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Methodologies employed in the collection, retrieval and storage of human factors information derived from first hand accounts of survivors of the WTC disaster of 11 September 2001

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Abstract
This paper provides a broad overview of project HEED (High Rise Evacuation Evaluation Database) and the methodologies employed in the collection and storage of first-hand accounts of evacuation experiences derived from face-to-face interviews of evacuees from the World Trade Center (WTC) Twin Towers complex on 11 September 2001. In particular the paper describes the development of the HEED database. This is a flexible research tool which contains qualitative type data in the form of coded evacuee experiences along with the full interview transcripts. The data and information captured and stored in the HEED database is not only unique, but provides a means to address current and emerging issues relating to human factors associated with the evacuation of high rise buildings.

1.0 Introduction
The evacuation of the WTC complex in 2001 is one of the largest full-scale evacuations of people in modern times with over 14,000 people escaping from the buildings. The people who evacuated can thus be regarded as unique witnesses who are able to give first-hand accounts of their evacuation experiences within the rapidly changing high-rise building environment. Their memories of the evacuation provide insights into the inter-related processes associated with high-rise building egress.

It is now widely acknowledged that there are three broad stages through which any egress proceeds; making sense of the situation, planning to leave, and then finding and using a route out of the building [1]. It has also long been recognised that there are important social processes [2] that shape and interact with the decision making of individuals, thereby modifying their egress patterns [3-5]. The accounts of those evacuating from the WTC towers not only enables us to develop a more detailed understanding of what processes underlie each of the main evacuation stages, but, due to the large number of people involved enables us to explore the impact of social and organisational factors on the evacuation activity. The complexities of the rapidly changing conditions adds a crucial dynamic quality to any understanding of the actions that took place, however the time period over which the thousands of people left the building was sufficient to allow some analysis of the dynamics to be carried out.

The project described in this paper called HEED – High-rise Evacuation Evaluation Database - is funded by the UK Engineering and Physical Science Research Council (EPSRC - project GR/S74201/01 and EP/D507790). It involves a collaboration between the Universities of Greenwich, Ulster and Liverpool and aims to collect first

hand evacuation experiences of survivors from the WTC twin towers evacuation. Thus far some 270 evacuees have been interviewed. Details on the project can be found on the HEED website www.wtc-evacuation.com. Several studies have already investigated the evacuation of the WTC [6-8] using published accounts from survivors, questionnaires and focus groups. However, the main features which distinguish HEED from other projects are:

- a more comprehensive approach to data collection drawing upon qualitative research methods to uncover people's experiences coupled with traditional measures used in Quantitative enquiry. This increases the potential richness of data not evident in other related projects and the opportunity for novel concepts to emerge [9],
- an attempt to understand more fully the social and organisational factors that influence evacuation activity by using both quantitative and qualitative enquiry e.g. the influence of groups, organisational structured, perception of risk,
- an inquiry into the relation between evacuation inertia in populations, flight behaviour and perception of risk in a rapidly deteriorating environment [10],
- accessibility of the data through the development of an on-line relational database of the evacuees' experiences which includes full interview transcripts which will be accessible in the future by *bona fide* users,
- The achievement of a strong partnership between researcher and participant leading to good quality data. Facilitated by addressing the power balance emphasising the role and importance of the participant thus empowering the participant [11].
- Enabling the participant to be part of the project by assisting with participant recruitment and being given membership of the WTC Evacuation Study participant's forum.

The main aim of project HEED is to distil, organise and present the activities of people involved in the WTC evacuation by creating the HEED Database. The objectives are to:

- collect and collate the human actions and experience in the WTC disaster and structure this into a database that will provide an interactive research environment,
- ensure that the data collected is transformed into information that is of immediate, medium and long term use to the managers, designers, enforcement agencies and owners of medium- and high-rise buildings in addition to the research community involved in the development of computer based evacuation models and those interested in understanding the social process that structure emergency and related situations,
- to ensure easy, free and immediate access to the database for *bona fide* users,
- use the information collected and collated to perform preliminary analyses of the data to identify some of the key factors that influence the design and management of medium- to high-rise buildings and to test some of the social psychological models of human actions in such circumstances.

1.1 Research issues

The HEED study identified an extensive range of human factors research issues of relevance to fire safety engineering. These included:

