABLE 7: Estimated times and distances reported by 431 evacuees

	1-25 feet	26-99 feet	>100 feet	%
30 seconds or less	54	43	3	18.6
31-60 seconds	70	72	15	27.0
61-120 secs	15	41	15	13.0
121-180 secs	12	21	2	6.2
181-240 secs	3	6	0	1.5
240-300 secs	6	14	8	5.1
	4	2	4	1.7
	2	1	1	0.7

Section 7. Actions

As the interest of researchers was in what behaviour took place and what this might be correlated with rather than the situational causes of behaviour, the link between cues and actions is not well established. For example, no data was obtained on what factors or combination of factors led people to major actions like evacuate or call the fire brigade. Wood points to a negative correlation between fire fighting and perceived seriousness of the fire. Bryan also states that with limited spread, more people went to the fire and tried to extinguish it. These two findings would support an (unstated) assumption of the Human Behaviour model that occupants will not attempt to fight a fire which is serious or perceived to be so.

Wood states that the questions on actions are the least satisfactory part of his questionnaire, not least because there is no indication of how long the actions took (1972, p. 89). Both researchers discriminate among first, second and third actions. In the light of Wood's statement, combining sequences of actions rather than treating them as separate entities may provide a more accurate picture. However, the time frame remains unknown. Tables 8 and 9 below present aggregated data in the second and third columns. The tables list categories of actions in order of frequency based on percentages of people undertaking them. It is well to remember the sample bias in considering these tables - the majority of respondents were people from single family dwellings. They had been close to the situation, not injured and spoke to firefighters. The tables show how the frequency of particular actions changes over time (an unknown time) and consequently how the percentage of people engaging in an action overall is modified.

Questions can be raised about the validity/reliability of the coding. Wood (p. 90) expresses surprise at the high rate of fire fighting. Fighting the fire represented almost a quarter of the first actions taken in factcries compared to only one tenth in dwellings (p.90). Although his sample contained factory fires, where arrangements may have been in place to fight fires, the figure may owe more to loose categorisation than to other factors. *Some fire fighting action* includes *Activities expressing the intention of fighting the fire*. This requires interpretation of actions by the coder but does not mean that the action of fighting the fire took place. In addition, the lack of sequential discrimination among cues and actions leads to statements which have a certain degree of oddity. An example is that 121 people who fought the fire as a first action had ambiguous cues (p. 53).

Another coded category which is not clearly explained is *Inaction*. 'Approximately 5% were inactive during the course of the event' (Wood, p. 46). Presumably this means throughout the incident. It may include those who decided not to leave or who did not know about the fire. *Doing nothing* was a considerably more popular response in the U.K. than in the U.S. according to Bryan's three tables lvii, lviia and lviib (pp. 246, 249 and 250) which compare the U.K and the U.S. data on a number of actions. Table 10 below selects the information provided *on Doing nothing.* No explanation is given for the difference but the most likely cause can be hypothesised to be that Bryan has adjusted the U.S. figures to allow for respondents who did not nominate three actions whilst Wood has concluded that not nominating an action meant that the person did nothing further. Such possibilities play havoc with statistical interpretations.

Another action, *Move towards fire* is a vague category. Wood states that it might represent an intention to fight the fire or to investigate. As people are likely to have reported either of these, it may also represent the behaviour of people who approach the fire merely to have a look.

TABLE 8: The twelve most common actions in order of frequency (based on Wood, Table 9, p. 43)

1st action	%	1st & 2nd combined	%	1st, 2nd, 3rd combined	%
Some fire fighting action	14.9	Some fire fighting action	16.6	Inaction (watch etc)	20.1
Investigate fire	12.8	Contact tire brigade	10.6	Some fire fighting action	15.2
Contact fire brigade	10.1	Protective action	9.0	Contact fire brigade	9.9
Protective action	10.1	Inaction	8.5	Leave building	8.4
Warn others	8.1	Leave building	8.4	Protective action	7.7
Leave building	8.0	Investigate fire	7.2	Investigate fire	5.0
Move towards fire	5.6	Warn other people	5.8	Warn other people	4.3
Get family out of building	5.4	Get family out of building	4.5	Move towards fire	3.3
Ask if fb contacted	2.8	Move towards fire	4.4	Get family out of building	3.2
Raise general alarm	2.7	Enquire if fb sent for	3.1	Enquire if fb sent for	2.8
Request help from others	2.2	Request help from others	2.3	Request help from others	2.0
Get dressed	2.2	Give help to others	2.2	Give help to others	2.0

