Understanding pedestrian behaviour at railway level crossings: Is there a need for more research?

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Abstract

Aim: Collisions between trains and pedestrians are the most likely to result in severe injuries and fatalities when compared to other types of rail crossing accidents. Currently, there is a growing emphasis towards developing effective interventions designed to reduce the prevalence of train–pedestrian collisions. This paper reviews what is currently known regarding the personal and environmental factors that contribute to train–pedestrian collisions, particularly among high-risk groups. Method: Studies that reported on the prevalence and characteristics of pedestrian accidents at railway crossings up until June 2012 were searched in electronic databases. Results: Males, school children and older pedestrians (and those with disabilities) are disproportionately represented in fatality databases. However, a main theme to emerge is that little is known about the origins of train–pedestrian collisions (especially compared to train–vehicle collisions). In particular, whether collisions result from engaging in deliberate violations versus making decisional errors. This subsequently limits the corresponding development of effective and targeted interventions for high-risk groups as well as crossing locations. Finally, it remains unclear what combination of surveillance and deterrence-based and education-focused campaigns are required to produce lasting reductions in train–pedestrian fatality rates. This paper provides direction for future research into the personal and environmental origins of collisions as well as the development of interventions that aim to attract pedestrians' attention and ensure crossing rules are respected.

INTRODUCTION

Railway level crossings are often defined as any location where a public (or private) roadway or footpath (or both) crosses a railway track (Rail Safety Regulators Panel 2008). Crossings are often equipped with different types of control devices, including passive warning devices (e.g. signs and markings), as well as active control devices that are activated prior to and during the passage of the train (e.g. flashing lights, gates and barriers). There are approximately 9400 public crossings in Australia (Tey, Ferreira & Wallace 2011) and an earlier estimate calculated that 64% were controlled by passive devices and 28% were controlled by active or automated devices (Ford & Matthews 2002).

Collisions at railway level crossings are often calculated to be the largest cause of rail-related fatalities (Sochon 2008) in a number of countries including the United States and the United Kingdom (Federal Railroad Administration 2006; Nelson 2008). In Australia there were 392 rail accidents that resulted in fatalities between January 2001 and December 2010, excluding suicides (Australian Transport Safety Bureau 2011). More specifically, pedestrian–train collisions are more likely than train–car collisions to result in fatalities (Australian Transport Safety Bureau 2004), with only one-third of pedestrians surviving the collision (Lobb, Harre & Terry 2003). As a result, understanding the origins of such collisions is of primary importance to the rail industry.

METHOD

Studies that reported on the prevalence and characteristics of pedestrian accidents, as well as research that focused on the origins of such incidents, between 1960 and June 2012 were searched in electronic databases including PsychINFO and ScienceDirect. Keywords used included pedestrian railway crossings, train collisions, pedestrian fatalities and violations. This was supplemented by scanning the reference lists of relevant manuscripts to identify other studies of direct relevance. This included analysis of PhD and masters theses.

Railway crossing fatalities: An overview

Three groups have consistently been demonstrated to be key high-risk users of level crossings: (a) heavy vehicle drivers, (c) older drivers (60+ years) and (c) pedestrians (Cooperative Research Centre for Rail Innovation (CRC) 2010). Train collisions with either vehicles or pedestrians at level crossings are surprisingly common, with 78 incidents recorded on average each year in Australia (Australian Transport Safety Bureau 2010). Between January 2001 and June 2010, there were 91 train–pedestrian collisions, which equates to an average of 10 per year (Australian Transport Safety Bureau 2010)[1]. In regards to serious injuries, an earlier report that examined data between 2003 and 2007 reported that 51 people on average were hospitalised each year due to train–pedestrian collisions (Henley & Harrison 2009). The consequences of such collisions are usually severe and are much more likely to result in fatalities when compared with other types of road collisions. This is particularly the case for train–pedestrian collisions and the personal and social impact of such events is often significant (CRC for Rail Innovation 2010). For example, an earlier study reported that pedestrians (excluding suicides) comprise 66% of all fatalities at crossings (Australian Transport Safety Bureau 2004). Given the heavy reliance on the rail transport industry, there is a critical need to understand the personal and environmental factors that increase the risks of such collisions occurring.