- **Cue recognition and response:** It was important to understand the participants' entire experience from the time they received a cue – Examining such areas as, What cues did they receive? How were they interpreted? How did the cues make them feel? What were they thinking? How did they respond**?** Currently, engineers use arbitrary values to represent occupant response times, often simply taking, for example, 0 to 2 minutes. In this study we hoped to determine a representative range of response times and provide data that may illustrate the interaction between response times and other factors, such as proximity of incident, risk perception and group membership to name a few.
- **Experience and training:** A number of people in the 9/11 evacuation had previous experience of evacuating the building during the earlier terrorist bomb attack of 1993 [12]. Additionally, many people had second hand experience of the 1993 evacuation through friends, family and colleagues. How did their first and second hand experience impact upon their evacuation? What training had people undergone in case of emergency situations and had they learned behaviours from this and other evacuation experiences.
- **Management and organisational structure:** The different ways in which the diverse organisations marshalled and instructed their employees to leave is also explored in order to determine its implications for various engineering provisions. For example, how bureaucratic was the company the participant worked for? Did this have any impact on the nature of the participant's emergency response? Did managers instruct their staff members to evacuate? Why or why not? Did employees inform managers of their decision to evacuate? Did their manager/superior communicate with them?
- **Group formation:** All engineering evacuation analysis currently assumes that occupants evacuate as individuals. This belief is implicit in all building design. This key assumption has an important influence on the unfolding evacuation dynamic and potentially on the overall efficiency of the evacuation. We wished to determine the participant's experiences as a member of one or more groups as they evacuated the WTC, and understand the group's lifecycle from the participant's perspective. How did the group form? What were the factors driving formation and dissolution? What was the nature of the group membership? How did the group operate?
- **Choosing and locating an exit route:** The key to understanding movement in an emergency is to discover why people choose a particular route. Was their exit route pre-planned? Was it the closest? Familiar? Used in fire drill? What were the reasons behind some participants choosing to evacuate by the elevator?
- **Conditions during egress:** We wished to explore whether the participant experienced any difficulties during egress (e.g. fire, smoke, congestion)? What did they think about that difficulty and what did it cause them to do? Did they walk or run and at what speed and why? What were the conditions like as they moved into and on stairs/elevators.
- **Merging flows and deference behaviours:** In high-rise building evacuations a key behaviour is the nature in which people on the floor merge with people on the stairs as this determines how the evacuation unfolds and how quickly any particular floor can empty into the staircase. We wished to explore fundamental questions concerning this behaviour, for which engineers do not have clear answers e.g., Did people on the stairs defer to people entering the staircase from the floor and allow

them to enter? Did the floor and stair occupants take turns and allow a one-for-one merging/filtering or does one flow win out over the other for long periods of time?

- **Fatigue:** All engineering analysis of high-rise building evacuation currently either ignores the impact of fatigue or treats it in a crude and arbitrary manner. Was fatigue an issue in the WTC evacuation, did it exert an influence on the overall evacuation and if so, in what way? We wished to determine the extent to which participants had to stop for a rest, and if so, where, for how long, and with whom? Similarly if they indicated any health problems, we wanted to explore how this impacted on their evacuation.
- **Travel speeds:** A very basic piece of data essential in all engineering evacuation analysis is the travel speed of people on stairs. Obviously, if this key parameter is incorrectly represented the entire evacuation analysis becomes invalid. There is some evidence to suggest that the travel speeds in the WTC evacuation were significantly lower than those typically used in engineering analysis [6,8]. What was the speed of people on the stairs and what contributed to it? How was the travel speed related to crowd densities, stair geometry and population demographics?
- **Perception of risk:** – This is an area which has been little explored in the fire literature. This research aimed to capture participants' level of perceived risk during their evacuation from the Twin Towers. Subsequent analysis will enable a better understanding of, for example, the relationship between response times and perceived risk and types of cues and perceived risk.

2.0 Project endorsement and facilitation

To undertake the large number of face to face interviews for the HEED project a team of up to six UK based research psychologists worked in New York for periods of up to two months at a time. The logistics of undertaking this operation should not be underestimated. Participants had to be recruited, suitable locations, in which to undertake the interviews arranged, and interview schedules agreed. In addition it was necessary to find appropriate New York accommodation for the interview team, develop appropriate personal safety protocols for the team while undertaking interviews in New York in participant offices and homes, provide backup support for interviewees if required, establish channels of communication with UK based management team, and organise medical insurance and visas for the interview team, etc.

It became obvious that to successfully conduct the HEED project, the research team had to seek project co-sponsors and facilitators. In order to identify and contact 9/11 survivors, partnerships needed to be built and this was achieved by networking with the institutions, agencies, companies and groups identified below.

It is only possible in this paper to introduce some of the project co-sponsors and facilitators; obstacles encountered as a consequence of working in New York and the corresponding actions necessary to progress the work. Invaluable advice concerning survivor groups and the NY political environment developing around 9/11 was provided by a number of organisations, including the Skyscraper Safety Campaign and its professional advisory panel. However, from the outset of the project it was recognised that we would need a New York based co-sponsor to facilitate the work in a variety of ways including availability of staff and contacts for WTC survivors wishing to register with the project. Through previous relationships with the investigators, John Jay

College Of Criminal Justice in New York (JJ) agreed to support and facilitate the project. In addition, Commissioner Patricia Lancaster of the New York City Department of Buildings and Commissioner Nicholas Scoppetta of The New York Fire Department when introduced to the project saw great value in it and came on board as co–sponsors.

A pre-requisite for the project was access to survivors willing to participate in our project and in this regard a number of avenues were pursued:

- access to NIST lists/data,
- access to the Port Authority badge lists.
- Access to the University of Columbia's list/data

Representations to NIST for access to participants and raw data, although well received, could not be accommodated by NIST for legal reasons. After meetings and much negotiation, access to the Port Authorities badge lists were eventually obtained but the delay in obtaining access together with the legal constraints imposed rendered their use impractical. Approaches to Columbia drew no response. As the project progressed contacts were made with various survivor groups; companies occupying WTC Towers 1 and 2 and community groups. As recruitment progressed project collaborators kindly offered space to facilitate interviews e.g. Euro Brokers; Pace University, Polytechnic University, September Space and JJ.