TABLE 9: Twelve most common actions in order of frequency (Bryan)

1st action	%	1st & 2nd combined	%	lst, 2nd, 3rd combined	%
Notify others	15.0	Notify others	12.0	Leave building	21.4
Investigate fire	10.1	Leave building	14.2	Some fire fighting action	12.7
Contact fb	9.0	Contact fb	11.7	Contact fb	12.1
Get dressed	8.1	Some fire fighting action	11.6	Notify others	10.1
Some fire fighting action	10.4	Get family	6.7	Get family	4.9
Leave building	7.6	Investigate	6.2	Investigate	4.4
Get family	7.6	Get others to call brigade	3.1	Get others to call brigade	3.4
Leave area	4.3	Get personal property	2.9	Get dressed	3.4
Wake up	3.1	Protective action	2.7	Leave area	2.7
Protective action	3.6	Go to, activate tire alarm	2.4	Protective action	2.3
Nothing	2.7	Try to exit	2.0	Get personal property	2.2
Go to, activate tire alarm	2.5	Go to fire area	1.5	Go to, activate fire alarm	2.1

TABLE 10: Comparison of U.K. and U.S. populations re *Doing nothing* as an action

		Wood		Bryan	
	1st action	N=2193		N=580	
		2.1%	n=46	2.7%	n=16
Do nothing as:	**2nd action**	N=2 193		N=506	
		14.9%	n=326	%	
	3rd action	N=2193		N=365	
		43.1%	n=946	%	

For the purpose of adjusting the data to CESARE-Risk needs, some of the original coding of Wood and Bryan is modified. *Protective action* combines three of Wood's categories: *Shut door(s), Switch off gas/electricity* **and** *Do something to minimise risk.* Two categories of Bryan are aggregated. *Some fire fighting action* combines three of *his* categories: *Fight fire, Get extinguisher, Try to extinguish.* Also from Bryan, *Protective action* combines *Remove fuel, Close door to fire area* and *Turn off appliances.*

The 3 main types of reaction reported in Wood's summary conclusions *(1972,* p. *2) Evacuate, Some fire fighting/containment,* and *Alert others,* are not apparently supported by the data here. Adjustments made to the categories are not causing this discrepancy - Column 1 for instance has not been modified.

Bryan nominates significant gender differences in four actions (Table xlivb, p. 118.) *Get extinguisher* and *Investigate* are favoured by males, *Call fire brigade, Get family* and *Leave building* by females. Wood (Table 17(b), p. 66, and p. 67) found women were significantly more *likely* to *Warn others, evacuate the family, Request assistance* and *Immediately leave the building* and they were significantly *less* likely to *Fight fire* and *Minimise risks.* The percentages committing themselves to these actions are low (all under 10% except for 20% of males who claimed to have fought the fire which may reflect recalling or interpreting behaviour according to social expectations as well as the fact that the category reflects intention as well as action.) The differences between males and females presented by Wood are only of an order of about 2 or 3%. They may reflect sample bias (eg. the influence of factory fires) as well as role behaviour within households. If the category *Minimising risks* is combined with *'Shut door(s)'* and *'Switch off mains'* the percentages change to men 10% and women 11% (presumably not significant.) The decision to avoid considering gender differences in the Human Behaviour Model appears to be reasonable.

Establishing probabilities for people giving warnings, contacting the fire brigade, fighting the fire, sounding an alarm, evacuating and so on is difficult using the data as presented in the reports because of the aggregation of data and because there is insufficient information on the 'prevailing situation for a start. For example, we do not know how many people are recipients of warnings or the location of recipients. Given the number of house fires, the majority of warnings must be to people within the house. This does not provide a basis for a probability figure for warning people in other apartments, let alone receiving a warning needed by the HB model. In calculating the probability of contacting the fire brigade, we need to know something of the prevailing conditions.

