An investigation of risk-takers at railway level crossings
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SYNOPSIS:
This report reviews level crossing statistics (both Australian and overseas), Australian investigations and risk assessment models, and human factors research on road user behaviour at level crossings in order to determine who is a high-risk level crossing user, and why.

This report reviews possible human factor contributors to the risky behaviour of these level crossing user groups. However, much of the information regarding the behaviour of these high-risk groups has had to be extrapolated from more general road safety research.

This review represents only the first step to improving level crossing safety by identifying high-risk groups. At the end of this review, there is still little understanding of why the level crossing user groups identified here are at high risk of being involved in collisions. Thus, the next critical step forward is to move beyond identifying particular groups, and towards uncovering their specific risky level crossing behaviours. Further to this, we need to know why high-risk groups behave in such risky ways.

REVISION/CHECKING HISTORY

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Executive summary

This project was commissioned by the Co-operative Research Centre for Rail Innovation (Rail CRC) in 2010, in order to provide a better understanding of the factors associated with railway level crossing accidents, and to tailor interventions to improve safety at these sites.

This report reviews level crossing statistics (both Australian and overseas), Australian investigations and risk assessment models, and human factors research on road user behaviour at level crossings in order to determine who is a high-risk level crossing user, and why.

However, statistics on occurrences at Australian level crossings are scarce and have numerous limitations, including missing data, and inconsistent definitions or inclusion criteria, and are rarely accompanied by normalising data such as road and rail traffic volume. Thus, there is currently only a limited picture of the human factor contributors to Australian level crossing occurrences.

Broadly, the available statistics identify heavy vehicle drivers, older drivers, younger drivers and pedestrians as disproportionately represented in level crossing collisions and fatalities. Recent Australian enquiries have also focused on some of these high-risk groups. Thus, these particular user groups comprise the focus of this report.

This report reviews possible human factor contributors to the risky behaviour of these level crossing user groups. However, much of the information regarding the behaviour of these high-risk groups has had to be extrapolated from more general road safety research.

This report offers little in the way of definitive answers or conclusions. Instead, many questions and areas of further research need are identified, and as a result, a number of recommendations are made to advance knowledge on level crossing safety. Specifically:

- More detailed statistics on both near-misses and collisions at level crossings are greatly needed to provide a more detailed picture of exactly who is at increased risk at level crossings, and why this is so.
- Reporting, data collection and occurrence classification all need to be improved to ensure that the resulting data are detailed, consistent across jurisdictions, and of high quality.
- Detailed data on the characteristics of accidents and near-misses at Australian level crossings must be made available to researchers.
- Occurrence history at this level of detail must be linked with the Australian Level Crossing Assessment Model database, so that the progressive upgrading of Australian level crossings occurs according to the level of objective risk that each crossing poses.
- Finally, much more research is needed into exactly what types of behaviour are putting specific groups of level crossing users at increased risk of collision. This research must extend to include more distal behavioural precursors — that is, the underlying reasons for this risky behaviour.

It is only when knowledge on the behaviour of high-risk level crossing users has improved in this way that countermeasures may be effective at preventing this risky behaviour, and any resulting near-misses and collisions, from occurring.
## Abbreviations and acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ALCAM</td>
<td>Australian Level Crossing Assessment Model</td>
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<tr>
<td>ARRB</td>
<td>Australian Road Research Board</td>
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<td>ATSB</td>
<td>Australian Transport Safety Bureau</td>
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<td>CFF</td>
<td>Contributing Factors Framework</td>
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<td>DIRN</td>
<td>Direct Interstate Rail Network</td>
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<td>FRA</td>
<td>Federal Railroad Administration</td>
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<td>ITS</td>
<td>Intelligent Transport Systems</td>
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<td>MUARC</td>
<td>Monash University Accident Research Centre</td>
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<tr>
<td>NTSB</td>
<td>National Transportation Safety Board</td>
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<tr>
<td>OC-G1</td>
<td>Occurrence Classification - Guideline One</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>ON-S1</td>
<td>Occurrence Notification - Standard One</td>
</tr>
<tr>
<td>QUT</td>
<td>Queensland University of Technology</td>
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<tr>
<td>PTSV</td>
<td>Public Transport Safety Victoria</td>
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<tr>
<td>Rail CRC</td>
<td>Co-operative Research Centre for Railway Innovation</td>
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<tr>
<td>ROE</td>
<td>Rate of expansion</td>
</tr>
<tr>
<td>UFOV</td>
<td>Useful field of view</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
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<td>UK</td>
<td>United Kingdom</td>
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1. Introduction

1.1 Background

A railway level crossing is a location where a public or private roadway, footpath or both crosses one or more railway tracks at grade (Rail Safety Regulators’ Panel 2008a). At the most recent count, there were over 23,532 railway level crossings in Australia (Rail Industry Safety and Standards Board 2009). Only 8838 of these crossings are on public roadways, with the remainder on private roads or farmland.