As work progressed in the field the research team were made aware of a register compiled by the New York City Department of Health and Mental Hygiene (NYC DOMHH) which included survivors of 9/11. It transpired that the NYC DOMHH database included details of some 3000 9/11 survivors from the twin towers. Access was sought and granted to the NYC DOHMH database. Despite some difficulties in terms of expediting this process, the co-operation of the NYC DOHMH was very welcome and they remained our principal recruiting mechanism.

As the project was now using various University premises and resources along with the NY DOHMH database, the project research protocols had to be submitted to each institution's Internal Review Board (IRB) i.e. NYC DOMHH, JJ and Pace University, as well as gaining the approval of the participating UK Universities Ethics Committees. All this was done from a distance i.e. remotely and took up to three months for each IRB submission. These time lapses were not anticipated and is something that should be taken into account when collaborating or receiving assistance and resources with projects from overseas institutions, particularly when working to funding agencies strict time scales and participants are to be recruited.

Other avenues of potential survivor recruitment were also pursued during the life of the project including pro-bono assistance of a NY strategic communications agency Brown Lloyd James, radio and television appearances by the investigators and extensive newspaper coverage within NY.

A novel approach adopted was to seek the co-operation of the churches e.g. the Archdiocese of New York and New Jersey through the offices of the Cardinal and Archbishop respectfully who provided access to parishes who in turn published details

of our project in their parish bulletins on more than one occasion. An added incentive to potential participants was the promise of a $20 donation to a nominated WTC charity in appreciation of their contribution to the project.

From the foregoing it is clear that working in a very different environ requires some lateral thinking; lots of willing facilitators and lots of good fortune.

3.0 Research protocols

This investigation focused on those persons who evacuated from WTC1 or WTC2 on 9/11. The research protocols are outlined below.

3.1 Recruitment

Participants for the interviews were recruited mainly from the World Trade Center Health Registry (WTCHR), compiled by the NYC DOHMH. The WTCHR is a voluntary list of individuals who evacuated from and/or were exposed to the environmental effects of 9/11. Invitation letters in two mail shots were sent to those healthy individuals on the registry who were over 18 years of age, present in Towers 1 or 2 of the WTC, and who had expressed an interest in receiving information about other WTC related studies. As the NYC DOHMH protects the confidentiality of those on their registry, they mailed the letters of invitation to individuals on their registry on our behalf. The materials sent included a cover letter from the NYC DOHMH, a HEED Invitation to Participate letter and a 'Your Questions Answered' study information sheet. The Invitation to Participate letter was our introduction about the study to the survivors. It informed potential participants about who we were, the project aims, the nature of their involvement in the study and our contact information. The 'Your Questions Answered' study information sheet informed the participant of the procedures involved, the duration of the interview, our commitment to confidentiality and anonymity, the benefits and risks of participating, their ethical right to withdraw, along with samples of interview questions and interview locations and times.

Individuals who wished to take part in the study were invited to register on the project's website (www.wtc-evacuation.com), and invited to complete the web based Pre-Interview Questionnaire. This questionnaire was designed to elicit basic demographic and background information about the individual to assist in the interview process and ensure our inclusion criteria were met. Once registered, the interview team leader then contacted the potential participant to make arrangements for the interview.

3.2 Interview-structure and content

The interview itself comprised a combination of participant narrative in 'free-flow' format and a semi-structured interview. At the beginning of the interviews the interviewers introduced themselves and their role and led the participant through the informed consent process. This included describing the format of the interview, expected duration, how data would be managed, confidentiality issues and the rights of the participant to refuse/withdraw and ask questions.

Having given consent to continue, participants were then asked to tell their story in their own words without interruption. They were asked to mentally take themselves back to the morning of 9/11 and describe their experiences from the point they entered the

World Trade Center towers until they evacuated the towers. This narrative format was used to uncover experiences and situations in the WTC evacuation which might not previously have been considered by the researchers and therefore explored, and to enable the participant to relax and remember the events of that day in their own way.

The free-flow narrative was followed by a semi-structured interview, during which the interviewer expanded upon and confirmed details previously provided in the free-flow and sought to ascertain more specific information regarding the participant's entire experience relevant to the specific areas of research interest. The semi-structured interview was piloted in New York over a period of six weeks. From the pilot study it became apparent that there were at least seven distinct phases that evacuees experienced during 9/11, namely: pre-recognition, recognition, response, horizontal evacuation, vertical evacuation, evacuation interruption (where participants chose to interrupt their evacuation, e.g. after the public announcement in WTC 2) and exiting the WTC complex. These phases constitute a new model of evacuation behaviours and as such informed the development of the database.

Throughout the interview, interviewers attempted to extract from the participant as much contextual information relating to time and location of the described experiences. For example, it was considered important to determine an estimate for the actual time (absolute) that something occurred, and the time taken for certain events to occur e.g. waiting in line, fire fighters to pass. Interviewers also attempted to establish where the participant was when this occurred (floor level, location on floor). Where absolute times couldn't be determined they tried to determine the times that things were occurring relative to global time markers e.g. time Tower 2 hit, time Tower 2 collapsed. This information was crucial to address specific engineering research questions related to e.g. response times, travel speeds, etc.

