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THE SCIENCE OF HUMAN BEHAVIOUR; PAST RESEARCH ENDEAVOURS, CURRENT DEVELOPMENTS AND FASHIONING A RESEARCH AGENDA

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ABSTRACT
The development of human behaviour in fire into an area of scholarly study of vital importance has been extremely rapid. The advent of performance based fire safety regulations and codes together with the needs for robust computer evacuation simulation models gives further impetus and sense of purpose for future endeavours. Hard fire science alone cannot solve the "fire problem". With increasing international emphasis on community fire safety policy initiatives knowledge of occupant behavioural characteristics associated with fire is essential. To develop the human behaviour knowledge base a coherent collaborative strategic research programme which delivers value for money is essential. In this paper some thoughts on the way forward are presented for discussion.

KEYWORDS:
Human behaviour, research, training, education, management, simulation.

1.0 INTRODUCTION

Given the title of this paper it is considered practicable and necessary to structure the content with respect to fire safety as follows: a few reflections on the phased development of studies on human behaviour in fire, some discussions on the transition from prescriptive to performance based codes with respect to human behaviour knowledge, and finally suggestions for a research agenda in times of decreasing research funding. Of necessity, the treatment of some of the discussion issues raised in this paper will be brief, but brevity in presentation does not dilute their importance.

2.0 PHASES IN THE DEVELOPMENT OF HUMAN BEHAVIOUR IN FIRE

In his paper presented at the First International Symposium on Human Behaviour in Fire in 1998, Pauls [1] partitioned the development of human behaviour in fire into four distinct phases. According to Pauls, Phase 1 commenced in 1956 with work by John Bryan [2] which was followed in 1972 by the Behaviour of People in Fires study by Woods [3]. Evacuation drills in large office buildings in Canada were documented through 1969 - 1974. Also in 1974, NBS Technical Note 818, Occupant Behaviour in Building Fires, authored by Ruben and Cohen was published [4]. In 1977, NBS published a report entitled: "An Assessment of the Technical Literature on Emergency Egress from Buildings" [5]. During the seventies individuals with interest in the field of human behaviour in fire met and organised various activities including a workshop on Human Behaviour in Fire Emergencies [1].

The second phase in the development of human behaviour in fire was characterised by major programmes of research and international seminars held in the United States of America [6] and United Kingdom [7]. During this phase, Canter edited his book "Fires and Human Behaviour" [8], as was published other major papers and reports in this field [9,10]. The following words used by Pauls in describing Phase 2 are significant and timely "with the drying up of research funding during the 1980's a bibliography by Paulsen [11] included most of the work in the field performed mainly during the second phase". The reasons why the research funding was drying up were not identified but perhaps similar reasons apply today as fire scientists perceive that their research funding is drying up if not disappearing. Today underlying reasons advanced for research funding reductions with respect to fire safety science include insufficient relevant beneficial application with respect to fire safety regulation.

The third phase saw major contributions from Sime [12] and Bryans [13] together with reports on major fire incidents characterised by large loss of life. The third phase also marked the emergence of new contributors to the field, e.g., Shields et al [14,15,16], Proulx [17,18,19] and Fahy [20,21]. A major International Symposium and Workshops on Engineering Fire Safety in the Process of Design in advance of draft performance based codes, sought to explore the integration of human behaviour and fire safety design in addition to addressing the concerns of impaired occupants of buildings [22,23]. The latter was a major theme of the third phase in which seminal works [14,15] were produced and continues into the fourth phase of human behaviour in fire. Also and importantly issues associated with flight behaviour were addressed. The concept of panic was critically appraised as an inappropriate way to describe and explain human behaviour in fire disasters [12,24].

Phase 4, according to Pauls, started with the First International Symposium on Human Behaviour in Fire in Belfast, 1998 [25]. As he eloquently put the intent of the organisers "the Symposium programme highlights the work of long established researchers as well as the work of the next generation of leaders - reflective musings on past accomplishments blend with a range of new contributions to the field".

We are pleased to say that the First International Symposium on Human Behaviour in Fire was an immense success. Two hundred and twenty three delegates from twenty three countries attended this event and seventy four papers were presented. It is worth remarking here, that the First International Symposium in Human Behaviour in Fire had its origins in the Fifth International Symposium on Fire Safety Science in Melbourne, in 1996.

Among the voices heard at the advent of the fourth phase Brennan [26] raised issues with respect to social equity which given some discredited national "care in the community health policies" is timely. Saunders [27] postulated that differences in observed behaviour in response to some fire emergencies in different environments could be explained by the mode of cognitive processing induced in emergencies. Ozel [28] discussed the role of

time pressure and stress on the decision making process during fire emergencies. She argued that distortions in the decision making capacity of individuals within the context of effective decision making during emergencies have never been considered. The different coping mechanisms of evacuees in emergencies, it was agreed need further research. Ozel identified many research questions including the effect of stress, negative associations, perceptual field reduction, building design, and information processing capacities of different age groups. Chubb [29] argued that although previous research may have produced a catalogue of human behaviours. There was only a relatively limited understanding of the processes which determine a persons actions or inactions in any given set of circumstances. He proffered a cognitive systems approach to understanding the decision making process of individuals exposed to fire by examining the dimensions of fire related situational awareness which affects the perception of those events by individual decision makers. Benthorn [30] reported on a study which sought to discover how evacuees evaluate information and choose an exit. His findings are supported by the results obtained in unannounced evacuation of retail stores [31,32,33,34]. In discussing the perception of threat in incipient cues by naive occupants Brennan [35] suggested that more research be directed towards how occupants perceive threat and especially with vague cues which characterized the early stages of a fire. Proulx [36] discussed the response change induced in elderly occupants of a high rise residential building receiving instructions by means of a voice communication system during an actual fire emergency. Shields et al [37,38] reported the results of unannounced evacuation of retail stores and the use of the data obtained in simulation modelling. Sime [39] in presenting an occupant response model, introduced variables such as visual accessibility, spatial configuration, usage patterns and exit magnetism.

