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INVESTIGATING THE IMPACT OF CULTURE ON EVACUATION RESPONSE BEHAVIOUR

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ABSTRACT

The aim of this work was to investigate whether social culture impacts how people respond to an evacuation alarm. As part of this work four unannounced library evacuations were conducted in the Czech Republic, Turkey, Poland and the UK. In an attempt to isolate social culture as the primary independent variable across the trials, the key parameters that are known to influence Response Phase behaviour and performance e.g. population demographics, type of structure, alarm system, etc were controlled across the trials. Response Phase behaviour was determined for a total of 477 individuals, 192 from Poland, 51 from Turkey, 70 from the Czech Republic and 104 from the UK. The results suggest that there are significant differences in the nature of the population behaviour during the Response Phase across the four trials. On average, the population with the quickest to the slowest response times are: Turkey, Poland, UK and Czech Republic. When applied to a simulated evacuation, the observed differences in response time distribution for the national groups resulted in significantly different evacuation performance.

INTRODUCTION

Project BeSeCu (Behaviour, Security and Culture)[1-5] is a European Union (EU) Framework Programme 7 (FP7) funded research project with the aim of studying how people react in an emergency, and to determine whether there are any cultural factors – both social culture and fire safety culture – which impact emergency behaviour. By social culture we mean a society's shared system of values, beliefs and attitudes that influences that society's perception of the world and its behavioural response to both every day encounters and unusual incidents. When discussing social cultures it must be emphasised that we are not talking about individuals but of large populations and so are attempting to compare one distribution of behavioural response for one population with that of another. Aspects of social culture which may differ from one society to another include degree of physical contact, nature and extent of eye contact, degree of physical social separation, sense of community, feelings of fatalism, levels of machismo, risk perception, response to authority, acceptable levels of public and private signs of emotion, etc. By fire safety culture we mean the regulatory fire safety framework, supported by legislation, prescriptive guidance, education efforts, performance guides and most important enforcement that exists within a society. This top-down safety culture (where safety levels are imposed) is, to some degree, supported by a bottom-up

expectation of the public regarding safety levels in general. This extends far beyond fire safety with the public having high expectations regarding the functionality and safety levels reached in all aspects of life. It is often suggested that differences in culture may influence the response of the public to emergency procedures. Specifically, it is hypothesised that differences in social and fire culture may result in differences in response behaviours and response times.

The experimental component of project BeSeCu addressed issues associated with Response Phase behaviours and the impact of culture. The evacuation process can be considered to comprise two broad phases, called the Response Phase and Evacuation Movement Phase[1-5]. It is now widely accepted that a key factor which can determine the success of an evacuation is the speed with which occupants respond to the call to evacuate and begin purposeful movement to a place of safety, commonly referred to as the response time (also called pre-movement time)[6,7]. In practical fire engineering applications it is common practice to assume that evacuation related data can be reliably applied more widely than the context from which the data was collected. In particular, this type of data is often applied to situations within cultural environments – both social and fire – different to that from which the data was collected. The majority of readily available published evacuation data (both response time and total evacuation time) that is used in fire engineering applications throughout the world originates from a small number of countries with broadly similar cultural backgrounds; i.e., UK, USA, Canada, Australia and New Zealand. There has been very little effort in exploring the impact of culture on fire evacuation behaviour, especially outside of the small number of countries mentioned. Here we take culture to mean both the social culture and the fire safety culture of the society that the occupants belong to.

This begs the question, can response time data collected from predominately Western European/North American type social cultures (UK, Australia, Canada, USA, New Zealand) be applied in significantly different social cultures such as in Japan, China, Korea, Turkey, Czech Republic, Brazil, etc? Is there a cultural component to the time required to complete the Response Phase? Furthermore, can response time data derived from countries with a well developed fire culture and legislative framework e.g., UK, Australia, Canada, USA, New Zealand, Japan be applied in countries with a less well developed fire culture and legislative framework e.g. Turkey, Brazil, Korea, Czech Republic, etc?

