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Human factors in evacuation simulation, planning, and guidance

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Abstract

Evacuation research shows growing interest in human factors and psychology. Before, humans were mostly modelled as homogeneous, without individual emotion, motivation or physical needs. Human factors had mainly been taken into account as physical characteristics or space requirements. In this paper, we give examples of relevant human factors from the literature and our own field research. Human factors include physical, cognitive, motivational and social variables. As yet, there is no validated set of variables most relevant for safe and fast evacuation. Models for classifying human factors from other domains are introduced for use in future research.

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1. Introduction

In research on evacuation, recent years have seen growing interest in human factors and psychology. Real evacuations in the past have taught the importance of human factors: Even where physical wellbeing and spatial aspects of the escape route were not a problem, they did not always run smooth. In a derailing accident in the Moscow Subway system in 2014, some passengers stated afterwards to the media that they had assumed it would be their end. In contrast to that other passengers took their time to take pictures of the derailed subway train instead of leaving the site immediately. Consequently, evacuation was slow and difficult to coordinate as people were injured, in shock waiting for help, or were actively searching for a way out through the dark subway tunnel by themselves.

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Incidents like that have inspired a long-standing tradition of research on behavior of humans in evacuation, especially from fires. Researchers often have addressed behavior that may seem irrational or not understandable, like delayed evacuation. Fridolf (2010) summarizes factors explaining the unwillingness to evacuate a subway train or subway station: information processing and social influence seem to be among the most important. After more than 20 years of research, a lot is known about human behavior in real events. But holistic collection and analysis of data on individual behavior or reasoning in real events is difficult and seldom tried. Field experiments give the opportunity of observing behavior, but here the problem is that usually participants know that there is no danger (e.g. in Zinke et al. (2014)). Field studies sometimes work with unannounced evacuation (e.g. Schmidt and Galea (2013)). As no real danger is present, even in this type of experiment, consequences of real threats and danger cannot be assessed. Also from analysis of real events and field studies, a lot is known about human behavior. Not all of analyses have been integrated into evacuation planning and modelling.

Due to practical and ethical problems of field studies, much evacuation research has been done by simulation and other modelling approaches (Peacock et al. (2011)). In the beginning of modelling research, human factors had not been in the focus; humans were modelled more or less as homogeneous quantity, without individual emotion, motivation or physical needs. Human factors had mainly been taken into account as physical characteristics or physical space requirements. These aspects are integrated into different calculating approaches when the overall time needed for the evacuation is determined (cf. for public transport systems: NFPA 2000; Predtetschenski and Milinski (1971)). In the last decade, also evacuation simulation and modelling have started to take human factors into account (cf. Galea (2014); Schäfer et al. (2013)). The primary motivation for that is expressed by Schatz et al. (2014, p. 1113) describing the performance-based approach: “Since the protection of human life is the primary aim […], predicting the behavior of people on danger is an essential purpose of such modeling”.

Many simulations take into account behavioral tendencies (cf. e.g. Galea (2014); Kostas et al. (2014); Schneider and Könnecke (2007)), e.g. walking towards a goal, taking the nearest exit, avoiding obstacles or following leaders. Even if operationalization is not always transparent, it seems that usually only a few of these variables are integrated. The reason might be that complex agents would not be scalable for larger crowds (Sung et al. (2004)). With advancing computer performance it will be possible to regard also more complex behavioral patterns.

Simulation of crowd behavior and pedestrian dynamics are closely related to evacuation modelling. As these approaches focus on normal conditions rather than emergencies, it is not clear which of their results can be transferred to evacuations. In this type of modelling, some aspects of human factors have been included, especially when regarding models of human behavior. Examples can be found e.g. Moussaïd et al. (2011), in Schadschneider et al. (2008), Helbing et al. (2001). But even though human factors meanwhile are generally accepted as relevant a rather limited range of human factors is integrated. There is a tendency for uniformities and thus oversimplification with respect to the complexity of human individuals (e.g. Klingsch et al. (2010)).

When trying to integrate, in addition to empirical restrictions and modelling limitations, the problem of selecting the right variables arises: “Human factors” include a great variety of different physical, cognitive, motivational and social variables, always regarded in relation to the socio-technical system, the task at hand, and the physical environment (cf. Karwowksi (2012); Badke-Schaub et al. (2012)). Although the need for integrating human factors has been widely recognized, there is yet no set of variables most relevant for safe and fast evacuation.

In section 2, we will discuss the relevance of human factors in evacuation planning and modelling. In section 3, we will give examples of evacuation research considering human factors. They show the broad range of relevant human factors. We also add some results from our own field studies. In section 4, we argue that human factors knowledge from psychology and human factors sciences can be valuable for establishing a set of relevant human factor variables. We also take a look on human factors classifications that could be helpful for evacuation research.

2. Human factors in evacuation - why are they relevant?

Planning for evacuations is a requirement for all infrastructures. Models used for practical evacuation planning, usually take into account mainly three dimensions (e.g. Kirchberger (2006)): The type of building or infrastructure and its environment, the incident with the rapidness of its impact / the type of danger, and human physical aspects.

Let us assume an office building as infrastructure and a fire originating from a printer in an office as an incident with a moderate level of imminent danger. There might be a number of different reactions by the occupants of the