Pedestrian crossing characteristics: Passive versus active controlled

Similar to general railway crossings, pedestrian crossing locations can be either passively controlled with signs and/or actively controlled with flashing lights, audible sounds, mazes and mini-booms or gates (CRC for Rail Innovation 2010). It has been proposed that risks are higher and pedestrian level crossing accidents are more likely to occur in more built-up areas with high pedestrian flow (Cairney, Gunatillake & Wigglesworth 2002) and high train volumes, although Australian statistics are not detailed enough to confirm this suggestion (CRC for Rail Innovation 2010). In regards to vehicles, passive crossing locations, when compared with active crossings, have been calculated to have higher collision frequencies for vehicles after normalisation for exposure rates (Federal Railroad Administration 2006). However, again, less is currently known about whether this is also the case for pedestrian crossings.

Contextual factors

Much of what is known about railway collisions originates from aggregated data that has been collected from accident sites and summated in databases. Additionally, an array of environmental or contextual factors has emerged that have been

1 However, it remains uncertain what percentage of these incidents involved suicide. Nevertheless, Australian reports and statistics attempt to exclude suicides given that they are not accidental, and no intervention can be developed to continually prevent trespassing if an individual is committed to ending their life on train tracks.

proposed to impact upon the likelihood of a collision. However, this research has tended to overwhelmingly focus on train–vehicle collisions rather than train–pedestrian collisions. The largest proportion of collisions (including those involving vehicles) have been recorded to occur during daylight hours (e.g. highest exposure times), in a number of developed counties including the United States, United Kingdom and Canada (Caird et al. 2002; Federal Railroad Administration 2006; Raub 2009). However, less is known (or published) about the specific times of the day when pedestrians are most likely to be struck by a train. In regards to this issue, conspicuity of crossings and trains has been proposed to be a contributing factor for collisions (Davey, Ibrahim & Wallace 2005). Preliminary research has revealed that pedestrian accidents are also more likely to occur during the day (Lloyd's Register Rail 2007), and it may be hypothesised that such times coincide with the highest volume (e.g. peak hour). A Melbourne observational study reported that pedestrians in a group scanned for trains less often than pedestrians who were by themselves (McPherson & Daff 2005). A second Victorian study also concluded that pedestrians travelling in groups were at an increased risk at crossings, most likely because of diffusion of responsibility or distraction (Lloyd's Register Rail 2007). However, other environmental factors (e.g. darkness, passive versus active crossings) may yet be proven to increase pedestrians' risk at night. Taken together, further research is required to determine the environmental or situational factors that increase pedestrians' likelihood of engaging in risky crossing behaviours.

Human factors

Errors

One of the central questions relating to train–pedestrian collisions is whether they result from making errors or deliberate violations. As highlighted above, the largest body of research that has focused on level crossing collisions has been on train–vehicle collisions. This literature has indicated that crossing users are likely to inadvertently engage in risky behaviours that include a range of factors such as not detecting crossings, failing to notice approaching trains and misjudging the risk of approaching trains (Australian Transport Safety Bureau 2002; CRC for Rail Innovation 2010; Wallace 2008). These factors can be broadly categorised as human error, and can involve various cognitive factors including inattention, distraction, poor knowledge, misjudgement and limited sight distance. Failing to detect warning signals or understand their meaning has previously been calculated to account for nearly half of all fatal level crossing crashes in Australia (Australian Transport Safety Bureau Statistical Unit 2002).

