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Systems-based approach to investigate unsafe pedestrian behaviour at level crossings

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ABSTRACT

Crashes at level crossings are a major issue worldwide. In Australia, as well as in other countries, the number of crashes with vehicles has declined in the past years, while the number of crashes involving pedestrians seems to have remained unchanged. A systematic review of research related to pedestrian behaviour highlighted a number of important scientific gaps in current knowledge. The complexity of such intersections imposes particular constraints to the understanding of pedestrians' crossing behaviour. A new systems-based framework, called Pedestrian Unsafe Level Crossing framework (PULC) was developed. The PULC organises contributing factors to crossing behaviour on different system levels as per the hierarchical classification of Jens Rasmussen's Framework for Risk Management. In addition, the framework adapts James Reason's classification to distinguish between different types of unsafe behaviour. The framework was developed as a tool for collection of generalizable data that could be used to predict current or future system failures or to identify aspects of the system that require further safety improvement. To give it an initial support, the PULC was applied to the analysis of qualitative data from focus groups discussions. A total number of 12 pedestrians who regularly crossed the same level crossing were asked about their daily experience and their observations of others' behaviour which allowed the extraction and classification of factors associated with errors and violations. Two case studies using Rasmussen's AcciMap technique are presented as an example of potential application of the framework. A discussion on the identified multiple risk contributing factors and their interactions is provided, in light of the benefits of applying a systems approach to the understanding of the origins of individual's behaviour. Potential actions towards safety improvement are discussed.

1. Introduction

1.1. Level crossings are complex intersections

Level crossings (LCs) are complex intersections where rail and road systems converge. At such intersections, road users are permitted to cross rail tracks when it is safe to do so (i.e. in the absence of an approaching train). There are two main categories of LCs according to the level of protection they provide to users. Passive LCs are equipped with static controls such as "STOP" or "GIVE WAY" road signs whilst active LCs, which are often riskier locations, are equipped with automatic controls such as red flashing lights or barriers. Based on feedback loops (top-down and bottom-up flow of information) between components, the ultimate objective of LCs' performance is to ensure road users' safe crossing through the rail tracks. At active LCs in particular, the system must provide enough and reliable information for the pedestrian to safely negotiate the crossing. Such information mainly consists of: raising the awareness of the crossing (e.g. LC approach signage); providing adequate physical characteristics of the crossing path (e.g. visibility, well defined LC quadrant); ensuring visibility and awareness of the warning controls and their purpose; raising awareness of the potential hazards at such crossings (e.g. risk of second train). Fatal crashes are more frequent at active LCs (characteristic of urban environments) than at passive (Australian Transport Council, 2010). Pedestrians are particularly vulnerable users of active LCs given the higher flow of pedestrian

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traffic in such areas (Cairney, 1992). Australia has widely deployed engineering interventions to improve pedestrian LC safety, such as automated pedestrian gates. However, despite such interventions pedestrian LC crashes still occur.

1.2. Crashes at level crossings

Despite a substantial decrease since the 1990s, the annual number of LC crashes worldwide remains unacceptably high (ATSB, 2012; Basacik et al., 2012; Evans, 2012; Werkman et al., 2012). Although not as frequent as other types of road traffic crashes, they are associated with greater potential for fatal outcomes for victims and are related to serious economic costs (Evans, 2012; Iorio et al., 2012; Werkman et al., 2012). Not only do crashes at LCs impede on the operation and effectiveness of both rail and road infrastructure, but they also result in significant economic costs due to railroad property damage, insurance payments and legal fees (Iorio et al., 2012; Metaxatos and Sriraj, 2012). In 2003, a cost per crash was estimated to range from $180,000 (AUD) in urban areas to $430,000 (AUD) in rural areas (Australian Transport Council, 2003). Data from the ATSB (2012) suggests that, similarly to data from the United States (Metaxatos and Sriraj, 2012), the number of crashes involving vehicles has noticeably declined in the last decades (i.e. between 2003 and 2007), whereas there has not been a significant change in the number of crashes with pedestrians.

1.3. Pedestrian behaviour at LCs

In a review of the literature examining the extent to which the systems approach has previously been applied to the investigation of a broad range of LC issues, Read et al. (2013) found that more than 70% of all existing publications on safety at LCs focused on the understanding and reduction of drivers' unsafe behaviour. Thus, only very limited information on the factors and conditions shaping pedestrians' unsafe behaviour at LCs is currently available. We subsequently carried out an in depth review of the literature with a strong focus on pedestrians' unsafe crossing.