Australian railway level crossings are equipped with different types of control. Of the public level crossings, the vast majority (67%) are equipped with passive warning devices (Rail Industry Safety and Standards Board 2009). Passive crossings control the movement of vehicular or pedestrian traffic by signs or devices which are not activated during the approach or passage of a train, and thus rely on the road user to detect the approach or presence of a train (Rail Safety Regulators’ Panel 2008a). These signs may include ‘crossbucks’, also known as railway crossing position signs (i.e. white retro-reflective x-shaped signs carrying the word ‘railway’ on one arm and ‘crossing’ on the other), give way signs, stop signs and road markings (i.e. ‘X’ and ‘RAIL’). The remainder of public crossings are equipped with active warning devices (33%). Active crossings control vehicular or pedestrian traffic by devices that are activated prior to, and during, the passage of a train through the crossing (Rail Safety Regulators’ Panel 2008a). These devices include flashing lights, bells or other audible warning devices, gates or barriers, or a combination of these. Active crossings are generally located at sites with a high volume of road and rail traffic.

Furthermore, there are at least 1659 pedestrian crossings (Rail Industry Safety and Standards Board 2009). This count is an underestimate, as two states had not completed their inventories at the time of this survey. While many pedestrian crossings are found adjacent to road level crossings, a number of level crossings are designated solely for pedestrians, for example, at train stations. Pedestrian crossings may be passively controlled by signage, fences or approach mazes to guide traffic flow, or active devices such as flashing lights, audible warnings, mini-booms or gates.

Collisions at railway level crossings are the largest cause of Australian rail-related fatalities (Bureau of Transport and Regional Economics 2002; Cairney 2003; Sochon 2008). National guidelines define a level crossing occurrence as ‘a collision of a train or rolling stock with a road vehicle, person, level crossing safety equipment or gate, or any other occurrence that endangers or has the potential to endanger the safety of a railway operations or level crossing operations’ (Rail Safety Regulators' Panel 2008a). This definition also includes collisions between road vehicles and level crossing equipment, and also near-miss incidents between road users and trains. Given that many researchers use the word ‘accident’ to describe collisions between level crossing users and trains, the words accident and collision will be used interchangeably throughout this report.

Across the last decade, there have been, on average, 78 train–vehicle and train–pedestrian level crossing collisions per year (Australian Transport Safety Bureau (ATSB) 2010a). An earlier report estimates an average of 37 fatalities at level crossings annually (ATSB 2004a). Compared with other road accidents, level crossing collisions are relatively rare occurrences; level crossing fatalities only represent about 1% of the national annual road toll (ATSB 2002; Davies 2010; Department of Infrastructure/VicRoads 2007). However, when level crossing accidents do occur, their consequences are much more severe. Level crossing collisions are much more likely to result in fatalities than other road collisions, with estimates ranging from three to 30 times (Afxentis 1994; Levasseur & Mitchell 2011; National Highway Traffic Safety Administration 2005; Operation Lifesaver 2011a; Raub 2009). When collisions involve heavy vehicles or buses, the consequences can be catastrophic, with the potential for train derailment and multiple fatalities. In 2007, a collision between a ‘B-double’ truck and a passenger train just outside of Kerang, Victoria, resulted in 11 fatalities on board the train and 20 people injured (Office of the Chief Investigator Transport and Marine Safety Investigations 2008). Additionally, a collision between a school bus and a passenger train at Salisbury, South Australia, in 2002 resulted in four fatalities (all on board the bus) and 26 injured (ATSB 2003).
Furthermore, level crossing accidents are costly. These costs include medical bills, lost work and household productivity and quality of life, and infrastructure costs, as well as delays in services, lost freight contracts, litigation and investigation. Australian level crossing accidents in 1999 were estimated to cost $32 million, with only $10 million of this estimated for collisions involving motor vehicles (Bureau of Transport and Regional Economics 2002). The higher cost of pedestrian accidents was almost entirely due to losses in productivity and quality of life (Bureau of Transport and Regional Economics 2002). This may be due to pedestrian incidents having a higher likelihood of serious injury and death (e.g. ATSB 2004a; Henley & Harrison 2009). Across all rail accidents (not limited to those occurring at level crossings), the cost of a fatality was estimated at $1.9 million, and a serious injury at $27,000 (Bureau of Transport and Regional Economics 2002). However, these estimates were likely to be very conservative, especially in regard to infrastructure repairs. It was conservatively estimated that eliminating Australian level crossing collisions would result in financial benefits of approximately $40 million per year, expressed in 2007 dollars (National Transport Commission 2007). More recently, the ATSB investigated nine level crossing collisions occurring between April 2006 and December 2007 involving heavy vehicles, which resulted in 19 fatalities and 60 people injured. Collectively, these collisions were estimated to cost well over $100 million, with one incident at Lismore involving a rigid tipper truck/quad axle trailer and freight train costing well over $30 million (ATSB 2008b).