In regards to making errors, the factors of distraction and inattention have received attention within the literature (Caird et al. 2002), although again it remains an under-researched topic in regards to pedestrians' behaviour at crossings. Poor knowledge of level crossing procedures and/or road rules has also gained attention within the field, as researchers have proposed that road users have poor knowledge of train speeds as well as the ability to slow quickly (if needed) to avoid an accident (Richards & Heathington 1990). More specifically, a study of 100 interviewed drivers revealed that participants had a poor level of knowledge regarding crossing signals compared to conventional road traffic signals (Pickett & Grayson 1996). Another study found that traffic control devices in the vicinity of level crossings can confuse drivers (Jeng 2005). Researchers have also noted that pedestrian level crossing users may have poor knowledge of the penalties associated with breaching crossing rules (Wallace 2008), although little research has been conducted into this area. One of the few studies to focus on pedestrians' knowledge of penalties revealed that almost half of a sampled group reported that they did not believe or were unaware that it was illegal to cross when a train was approaching (Lloyd's Register Rail 2007). The same Victorian study reported that 18% of the survey sample admitted to unintentionally being caught on train tracks when a train was approaching (Lloyd's Register Rail 2007). The most common reason reported for this outcome was not being aware of the train approaching (or a second train approaching), which could be for a range of reasons including headphone usage, use of a mobile phone, media players, or inattention.

The issue of the presence (and awareness) of a second train shortly after the first has passed, is receiving increasing focus within the literature. An American study reported that 18% of pedestrian accidents were related to the presence of a second train (Federal Railroad Administration 2008; Illinois Commerce Commission 2005). A similar Victorian study revealed that 16% of the sample would at least sometimes cross (and violate warning signals) after one train had passed (Lloyd's Register Rail 2007). The researchers also examined Victorian coroners' reports of pedestrian level crossing fatalities, which revealed that the presence of a second train was often mentioned (Lloyd's Register Rail 2007). Poor knowledge of train speeds has also been proposed to be a contributing factor, as pedestrians may underestimate the speed of oncoming trains (CRC for Rail Innovation 2010). For example, an earlier review of 18 pedestrian fatalities between 2002 and 2004 revealed that misjudgement was a primary factor in 8 cases, and that 6 pedestrians were under the influence of alcohol or drugs (Australian Transport Safety Bureau 2004).

Deliberate violations

Although it has been hypothesised that road users are more likely to make errors (rather than commit violations) at crossings, research has also emerged that indicates drivers deliberately break the rules. For example, a European study that examined approximately 2000 accidents (including 600 fatalities) concluded that most collisions were due to users' 'misbehaviours' (European Level Crossing Forum 2011). Preliminary research has also suggested that deliberate violations of crossing rules may be a significant factor in train–pedestrian collisions (CRC for Rail Innovation 2010). For example, that pedestrians ignore warning signs has been found to be a contributor in some United States studies (Federal Railroad Administration 2008; Illinois Commerce Commission 2005). One of the few Australian studies into the area also reported that 31% of a sample of pedestrians reported crossing the tracks even when they knew a train was approaching (Lloyd's Register Rail 2007). The most common reason reported for such behaviour was being in a hurry. An earlier review commissioned by the CRC for Rail Innovation (2010) found that a small group of studies reported that most pedestrians who violated traffic or level crossing rules did so to maximise convenience (Daff & Cramphorn, 2006; Federal Railroads Administration 2008; Lobb, Harre & Suddendorf 2001; Lobb 2006). It has been hypothesised that pedestrians weigh the perceived safety of a route against the time and effort that would be required to use it (Lobb 2006). Additionally, researchers have suggested that risky crossing behaviour may be reinforced if individuals consistently engage in such behaviour and avoid the negative consequences (CRC for Rail Innovation 2010; Davey et al. 2008). Preliminary research has also found that violations are more likely to occur in the presence of other pedestrians (Khattak & Luo 2011). In regards to trespassing, international research has also reported that people walking illegally on tracks or sitting near tracks are over-represented in fatality statistics (Cina et al. 1994; Lerer & Matzopoulos 1996; Pelletier 1997), and trespassing is more likely to occur in high-density locations (Silla & Luoma 2009).