Percentage figures for the U.K and the U.S. presented by Bryan (Tables lvii, lviia and lviib pp. 246-250 - the U.K. figures are from Wood, Table 9, p. 63) were used to calculate the actual numbers of people involved for first, second and third actions. The data on three actions in Table 11 below is selected from data on a number of actions.

Whilst converting the percentages does not lead to whole numbers and so casts doubt on the accuracy of the percentages, the process gives some indication of the numbers taking particular actions. Three actions were considered for this exercise: *Contacting the fire brigade, Pulling an alarm* and *Notifying others.* The figures suggest that of the people close to the fire (ie. those interviewed) approximately 30% will contact the fire brigade, 2-4% will sound the alarm, and between 12% (U.K.) and 27% (U.S.) will notify others. Of course, the time of occurrence of an action like contacting the fire brigade is very significant. As a second or third action it may well occur after evacuation. This cannot be ascertained from the data. Reasons for the similarities and differences in response frequency can only be surmised.

TABLE 11: Frequency of specific actions reported by respondents
Table is based on Bryan, Tables lvii, Iviia, Iviib, pp. 246, 249, 250

		Wood (N=2193)		Bryan*	
contact fb	**1st action**	10.1%	n=221	9.0%	n=52
	2nd action	**11.1%**	**243**	**14.5%**	**73**
	3rd action	**8.5%**	**186**	**12.7%**	**46**
		650/2193 = **29.6%**		**1681580 = 29.5 %**	
Pull alarm	**1st action**	**2.7%**	**59**	**0.9%**	**5**
	2nd action	1.1%	**24**	**0.6%**	**3**
	3rd action	**0.2%**	**4**	**0%**	**0**
		8712193 = 3.9 %		8/580 **= 1.7 %**	
Notify others	**1st action**	**8.1%**	**177**	15%	**87**
	2nd action	**3.6%**	**79**	**9.6%**	**49**
	3rd action	1.1%	**24**	**5.8%**	**21**
		28012193 = 12.8 %		**1571580 = 27.1%**	

Note: *Bryan: 1st action N=580, **2nd action** N=506, 3rd action N=365.
580 is taken as the sample size

Section 8 Summary and conclusion

The research of Wood and Bryan seeking data on human behaviour across a large number of fires constitutes an important body of data in the area of human response where most field studies refer to only one incident. At the same time, the broad base reduces the potential of the research for providing the information on emergency response in specific occupancies required by the CESARE RISK model. The aggregation of data gives a general picture of response. The studies did not aim to compare behaviour by occupancy. One table presented by Wood however hints that response in houses is similar to that in apartments. Further support for this would open the way to extending the CESARE RISK database, although it would entail ignoring major features of behaviour such as warning neighbouring apartments.

The studies, responding to a need of the time, placed emphasis on actions rather than on the triggers for the actions. The CESARE-RISK model gives particular emphasis to the connection between cues and actions, seeking the probabilities of different occupant groups to respond to different cues and to decide to evacuate. One cue-action link explored in some detail in the research is about preparedness to move through smoke. This has some relevance to the Evacuation model but not to the Response model which focuses on why people move in the first place. The importance of smoke, hearing shouts and being warned as initial alerting cues is evident. Again, however, these cues are not linked to actions.

The CESARE RISK model is concerned primarily with the move to evacuate. Other actions are of interest because of their potential for time delay or because they are actions which influence other people such as warnings. Much of the detail on types of actions in the reports is not of value to the model. The concern of early researchers with time loss as a safety issue was not translated into seeking data on actual times. Cues and actions are not time or place located.

A response mentioned in the studies that is not considered in the present Evacuation model is that of re-entering a building after evacuating it, an action that is not uncommon. Given that these fires were serious enough to warrant calling the fire services, the frequency of non-evacuation, at least among Wood's subjects, is also worth repeating. The studies give some support to the decision to not consider gender differences or fire-fighting behaviour in the model.

In summary, it is more appropriate to see the findings of the research of Wood and Bryan as indicating the direction of action probabilities rather than providing reliable data on them. They have use as a comparative standard for Australian data but do not have the detailed information required by the CESARE-RISK model.