An area as yet relatively unexplored, i.e., the behaviours of occupants with learning difficulties was introduced by Shields et al [40]. Preliminary work in this area suggests non-transferrable behaviours between daytime and night-time evacuation activities and individuals. Hinks [41] et al argued that there is little integration into design solutions of the substantially large body of sophisticated understanding about the interrelationship between visual impairment and navigational behaviour from social sciences. Tanaka [42] discussed the results of a study into wayfinding in subterranean spaces raising issues with respect to the cognitive processes employed by the participants and increased levels of anxiety. Horasan et al [43] in discussing orientation problems in large spaces argued, that floor layout simplicity must be the main criteria. Yaping and Brennan [44] discussed a way to convert physical smoke parameters into smoke categorization related to the smoke visual appearances. Heskestad et al [45] presented a framework for the next generation of escape through smoke experiments. Groner [46] in proposing an intentional systems representations of fire related human behaviour detailed the limitation of physical systems representations in modelling cognitively-derived human behaviours. Brannigan & Smidths [47] postulated that fire protection engineers do not receive extensive training in human decision making and distinguished between estimations as credible values for real data points and conditions as requirements for model validation.

3.0 TRANSITION FROM PRESCRIPTIVE TO PERFORMANCE BASED FIRE REGULATIONS

As fire safety engineering matures and the domains of prescriptive and based regulations are better defined, it is worth reflecting on the words of Groner [48], "of all the intractable elements that can be enlisted in a defence against fire, people are the most neglected by prescriptive codes. Yet, in most settings, favourable outcomes to fire emergencies depend in large part on the actions and decisions taken by building occupants. The use of a performance based design options is an opportunity to fully integrate human performance into the engineering of fire safe buildings. If we miss this opportunity, our efforts to model total systems performance will be less accurate, resulting in performance based designs that are needlessly risky or cost-inefficient."

It is not intended to present a detailed historical review of the development of performance based fire safety regulations and/or codes. Neither will any distinction be made between performance based regulation and codes as there is already much in the literature [50,51]. Suffice to say, the performance based movement is global and apparently gaining in momentum. None the less, it is useful as the transition from prescriptive, through functional, to performance based fire safety continues to reflect, with respect to human behaviour in fire, first on prescriptive regulations and secondly, performance based codes and documents.

Prescriptive-based fire regulations are in effect silent with respect to human behaviour in fire. The provision of let say, means of escape from fire, based on geometric considerations was deemed adequate irrespective of occupant response patterns to fire cues, attitudes toward fire safety, contra flows in egress routes, demographic trends and the growing number of occupants presenting either physical and/or psychological impairments. Further, in many jurisdictions as a convenient expediency, good management was deemed in place and effective: "this document has been written on the assumption that the building concerned will be properly managed. Failure to take proper management responsibility may result in the prosecution of a building owner or occupier under legislation such as the Fire Precautions Act or the Health and Safety at Work etc Act and/or prohibition of the use of the premises" is a quote from Building Regulations (England and Wales) 1991, Fire Safety, Approved Document B [53].

Fire safety engineering and performance based codes will principally assist with novel and complex designs, with much of the bread and butter fire safety being more economically handled by simple prescription [54]. This may in fact be the case but simple prescription with respect to the intrinsic safety of buildings may not in affect induce a significant reduction in the loss of life and number of casualties caused by fire, eg, especially in residential occupancies. It is an established fact that most fire fatalities occur in dwellings, and given a value of life, in fire regulatory terms, of around £1,000,000 [55], simple effective economical prescription to reduce life loss etc. is an unachievable ideal. The real issue that has not yet been addressed is how knowledge of human behaviour can be effectively used within or as complimentary to a prescriptive regulatory system.

Even within a partially prescriptive commonly called functional system, to obtain tangible sustainable benefits, it is necessary to change long established ingrained attitudes and behaviours in people with respect to fire safety. Prescription must be complimented by community fire safety policies that emphasise fire safety education and training with special efforts directed towards people in society most at risk from fire. However, effective implementation of community based fire safety policies will only be achieved if the tactics employed are based on sound knowledge of human behaviour with respect to fire.

Now to focus for a little while on recent developments towards performance based fire codes. In the BSI DD240 [56] document under the quantitative design review procedures, an occupant characterisation exercise is required. The occupant characteristics which influence responses in a fire emergency are given: familiarity with the building, alertness, mobility, role and responsibility, position within the building, commitment, and presence of focal points within the building. Some treatment of these occupant characteristics is offered for discussion.

Familiarity is described "as occupants who use the building daily and are trained in or are aware of the fire safety procedures. In an unfamiliar building, people will tend to evacuate via the route they came in. It is well known that the preference of most occupants is to evacuate the way they came in if they can!" Occupants who use a building daily may not be trained or even be aware of the fire safety procedures, ie, using a building daily does not necessarily make a person familiar with the fire safety features for that building. Also familiarity is not a guarantee that during a fire occupants will use an alternative way out. Consequently the treatment offered is not helpful and familiarity is not a sufficient indicator/descriptor of likely occupant behaviours. The fundamental question yet to be addressed is "why do people want to evacuate the way they came in". These actions have been observed but the "why" has not been determined.

The characteristic alertness is described as "the involvement of people with the activities being carried out within the building, or their interaction with the other occupants of the building which can effect their awareness of other circumstances. For instance, if people are in bed and asleep, their response to a fire alarm is likely to be considerably delayed". How are these two statements connected, especially if activity is associated normally with functioning in an awakened state, it also begs the question as how information is actually processed by different occupants engaged in different activities and hence what can be done to interrupt normal occupant information processing to obtain a shift of attention onto the existence of an emergency.

The characteristic of mobility is treated with respect to travel speeds associated with evacuation with little discussion of the many factors which may first induce and affect the direction and speed of movement. For example the capability to manipulate door furniture is not considered.

The treatment of social affiliation almost ignores group dynamics; gathering and clustering behaviours, and the fact that in certain settings the groups dynamic may result in non-evacuation behaviours [57].