The experimental component of project BeSeCu involved four unannounced library evacuations run in the Czech Republic[1], Turkey[2] and Poland[3] and the UK[4]. Response Phase behaviours derived from these trials have been extracted and analysed in isolation[1-4]. In this paper we present a cross-cultural analysis of this data in an attempt to identify whether social culture influences Response Phase behaviour.

RESPONSE PHASE BEHAVIOURAL FRAMEWORK

The proposed evacuation behaviour framework has been described several times before and so is only briefly discussed here[1-5]. The evacuation process is considered to comprise of two broad phases the; Response Phase and Evacuation Movement Phase. The framework attempts to convey the nature of the human factors processes that characterise

Response Phase behaviours. This description not only provides a consistent method for describing Response Phase behaviour, but also provides a useful framework for classifying and quantifying the Response Phase other than simply using the overall response time. Using this framework we may eventually be able to develop predictive models to estimate response times. A key part of the Response Phase analysis is the determination of the Notification, Cognition and Activity stage start and end points[5].

Notification Stage

The first stage of the Response Phase is the Notification stage in which notification cues such as an alarm conveys to the occupants that an unusual and potentially hazardous event has occurred, requiring the occupants to evacuate. The start of the Notification stage is marked by the occupants being exposed to the first cues. For each exposed occupant, the end of the Notification stage is marked by the occupants responding to the notification cues by mentally and/or physical disengaging from the tasks they were previously involved in and the recognition that the cue(s) they have been subjected to indicate that something unusual may be occurring in their environment. At the end of the Notification stage, while the occupants are alerted, they have not started to physically react to the situation. The end of the Notification stage marks the beginning of the Cognition stage. The duration of the Notification stage is the Notification Time (NT).

Cognition Stage

During the Cognition stage the alerted occupants interpret the information provided by the initial notification cues, and potentially other sources of information (e.g. further incident related cues, staff intervention, etc), and decide how they should respond. There are essentially three broad types of response the occupant may decide to undertake:

- The notification cues are ineffective resulting in the occupant re-engaging in their previous activity until further cues or information is received.
- The occupant acknowledges the initial notification cues and immediately commences evacuation movement without undertaking any other activity. Here, the end of the Cognition stage marks the end of the Response Phase.
- The occupant acknowledges the notification cues indicate that something potentially hazardous is occurring and commences a series of Action and/or Information tasks, marking the start of the Activity stage. Cognitions may be occurring at the same time as activities, activities could be sparking new cognitions and cognitions could initiate one or more new activities. The Activity stage runs in parallel to the Cognition stage. The duration of the Cognition stage is less well defined as it may have several possible end points and so is taken to run to the end of the Activity stage.

Activity Stage

During the Activity stage the occupant performs a series of Information and/or Action tasks[1-4,8] conceived during the Cognition stage. These are defined as follows:

- An Action task involves the occupant physically undertaking an activity such as: shutting down a work station; packing work items; moving to another location, etc. NAT is the Number of Action Tasks undertaken by an individual.
- An Information task involves the occupant seeking, providing or exchanging information concerning the incident or required course of action. Information tasks may thus involve the physical movement of the occupant; however, what distinguishes this activity from an Action task is the end purpose of the movement i.e. to obtain information or to undertake a physical task. NIT is the number of Information Tasks undertaken by an individual.

It is hypothesised that the Cognition stage may run in parallel to the Activity stage, and so the occupant may return to the Cognition stage to interpret new information gained, assess their current situation and contemplate their next course of action, which may in turn require further Action/Information tasks to be executed. The start of the Activity stage is marked by the commencement of the planned tasks while the end of the Activity stage is marked by the completion of all tasks conceived during the Cognition stage. The end of the Activity stage usually denotes the end of the Response Phase and the beginning of the Evacuation Movement Phase. At the start of the Evacuation Movement Phase the occupant begins purposeful movement to an exit or stair or place of safety.