In regards to gender, preliminary research into the area has revealed that males are more likely than females to violate pedestrian crossing rules (Australian Transport Safety Bureau 2004; Lloyd's Register Rail 2007). For example, a Victorian study reported that 40% of males but only 12% of females surveyed indicated they would at least sometimes cross a train line when the lights/bells/gates were activated but the train was not in sight (Lloyd's Register Rail 2007). However, it is important to note that research has yet to clearly determine the proportion of making errors versus deliberate violations that contributes to the largest percentage of train–pedestrian collisions, which has flow-on restrictions for the development of effective implementations. Additionally, other factors that have been proposed to influence level crossing behaviour include familiarity, deliberate risk taking, fatigue, alcohol and drugs; although it is again noted that examination of these factors has predominantly focused on vehicle drivers (CRC for Rail Innovation 2010). In regards to alcohol and drugs, preliminary studies have recorded elevated blood alcohol levels in pedestrians killed or injured on train lines, although such research has not focused purely on pedestrian crossings but train track fatalities in general (Lerer & Matzopoulos 1996; Lobb 2006; Nixon et al. 1985). As a result, research has yet to confirm which factors should become central components of prevention strategies and interventions.

High-risk groups

Analysis of the individual characteristics associated with fatalities and serious injuries at level crossings reveals that some groups are at a disproportionate risk. These are (a) males, (b) school children and other young persons, (c) people with disabilities and (d) older pedestrians (Lloyd's Register Rail 2007). However, consistent with the main theme of this review, comprehensive information about why these groups remain at-risk has yet to be obtained (CRC for Rail Innovation 2010). For example, one of the more recent large-scale reviews of the pedestrian research literature mostly relied on general pedestrian research rather than specific level crossing pedestrian research (Lloyd's Register Rail 2007).

Nevertheless, what is known is that males are consistently over-represented in both vehicle and pedestrian incidents at level crossings (CRC for Rail Innovation 2010; Henley & Harrison 2009). For example, an earlier Australian study calculated that 84% of train–pedestrian fatalities involved males (Australian Transport Safety Bureau 2004), which is also the case in 80% of train–vehicle collisions (Australian Transport Safety Bureau 2002). Additionally, younger males are also over-represented in pedestrian accident rates, as between 1997 and 2002 43% of fatalities involved pedestrians aged between 15 and 49 (Australian Transport Safety Bureau 2004). A similar European study also found males were over represented in train–pedestrian fatalities (Silla & Luoma 2012).

School children have also been reported to be at an increased risk at level crossings (Khattak & Luo 2011; Lobb et al. 2003; Spicer 2008). A recent study involving video surveillance of a crossing in Nebraska revealed that children approximately 8 years of age accounted for a disproportionate number of gate violations (25%) compared with older pedestrians and cyclists (Khattak & Luo 2011). An earlier New Zealand study calculated that 50% of train–pedestrian fatalities and 40% of injuries involved persons aged between 10 and 19 (New Zealand Health Information Service 1999, cited in Lobb et al. 2003). However, there is limited research into the aetiology of why school children are at an increased risk (CRC for Rail Innovation 2010). Nevertheless, a range of hypotheses have been proposed, including poor scanning behaviours, underdeveloped cognitive and risk perception abilities and impulsiveness (CRC for Rail Innovation 2010). In regards to scanning behaviours, a preliminary study reported that pedestrians aged between 12 and 17 years of age had the poorest scanning behaviours at crossings (McPherson & Daff 2005). This is consistent with broader developmental neuroscience research that has indicated adolescents have a heightened propensity to make risky decisions (Albert & Steinberg 2011). Other researchers have suggested that underdeveloped perceptual or cognitive skills may increase risk for this group (Congiu et al. 2008) or they may not calculate approaching train speed effectively (Congiu et al. 2008). Additionally, divided attentional skills combined with poor scanning have been proposed as further contributing factors (Dunbar, Lewis & Hill 2001), as has reduced experience with crossings (Connelly et al. 1998). It has also been hypothesised that intentional risk taking could be a significant contributing factor (Lloyd's Register Rail 2007), although, similar to above, it remains unclear why this group is at an increased risk of being struck by a train.