It is understood that culture, role and responsibility will influence behaviours but unfortunately, the document is not explicit with respect to which behaviours can be related to which roles and responsibilities, never mind organisational and national cultures.

With respect to the characteristic of position does the treatment in DD240 apply to fire stations? Is position really an occupant characteristic? Is motivation really a function of position? Does a mobile occupant's position really matter very much if the threat of imminent danger from fire is graphically and immediately conveyed.

Commitment is an important characteristic related to the activity in which the occupant is engaged. It can also be a positive aspect, which can be used to good effect in fire safety design. Unfortunately, only the potentially negative aspects of commitment are conveyed in DD240.

Settings and focal points in buildings in combination with commitment and good management are extremely important in fire safety design. Using natural occupant flows, focal points, queuing and occupant commitment, emergency exits which automatically open in an emergency can be positioned in a building to maximise the evacuation potential of their respective focal areas. Still the question remains, how are settings and focal points actually integrated into a fire safety engineering design?

In BS DD240 pre-movement is defined in terms of recognition and response. Unfortunately, the response element as it is defined is not devoid of movement and hence is in conflict with this notion of pre-movement. It follows perhaps if pre-movement is rather ambiguously defined the associated human behaviours may not be well enough understood by the code writers.

In the development of ISO/CD 13387-8, documents [58] occupant characteristics similar to those discussed above are included and similar criticisms apply. However by virtue of being a stand alone technical document there is room for discussion on some of the behaviour inducing effects of fire and the internal building environment. In essence, the psychological as well as the physiological effects of exposure to fire and smoke are introduced to the reader.

The ISO document in discussing engineering methods categorises simulation evacuation models in terms of; a) attempts to describe aspects of behaviour and/or movement by an equation or equations, b) attempts to describe various aspects of human movement, and c) attempts to link movement with behaviour. The evolution of evacuation modelling is depicted with emphasis on models which link behaviour and movement and which vary

in complexity and sophistication [20, 59]. The lack of basic data on many aspects of human behaviour is acknowledged together with its affect on the potential predictive power of behaviour/movement linked simulation models.

Behaviours associated with occupants of buildings and fire are complex. They involve people, spatial and environmental interactions and cross impacts which occur in the psychological, sociological and physiological domains as identified by Bryan [13] some time ago. In the ISO document in contrast to the BSI DD240, human behaviour in fire in all its complexity is at least introduced and developed to inform the reader of the state of the art and therein lies a challenge to performance based fire code writers: "to ensure that what is contained in Codes with respect to human behaviour is based on work of some substance".

To arrive where we are, at the present time it has been sufficient to use the results of research which identified action patterns and sequences. In effect not much work has been conducted to really determine the underlying causation of such action patterns and sequences and whether or not they are transferable from occupancies of similar types. As an example, the documents discussed earlier use the term familiarity as a "positive" occupant characteristic. If occupants are constantly exposed to a stimulus, such as emergency exit signs, the magnitude of their responses will decline and the response on occasions may not occur at all, ie something which is a frequent occurrence with respect to the emergency exits. Although the documents attempt to introduce aspects of human in fire phenomenon such as habituation are ignored. Another area directly associated to the previous discussion is stimulus equivalence in that many stimuli could serve the same function, for example, those used to convey sources of help, reassurance and safety in emergencies applied to e.g. emergency exits. One wonders what precisely was the human behaviour input into current codes regarding provision of emergency signs in buildings.

Clearly even a brief examination of developments towards performance based codes will identify a rather insecure foundation for some content purporting to be based on substantive human behaviour studies in fire. Nevertheless, a substantive start has been made and developments in fire safety engineering and performance based fire codes gives new life to human behaviour in fire studies. We strongly believe that development of credible performance based codes cannot be successfully realised done carried out without detailed knowledge of human behaviour, or perhaps more correctly put, human performance in fire. While we are establishing where we are at in the development of the subject and looking forward with enthusiasm and high expectations, let us not forget the admonition from Mark Twain: "there is something fascinating about science, we get such a wholesale return of conjecture from such a trifling investment in fact". The forth phase in the development of the subject of human behaviour or human performance in fire must take us way beyond mere conjecture. That is the challenge for the not so new, newer and newest practitioners in this fascinating field.

4.0 SHAPING THE FUTURE

Human behaviour in fire is not an isolated issue, most of us work and live under some sort of health and safety legislative umbrella. There are many other groups working in sister areas such as safety, accident prevention, ergonomics and accessibility which are complimentary to our endeavours in the field of human performance in fire. To echo a call made during the plenary session at the First International Symposium in Human Behaviour in Fire [25] in 1998 by Pauls, "Let's join the rest of the world on safety and usability issues", there is much to be gained. Some national standards bodies should think about inclusiveness and widening access to key committees particularly those dealing with human performance in fire. The issues to be discussed are too important for those with something to contribute to be excluded from participation on grounds of geographical location and/or costs. Fuller involvement of people with knowledge of the subject would be a major step forward.

At the present time, we know that the vast majority of fatal and not fatal casualties occur in residential occupancies of all types. Performance based regulation of fire safety is likely to have little impact on current national fire casualty rates in dwellings. Over the Christmas period of 1998 in Northern Ireland, ten people died in house fires from January to March 13th 1999, 19 people lost their lives in house fires, ie, more than the total life loss from fire in Northern Ireland in 1990 [60], some died because batteries were removed from smoke alarms and not replaced. More "Hard Fire Science" as we know it, won't change ingrained attitudes to fire safety. To effect sustainable fire safety in the home and other occupancies, we need first to understand the formative processes which have resulted in current attitudes toward fire safety and seek cost effective long term solutions to effect change. The solution won't be a Fire Safety Engineering solution in the sense that fire safety engineering is currently promoted. It will be a global fire safety engineering solution based on effective implementation of community fire safety policies [61], ie, the vast majority of fatal fires are accidental and preventable. Thus prevention has primacy. The implementation strategies employed to be effective must be rooted in knowledge of human performance in fire.