A number of keywords were used to identify publications relevant to: level crossings (i.e. level crossings; railway crossings; grade crossings; rail crossings); pedestrians (i.e. pedestrians; passengers; rail users; trespassers) and the rail industry more generally. The search was undertaken in the following electronic databases: Science Direct; EBSCOhost; Google and Google Scholar; HERDC (Higher Education Research Data Collection; Australia); and among researchers' network (conference proceedings and publications). Only 23 relevant publications; up to and including 2013 were identified. Four major gaps in the literature on pedestrian crossing at LCs emerged from the review of these papers (see Appendix A for detailed description):

- The influence from research on motorist's behaviour.

Consistent with the large majority of the existing publications being on motorists, the review of the contributing factors applicable to pedestrian unsafe crossing have often been based on research on drivers' behaviour at LCs or on road safety publications more generally. Literature reviews underpinning past studies include only a small number of publications on pedestrians' behaviour at LCs. Moreover, there are publications which do not clearly report outcomes which apply to pedestrians versus motorists. The degree to which outcomes of driver focused literature can be inferred to pedestrians is unclear as the required skills and the corresponding constraints (e.g. legal, social) related to both types of users are different.

- The availability and quality of occurrence data.

In Australia and worldwide, the criteria for the classification of occurrence data are not always consistent between authorities and may include cases of suicide or trespass (i.e. walking across or along rail tracks at non designated crossing areas), which are known to have different precursors than transgressions at LCs (Evans, 2012; Meiers et al., 2012). Thus, outcomes based on such data are hardly applicable between countries and even between regions. In addition, such data is associated with a limited range of identifiable risk factors, and struggles to comment on the cognitive or motivational origins of behaviour.

- The lack of empirical research into the origins of unsafe behaviour.

Instead of investigating the origins of unsafe crossing, studies often focus on providing frequencies of illegal behaviour or identifying high risk groups of users, and examine only a small number of key variables such as the observed reported efficacy and awareness of various controls (Basacik et al., 2012; Parker, 2002; Stewart et al., 2004) or else the efficacy of education and enforcement campaigns (Lobb et al., 2001, 2003; Sposato et al., 2006). One study demonstrates pedestrians' likelihood of underestimating the speed of an approaching train as a result of a perception bias (Clark et al., 2013). Self-reported data from another study provides indication of the most relevant factors influencing decision-making of different types of users (Beanland et al., 2013).

- The lack of research on multiple interacting risk-contributing factors.

Several authors have pointed to the advantages of investigating simultaneous interactions between multiple risk contributing factors as opposed to considering a single factors' contribution in isolation (Iorio et al., 2012; Read et al., 2013; Werkman et al., 2012).

High risk groups of users (i.e. young males) or times of the day (i.e. peak hours) have been predominantly associated with risky crossing along with a number of contributing factors such as: large groups of pedestrians, being in a hurry, inattention (distraction), sensation (thrill) seeking tendencies, status of the controls (closing *vs.* closed gates) or presence of a (visible) approaching train (Beanland et al., 2013; Clancy et al., 2007; Edquist et al., 2011; McPherson and Daff, 2005; Metaxatos and Sriraj, 2013; Searle et al., 2011; Sposato et al., 2006). Davis Associated Limited (2005) are among the few who provided a classification of multiple factors influencing crossing behaviour, however they did not investigate the associations between different factors. In contrast, examining the interactions between various contributing factors Metaxatos and Sriraj (2013) showed that the presence and the larger number of pedestrian gates (i.e. at all LC quadrants) reduced the reported deliberate and observed (legal) violations independently of the train's direction. They also reported an increase in violations with the increasing number of pedestrians in a group (i.e. alone *vs.* in a group of two *vs.* in a group of more than two) independently of the time of the day. Finally, even though a number of authors have recently recognised the need to consider characteristics of the socio-economic area (e.g. presence of schools, industrial buildings) as a key factor shaping behaviour, to our knowledge such results have not yet been demonstrated (Edquist et al., 2011). While initial steps have been made to undertake research considering LCs as a complex system, these are rare and even rarer still is pedestrian focused systems research.