Participants were also asked to examine floor plans in order to, orientate themselves and identify their respective evacuation routes. Although the efficacy of this was greatly dependant upon the participants spatial awareness and ability to relate to diagrams/maps. However, many participants came from a technical background and coped well with this task. Computer generated animations of people descending stairs based on the classic Fruin densities [13] were periodically administered in order estimate crowd densities in the escape routes (Figure 1). The animations were generated using the buildingEXODUS evacuation software [14,15] which was configured to generate the appropriate average Fruin density for a generic stair configuration of dimensions representative of those in the WTC. These animated images were introduced whenever the participant entered or exited a stairwell, and whenever they mentioned crowding on the stairs. This information, together with information on time periods where important events occurred on stairs, assists in identifying travel speeds on stairs and associated crowd densities.

Participants were also asked to complete two questionnaires during the interview, a risk perception questionnaire and an organizational structure questionnaire. The risk perception questionnaire comprised a general question on how at risk they felt at the time (rated on a seven point likert scale, from 1=no risk, to 7 =very high risk) followed by a series of statements related to different risk attributes, identified from psychometric

risk perception studies e.g. information available, hazard, immediacy of hazard, control, dread etc [16] to which they had to rate their level of agreement (7-point likert scale where 1 = strongly disagree, 4 = neutral, and 7 = strongly agree). Participants were asked to complete the risk perception questionnaire at up to four different times during their evacuation if appropriate, at WTC1 impact (or when participant noticed something unusual happening), when the participant was deciding to evacuate, when the participant knew that WTC2 had been hit (if applicable) and when the participant knew WTC2 had collapsed (if applicable).

(a) Fruin A: representing an average of 0.5 people/m^2

(b) Fruin F: representing an average of 3.0 people/m^2

Figure 1. Single frames from computer generated animations of Fruin stair densities

In the organisational structure questionnaire, the participant was asked to rate their level of agreement on a 5-point scale with each of 10 statements related to the how the company functioned, e.g. In my job, my authority was precisely defined; In my organization, clear lines of reporting and authority were made known.

3.3 The sample

In total, 3,064 letters of invitation to participate were distributed via the DOHMH, through which 287 persons registered their interest in participating in our study, i.e. a response rate from these mail outs of 9.3%. The total number of people registered to participate in the study to date is 471.

Interviews were conducted during three extended periods by the researchers in New York. Participants were offered a choice of locations around the NY Metro area, all of which were provided free of charge by our US based facilitators. Alternatively participants were able to nominate their own home or place of work as their preferred interview location. Those persons based outside the tri-state area were interviewed by telephone. At the time of writing, 271 persons who evacuated the WTC on 9/11 have been interviewed; this comprises 248 face to face and 23 telephone interviews.

4.0 Development of HEED database and the coding process

The HEED database, developed using Microsoft (MS) Access, is a flexible qualitative research tool designed specifically to store data extracted from transcribed interview accounts from the HEED WTC evacuation study. The information stored in the HEED database provides a means to address key research questions relating to human factors issues associated with evacuation from high rise buildings.

A content analysis of a small sub set of participants' accounts indicated that WTC evacuations comprised a rich variety of experiences, ranging from observations and interpretations of events to subsequent cognitions and actions. A method was required to systematically identify, categorise and store this experience information into a logical structure for later analysis. From this initial content analysis, a three level Experience hierarchy was suggested which was refined and expanded in an iterative manner as more accounts were examined. As part of the Experience hierarchy a large number of codes and associated code definitions were developed to uniquely categorise each experience.