From pioneers in the field of human behaviour we have inherited templates of behaviours for occupants of some types of buildings. These templates are in essence used as schemes to organise the decision processes and corresponding behaviours of building occupants from computer simulation through the reconstruction of fire events [1] and in practice, over time have been subject to some over generalisation. Issues arise as to precisely how characteristic such as existing schemes are, with respect to particular applications, how the schemes of behaviours were actually obtained in the first place, the underlying causes of behaviour and the strengths of the linkages between transition states. We need a robust set of occupancy specific human behaviour/performance templates that can be reliably used to formulate solutions to particular problems. It is not glamorous research but it needs to be done.

Following directly from the previous section, consideration needs to be given to

occupancy classifications currently in use in various jurisdictions. In some cases the occupancy classification is there to facilitate the administration and application of prescriptive regulations and without the use of sub-classifications are rendered inappropriate by multi-functional complexes and performance based engineering. Strangely, some occupancy classification schemes in use are related to fire load instead of; occupant characteristics, susceptibility to fire, emergency response capabilities and management. Fire protection afforded to escape routes is related to fire severity via fire load, not to occupant evacuation capability. Clearly, there is a need to develop occupancy classifications based on variables affecting human behaviour/performance in response to an emergency. Then an agreement on data used for performance based fire safety design should follow.

Many of the myths surrounding human behaviour in fire have been exposed. The best example being the notion of panic [12,24,62] which as previously discussed is now understood to be a very rare event. Today, human behaviour in fire, including flight behaviours are understood as a logical attempt to deal with a complex rapidly changing situation in which minimal information is available for decision and action. In this context, there is still much to do to develop our understanding of people as information processing units in emergency situations and buildings as information systems.

The design challenge of wayfinding in the architecturing of space [63,64,65,66] has been simplistically reduced to emergency exit identification and escape route illumination. This failed minimalistic approach ignores the cognitive and perceptual processes associated with movement, visual access and spatial behaviour of occupants evacuating under emergency conditions. It is surely unacceptable that wayfinding and wayfinding provision by means of conventional code complying directional signs, is deemed sufficient in eg, health care buildings with young inpatients and/or outpatients with learning difficulties or mental impairments. Wayfinding to remind ourselves is the ability to reach desired destinations in the natural and built environment in our case a place of safety in an emergency. From a design aspect wayfinding comprises two distinct elements; spatial organisation and environmental communication. The former relates to function, ordering of functions, provision of facilities and the creation of circulation systems which in effect from the outset, set the wayfinding problems users have to solve. The latter of course refers to the environment as an information system, ie, the graphical and architectural articulation of information which is necessary to solve the wayfinding problem. In point of fact, by definition the characterisation of the building and its occupants by the design team solves the wayfinding problem [65,66]. We don't believe that what passes for performance based codes and fire safety engineering guidance documents address this universal design issue. The whole issue of wayfinding in buildings needs to be revisited such that natural flows of occupants, focal points, visual perception, occupant visual accessability and expectation about building design are taken into account.

With advances in computer science and computing power, the decision making schemes

referred to earlier have been used to some effect in the development and production of computer and evacuation simulation and risk assessment techniques. Suffice to say that we know that real human evacuation decision making and movement is significantly more complex that water flowing in pipes or snooker balls rolling on a snooker table. There is still much to learn about human behaviour in real emergency evacuations which will advance the next generation of human behaviour evacuation simulation models. However, as we stand today there are concerns [67] about the use and misuse of human behaviour research in computer based evacuation simulation. These concerns include the validation of models in "normal" evacuations or evacuation drills, ie, these types of evacuations are not characterised by behaviours associated with real emergency evacuations; the notion that movement speeds or evacuation flow rates will be higher in a real emergency than in a drill is without foundation but it is often assumed. As Byran [67] put it, "the increased application of the human behaviour in fire research into computer evacuation models for performance codes requires that all human behaviour researchers must continue the highest standards of professional integrity and responsibility".

At the present time there are over twenty-two different evacuation models at various stages of development [59]. The view was expressed at the plenary session of the First International Symposium on Human Behaviour in Fire [25] in 1998 that there are too many models and that regulators want fewer, better, universally accepted computer based evacuation simulation models. Thus, with respect to future developments a strategic approach is required which addresses resourcing and rationalisation.

We believe that:

- a collaborative evacuation simulation modelling strategy should be developed which would deliver the required universally accepted fire safety engineering tools. This requires the co-operation of national institutions, international bodies and universities. Some sacred cows may have to be put out to grass but it is perhaps a price worth paying,
- transparency of simulation protocols is an essential pre-requisite to the adoption of any model,
- The meaning of validation with respect to simulation modelling and validation procedures must be agreed and universally accepted,
- behavioural models must include pre-evacuation activities and the associated time delays including means of alerting building occupants,
- there must be agreement on evacuation protocols for use in experimental studies. Such agreement will promote uniformity in data collection, and improve data quality,
- the influence of staff involved in managing fire safety and emergency evacuations is crucially important and must be included in future model developments,
- the evacuation capabilities of mixed ability occupants based on knowledge of predictable behaviours including occupants with learning difficulties or mental

impairments must be accommodated in simulation modelling of evacuations, where appropriate,

- fire safety education, training and experience influence emergency evacuation behaviours and must be included in the occupant characterisation process and hence in simulation models.
- evacuation simulation models by definition in some sense model the building consequently, issues associated with wayfinding, visual access, spatial configuration, alternative destinations and focal areas must be addressed,
- the potential impact of the choice, positioning and setting of common building elements is not sufficiently taken into account an evacuation simulation. By way of example:

    - the positions of doors in corridors close to intersections can deny access to wheelchair users,
    - closing forces associated with door closers are not matched to the opening forces capable of being exerted by some occupants,
    - negotiation of doors by disabled people can be an extremely complex, time consuming process,
    - door furniture may not be chosen to match occupants capabilities,
    - spatial visual perception affects movement, ie, direction and speed of movement,visual perception affects movement on stairs, movement of mobility impaired people is noticeably different on stairs, ie, they may move more quickly up rather than down,
    - type and positioning of handrails can affect movement and movement speed,
    - visual accessability is also affected by illuminance.

