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Introducing human factors in pedestrian crossing behaviour models

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ABSTRACT

The objective of this research is the development of pedestrian crossing choice models on the basis of road, traffic and human factors. For that purpose, a field survey was carried out, in which a panel of 75 pedestrians were asked to take 8 short walking trips (each one corresponding to a different walking and crossing scenario) in the Athens city centre in Greece, allowing to record their crossing behaviour in different road and traffic conditions. The same individuals were asked to fill in a questionnaire on their travel motivations, their mobility characteristics, their risk perceptions and preferences with respect to walking and road crossing, their opinion on drivers, etc. The walking and crossing scenarios' data were used to develop mixed sequential logit models of pedestrian behaviour on the basis of road and traffic characteristics. The modelling results showed that pedestrian crossing choices are significantly affected by road type, traffic flow and traffic control. The questionnaire data were used to estimate human factors (components) of pedestrian crossing behaviour by means of principal component analysis. The results showed that three components of pedestrian crossing behaviour emerge, namely a "risk-taking and optimisation" component reflecting the tendency to cross at mid-block in order to save time, etc., a "conservative" component, concerning individuals with increased perceived risk of mid-block crossing, who also appear to be frequent public transport users, and a "pedestrian for pleasure" component, bringing together frequent pedestrians, walking for health or pleasure, etc. The introduction of these components as explanatory variables into the choice models resulted in improvement of the modelling results, indicating that human factors have additional explanatory power over road and traffic factors of pedestrian behaviour. Therefore, the development of integrated choice and latent variables models appears to be an appropriate field for further research.

1. Background and objectives

The analysis of pedestrians crossing behaviour in urban areas may assist in the understanding of the way pedestrians interact with the road and traffic environment, as well as with other pedestrians, and the way they balance the need for comfort and safety with the cost of delays, within the framework of existing traffic rules (Das, Manski, & Manuszak, 2005). Eventually, it may assist in the better adjustment of urban road networks to pedestrians' needs and the more accurate estimation

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of pedestrians road accident risk exposure in urban areas (Lassarre, Papadimitriou, Golias, & Yannis, 2007) and thus to the improvement of pedestrians safety.

Although signalised junctions provide pedestrians a protected crossing phase, most pedestrians tend to prefer using the available traffic gaps for crossing (Hamed, 2001). Moreover, mid-block crossing and diagonal crossing are common practice among pedestrians aiming to save travel time or distance (Chu, Guttenplan, & Baltes, 2003). Because of their flexibility and adaptability, pedestrians generally experience smaller delays compared to other road users, but increased road accident risk exposure (Grayson, 1987).

Existing research on pedestrians crossing behaviour in urban areas is extensive and has contributed very useful insight on the role of road, traffic and pedestrian characteristics on pedestrian crossing decisions, their compliance with traffic rules and the related safety implications – for complete reviews see Ishaque and Noland (2007), Papadimitriou, Yannis, and Golias (2009), Papadimitriou, Auberlet, Yannis, and Lassarre (2014). A distinct part of existing research on pedestrian crossing behaviour is devoted to analyses of psychological, attitudinal, perceptual and motivational factors (Bernhoft & Carstensen, 2008; Diaz, 2002; Evans & Norman, 1998).

However, human factors are seldom incorporated in pedestrian behaviour and safety models, so that the explanatory power of these factors on the observed behaviour can be tested. It is common to analyse the observed behaviour of pedestrians in relation to road and traffic characteristics, or the self-reported behaviour, attitudes and perceptions on the basis of questionnaire surveys, but the entire set of potential determinants has not been jointly explored in the existing studies.

The objective of this paper is the analysis of pedestrian crossing behaviour along entire trips in urban road networks, with particular emphasis on the introduction of human factors (pedestrians' attitudes, perceptions, etc.) in the potential determinants. More specifically, this research aims to develop choice models for estimating the probability to cross at each location along a pedestrian trip in relation to roadway design, traffic flow and traffic control, as well as human factors.

This paper starts with a literature review on pedestrian crossing behaviour data collection and analysis methods (Section 2). The description of the data collection scheme used for the purposes of this research is then presented, as a combination of field observations and questionnaire survey (Section 3). In Section 4, the analysis techniques are presented, which include mixed sequential logit models for pedestrian crossing behaviour (applied on the field observations data) and categorical principal components analysis (applied on the questionnaire data). The results Section 5 follows, including the sequential choice models of pedestrian crossing behaviour (Section 5.1), the components of pedestrian human factors (Section 5.2), and the introduction of these components into the choice models (Section 5.3). The paper ends with a discussion of the findings, also in light of the limitations and next steps of the research (Section 6).

2. Literature review

Traditional methods for the observation of pedestrian behaviour include video recordings of local level behaviour (e.g. at a junction area, on a train platform, etc.); this is the most common data collection method used and its main limitation rises from the obvious difficulty to capture more than the local level behaviour of pedestrians, beyond the video camera range (Papadimitriou, Yannis, & Golias, 2012; Lassarre et al., 2011). Other methods for the observation and tracking of pedestrians include following pedestrians and recording their path by means of a GPS or similar device (Li & Tsukaguchi, 2005; Pulugurtha, Krishnakumar, & Nambisan, 2007); in this case, in addition to the common signal accuracy problem, it is often not possible to obtain information on the road and traffic environment in which the trip takes place. A combination of following pedestrians and using a video camera for capturing the environment has been attempted in Papadimitriou (2012), but not without limitations, including practical difficulties in video recording in motion. In a few studies (e.g. Dommes, Granié, Cloutier, Coquelet, & Huguenin-Richard, 2015), local level behaviour observations are combined with questionnaire survey. Recently, some emphasis was placed on pedestrian simulators, in which pedestrians are often asked to negotiate oncoming traffic in a virtual environment (e.g. Cavallo, Lobjois, & Vienne, 2006).

Regardless of the data collection scheme implemented, pedestrian crossing behaviour models developed may concern gap acceptance models, in which each pedestrian is associated with a critical gap for road crossing (Himanen & Kulmala, 1988; Oxley, Fildes, Ihsen, Charlton, & Days, 2005; Sun, Ukkusuri, Benekohal, & Waller, 2003). In several researches, a level of service approach is implemented for road crossing, in which the difficulty to cross is used as a measure of effectiveness for pedestrian level of service (Baltes & Chu, 2002; Sarkar, 1995). Moreover, pedestrians' crossing choices among a set of discrete alternatives are often modelled on the basis of utility theory (Chu et al., 2003; Muraleetharan, Takeo, Toru, Kagaya, & Kawamura, 2004; Papadimitriou, 2012), with different models being proposed, including sequential, nested and cross-nested models. These models aim to explain pedestrian crossing behaviour in relation to road, traffic and pedestrian characteristics, but succeed in doing so only to some extent. In fact, a large part of pedestrian behaviour appears to be random, and simulation may be a more appealing option, but not without limitations either. For detailed reviews on the advantages and limitations of existing methods for modelling pedestrian behaviour, the reader is referred to Papadimitriou et al. (2009), Papadimitriou et al. (2014).

Another reason for pedestrian models failing to explain a large part of their behaviour may be the fact that there are underlying unobserved factors involved, such as behavioural routines and patterns, human factors like perceptions, attitudes, and preferences. Human factors of pedestrian behaviour are mostly examined by means of dedicated questionnaires, testing various psychological or behavioural theories (e.g. theory of planned behaviour) in terms of their applicability on