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REPORT ON FINDINGS OF J.D. SIME
RELEVANT TO HUMAN BEHAVIOUR MODEL

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REPORT ON FINDINGS OF J. D. SIME RELEVANT TO HUMAN BEHAVIOUR MODEL

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Jonathan Sime has been working in the area of human behaviour in fires for some 20 years. He has been the author or co-author of a large number of articles and research papers. He completed his PhD Thesis Escape Behaviour in Fires: panic or affiliation? in 1984. This thesis contains the bulk of his empirical findings on human behaviour in fires. His articles show an increasing predilection for using acronyms and initial letters of words which can interfere with communication of information (eg. Sime, 1996). Recent papers indicate a broadening of interest to other areas of applied environmental psychology.

Along with Wood, Bryan, Canter and others he demonstrates that peoples' behaviour in a fire situation is predictable. His early work highlighted the role of certain social-psychological characteristics in determining response patterns and so gave a theoretical perspective to observations of behaviour. He has since then argued consistently for the reconciliation of two ways of approaching fire design - the so-called physical science model which uses objective features of the situation (eg. fire and smoke spread, distance to and width of exits, number of people present) as the determinants of time to escape and the psychological model which considers the subjective perception of participants in the situation (eg. knowledge of the fire situation and the building, affiliative movement in and towards *family* groups, the preference for familiar escape routes, and social role). Because of its emphasis on environmental determinism, Sime links the physical science model to engineering and fire science and to media reporting of fires, and associates it with the persistence of the concept of panic (a response for which field researchers find very little if any evidence and which Sime argues is operationally untestable in any case) because it promotes the idea of the individual as an object.

Sime (1994, p. SO) notes that knowledge about social psychological influences on human response in fire emergencies has not been translated into specific recommendations in fire design codes but is reserved as commentary. Many of his articles expound the themes of the psychological model with particular emphasis on affiliation. The principles are generally illustrated with reference to some major fire incidents which have been examined in some detail (usually on the basis of police witness reports) and to experimental studies, and supported with reference to other related findings. It is not always possible to accurately assess the findings which represent summary conclusions from unpublished in-house reports.

Sime's interest in time is more about how it is to be expressed in fire engineering models and building codes than in the provision of empirical data to substantiate the claims. He stresses the importance of reaction in the initial stages of alert on total response time, distinguishing pre-movement time from evacuation ('flow' or 'travel') time. Sime categorises investigation, gathering and other activities not directed towards immediate egress as possible in both phases (Sime, 1996 p.768), recognising that the phases are not necessarily discrete. He also, however, suggests that pre-escape movement is a phase in its own right. Escape behaviour is seen as a final strategy if alternatives don't reduce threat (1984, p.10).

> *The Human Behaviour Model avoids the practical difficulties which arise if one tries to distinguish the time for different responses or a set of responses with very different goals to occur before evacuation by treating time-related behaviour [but not the probabilities for the behaviour) in two periods: the time before evacuation begins and the time for the actual process of evacuation to be carried* out.

Sime proposes the use of a baseline figure for evacuation with adjustment according to a safety factor based on occupancy type and occupant. Estimates of **basal** times for the pre-movement period are not apparently based on empirical data but put forward as a starting point to demonstrate the process. The times are then adjusted according to an occupant efficiency factor. This is assessed by profiling the occupancy and its population using a complexity of characteristics. Some key parameters are whether the occupants are alert (awake/asleep), numbers, primary groups, activities, organisational hierarchy and roles, mobility, familiarity of different groups (eg. staff and public), warning systems, training, wayfinding and architectural layout. Sime's occupant efficiency factors nominate determinants of different response times across occupancies but do not appear to be applied to effectively distinguish occupants within a building. The estimates of the values are subjective and rely on expert opinion (from individual research and work with others at the Fire Research Station) more than empirical data.

While some of these characteristics are pre-defined in the Building Model, the Human Behaviour Model takes into consideration alertness, numbers, family groupings, mobility and warning systems. It also considers whether the person is alone or in contact with others. It assumes that the population is naive or untrained. Estimates of pre-evacuation times for the Response Model will be based on quantitative data from actual fire evacuations considering population sub-groups. Times for the Evacuation Model are calculated using algorithms from Pauls and Fruin.