This list is not exhaustive by any means but their individual and combined potential impacts must somehow be quantified if they are to be modeled,

- cues or stimuli and associated actions linked to some notion of fire severity for which there is no agreed definition are inherently unreliable. There must be evidence for the input values used, for which are psychological responses to perceived threats,
- that there should be agreement on the protocols to be used to determine the suitability of evacuation simulation models for particular application and that such protocols and guidance on the use of models should be included in future fire safety engineering codes.

In short, a coherent, unified strategy is necessary to advance the development of evacuation simulation modelling.

The performance based documents [56,58] quoted in this paper use fire scenarios and design fires as part of the building characterisation process and overall fire safety design strategy. However, these documents are silent with regard to evacuation scenarios and design evacuations. Does it follow that having determined the fire scenarios and design fires to evaluate the life safety provisions the evacuation scenarios and design evacuations automatically present themselves? We would like to think that there is some correspondence and that in future drafts of these documents and in the development of similar documents some useful guidance on this issue will be included. However, we believe that this is an issue for the people working in human behaviour and evacuation modelling to resolve and resolve quickly.

Before BS DD240 [56] was published work was commissioned the results which might be used to give guidance on the limits for the equations in Part 1 of DD240[ ]. The work which is published as DD240 : Part 2 : 1997 [68] as received from the consultants contained no useful guidance on the formula contained in the pre-publication draft of DD240 Pt. 1 Sub System 6 Evacuation. Subsequently all the formulae in Sub System 6 Evacuation[ ] omitted from the published DD240 Part I document. So what is the message? Simply that much that has been apparently excepted in the past must be revisited and where necessary work repeated to ensure the robustness of relationships used to determine travel speeds, flow rates, converging flows, evacuation times, etc.

The developed nations of the world are today confronted with the happy problem of aging populations [22]. The demographic trends are there for all to see. In addition we know that older and impaired people frequently use public buildings and many of them live independently [69]. This knowledge must inform efforts at developing performance based codes, evacuation simulation models and human behaviour studies. Projections on numbers and disability/capability [70,71,72,73] must be considered in the context of new occupancy classifications and acceptable tenability limits. Issues have been raised concerning the impact on some occupants of limited exposure to non acute doses of carbon monoxide [74]. Clearly the tenability data currently used need to be urgently revisited. In some countries there is information on the prevalence of learning disabilities. The rates of such disabilities are much higher than perhaps some people might think or wish to acknowledge. Some preliminary work has been done in this area [40] but given the prevalence of learning disability and use of buildings by people with such impairments much work is still to do. The classical behavioural schemes used to characterise non learning impaired people are not transferable to the learning impaired, neither is day time training transferable to night time application. To put it quite bluntly, we have a lot of work to do to ensure social equity in fire safety provision. As we pointed out, previously conventional signage is expediently deemed sufficient wayfinding for people with mental impairments.

We have known for quite some time that evacuees prefer the familiar to closest evacuation route. Because we have known via observed actions does not mean we understand why. Understanding why, requires a study of the alternatives and how in an emergency the alternatives present themselves to an evacuee matters, i.e., spatial perception related to movement under stress.

What has also not been addressed in recent times is how the architecture and use of spaces affects exit route choice. Factors such as habituation and how it can be beneficially used or interrupted have not been seriously studied with respect to fire. It is possible to think of emergency exits with specific attributes in term of catchment areas or spheres of influence i.e. exits can be planned to attract evacuees, by opening automatically on alarm, by being well lit and inviting thereby conveying to the evacuee safety and security [30, 31, 32, 33, 34].

It is known that untrained, ill prepared, inexperienced people resort to unstructured, information processing in emergency situations and acquiesce to authoritative instructions or other leadership when available. People who are trained, otherwise prepared or experienced use task specific cognitive information processing which facilitate recognition, rationalisation and effective action [31,32,34,35]. In this context, it is preferable to think of buildings as closed or open systems. By closed-building system we mean that the activities and processes are controlled, and defined management structures are in place, e.g., offices. By open-building system we imply houses in multiple occupancy through single family dwellings and mobile homes, i.e., there is no well defined management structure. However, in the latter, fire safety is approached by means of community fire safety programmes discussed previously and by insurance driven tenancy agreements.

Staff training is important, an investment worth making and must be included in performance based design. In this connection staff training should not be considered independently of warning and communication systems in keeping with research and patterns of human behaviour.

Gradually there is a growing realisation among fire scientists that businesses manage risk on a daily basis. How the business is managed is important, and we fire scientists, fire protection engineers [75], or code developers have little real knowledge of business enterprises. By this we simply mean that data presented in codified form, must, reflect, where appropriate, e.g., the changes in retailing practices in developed societies. Advances in information technologies, economic pressures, and visual merchandising may mean reduced fire loads, as transaction data is fed to distribution centres from which retail stores are drip fed [76]. Trading practices such as visual merchandising influence visual accessibility, habituation and focal location and hence human behaviour. Thus business activity can and does affect human behaviour.

We must also acknowledge that, less, than best guess, data is published in some performance based documents without any disclosure as to the origins of that data. This is simply unacceptable and "could do better" is not a sufficiently strong criticism of code committees which adopt this practice and institutions which allow it. The challenge is to produce better quality data and for those who can, to fund the necessary research.

Clearly, as we consider people in buildings, who may be put at risk from exposure to fire, there are occupant and building interactions and cross impacts which are important. In characterising the occupants, population and activity profiles together with pre-movement distribution or indices are needed. Data on the impact of the fire on occupants, the perception of smoke and flames on occupants' information processing and decision making is also needed. As we stand today and look towards a performance fire based future, we have little real understanding of how evacuees actually process information in fire emergencies. We have coped because previous research

identified patterns in actions and repeatable action sequences. The time has arrived to take the next step and investigate how information related to fire threat is perceived, received, processed and actioned.