THE TRIALS

A summary of the trials is presented here for completeness. Full details of each trial can be found in a series of papers[1-4] describing the results of each trial. The building type used in all four evacuations was identical i.e. university libraries. All four evacuations were unannounced, with staff and students not knowing that they were participating in an evacuation experiment. The three BeSeCu trials were undertaken at the following locations:

- Czech Republic: VSB-Technical University of Ostrava, 21 October 2009
- Turkey: Izmir Yuksek Teknoloji Enstitusu, 2 March 2010
- Poland: University of Warsaw Library, 26 May 2010

A similar evacuation protocol was implemented at each site. This involved the activation of a voice alarm to initiate the evacuation. The fourth trial took place at the Dreadnought Library of the University of Greenwich on 22 January 2007. The University of Greenwich evacuation did not involve a voice alarm but a standard fire alarm tone. The three evacuations that were conducted as part of project BeSeCu generated detailed Response Phase behaviours for 373 individuals. Combined with the data analysed from the UK evacuation, the Response Phase data-set studied in BeSeCu comprised 477 individuals, 192 from Poland, 51 from Turkey, 70 from the Czech Republic and 104 from the UK. Every effort has been made to ensure that the initial conditions for each evacuation were as similar as possible. This is essential to ensure that as far as possible the main variables that may influence the evacuation relate to social culture. The similarities and differences between the various populations involved in the four trials are summarised as follows:

- The age distribution of the populations involved in each of the three BeSeCu trials were similar, with at least 99% being between 18-34 years of age. The age in the UK

sample was derived differently to that of the BeSeCu trials, but was determined to be 100% between 18-39 years of age.

- The gender mix for three of the four libraries is similar, being between 49% to 54% female, with the Czech Republic standing out as having only 13% females. The predominance of males in the Czech Republic trial may have an influence on the results, but this may also be a social cultural influence associated with gender.
- The three BeSeCu library populations have a similar evacuation experience base with over 90% of each population not experiencing an evacuation drill of any sort prior to the trials. For the UK population, approximately 54% had not experienced an evacuation drill of any sort prior to the trials. However, as with the other three populations, the majority of the population in the UK library had no experience of an evacuation trial.
- In each of the three BeSeCu library populations, the majority of participants (over 60%) felt that they were normally at no or little risk from serious injury from fire in the library. Of the three populations, the Polish population felt least safe in the library.
- Three of the four libraries had almost 90% of their populations involved in work related activities immediately prior to the alarm however; the Turkish population had only 57%. Furthermore, Turkey, Czech Republic and the UK had about half the population involved in computer based work while Poland had about a quarter. Being engaged in a work activity, in particular a computer based activity, may make the participant more reluctant to disengage from their work activity and engage in evacuation activities. Unfortunately, this variable was beyond the control of the experimental procedure.

RESPONSE TIME ANALYSIS

A statistical analysis was performed on the response time distributions derived from each experiment to determine the significance of the differences between the curves. The response time distributions that were used in the analysis are: Turkey, Poland, Czech Republic (alarm only) and UK (alarm only). The Czech Republic data-set was restricted to the alarm only respondents as the occupants who responded to staff intervention did not hear the voice alarm[1]. As the notification cues and likely response associated with staff intervention and voice alarm are considered to be significantly different, it was considered justified to exclude the staff intervention sub-population from this analysis. Similarly, the UK data-set was restricted to those participants who only reacted to the alarm[4]. The response time curves for these four populations are displayed in figure 1. While all four curves are log-normal in appearance they appear to be significantly different to each other.

In order to determine whether or not the differences between the curves are statistically significant, non-parametric testing was performed on the response time distributions from the four libraries. If the data-sets are not normally distributed two non-parametric tests that can be used are, the Kruskall-Wallis test and the Mann-Whitney test. All the statistical analysis was completed using the SPSS software. The Kruskall-Wallis analysis (with three degrees of freedom) was applied to the four data-sets (Poland, Turkey, Czech Republic (alarm only), and

UK (alarm only)) and the result is significant at the p = 0.01 level (H(3) p = 0.000, p < 0.01) indicating that there is a significant difference between the four data-sets.