The videoed simulations (field experiments) which provide precise information on time (but lack fire cues) are of evacuations of a lecture theatre in response to an alarm and an instruction to leave and evacuations of Monument Station, Newcastle under four types of warning systems. The former showed that two thirds of the total evacuation time was pre-movement time. Proulx and Sime amply demonstrated in the latter that the type of warning significantly modified the time to start evacuation, use of a directive public announcement being most efficient and of a bell being least effective. This confirmed findings from other studies (Keating & Loftus, 1974,1977; Canter et al, 1988; Bellamy & Geyer, 1990; Proulx et al,1994).

The Human Behaviour Model distinguishes among break glass alarms, local (smoke) alarms, EWIS, and direct (person to person) warnings and instructions as cues for action.

Sime's thesis considers behaviour in 14 house fires (21 occupants, 13 neighbours), a hotel fire (28 occupants), and the Marquee Showbar (75 people) and Solarium (128 people) in the Summerland fire of 1973. Other main fire incidents Sime researched and refers to include the Woolworth's department store of 197.5 and a nurse's hall of residence (Sime, 1994). Aspects of many smaller incidents including house fires were investigated with researchers (eg. Canter, Breaux) connected with the Fire Research Station, U.K.

The incident types reviewed in the thesis are treated separately and are used to illustrate different themes (there is of course some overlap): sequences of behaviour (house fires), movement patterns (hotel fire), exit choice behaviour (Marquee Showbar, the area most exposed to the fire) and affiliative behaviour (Solarium). Using police witness statements, Sime investigated the response of people in the Marquee Showbar at Summerland to provide evidence for the following as significant social-psychological features in the *direction* of escape behaviour:

1. movement was towards and/or with family groups (affiliation)
2. people tended to use familiar escape routes, the public following their entrance route and the staff selecting fire stairs they frequently used. Location at the time of cue in relation to other group members and exits was also relevant.
3. the public took guidance from staff

4. role behaviour was reflected in 2. and 3.
5. family members who started evacuating together tended to be together when they exited the building, mixed group members were more likely to be separated.

Sime sees affiliation as a key psychological reaction. In the Solarium affiliation to others was to family members. In practice affiliation seems to cover a wide range of social behaviour - people waiting for others, returning to others after investigating, moving towards others (and towards familiar places) when entrapment threatens.

Sime also found that for both areas of Summerland people in family groups which were intact at the time of first cue were slower to respond initially than people who were separated, slower to evacuate because they moved at the pace of the slowest member, and more likely to suffer injury. This finding for Summerland is influenced by the fact that, for some adults from non-intact family groups at first cue, movement meant a search for children who happened to be below the fire floor.

> *The Human Behaviour Model assumes that five of the six nominated occupant groups of apartments will respond as a group. The sixth group (non-related individuals} can act independently.*

It is to be noted that the Summerland fire was a recreational complex not a residential building. An important feature of the incident was that there was very little time between the first cue reaching the majority of people (a warning) and arrival of the well advanced fire, reflecting delay in realisation of the danger, in contacting the fire brigade and in warning people. An additional delay factor was that people were engrossed in activities. No times are attached to actions and cues are not detailed. Basically the people were responding to alarms and smoke as they were evacuating because of the delayed warnings. The interaction of people with each other is interpreted as a response feature and not considered as a potential cue for further action.

Other fires that have been investigated provide even less information on the pre-movement stage of the incidents. They are really studies of the direction of movement in relation to evacuation. There was a similarity between the Woolworth fire and the Surnrnerland fire in the causes of delay (1994 p.69). From the Woolworth fire, Sime determined that there were interrelationships between floor level, role (staff or public) and exit route, from the nurses' hall of residence exit used was determined by one's floor location and smoke severity, and likelihood of injury was related to the exit used (probably because of the eight of thirteen people on the fire floor who jumped from second floor windows!). Fire cues and fire location, however, can be seen as the overall determinant of exit route in both cases as smoke and fire blocked exit routes.

> *The direction and progress of actual evacuation in the Evacuation Model is governed by fire conditions.*

Summary

Sime has been a consistent advocate for the inclusion of social-psychological aspects of human behaviour in fires in the planning of building codes and in fire science generally. His earlier investigative work in the 'eighties has been the empirical basis for his position. Perusal of these studies shows that quantitative data in them is mostly related to the Evacuation sub-Model of the Human Behaviour Model. However, they provide support for many aspects of the Response Model.

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