On the building side of the equation, visual accessibility and wayfinding indices together with means of escape data are required. Integrating the occupant response times as influenced by the building and the fire at different stages with the travel time gives a more realistic estimate of available safe egress time. This kind of holistic view of the information transmission processes in motion in real spaces is essential to the realisation of useful, applicable performance based codes, designs and evacuation simulation modelling. Although "clustering" behaviour has been identified with particular types of building, ie, in office buildings what precisely triggers the clustering and gathering activity and when, is not understood. If it is not understood, it is not predictable and as such at present cannot be reliably modelled. Programmes of work are needed to further investigate clustering behaviours. Associated with the foregoing issues of complexity and wayfinding, the processes of cognitive mapping with respect to subterranean spaces has not been sufficiently addressed.

From the literature some health warnings are already appearing; mention has been made regarding the acceptability of low doses of carbon monoxide. In a similar vein, the impact of stress on evacuation decision making and associated behaviours has not been thoroughly investigated and cannot be ignored. Not only the magnitude of the impact but also its nature, ie, negative or positive needs to be determined.

There is much to do but clearly education and training are paramount, ie, across the spectrum community fire safety programmes, sub-degree, degree and postgraduate studies in fire safety engineering design fire safety management orientated programmes. Educational fire safety objectives which of necessity require transfer of learning cannot be fully realised without knowledge of human behaviour in fire.

These issues together with others and the efforts required to move them forward will be discussed at the 2nd International Symposium in Human Behaviour in Fire in 2001. In the meantime as research funding become more difficult to obtain increased networking activity is necessary to build strategic collaborative human behaviour/performance research programmes, the outputs from which will address the fire safety problem and advance the engineering of fire safety in the build environment.

CONCLUDING REMARKS

Reduction of casualties in fires will not happen through more "Hard Fire Science" or prescriptive requirements for more fire protection in buildings but through the development of knowledge regarding human behaviour in fire.

The advent of performance based fire safety design presents the opportunity and challenge to integrate human performance into the engineering of fire safe buildings which must be taken up.

The content of performance based codes and fire safety guidance documents should, with respect to human behaviour in fire, be based on work of substance. We who have the ultimate

responsibility for the safety of many lives must provide truthful and salian information that people need, to make life saving decisions.

Occupancy classifications used in fire safety regulations should be based on appropriate occupant characteristics and not, for example, fire loading/fire severity.

The universal issue of wayfinding in emergencies has not received the holistic treatment it deserves and consequently is not integrated into many fire safety engineering design solutions.

A programme of work is necessary which will deliver acceptable engineering relationships to determine occupant flow rates, etc, for different occupancy classifications.

A coherent unified strategy to advance the development of universally acceptable evacuation simulation models is necessary. Agreement on design evacuation scenarios and design evacuations is urgently required.

In addressing tenability limits for fire safety engineering design consideration may need to be extended to health as well as safety, ie, the long-term health of occupants exposed to fire environments.

As we approach the year 2000 the future for those working in the field of human behaviour in fire is packed full with opportunity and challenge. We know that the opportunities and challenges presented will be met with relish.

REFERENCES

1. Pauls, Jake, "A Personal Perspective on Research, Consulting and Codes/Standards Development in Fire Related Human Behaviour, 1969-1997, With the Emphasis on Space and Time Factors", Proceedings First International Symposium, Human Behaviour in Fire, Shields, T.J. (Ed.) Fire SERT, University of Ulster, 30th August - 2nd September 1998, pp 71-82.
2. Bryan, J.L., "A Study of the Survivors Reports on the Panic in the Fire at the Arundal Park Hall, Brooklyn, Maryland on January 29th 1956", University of Maryland, 1957.
3. Wood, P.G., "The Behaviour of People in Fires", Fire Research Note. 953, Building Research Establishment, Fire Research Station, Borehamwood, Herts, England, November 1972.
4. Rubin, A.I., and Cohen, A., "Occupant Behaviour in Building Fires, NBS Technical Note 818", U.S. Department of Commerce, National Bureau of Standards, February 1974.
5. Stahl, F.J., and Archer, J., "An Assessment of the Technical Literature on Emergency egress from Buildings", U.S. National Bureau of Standards, NBSIR 77-1313, October 1977.
6. Levin, B.M. and Paulsen, R.L. (Editors), "Proceedings of Second International Seminar on Human Behaviour in Fire Emergencies", October 29 - November 1st, 1978, U.S. Department of Commerce, National Bureau of Standards, NBS-GCR-78-138, 1978.
7. Marchant, E.W. (Ed.) "Proceedings of Seminar Fire Safety for the Handicapped", Edinburgh, 21st March 1975, University of Edinburgh.
8. Canter D., (Editor), "Fire and Human Behaviour", John Wiley and Sons, Chichester, 1980.
9. Bryan, J.L., "Human Behaviour in Fire", A Bibliography, U.S. Department of Commerce, NBS-GCR-78-138, 1978.
10. Pauls, J.L. and Jones, B.K. "Research in Human Behaviour", Fire Journal, Vol. 74 No. 3 May 1980, pp 35-41.
11. Paulsen, R.L., "Human Behaviour and Fire Emergences", An Animated Bibliography, U.S. Department of Commerce, NBSIR 81-2438, 1981.
12. Sime, J.D., "Escape Behaviour in Fires : Panic or Affiliation?", Thesis submitted to fulfilment of the Degree

of Doctor of Philosophy, Department of Psychology, University of Surrey, England 1984.