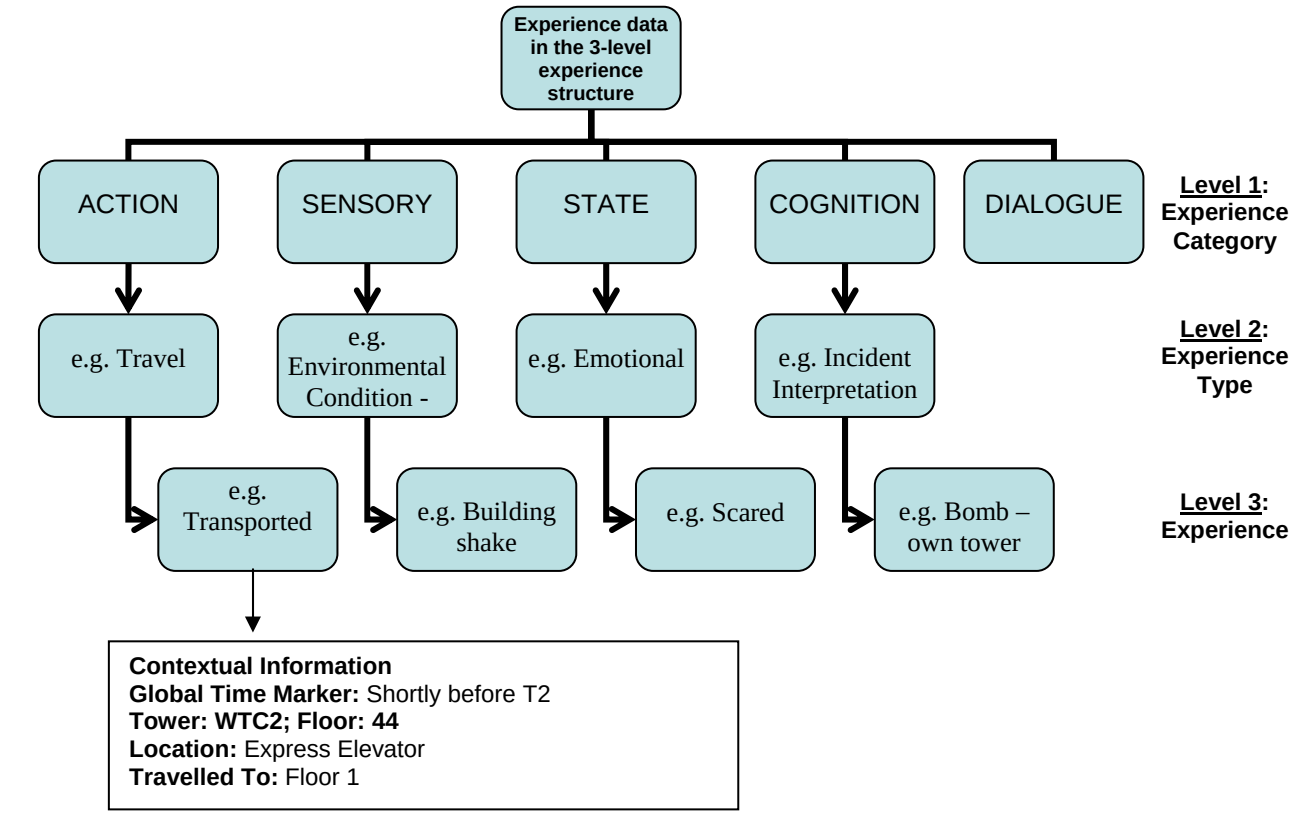

Figure 2. Flow diagram illustrating the three-level experience structure with contextual information associated with the Action Experience Type Travel

The Experience hierarchy served as a coding framework enabling the identification of the participants' experiences from interview transcripts and the unambiguous and systematic categorisation of those experiences. The development of the HEED database structure was undertaken in parallel with the development of the three-level Experience hierarchy and associated Experience codes. Data within HEED is stored using the logical arrangement of the three-level Experience hierarchy. In addition to coded Experience information, the HEED database also includes the full edited transcripts for each interviewed participant.

The HEED database captures all of the participants' evacuation experiences such as stimuli (e.g., observational cues), cognitions (e.g., incident interpretations) and

individual and group behaviours (e.g., actions and reactions) within the three-level experience hierarchy. Data such as the approximate time of an experience and participant's location are captured by associated contextual information. The conceptual structure of the database is displayed in Figure 2. The highest level of the hierarchy is the Experience Category or Level 1 experience. There are five core experience categories; namely Action, Sensory, State, Cognition and Dialogue. Below the Experience Category is the Experience Type (Level 2 experiences) which identify the nature of the experience. The final element in the hierarchy is the actual Experience extracted from the text, also referred to as the Level 3 experience. Each of the five Level 1 experience categories and their relation to the Level 2 and Level 3 experiences are expanded on below.

Action: The act or process of doing/receiving something physically active, this includes the following Level 2 Experience Types: assistance given/received, collect/distribute item, comfort break, deference/preference behaviour, emergency action, travel and working. An example of a Level 3 Experience is 'Carried by others' which is associated with the Level 2 Experience Type 'Assistance received'. There are 13 Level 2 Experience Types and 94 Level 3 Experiences related to this Level 1 Experience Category.

Cognition: Cognition refers to all mental thoughts and processes. It includes the following Level 2 Experience Types: disorientation, incident interpretation, knowledge, made decision and recollect prior experience. An example of a Level 3 Experience is 'Small aircraft hit WTC1' which is associated with the Level 2 Experience Type 'Incident Interpretation'. There are 5 Level 2 Experience Types and 166 Level 3 Experiences related to this Level 1 Experience Category.

Dialogue: Dialogue refers to speech between two or more persons. This includes the following Level 2 Experience Types: conversation, information given/received/sought/withheld, instruction given/received, opinion given/received. An example of a Level 3 Experience is 'Stairway blocked – B' which is associated with the Level 2 Experience Type 'Information given'. There are 11 Level 2 Experience Types and 166 Level 3 Experiences related to this Level 1 Experience Category.

Sensory: Sensory refers to all information gained through four of the participant's senses; what they could see, hear, feel and smell. It includes the following Level 2 Experience Types: environmental condition - smelt, saw other/s collect item, saw other/s emotional state, saw other/s give assistance, saw sign. An example of a Level 3 Experience is 'Burning/Smoke' which is associated with the Level 2 Experience Type 'Environmental condition – smelt'. There are 14 Level 2 Experience Types and 185 Level 3 experiences related to this Level 1 Experience Category.

State: State encompasses the participant's physical and psychological condition. It includes the following Level 2 Experience Types: emotional, physical and spiritual condition. An example of a Level 3 Experience is 'Felt Faint' which is associated with the Level 2 type 'Physical'. There are 3 Level 2 Experience Types and 29 Level 3 experiences related to this Level 1 Experience Category.

In addition to coding the Level 3 experience, 'contextual information' is required to clarify the detail of the experience. For example, the contextual information could be the time at which the experience occurred or an estimation of the crowd density when the experience occurred. As noted earlier crowd density estimations are provided by the participant during the semi-structured component of the interview using a specially devised Fruin based tool. The time at which an experience occurred is represented within HEED in several ways. It can be the actual time if explicitly provided by the participant, an estimated time based on proximity to key global times (such as impact of WTC2) provided by the participant during the semi-structured component of the interview or a time interval estimated by the research team based on the evidence provided within the transcript.