Current projections indicate that both rail and heavy vehicle road transport traffic are increasing (Bureau of Infrastructure, Transport and Regional Economics 2009b; 2010). These factors, combined with the advent of high-speed rail in some states (e.g. trains on the four Victorian Regional Fast Rail lines, which travel up to 160 kph), mean that there will be an even greater likelihood of accidents that result in catastrophic consequences in the future.

Therefore, there is a great need to learn more about the characteristics of level crossing accidents, to be able to target both high-risk crossings and high-risk users for interventions.

Currently, minimal data are available regarding these incidents, and unfortunately, what is available has two main issues:

- Data are aggregated at a high level and lack specific information, such as crossing type (i.e. active or passive), location (i.e. urban or rural) and time of day, to target an intervention.
- There is little information available on the contribution of human factors (e.g. age, sex, personality and fatigue/sleepiness) to railway level crossing accidents. Information is lacking on the characteristics of people who are involved in accidents and near-misses at level crossings, or who violate level crossing rules, and thus are at high risk of having an accident in the future.

It is important to note that these two broad problems are not mutually exclusive, and railway level crossing accidents are generally the result of a complex interaction of numerous factors at both the environmental and human levels (ATSB 2003; Caird et al. 2002). Therefore, high-risk user groups may be especially at risk at certain types of crossings.

1.2 Aim and scope of project

There were two main aims of this project:

- to review and further define the gaps in knowledge regarding high-risk users of level crossings
- to report on existing knowledge and statistics on high-risk users.

This report takes a ‘safe system’ approach, which has been adopted by the National Railway Level Crossing Safety Strategy 2010–2020 (Australian Transport Council 2010), and is considered as international best practice by the Organisation of Economic Co-operation and Development (OECD), as detailed in its recent report Towards zero: Ambitious road safety targets and the safe system approach (2008). The safe system approach recognises that humans are fallible and make errors, and therefore accidents will never be entirely prevented. However, this approach also recognises that level crossing accidents result from the complex interaction between level crossing users (e.g. pedestrians, older drivers), vehicles (e.g. heavy vehicles, high-speed trains), the level crossing...
infrastructure (e.g. sight distances, signage) and the broader environment (e.g. weather conditions). Thus, level crossing users are not given sole responsibility for level crossing safety, and the key to safer level crossings arises from shared responsibility between road users, transport industries and government bodies. Countermeasures adopted through the safe systems approach seek to make the characteristics of level crossings more forgiving of human error, and to minimise the level of unsafe road user behaviour.

This report also adopts risk management and cost–benefit perspectives by placing greater focus on high-risk groups and associated human factors that:

- are associated with greater losses, for example, in terms of money, infrastructure or life
- have a higher frequency of occurrence
- are more easily modifiable.

Thus, our recommendations are prioritised with these factors in mind.

This report is not intended to be a comprehensive review of all possible human factors that may contribute to level crossing accidents. Instead, we highlight those that:

- are identified as particularly significant contributors within Australian and overseas statistics and the academic literature
- are associated with level crossing occurrences in key high-risk user groups
- lend themselves to the development and implementation of possible countermeasures and interventions.

Results presented in this scoping study are intended to provide guidance for developing a full research proposal for follow-up studies.

For a more detailed discussion of the human factors associated with level crossing accidents, the interested reader is referred to the comprehensive literature reviews commissioned by the US Federal Railroad Administration (FRA) (Yeh & Multer 2008) and Transport Canada (Caird et al. 2002). Two recent Australian reports also discuss broad human factors associated with level crossing accidents — a Monash University Accident Research Centre (MUARC) report, which was commissioned by the Victorian Railway Crossing Safety Steering Committee (Edquist et al. 2009), and a report commissioned by the Rail CRC (Wallace, McCusker & Hirsch 2008). However, these reports do not explicitly identify, or provide in-depth discussion of, specific high-risk user groups at railway level crossings.