13. Bryan, J.L., "Behavioural Response to Fire and Smoke", SFPE Handbook of Fire Protection Engineering, Di Nenno, Editor, Society of Fire Protection Engineering Engineers and National Fire Protection Association, Section 1, Chapter 16, 1988, pp 1-269-1-285.
14. Shields, T.J., "Fire and Disabled People in Buildings", BR231, ISBN 085123 5469, Building Research Establishment, Garston, 1993.
15. Shields, T.J., Dunlop, K.E., Silcock, G.W.H., "Escape of Disabled People from Fire : A Measurement and Classification Capability for Assessing Escape Risk", BR301, Building Research Establishment, London, ISBN 1 86081 0675, 1996.
16. Dunlop, K.E., Shields, T.J., and Silcock, G.W.H., "Towards the Quantification of Emergency Egress Capabilities for Disabled People in Fire Engineering and Emergency Planning", Barham, R. (Editor) Spon, 1996, pp 154-161.
17. Proulx, G. and Sime, J.D., "To Prevent Panic in an Underground Emergency : Why Not Tell People the Truth? Fire Safety Science", Proceedings of the Third International Symposium, Elesevier Applied Science, New York, 1991, pp 843-852..
18. Proulx, G. and McQueen, C., "Evacuation Timing in Apartment Buildings", National Research Council of Canada, Institute for Research in Construction, Internal Report No. 660, Ottawa, June 1994
19. Proulx, G., Latour, J. and MacLaurin, "Housing Evacuation of Mixed Abilities Occupants", National Research Council of Canada, Institute for Research in Construction, Internal Report NO. 611, Ottawa, July, 1994.
20. Fahy, R. "EXITT89 - An Evacuation Model for High Rise Buildings - Model Description and Example Applications", The Proceedings of the 4th International Symposium on Fire Safety Science, International Association for Fire Safety Science, 1994, pp 657-668
21. Fahy, R.F., "EXITT89 - An Evacuation Model for High Rise Buildings - Recent Enhancements and Example Applications", The Proceedings of the International Conference on Fire Research and Engineering, Society of Fire Protection Engineers, Boston, 1995.
22. Shields, T.J., (Editor), "Proceedings of International Symposium and Workshops on Engineering Fire Safety in the Process of Design Equivalency, Parts 1, 2 and 3", Fire SERT, University of Ulster, September 13-16th, 1993
23. Pauls, J. and Juillet, E., "Life Safety of People with Disabilities : How Far Have we Progressed", International Symposium and Workshop on Engineering Fire Safety in the Process of Design, Part 1, Engineering Fire Safety for People with Mixed Abilities, Shields, T.J. (Editor) Fire SERT, University of Ulster, September 13-16th, 1993, pp 17-40
24. Keating, P.J., "The Myth of Panic", Fire Journal, May 1982, pp. 57-61.
25. Shields, T.J. (Editor), "Human Behaviour in Fire", Proceedings of the First International Symposium on Human Behaviour in Fire, Fire SERT, University of Ulster, August 30th - September 2nd , 1998, pp 1-820.
26. Brennan, P., "Victims and Survivors in FATAL Residential Building Fires", Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd , 1998, pp 157-166.
27. Saunders, W.L., "Comparison of Behaviour in Buildings and Bushfire Emergencies", , Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd , 1998, pp 181-190.
28. Ozel, F., "The Role of Time Pressure and Stress on the Decision Process During Fire Emergencies", Proceedings First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor), University of Ulster, August 30th - September 2nd 1998, pp.
29. Chubb, M.D., Groner, N.E., Shepard, G., "A Hypothetical Cognitive Model for Understanding Human Behaviour in Fire", Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd , 1998, pp 211-
30. Benthom, L., "Fire Alarm in a Public Building : How do People Evaluate Information and Choose Evacuation Exit?", Proceedings First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor), Fire SERT, University of Ulster, August 30th - September 2nd 1998, pp 213-222
31. Shields, T.J., Boyce, K.E. and Silcock, G.W.H., Client Report, "Unannounced Evacuation of Marks & Spencer, Sprucefield Store", Fire SERT, University of Ulster, 1997.
32. Shields, T.J., Boyce, K.E. and Silcock, G.W.H., Client Report, "Unannounced Evacuation of Marks & Spencer, Sprucefield Store", Fire SERT, University of Ulster, 1997, pp....

33. Shields, T.J., Boyce, K.E. and Silcock, G.W.H., Client Report, "Unannounced Evacuation of Marks & Spencer, Culverhouse Cross Store", Fire SERT, University of Ulster, 1997.
34. Shields, T.J., Boyce, K.E. and Silcock, G.W.H., Client Report, "Unannounced Evacuation of Marks & Spencer, Queen Street Store", Fire SERT, University of Ulster, 1997.
35. Brennan, P., "Perception of Threat in Incipient Cues by Naive Occupants", Proceedings First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor), Fire SERT, University of Ulster, August 30th - September 2nd 1998, pp 223-229.
36. Proulx, G., "The Impact of Voice Communication Messages During a Residential High Rise Fire", Proceedings of the First International Symposium on Human Behaviour in Fire, Fire SERT, University of Ulster, August 30th - September 2nd , 1998, pp 265-274.
37. Shields, T.J. et al, "Towards the Characterisation of Large Retail Stores", , Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd , 1998, pp 271-290.
38. Ashe, B., Shields, T.J., "Analysis and Modelling of an Unannounced Evacuation of a Large Retail Store, Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th -September 2nd, 1998, pp 291-298.
39. Sime, J.D., "An Occupant Response Escape Time (ORET) Model", , Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd , 1998, pp 299-308.
40. Shields, T.J., Smyth, B., Evacuation Behaviours of Occupants with Learning Difficulties in Residential Homes, Disability and Rehabilitation, 1999, Vol., 2, No. 1, 39-48.
41. Hinks, J., Green, P., Thompson, W.J., Bartholew, C., Robertson, B., Webb, R., Aspinall, P., Perrier, C., "Strategic Research Issues in Emergency Wayfinding by the Blind and Partially Sighted, Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd, 1998, pp 541-551.
42. Tanaka., A., Imaizumi, Isei, T., "Wayfinding in an Underground Space", Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd , 1998, pp 563-572.
43. Horasan, M.B.N., "Occupant Evacuation and Orientation Problems in Large Halls - An Exhibition Case Study, Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd , 1998, pp 573-582.
44. Yaping, He, Brennan, P., "On Quantifying Perception of Smoke", Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd , 1998, pp 611-620.
45. Heskestad, A.W., Pedersen, K.S., "Escape Through Smoke : Assessment of Human Behaviour and Performance of Wayfinding Guidance Systems", Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd , 1998, pp 631-638.
46. Groner, N., "International Systems Representations are Useful Alternatives to Physical Systems Representations of Fire Related Human Behaviour", Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd , 1998, pp 663-672.
47. Brannigan, V., Smidts, C., "Performance Based Fire Safety Regulation Under International Uncertainty, Proceedings of the First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd, 1998, pp 411-420.
48. Groner, N.E., "Putting People Into Performance Based Design Option", Fire Technology (32) (3) August/September, 1996, pp 281-284.
49. Lund, P., Proceedings of International Conference on Performance Based Codes and Fire Safety Design Methods, September 24th-26th, Ottawa, Canada, Society of Fie Protection Engineers, 1997.
50. Hadjisophocleous, G.V., Benichan, N., Tamin, A.S., Literature Review of Performance Based Fire Codes and Design Environment, Journal of Fire Protection Engineering, 9 (1) 1988, pp 12.
51. Meacham, B.J., "Evaluation of Performance Based Codes and Fire Safety Design Methods, Society of Fire Protection Engineers, Boston, 1996.
52. Bukowski, R.W., "Fire Safety Engineering in the Pursuit of Performance - Based Codes: Collected Papers: CIB Report CIBW14/96/5 "(USA) NISTIR 5878, 1996.