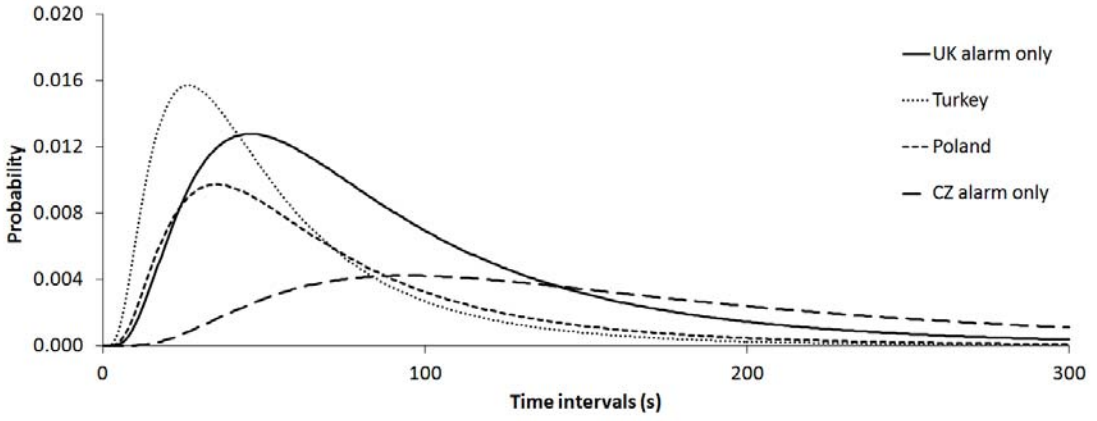

Figure 1. Response time distributions for the four library evacuations.

The Mann-Whitney test is then performed on pairs of data-sets to identify where significant differences between the data-sets lie. This revealed that there is a significant difference between each pair of response time distributions at the 5% significance level.

The UK (alarm only) response time data is:

- quicker on average than the Czech Rep (alarm only) response time data.
- slower on average than the Poland response time data.
- slower on average than the Turkey response time data.

The Poland response time data is:

- quicker on average than the Czech Rep (alarm only) response time data.
- slower on average than the Turkey response time data.

The Turkey response time data is:

- quicker on average than the Czech Rep (alarm only) response time data.

Response Phase Parameters

Presented in Table 1 is a summary of the Response Phase parameters for all the distributions along with an average for the Poland, Turkey, Czech (alarm only) and UK (alarm only)[1-4]. If culture influences Response Phase behaviour and response time, then it can be expected that culture would also influence the Response Phase parameters of NT, NAT, NIT, ATT (Action Task Time – average duration of an Action Task) and ITT (Information Task Time – average duration of an Information Task). Comparisons between the four national sets are made by comparing relative trends between parameters and also comparing parameter values with cross national average values. In Table 1, individual parameters which are greater than the national

averages are italicised, those which are less than the national average are in normal font while those that are equal to the national average are in bold.

From Table 1 it is possible to identify trends in the average number and average duration of Response Phase tasks (NAT, NIT, ATT and ITT) for the national average and the individual national groups.

- Taken across all four populations, the national average population:
  - Undertakes more Action than Information Tasks and
  - The average duration of an Information Task is greater than the average duration of an Action Task.

