Safety Science 82 (2016) 421–431

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

A study of herding behaviour in exit choice during emergencies based on random utility theory

Ruggiero Lovreglio [a,*], Achille Fonzone [b], Luigi dell'Olio [c], Dino Borri [a]

[a] Department of Civil, Environmental, Planning, Building and Chemistry, Politecnico di Bari, Via Edoardo Orabona, 4, 70126 Bari, Italy
[b] Transport Research Institute, Edinburgh Napier University, 10 Colinton Road, Edinburgh EH10 5DT, United Kingdom
[c] Transport Systems Research Group, Universidad de Cantabria, Avda. de los Castros, s/n, 39005 Santander, Spain

ARTICLE INFO

Article history:
Received 12 January 2015
Received in revised form 19 October 2015
Accepted 27 October 2015
Available online 12 November 2015

Keywords:
Evacuation modelling
Herding behaviour
Exits choice
Social influences
Random utility theory

ABSTRACT

Modelling human behaviour in emergencies has become an important issue in safety engineering. Good behavioural models can help increase the safety of transportation systems and buildings in extreme situations like fires or terrorist attacks. Although it is well known that the interaction with other decision makers affects human behaviour, the role of social influences during evacuations still needs to be investigated. This paper contributes to fill this gap by analysing the occurrence of Herding Behaviour (HB) in exit choice. Theoretical explanations of HB are presented together with some modelling approaches used in different fields where HB is relevant. A discrete choice stated preference experiment is then carried out to study the role of HB in the decision-making process concerning exit choice during evacuation. A binary logit model is proposed showing that the occurrences of HB are affected by both environmental and personal factors. In particular, the model shows that the personal aptitude to HB can have a key role in selecting an exit.

1. Introduction

Many studies on evacuation issues, in the last few decades, have proved that the existing transportation systems and buildings do not always provide adequate levels of safety (Fridolf et al., 2013; Averill et al., 2005). An estimate of the safety condition of transportation systems and buildings can be performed with the application of a performance based design approach, e.g. by comparing the *available safe egress time* and *required safe egress time* (Purser, 2003). Several macroscopic and microscopic models and software packages have been developed to estimate the *required safe egress time* (Kuligowski et al., 2010; Gwynne et al., 1999). However, the validity of these models may be limited due to the existing lack of knowledge regarding human behaviour during emergencies, as reported in the literature (Lovreglio et al., 2014c).

The act of evacuating from a building and transportation systems requires the occupants to develop and take different decisions (e.g. to investigate and to seek more information on the situation, to evacuate, to choose an exit, etc.) (Lovreglio, 2014; Lovreglio et al., 2015b,d, in preparation). Among these, once the decision to evacuate has been taken, exit choice is surely one of the most important (Ronchi et al., 2012a,b). Exit choice can be influenced by both physical factors (e.g. evacuees' mobility, presence of obstacles, visibility, etc.) (Jeon et al., 2011; Kobes et al., 2010) and social factors (e.g. behaviour of other evacuees, etc.) (Lovreglio et al., 2014a; Kinateder, 2012).

Different models and theories have been developed to explain social interactions during evacuations. The four commonly accepted theories are the *Role-rule Theory* (Canter et al., 1980), the *Affiliative Theory* (Sime, 1985), the *Social Influence Theory* (SIT) (Nilsson and Johansson, 2009) and Caldini's *Social Proof Theory* (SPT) (Cialdini, 1993). Three types of interactions among evacuees have been identified: *HB* (i.e. following others' behaviour), *cooperative behaviour* (i.e. working or acting together for the common/mutual benefit) and *competitive/selfish behaviour* (Heliövaara et al., 2012; Pan, 2006; Helbing et al., 2000). This work focuses on the occurrences of HB during exit choice. HB occurs whenever a decision-maker prefers, among different options, to follow other people's choices (Banerjee, 1992; Heliövaara et al., 2012). As regards to the exit choice, this can be explained by the decision

Abbreviations: HB, Herding Behaviour; HC, High herding Class; ISI, Informational Social Influence; LC, Low herding Class; MC, Medium herding Class; NSI, Normative Social Influence; RUT, Random Utility Theory; SIT, Social Influence Theory; SPT, Social Proof Theory.

* Corresponding author at: Transport Research Institute, Edinburgh Napier University, 10 Colinton Road, Edinburgh EH10 5DT, United Kingdom. Tel.: +44 7707 796624.

E-mail addresses: ruggiero.lovreglio@poliba.it (R. Lovreglio), a.fonzone@napier.ac.uk (A. Fonzone), luigi.dellolio@unican.es (L. dell'Olio), dino.borri@poliba.it (D. Borri).

http://dx.doi.org/10.1016/j.ssci.2015.10.015
0925-7535/

of the evacuee to choose an exit just because other evacuees had selected it, instead of striving to identify the exit that would provide them with the best evacuation conditions. The literature argues that HB could have both positive and negative effects depending on the evacuation conditions (Alavizadeh et al., 2008). In fact, it can lead to unwanted situations in highly crowded buildings, with limited visibility situations (i.e. heavy presence of smoke) or when exits are difficult to find (e.g. because evacuation paths are not well indicated) causing damage to transportation systems and loss of life during evacuations since it could lead to a non-optimised use of the exits (Helbing and Johansson, 2011; Schadschneider et al., 2009; Alavizadeh et al., 2008; Saloma and Perez, 2005). However, it may help evacuees exit faster when the building is not highly populated and when evacuees are mostly unfamiliar with exit paths (Alavizadeh et al., 2008; Kirchner and Schadschneider, 2002). In fact, the choices made by evacuees familiar with the building could positively affect the choices of unfamiliar evacuees. Therefore, a full understanding of this behaviour can be indispensable to improve the evaluation of safety condition of transportation systems and buildings.