53. "Building Regulations (England and Wales) 1991", Approved Document B Fire Safety HMS, London, 1992.
54. Christian, S.D., Progress in Achieving Acceptable Fire Engineering Solutions, International Symposium and Workshops on Engineering Fire Safety in the Process of Design : Demonstrating Equivalency, Proceedings Part 1 CIB W14 : Shields, T.J. (Editor) Fire Safety Engineering, University of Ulster, September 13-16th, 1993, pp 3-15.
55. Fire Advisory Panel, DOE, Private Communication 1996.
56. "DD240 : Part 1 : 1997 Fire Safety Engineering in Buildings: Part 1, Guide to the Application of Fire Safety Engineering Principles"BSI 1997.
57. Bryan, L.J., "An Examination and Analysis of the Dynamics of the Human Behaviour in the MGM Grand Hotel Fire", National Fire Protection Association, USA, 1980.
58. "ISO/CD 13387-8 Fire Engineering Draft Technical Documents", Private Communication.
59. Gwynne, S. and Galea, E.R., "A Review of the Methodologies and Critical Appraisal of Computer Models Used in the Simulation of Evacuation From the Built Environment", CMS Press, University of Greenwich, ISBN No. 18999991212 pp 1-93, 1997.
60. Northern Ireland Monthly Fire Statistics : Private Communication to Shields, T.J.
61. Home Secretary's Speech : LGA Conference, Home Office, London, March 3rd, 1999.
62. Sime, J.D., "The Concept of Panic", in Fire and Human Behaviour, Canter D., (Ed.), John Wiley and Sons, Chichester, 1980, pp.63-81
63. Passini, R., "Wayfinding in Architecture", Van Nostrand, Reinhold, 1992.
64. Arthur, P., Passini, R., "Wayfinding People, Signs and Architecture", McGrair-Hill Ryeson, 1992.
65. Passini, R., Rainville, C., "March, N., Joanette, Y., "Wayfinding and Dementia : Some Research Findings and a New Look Design", Journal of Architectural and Planning Research 25 : 2 (Summer 1998), pp 131-151, Locke Science Publishing Co.

66. Brown, B., Wright, H., Brown, C., "A Post Occupancy Evaluation of Wayfinding in a Pediatric Hospital : Research Finding and Implications for Instruction", Journal of Architectural and Planning Research 14:1 (Spring 1997) pp 35-51, Locke Science Publishing Company, Chicago.
67. Bryan, J.L., "Human Behaviour in Fire: The Development and Maturity of a Scholarly Study Area", Proceedings First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor) Fire SERT, University of Ulster, August 30th - September 2nd, 1998.
68. "DD240 : Part 2 : 1997, Fire Safety Engineering in Buildings, Part 2, Commenting on Equations in Part 1", BSI 1997
69. Boyce, K.E., "Egress Capabilities of People with Disabilities", Thesis submitted to fulfillment for the degree of Doctor of Philosophy, University of Ulster, 1996.
70. Boyce, K.E., Shields, T.J., Silcock, G.W.H., "Towards the characterisation of Building Occupancies for Fire Safety Engineering : Prevalence, Type and Mobility of Disabled Persons", Fire Technology, Feb 1999, Vol. 35 No. 1.

71. Boyce, K.E., Shields, T.J., Silcock, G.W.H., "Towards the Characterisation of Building Occupancies for Fire Safety Engineering : Capabilities of Persons with Disabilities to Move on Horizontal and Inclined Surfaces", Fire Technology, Feb 1999, Vol. 35 No. 1..

72. Boyce, K.E., Shields, T.J., Silcock, G.W.H., "Towards the Characterisation of Building Occupancies for Fire Safety Engineering : Capability of Persons with Disability to Negotiate Doors" Fire Technology, Feb 1999, Vol. 35 No. 1.

73. Boyce, K.E., Shields, T.J., Silcock, G.W.H., "Towards the Characterisation of Building Occupancies for Fire Safety Engineering : Capability of Persons to Locate and Read Signs", Fire Technology, Feb 1999, Vol. 35 No. 1.

74. Christian, D., Shields, T.J., "Toxic potency and their relationship with long term sequelae from a single, acute, sub-lethal exposure to carbon monoxide", Journal of Fire Science, 1999.

75. O' Brien, D., Aitken, J., Shields, T.J., A Way Forward, Proceedings First International Symposium on Human Behaviour in Fire, Shields, T.J. (Editor), University of Ulster, August 30th - September 2nd 1998, pp 59-67.

1. Shields T.J., Boyce, K.E., Silcock, G.W., Client Report, "Fire Load Survey of Four Marks & Spencer Stores".