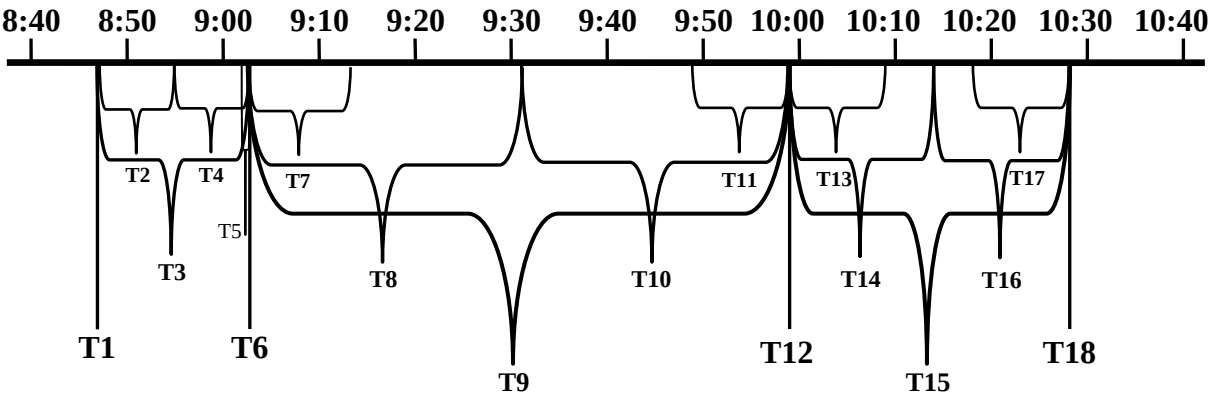

Figure 3. Time references used in analysis of interview data

The process involved defining a total of 18 time sub-intervals (Figure 3) around the four known global event times, namely the impact into WTC1 at 8:47am (**T1**), the impact into WTC2 at 9:03am (**T6**), the collapse of WTC2 at 9:59am (**T12**) and the collapse of WTC1 at 10:28am (**T18**). As an example of this process, consider the time span between T1 and T6. This was divided into four sub-intervals with **T3** being the sub-interval "Between T1 and T6" i.e. 08:47 < event time < 09:03, while sub-interval **T2** is "Closer to T1 than T6" i.e. 08:47 < event time < 08:55 and sub-interval **T5** is "Shortly before T6" i.e. 09:02 < event time < 09:03. The process of estimating the time when an event occurred involved the analyst reading the interview transcript and from the evidence provided determining which time sub-interval best captured the event time.

The contextual information expands upon the identified experiences and puts them into context by providing the where, when, and why the experiences occurred, who the participant interacted with during the experience and how, whether the experiences occurred while the participant was part of a group or acting alone, etc.

Before the experience can be coded into the database it must first be identified. This is achieved by identifying relevant experiences in the interview transcripts which form a Behavioural Pattern (BP). BPs are chunks of text which contain experience and

corresponding contextual data. Once a BP is identified the relevant experience codes and contextual information relating to the experience are determined and coded into the database, along with the actual BP and its location within the transcript. A BP can have several mutually exclusive experience categories attached. The following chunk of text represents a BP:

"I worked in WTC1 floor 64. Almost immediately after WTC1 was hit, *I ran* **into stairwell A."**
This BP contains both experience data (italics) and contextual data (underlined). To code this experience data within the database requires the three experience levels to be identified:

Level 1**:** Experience Category: **'Action'**
Level 2: Experience Type: **'Travel'**
Level 3: Experience **'Run'**

The contextual information relates to the start location (WTC1 floor 64), stair used (Stairwell A) and provides an indication of when the event occurred through identification of a time sub-interval (T2).

As part of the data entry, the entire edited transcript of the interview is linked to the database, as is factual information obtained from the pre-interview questionnaire. Names of people and companies are removed from all entries, being replaced with coded IDs, ensuring that the identity of the participant remains confidential.

Information within the database can be retrieved by constructing and running queries using MS Access Query. However, this is only for local use and therefore a web based query builder will be developed for accessing the data remotely. This will enable a wider audience to access the information contained within HEED.

The coding team comprised the five research psychologists who conducted the interviews. The team spent considerable time familiarising themselves with the various codes and training to identify relevant BP's, use of the codes and coding into the database. Following the initial training, the team underwent an Inter-Rater Reliability (IRR) exercise. The purpose of the IRR was two-fold: first, to further assist coders in their familiarisation of the database codes and their definitions; and second, to establish how reliable the coders were at identifying and coding information from transcripts that were relevant to the first pass of coding. In particular, the IRR was focused on establishing the coders' ability to:

- identify relevant events from participants' evacuation accounts
- code the different components (experiences plus context) of those events
- identify group data from participants' evacuation accounts
- code the different components (e.g., group interactions, group size) of that data

For this exercise, ten edited transcripts were selected, five from each building. These included accounts of evacuations from the upper floors (sky lobby on floor 78 upwards), middle floors (floor 77 down to the sky lobby on 44), and lower floors (floor 43 down to the ground floor lobby) of each of the twin towers.