Table 1: Summary of response phase parameters

	Poland	**Turkey**	**Czech Alarm**	**UK Alarm**	**Average**
People	**192**	**51(50)**	**20**	**63**	**326**
NT (sec)	8.3	10.0	*88.6*	*17.8*	**10.4**
NIT	3.8	*5.1*	*7.4*	3.9	**4.2**
NAT	*6.1*	3.5	*5.7*	4.9	**5.4**
TNT	*9.9*	8.6	*13.1*	8.8	**9.7**
ITT (sec)	6.1	4.7	*9.9*	*11.2*	**7.1**
ATT (sec)	**6.4**	5.2	**6.4**	*7.6*	**6.4**
Average RT (sec)	69.9	56.1	*193.7*	*91.8*	**79.6**
Predicted RT (sec)	**67.8**	**49.8**	**194.8**	**95.4**	**71.3**

These trends can be compared with the trends observed in each of the national groups to determine whether the national groups display similar or different trends.

- The UK (alarm only) population:
  - Undertakes more Action than Information Tasks and
  - The average duration of an Information Task is greater than the average duration of an Action Task.

- The Polish population:
  - Undertakes more Action than Information Tasks and
  - The average duration of an Action Task is greater than the average duration of an Information Task.

- The Czech (alarm only) population:
  - Undertakes more Information than Action Tasks and
  - The average duration of an Information Task is greater than the average duration of an Action Task.

- The Turkish population:
  - Undertakes more Information than Action Tasks and
  - The average duration of an Action Task is greater than the average duration of an Information Task.

The UK (alarm only) population is the only one of the four national groups whose trends in Response Phase characteristics matches that of the trends of the average population. The Polish and Czech (alarm only) populations match different aspects of the average trend, with the Polish population matching trends in the number of tasks, while the Czech (alarm only) population matches trends in the average duration of the tasks. The Turkish population behaves in a way which is opposite to the national average trends. Thus it is clear that trends in the number and duration of Response Phase tasks differ between the national groups.

In addition to comparing trends in Response Phase parameters, it is also possible to compare how the values of these parameters compare with the national average values. Virtually all the Response Phase parameters for the Czech (alarm only) group are greater than or significantly greater than the group averages, indicating that this group will take considerably longer in the Response Phase than the national average, and is likely to have the longest response time.

For the UK (alarm only) group, the NT is significantly greater than the national average. While the number of Action and Information Tasks undertaken are less than the national averages, the average duration of both Action and Information Tasks are greater than or significantly greater than the national group averages. This suggests that the UK (alarm only) group will take longer in the Response Phase than the national average. For the Polish group, the NT is smaller than the national average. While the number of Action Tasks is greater than the national average and the number of Information Tasks is less than the national average, the average duration of Action Tasks is the same as the national average and the duration of Information Tasks is less than the national average. This suggests that the Polish population is likely to have a shorter Response Phase than the national average.

For the Turkish group, the NT is smaller than the national average. While the number of Action Tasks is less than the national average and the number of Information Tasks is greater than the national average, the average duration of both Action and Information Tasks is less than the national group averages. This suggests that the Turkish population is likely to have a shorter Response Phase than the national average, and is likely to have the shortest Response Phase of the four groups. It is interesting to note that a number of people in the Turkish library evacuation left all of their belongings behind when they evacuated the library. This includes personal computers, bags and books. This behaviour was not noted in any of the other library evacuations. This may explain why the average number of Action Tasks for the Turkish library is less than that for the other four libraries.

In terms of average notification times, the UK (alarm only) and Czech (alarm only) are 71% and 752% greater than the national average respectively, while the Turkish and Polish are 4% and 20% less than the national averages respectively. In terms of average response times, the UK (alarm only) and Czech (alarm only) are 15% and 143% greater than the national average respectively, while the Polish and Turkish are 12% and 30% less than the national averages respectively.

Given that the parameters that influence Response Phase behaviour and performance (e.g. population: level of familiarity and training, age distribution and gender mix and type of

structure) were reasonably controlled in these trials, it is possible that the observed significant differences in response time distributions and the differences in Response Phase parameters are the result of cultural influences in Response Phase behaviour.

Other Factors which may have Influenced Response Times and Response Phase Behaviours

Several factors complicate the nature of the cross national comparisons undertaken in this assessment. Each of these is briefly examined in turn.