People with physical disabilities or mobility aids are also at risk of being struck by a train. It has been suggested that this risk stems from a number of reasons including (a) getting mobility aids (e.g. wheelchairs) stuck in tracks, (b) uneven or poorly maintained surfaces that increase the risk of falls for this population and (c) slower crossing speeds (CRC for Rail Innovation 2010; McPherson & Daff 2004). However, again, the current analysis revealed that little is currently known regarding the exact risks for this group.

IMPLICATIONS FOR FUTURE RESEARCH AND PRACTICE

Research

Origins of behaviour

Taken together, there is a need for further research into a range of different areas. These include (a) whether errors or deliberate violations are the primary cause of train–pedestrian collisions, (b) the core reasons for why high-risk groups (such as younger persons) are disproportionately represented in collision databases, (c) the environmental factors that increase the likelihood of risky pedestrian behaviour (e.g. reduced surveillance, passive crossings), (d) how long pedestrians are prepared to wait (on average) before they consider violating crossing rules and (e) what countermeasures are required (e.g. surveillance/deterrence-based/education) to reduce the incidence of collisions. It may yet prove to be of value to also investigate what particular aspects of active or passive environments (including the different types of signage, such as flashing versus fixed) influence decisions to cross tracks. There has been corresponding research into road users at level crossings that has indicated that compliance to passive signals was poorer than for active signals, and boom gates proved more effective than flashing lights at stopping violations in urban environments (Meeker, Fox & Weber 1997; Tey, Ferreira & Wallace 2011)[2]. However, preliminary research has shown that boom gates are not necessarily superior to flashing lights at stopping train–vehicle collisions (Rudin-Brown et al. 2012).

The application of appropriate psychological models may also prove valuable. For example, Reason's model of 'Human Error' may provide a framework to undertake a more in-depth examination of

2 It should be noted that opposing research for road users at level crossings has indicated that making bigger and brighter signs did not lead to favourable changes in drivers' behaviour (Stackhouse 1996, p. 37).

pedestrians' behaviour at crossings. In relation to this theory, making an error in the context of crossing the tracks unsafely may be associated with slips or lapses or with rule or knowledge-based mistakes (Reason 2008). In other words, risky crossing behaviour might be explained by a combination of attention, memory or recognition failures, including signal misidentification. In addition, risky behaviour might also be explained by poor knowledge about the situation (e.g. how fast an approaching train travels) or by failing to apply rules such as visual checking for the presence of trains in both directions.

There is also the assumption that crossings do not convey the necessary urgency and dangers associated with the site (Rudin-Brown et al. 2012) and/or that crossing control design hasn't historically been based on current knowledge of human factors (Green 2002). Recent research suggests that more warnings at crossings result in increased crossing compliance for drivers (Lenne et al. 2011), although this has yet to be tested with pedestrians. Advancements may yet be found within Signal Detection Theory or similar technologies that can assist identify, and develop, effective signage that compels pedestrians to comply with essential crossing rules. In contrast, preliminary education-based campaigns with students have produced limited results. Insights may yet be gleaned from general traffic-pedestrian research that has demonstrated that non-compliance with crossing rules is not necessarily perceived as increasing one's risk (King, Soole & Ghafourian 2009). Pedestrian enforcement campaigns have also not been particularly effective due to minimal fines not proving a strong deterrent threat (Shonfeld & Musumeci 2003) or the perceived low risk of apprehension. However, a preliminary education intervention with school students in New Zealand found that highlighting the legal consequences of being caught breaking the rules resulted in a significant decrease in unsafe crossing behaviours, compared to general road safety education (Lobb et al. 2003). This is consistent with an earlier study by the same leading author that found raising awareness of the risks alone may not produce lasting behavioural change (Lobb et al. 2001). As a result, additional community discussions (and contributions from coroners and the courts) about what the community expects in regards to pedestrian level crossing safety management may also be of assistance.