The IRR exercise confirmed that, the coders were sufficiently reliable at identifying and correctly coding the relevant events. The coding of the underlying experiences which comprise the events, although less reliable, was however within the bounds of acceptability set by the management team. Likewise, the coding of the floor/region which participants were on/in at the time of the experience, and the assigning of global time markers. The IRR exercise, in addition to being an excellent training tool for the coders also identified areas were consistency could be improved. The identified issues were addressed by improving the definition of the codes providing detailed feedback to the coders and recoding some of the transcripts.

It should be noted that processing the interviews from audio tape to coded information stored in the database is an extremely time consuming process. The entire process involves the following tasks:

- transcribing the interview by a qualified audio typist: 1-1.5 days,
- editing the transcript by a member of the interview team: 1-3 days depending on individual coder, length of transcript and quality of transcription,
- coding transcript by a member of the interview team: 1-2.5 days depending on individual coder and length of transcript,
- entering coded data into HEED database by database developer: 1 – 4 hours depending on length of transcript.

Given the time involved in the data extraction process, the team decided to focus their initial coding efforts on a set of identified key engineering questions.

5.0 Extracts from selected transcripts

At the time of writing this paper the coding process is well underway but far from completion. As a result it is premature to perform any detailed analysis of the data or draw any firm conclusions. However, to demonstrate the richness of the data, extracts from several transcripts are presented that have relevance to the key engineering issues identified above. These include extracts from both the free-flow and semi-structured interview components. It should be noted that names of the interviewees or other people that they name during the course of the interview are replaced by codes.

- **Example of response time, group formation and time to enter staircase.**

An evacuee from WTC2 (WTC2/090/0001), initially located on the 90th floor, describes her initial movements and descent down the stairs with a colleague WTC2/0001/N. Her movements are described immediately after the WTC1 impact:

> "I went back to my office and immediately called my husband … and fortunately he was not there and I left a message which I listened to about a month later and it said something to the effect that building 1 had just blown up which I had no recollection of saying that and that we were ok and we were gonna leave the building goodbye and I stood in my office for 15 or 20 seconds trying to decide whether to take a bag with my cell phone and you know stuff in it and decided I would leave it because it

> might be cumbersome going downstairs so I went out to find the person whose name is WTC2/0001/N he's at the time was 75 ……. and he and I kinda looked around in the general area to see if anybody else was there in the offices and we didn't see anybody ……and we walked out to the what do you call it the corridor that leads you come up from the local elevator……by the time we got there there were maybe I don't know 40 people in this corridor standing around and there was a young tax guy who was trying to access the red firebox to find out from the Port Authority ……but so nothing was coming from the Port Authority and WTC2/0002/N who was head of human resources told people well why don't you take the stairs maybe the express elevators were still working go to the Sky lobby on 78 because to get to the local elevators was totally blocked and WTC2/0001/N and I looked at each other and we said yes let's get outta here" [page 1, line 29 to page 2, line 7]

This statement provides a considerable amount of information from which key data can be extracted. It provides information that can be used to estimate a response time for WTC2/090/0001, it provides information regarding the number and nature of activities undertaken by the person during the response phase, it provides information relating to the formation of a group consisting of two individuals (WTC2/090/001 and WTC2/0001/N) and it provides a means to estimate the time (time sub-interval) at which WTC2/090/0001 entered the stairs.

- **Examples of fatigue, group behaviour and stair travel speed.**

From the same transcript we also learn about their descent down the stairs:

> "I couldn't tell who was in front of me who was in back of me except I knew WTC2/0001/N we kinda kept track of each other this whole time period I knew he was behind me and we got to 78 and WTC2/0001/N said he couldn't go down the stairs any further cos he's 75 and he just couldn't go any farther so we got out and at that point which was probably I don't know 2 minutes to 9 or something there were probably about 200 people on this huge Sky lobby ….. then a man from the bank came over and said we should continue down the stairs and WTC2/0001/N said again I can't go down the stairs and we must have stood there maybe a minute trying to decide what to do there were no elevators coming… At about a minute 90 seconds after we got there an elevator came so we didn't discuss it any further the three of us got on….." [page 2, lines 10-41]

This passage provides information relating to the onset of fatigue for WTC2/0001/N, approximate stair travel speeds and the nature of the group interaction while descending the stairs. The issue of fatigue was pursued by the interviewer later on in the interview:

> **"Interviewer 2 (I2):** Was WTC2/0001/N tired at all cos you said he wasn't comfortable walking down..…

> **Participant (P):** Well unbeknownst to me I think he felt out of breath but I mean he was managing ok for that 12 flights ….” [page 12, lines 27-36]

- **Examples of conditions at staircase entry, congestion levels on the stairs and deference behaviour.**

An evacuee from WTC1 (WTC1/060/0001), initially located on the 60th floor, describes his descent down Stairway C:

> **“Interviewer 1 (I1):** Ok. When you yourself entered onto the stairs, were there other people coming down at that point?
> **P:** No.
> ……..…
> **I1:** So basically you were able just to step into, enter the stairs and follow the…
> **P:** Boom. No problem. Gone. First five floors, there was no one coming in. So we were able to run down the first five floors, not a soul in the stairwell, until we got down to about 55 when all of a sudden it came to a halt.” [page 1, line 29 to page 2, line 7].

The above passage indicates that when the participant entered the stairs on the 60th floor, the staircase was clear of congestion. At around the 55th floor he encountered congestion.