Level of repeatability

Only a single evacuation trial was conducted in each of the four libraries. Thus the question arises as to how representative is the response time distribution and Response Phase behaviours measured in these trials. It is suggested that given the large number of people involved in the trials and given that we are considering the population response time distribution that it may not be necessary to undertake repeat trials. It is suggested that response time distributions generated from a given structure type, with identical notification systems and different populations but with similar demographics will be very similar.

Detailed evidence to support this view is limited as repeat evacuation trials under identical conditions are seldom undertaken. However, the authors have undertaken such a repeat series of trials as part of the EU FP7 project SAFEGUARD[9] involving two semi-unannounced evacuation trials were conducted on a large passenger vessel. For these trials, the nature of the structure was identical and the nature of the population in both trials was very similar, with a similar gender, age and nationality mix. The alarm system used in each trial was identical and the assembly process was identical. In the first trial 533 response times were collected and in the second trial 470 response times were collected. The two log-normal response time curves for the two trials were remarkably similar. Statistical analysis suggests that the two distributions are identical (5% significance level, with a p-value = 0.0795). As both distributions are identical this suggests that if the trial were to be repeated again within the same environment with a different group of people with similar demographics, we would expect to generate the same RTD. This is a powerful result and supports the view that we may expect repeat evacuation trials in the same structure with a different population but with the same demographics to produce similar response time distributions. Thus not undertaking repeat evacuation trials in the four libraries may not significantly impact the conclusions.

Nature of the alarm in the UK building

The nature of the notification system is known to have an impact on response time. Therefore in an attempt to control the influence of this parameter it was essential that the populations in all three BeSeCu trials were subjected to the same type of alarm. This was achieved in each of the three BeSeCu buildings in which a voice alarm system was used. However in the UK building, a traditional alarm bell was used. A simple conventional tone alarm is known not to be as efficient as a voice alarm in motivating the population to respond to the call to evacuate. Thus we may reasonably expect that had a voice alarm system been used in the UK building that a shorter average response time may have been produced. It is thus difficult to isolate

culture as the only distinct variable in the UK data-set. However, if the UK distribution is removed from the cross comparisons, there are still significant differences between the three BeSeCu response time distributions and Response Phase behaviours.

Nature of the pre-alarm activities

The nature of the pre-alarm activities may influence how rapidly the population responds to the alarm. In an attempt to control this variable, the same type of building was used in all four trials i.e. university libraries. By using the same type of building it was hoped that the nature of the activities that the population were involved in would be broadly similar. Within a library environment it was anticipated that the majority of the population in each case would be involved in study/work related activities. This is indeed the case with 57% or more of the population in each library being involved in study/work related activities. The difference in the proportion of the various populations involved in work related activities prior to the alarm is not considered to have greatly contributed to the observed significant differences in the response time distributions and Response Phase behaviours. However, the relatively small proportion of the Polish population involved in computer work related activities at the time of the alarm compared to the other populations may have had some impact on the notification time distribution with some effect on the response time distribution.

GAUGING THE IMPACT OF THE DIFFERENT NATIONAL RESPONSE TIME DISTRIBUTIONS

The response time distributions for the four national groups (see figure 1) have been shown to be statistically significantly different. However, it is not clear what impact these differences would have on the duration of an evacuation. In order to assess the impact of these four different response time distributions on evacuation time, each distribution is applied in turn to an evacuation simulation of the Turkish library. The simulations make use of the Turkish library geometry and initial population distribution[2]. The setup for the evacuation simulation has been described previously[2] and so will not be repeated here. However, note that in these simulations, the agents attempt to exit via their nearest exit and a turnstile model has been included to represent the delay associated with the turnstile at the main exit. Also note that there are two exits to the building on the ground floor, a main exit, which is normally used for entrance/exit to the library and an emergency exit. The buildingEXODUS evacuation simulation software[2] is used for these simulations. In each of the four scenarios there are 100 agents and each scenario is repeated 20 times. The only difference between the four scenarios is the response time distribution utilised. The egress curves shown in figure 3 represent the average of the 20 repeat simulations for each scenario.