This paper presents a study of the decision-making process underpinning exit choice by using data collected through an online survey. The research consists of two steps: in the first step, a conceptual framework of HB is derived by reviewing the existing theories on social interaction. The outcomes of the review are used to make sense of the experimental results. In the second part, a stated preference experiment is carried out by asking participants to select an exit in relation to several hypothetical situations presented in short videos. A behavioural model based on the Random Utility Theory (RUT) is proposed to explain the occurrence of HB. A small qualitative study is performed to confirm the validity of the researchers' interpretation of the survey. The RUT has already been used to investigate exit choice and route choice in normal (Hoogendoorn and Bovy, 2004) and emergency situations (Guo and Huang, 2010, 2011; Lovreglio et al., 2014a; Guo et al., 2013). In these previous studies, the goal was to identify the exit or the route selected by pedestrians/evacuees considering the utility associated with each available exit/route. By contrast, this work aims at identifying the evacuees' utility to select the most crowded exit manifesting HB. This goal is achieved showing that HB can be the outcome of a rational decision-making process contrary to the Irrational Paradigm adopted by several existing models (Helbing et al., 2002; Kirchner and Schadschneider, 2002) and that both environmental and personal factors can influence the occurrence of this behaviour.

The paper is outlined as follows: Section 2 presents a review regarding the *SIT* and the *SPT* and how these theories can explain the occurrences of HB. A summary on the modelling approaches used so far to model HB is provided in Section 3. Then, the proposed approach is presented and compared with existing ones. The methodology adopted is described in detail in Section 4. Section 5 reports a case study and the analysis of the data collected through the online survey. A qualitative analysis of face-to-face interviews, aiming to investigate the reasons, which made respondents choose the most crowded exit is also presented. A discussion of the estimated model, a sensitivity analysis and an implementation of the proposed model are provided in Section 6. Conclusions are presented in Section 7.

2. Social interaction and herding behaviour

As reported in the literature, evacuees usually behave differently depending on whether they are alone or in a group (Pan et al., 2007; Braun et al., 2003). Previous studies found that the decision to evacuate a building or a transportation system (Nilsson, 2009; Fridolf et al., 2013; Latane and Darley, 1968; Lovreglio et al., 2015b), or exit choice (Lovreglio et al., 2014a, 2015d, in preparation; Kinateder, 2012) can be strongly influenced by the behaviour of other evacuees. In fact, evacuees can behave differently in accordance with their role during emergency egress (i.e. the Role-rule Theory (Canter et al., 1980)) and whether they are experiencing this situation with other evacuees that are familiar to them (i.e. the Affiliative Theory (Sime, 1983)).

The following section aims to investigate how the SIT and the SPT can provide interesting insights on HB. The SIT was introduced in safety science by Nilsson and Johansson (2009) to explain the social interactions among evacuees. According to this theory, two types of social influences exist. One refers to people who are afraid of standing out by not complying with prevalent social norms, they try "*to conform to the positive expectations of another*" and so they are subject to the so called Normative Social Influences (NSIs) (Deutsch and Gerard, 1955; Nilsson and Johansson, 2009). The Informational Social Influences (ISIs) refer to those arising when an individual accepts "*information obtained from another as evidence about reality*" (Deutsch and Gerard, 1955).

Cialdini's SPT argues that "*we view a behaviour as more correct in a given situation to the degree that we see others performing it*" (Cialdini, 1993). The SPT is directly related to the ISI. In fact, it implicitly assumes that the acts/choices of other people provide an external cue that could influence the decision-making process.

These two theories could help define some reasons that lead people to manifest HB. According to SIT, actions and choices made by others may be a source of information to understand what is going on during situations characterised by uncertainty (Kinateder, 2012; Pan, 2006). For instance, during exit choice, a decision maker can understand that an exit is available for escape because other evacuees are already heading towards it (Fig. 1). A decision-maker exposed to others' actions might choose among different objectives/actions following others' behaviours. In exit choice, this means that a decision-maker chooses the most crowded exit. According to existing theories, two reasons can be provided to explain this behaviour. A decision-maker may choose the most congested exit just because he/she trusts the majority of other occupants' behaviour considering it as the right one (SPT). Another interpretation may be that he/she is concerned about being judged by others and prefers to avoid embarrassment due to a counter-current choice (NSI) (Fig. 1). As reported in the literature, both the preference to trust in the majority's behaviour (SPT) and the fear to look foolish (NSI) are triggered by the uncertainty of the context of choice (Nilsson, 2009; Pan, 2006; Cialdini, 1993). In addition, Cialdini argues the trust in the majority's behaviour may also occur when people are unsure of themselves (i.e. lack of self-confidence) (Cialdini, 1993).

Therefore, it is possible to argue that the choice to herd can be result of a rational decision (i.e. a choice "*procedurally reasonable in light of the available knowledge and means of computation*") (Simon, 1986; Lovreglio et al., 2015d, in preparation) instead of an irrational decision due to the 'panic' as proposed by several existing models (Helbing et al., 2002; Kirchner and Schadschneider, 2002). In fact, a decision-maker living an ambiguous situation tries to find a trade-off between the possibility to choose the less crowded exits (which could allow a faster evacuation by taking the risk to make a counter-cultural choice) and the most crowded exit by trusting in the majority's behaviour. Then, the degree of uncertainty can make the difference in the choice since the higher the uncertainty the more decision-maker could manifest HB.

3. Modelling approaches for HB

Several evacuation models have been developed in the last few decades (Kuligowski et al., 2010; Gwynne et al., 1999). However,