Taken together, there seems value in examining warning signals that not only attract pedestrians' attention, but also their respect. Preliminary research has demonstrated that drivers who are most likely to cross the tracks during the warning period do so within 5 seconds of arriving at the crossing and that drivers lose confidence in the signals if they wait for more than 40 seconds (Richards & Healthington 1990). Research has yet to quantify similar waiting times for pedestrians or whether clear warning signs highlighting the dangers at 'black spots' would increase compliance levels. A preliminary study found that pedestrian gates were more effective at stopping violations compared to signs and flashing lights, however those who walked under the gate were least likely to stop or look both ways once a train had passed (Siques 2002). The author of this research suggested that a 'second train approaching' sign may result in safety improvements. Additionally, there is a need to examine whether pedestrians have sufficient information or knowledge to make informed crossing decisions, or whether crossing interventions should focus on increasing incapacitation (e.g. gates), deterrence (e.g. increasing detection and enforcement approaches), knowledge-based initiatives or a combination of the three approaches. In regards to barriers and preventative approaches, preliminary research has shown that physical countermeasures (e.g. landscaping and building a fence) can reduce the frequency of trespassing (Silla 2009). However, researchers have yet to determine what approach (e.g. landscaping, fence or signage) creates the greatest effects (Silla 2009).

Methodology

The above research could take the form of a variety of methods, including focus groups or interviews with high-risk groups, distribution of quantitative questionnaires and simulator studies, as well as observational analyses that involve intercepting and interviewing those who breach crossing rules. It may also prove necessary to collect data on 'near misses' at level crossings that could otherwise have resulted in severe injury or fatalities (CRC for Rail Innovation 2010). Given that 'near-misses' are likely to outnumber actual accidents, this form of data can act as a proxy and provide a great opportunity to gain a deeper understanding of the human factors that contribute to such incidents (CRC for Rail Innovation 2010). However, it is noted that the concept of 'near misses' is somewhat subjective and quite broad (Davey et al. 2005) and further research is needed to define the specific circumstances that constitute the event and how best to capture the data (e.g. surveillance cameras). It is noted that

CRC-funded research is currently underway that utilises locomotive-mounted surveillance cameras to measure the frequency and type of such 'near misses.' Additionally, surveillance cameras are currently installed at numerous train stations. Comprehensive analysis of such footage could allow researchers not only to quantify the tolerated waiting time after warning activation, but also to identify other factors that may impact upon pedestrians' decisions to cross. More precisely, such an approach would provide evidence on whether the accepted waiting duration for pedestrians is influenced (increased or decreased) by the presence of others who either comply with, or breach, crossing rules.

One pillar stone for any of the above pursuits is to compile accurate in-depth information of the causes of collisions. It has recently been suggested that current information is poor, and results from two main issues: (a) accident data is usually aggregated and lacks specific contextual information regarding the crossing type (active/passive), location (urban/rural) and time of day, and (b) there is a lack of information that focuses on the human factors (e.g. gender, personality, attitudes, knowledge) that increase the risk of accidents as well as near-misses (CRC for Rail Innovation 2010). Researchers have also noted that these two issues are not mutually exclusive, and that, in fact, some high-risk user groups may be at increased risk at particular types of crossings (CRC for Rail Innovation 2010). Considerable benefits may also be gained by adopting national guidelines for level crossing accident investigations, and developing aA national-level crossing accident investigation database, so that such a database can assist in the scientific pursuit of better understanding the causes of collisions. This should include complementary studies that highlight exactly what data the scientific community (including academia) needs to achieve these outcomes. It is noted that there are no current national databases that catalogue the specific circumstances surrounding Australian level crossing accidents (CRC for Rail Innovation 2010). Without developing a comprehensive database of level crossing incidents and near misses, the main factors that lead to such occurrences cannot be identified, which also limits the development of effective interventions (CRC for Rail Innovation 2010). This makes it difficult to determine the predominant causes of train–pedestrian collisions and discussions are currently underway to resolve this issue. There are other resources that may be utilised in the future to further identify risky pedestrian crossings, such as the Australian Level Crossing Assessment Model. Overall, there remains little contemporary and reliable published research on characteristics and reasons for train–pedestrian collisions nor what effective countermeasures are needed to reduce such occurrences.