For the purposes of this analysis the differences between the model predictions for the different response time distributions is of interest. From figure 3 we note that Polish simulation produces the most similar total evacuation time to the Turkish simulation while the Czech predications produce the greatest difference in total evacuation time. These differences are not only in the time for the last agent to exit, but are apparent throughout the simulations. While the Turkish and Polish exit curves are quite similar, those produced using the Czech and UK response time distributions are significantly different to the Turkish exit curves. Clearly using

the response time distributions generated from the different national groups can lead to very different evacuation predictions. In the best case (comparing the Turkish prediction with the Polish prediction), differences in evacuation times can be up to 5% while in the worst case, (comparing the Turkish prediction with the Czech prediction), differences in evacuation times can be as much as 93%.

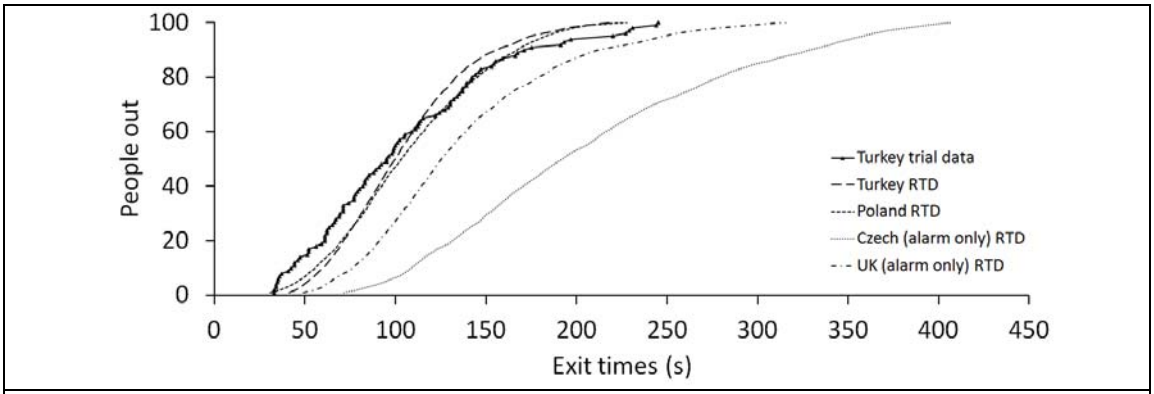

Figure 3. Average predicted and measured exit counts using different RT distributions

CONCLUSIONS

The main purpose of this work was to examine if social culture influences the manner in which people respond to the call to evacuate. The work involved four library evacuations conducted in four different countries. Differences in the relative trends between key Response Phase parameters (NAT, NIT, ATT, ITT and NT) defining Response Phase behaviour were noted. Furthermore, the response time distributions for the four national groups have been shown to be statistically significantly different. However, this in itself does not imply that significantly different evacuation performance may result from differences in population response times. In order to assess the impact of these different response time distributions they were each applied in turn to the Turkish library evacuation and the buildingEXODUS evacuation simulation software was used to gauge the impact these different response time distributions would have on the evacuation.

The four evacuation simulations produced using the four national response time distributions resulted in different evacuation predictions, which in some cases were considered to be significantly different. Thus if significant differences in national representative response time distributions exist, they can lead to very different evacuation outcomes. It is thus important to ensure that the response time distribution used in computer egress simulations in different countries are representative of that national group.

Given that the parameters that influence Response Phase behaviour and performance were reasonably controlled in these trials, it is possible that the observed significant differences in response time distributions are the result of cultural influences on Response Phase behaviour. While this work suggests that social culture will influence Response Phase behaviour and hence response times, further work is required before a definitive link can be confirmed.

ACKNOWLEDGEMENTS

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