> **P:** That’s where congestion came in, about 55.
> **…**
> **I1:** More than that, ok. [Continues onto next Fruin]
> **P:** Yes.
> **I1:** Ok, that one is Orange. I’m just going to, as I say, go through them all.
> **P:** Sure. [Views remaining Fruins] No, Orange is definitely the right one, definitely not Purple! [Laughs]

At around the 55th floor the participant encounters congestion and using the Fruin based tool, describes it as ‘orange’ (Fruin Level F, approximately 3 people/m^2).

> **I1:** Okay, so that’s Orange. And so when it got congested, did you say this was because other people were coming into the stairs?
> **P:** Yes, other people were coming in as well as already in the stairwell from whatever floor they had come from.
> **I1:** Right. And what happened? How did they come into the stairs? Were people making way to let them in or were they…
> **P:** Yeah, it was generally an organised, civil exodus. There weren’t… there was no pushing, no shouting, no panic. So, when people were

> coming in the stairs, it was just like you were getting on the subway; one next, one next, and it was pretty organised.
> **I1:** And how did that affect the travel speed?
> **P:** It slowed down dramatically.

The higher density on the stairs appears to be caused by large numbers of people from the lower floors entering the staircase. It appears that the stair flow deferred to the floor flow and allowed people from the floors to enter the staircase. The participant describes a merging process that is equally shared between the floor and stair flows. However, this merging process greatly reduces the speed of the stair flow.

> **I1: …..** Can we just go to the fire fighters for a moment? Were there many of them coming up the stairs?
> **P:** About 20.
> **I1:** And were they all grouped together, or spread out?
> **P:** Yeah, grouped together. They were all grouped together. They all came on their right. They instructed us, "Make a hole, step to your right, let the firemen through". They came up and then the same thing happened on the way down, "Make a hole, injured coming down, everyone step to their right and let the other side open for injured".
> **I1:** Did that mean that you had to stop?
> **P:** Stop.
> **I1:** Ok, so you stopped completely.
> **P:** We stopped completely while they were passing. And as soon as they went past, then you went back out and filled the stairwell and continued the progress down.
> **I1:** How long would you say you were stopped for in these periods?
> **P:** Two minutes. No, you know what, that's not true. One minute. It was about, less than or…a minute. I mean I can't say for sure, but it wasn't two minutes. One minute." (page 13, lines 1-31)

Here we learn that the fire fighters ascending WTC1 (on Stair C) that are encountered by this participant came up in a group of 20. The fire fighters requested that the evacuees should form a single line to their (evacuees') right. When the evacuees stepped to the right they effectively came to a standstill until the fire fighters passed by and then the evacuees resumed their downwards motion, two abreast.

- **Examples of conditions at staircase entry, congestion levels on the stairs, deference behaviour and group behaviour.**

An evacuee from WTC1 (WTC1/071/0006), initially located on the 71st floor describes her entry into Stairway C:

> **Il:** right okay and did you have to stop, wait in line to get into the stairwell?
> **P:** no (page 15 line 41-42)

> **Il:** so it was like blue as your entering the stairwell? [FRUIN DENSITY]

> **P:** yeah (page 16 line 14 -15)

The participant suggests that they did not have to wait to get onto the stair and when they merged onto the stair the population density was approximately equivalent to Fruin C, about 1 people/m^2. At this population density, the person experienced no difficulty in entering the staircase flow.

> **Il:** so you both shared the step?
> **P:** yes [GROUP ID:WTC1/0014]
> **Il:** right and in terms of if you could describe your…
> **P:** but for the most part we did. There were points were people were spaced out a little bit and then we got crunched up a little bit, he might have held my elbow (Page 16 Lines 19-24)

The participant formed a group of two with a blind person from her floor and assisted him down the stairs. The group were moving down the stairs two abreast.

> **Il:** okay and did people um, you said people coming down, did they overtake you in the stairwell?
> **P:** some did yeah, if they were moving faster than us and that there was space yeah. People were courteous, people weren't panicked….. (Page 16 lines 41-43)
> …..
> **P:** no its more when you got to the landing it was wide that they would just kinda move around us but that wasn't happening a whole lot. It did toward the lower stairs when it became really treacherous. We kept up a fairly good pace, like I don't think we were bottle necking at all even though there were two of us, there. (Page 17 lines 8-11)

Other evacuees could and would overtake the group of two (participant and blind colleague) on the landings where there was space to do so.

Analysis of the transcripts is currently underway to identify BP's, from transcripts and to then code the information into the database. Eventually all the transcripts will be coded in this manner allowing systematic and detailed analysis of evacuee behaviour across all the accounts.

6.0 Concluding remarks

The evacuation of the WTC complex is one of the largest full-scale building evacuations in modern times. As such it is of fundamental importance to our understanding of the complex interaction between structure, procedures, environment and human behaviour; and how these factors interact to determine evacuation performance. The WTC evacuation provides an opportunity to probe into and understand the very nature of evacuation dynamics and with this improved understanding, contribute to the design of safer, more evacuation efficient, yet highly functional, high rise buildings. At the time of writing, work on project HEED continues to populate the database and commence the preliminary analysis of the data.

However, we believe that the HEED database will be an invaluable research tool and resource for anyone with an interest in developing fire safe built environments. The database will remain live after the end of this current project to accept, where considered appropriate additional input. Latest developments in project HEED can be found on our web site at www.wtc-evacuation.com.

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