Countermeasures

A complete review of the effectiveness of the different types of pedestrian interventions is beyond the scope of the current paper, but there is merit in highlighting the direction of current efforts to reduce pedestrian trauma at crossings. However, and consistent with the above theme, it has recently been suggested that many of the current interventions have not yet been properly evaluated (CRC for Rail Innovation 2010) and/or that current evidence is limited or mixed (Edquist et al. 2009; Lobb 2006). The first countermeasure approach is increasing the conspicuity of both crossings and trains, although the approach seems more suited to motor vehicle drivers than to pedestrians. Nevertheless, increasing the conspicuity of trains (such as installing flashing lights on trains) may have benefits for pedestrians, and this option may be trialled in the future (Parliament of Victoria 2008). A second approach is ensuring that crossings are installed with warning devices to signal an approaching train. This is considered paramount (particularly at passive crossings), and a number of trials are currently underway to explore different methods to signify an approaching train, such as lights and warning sounds (Larue, Soole & Rakotonirainy 2010; Wullems 2011). Although flashing lights with a boom barrier is currently considered the most effective active level crossing control for drivers (Rudin-Brown et al. 2012), it has yet to be determined if this is the case for pedestrians. Thirdly, increasing users' knowledge of the risks associated with pedestrian crossings has been proposed as a direction for future interventions, which include improving the ability to estimate train speeds and time-to-arrival (CRC for Rail Innovation 2010). This could also be extended to increasing pedestrians' awareness of the dangers associated with crossings through social media forums, such as the highly awarded 'Dumb Ways To Die' Metro Trains education campaign. Fourthly, incapacitation-based measures, such as physically preventing pedestrians from crossing tracks, have initially been trailed in a number of jurisdictions, although upgrading level crossings to ensure pedestrians are prevented from crossing is costly (CRC for Rail Innovation 2010), and cost-benefit analysis may reveal education is a more effective approach. Finally, increasing enforcement techniques such as installing surveillance cameras to detect and fine individuals breaching crossing rules has been proposed (CRC for Rail Innovation 2010), although this approach may prove more complicated for identifying and contacting individual pedestrians. Nevertheless, early research into the installation of cameras at crossings has reported a reduction in violations of between 34% and 92% for car drivers (Carroll & Warren 2002). This is consistent with general research that has shown that the presence of CCTV cameras has the potential to reduce offending behaviours (Gill & Hemming 2006). Taken together, pedestrian research and countermeasure implementation are not mutually exclusive, and each will need to rely on the other if reductions in current collision rates are to be achieved. Siques (2001) suggested that four factors enable safe pedestrian behaviour at crossings: (a) pedestrian awareness of crossings, (b) existence of adequate paths, (c) pedestrian awareness and ability to see approaching trains, and (d) pedestrian understanding of the potential hazards at crossings.

CONCLUSION

A number of questions remain regarding the origins of train–pedestrian collisions and, importantly, what at-risk groups should become the focus of pedestrian crossing interventions and the form these interventions should take. This is further evidenced by the fact that much of the detailed information of the human factors that impact on crossing behaviours is quite dated, and is often drawn from the wider road safety literature such as train–vehicle incidents (CRC for Rail Innovation 2010). Additionally, it often contains a retrospective analysis of collisions (Read, Lenne & Moss 2012). Due to the paucity of knowledge of pedestrians' behaviour at crossings, research draws heavily on road-user crossing research, despite a range of clear differences between the two groups, such as the speed at which crossings are approached. As a result, a number of key questions remain unanswered and there is an ongoing need to understand the origins of train–pedestrian collisions in order to develop appropriate and effective crossings. This review of the literature is part of the initial stage of a two-year CRC-funded research project that aims to (a) conduct an in-depth analysis of pedestrians' decision-making processes that contribute to violating crossing rules (e.g. human factors) and (b) develop a set of recommendations to increase pedestrians' awareness of the risks associated with railway crossings as well as to increase pedestrians' compliance with crossing rules.

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