1.3 Report structure

The remainder of this report is organised in the following way:

- In section 2, statistics on level crossing occurrences are presented, and level crossing occurrence databases are discussed.
- Section 3 discusses the current Australian model of risk assessment for level crossings.
- Section 4 touches on general human factor contributors to level crossing accidents.
- In section 5, high-risk user groups at level crossings are discussed, as are the combination of human factors that influence their behaviour.
- Section 6 provides a summary of the state of research into the human factor precursors of level crossing occurrences.
- Finally, section 7 provides a list of recommendations for future research into the behaviour of high-risk users at Australian railway level crossings.

The focus of this report is on identifying and describing the behaviour of high-risk users of level crossings. However, we chose to discuss human factor contributors at a more general level first, given that many of these factors apply to several of the high-risk groups identified. Thus, these factors are first introduced at a general level, before they are applied to the high-risk user groups. By considering each high-risk user group in turn, it then becomes easier to consider the behaviour of each group holistically, as a unique combination of several human factors.
1.4 Project method

A literature review was conducted using the following sources:

- Google and Google Scholar
- academic search engines ISI, PsycINFO and Scopus
- international industry and government websites, including the FRA, the UK Rail Safety and Standards Board, the US National Transportation Safety Board (NTSB) and Transport Canada
- Australian industry and government websites, including, but not limited to, the Australian Road Research Board (ARRB), the Australian Transport Council, the ATSB, Austroads, the Rail Industry Safety and Standards Board, the Rail CRC, the Australasian Railway Association, the Rail Safety Regulators’ Panel, Australian Rail Track Corporation, the Bureau of Infrastructure, Transport and Regional Economics and the National Transport Commission, as well as various state and jurisdictional websites
- transport and industry search engines, including the American Transportation Research Institute, the ARRB Rail Knowledge Bank, and TRID (an online database which integrates the Transportation Research Information Services and OECD databases)
- key peer-reviewed journals that had previously featured railway level crossing research, e.g. Safety Science, Journal of Safety Research, Accident Analysis and Prevention, Applied Ergonomics, Australian Road Research and Transportation Research Record.

Additionally, reference lists within documents found through these methods were searched for relevant material.

The following keywords were entered into the search engines:

- grade crossing, level crossing, rail* crossing, railroad-highway crossing
- driver, vehicle, train, pedestrian
- accident, incident, collision, occurrence, near-miss, violation, fatality, injury, comply, error, crash, death
- human factors, risk factors, behavio*r, error, characteristic, attitude, comprehen*, risk-taking, percept*, inattent*, cognition, expectation, decision making
- countermeasure, success, trial, pilot, intervention, cost-benefit analysis.

Once high-risk groups were identified from within this literature, these groups were then used as search terms. Due to the paucity of literature on the behaviour of these high-risk users at level crossings specifically, the scope was widened to include research on high-risk users in the broader road-rail safety context.
2. Level crossing accidents and statistics

2.1 Overseas

In many countries, including the US, UK and Canada, most accidents occur during the day; across a 24-hour period, between 40% and 78% of level crossing accidents occur in daylight hours (excluding dawn and dusk) (Caird et al. 2002; FRA 2006; NTSB 1998b; Raub 2009). Additionally, approximately 70% of collisions occur in clear weather conditions (FRA 2006; Raub 2009). However, these figures were not normalised for road or rail traffic, so they cannot address the possibility that more daytime accidents may occur simply due to the higher traffic flow. Additionally, as the data were analysed for all crossings, regardless of control type, it is not known if different trends would emerge when analysing passive and active crossings separately.

When data are normalised by exposure rates, such as average daily traffic or by 10 million crossing vehicles, passive crossings have much higher rates of collisions than active crossings (Evans 2011; FRA 2006; Raub 2009). Specifically, between 1998 and 2007, crossings controlled by stop signs only had the highest rate of collisions, being nine times higher than rates for active control devices (Raub 2009). Additionally, collision rates at crossings with other passive devices (e.g. crossbucks only, and give way signs) were five times higher than rates for active crossings (Raub 2009).

One-third of accidents at US passive level crossings during 1996 were attributable to physical characteristics of the crossing, such as inadequate sight distance, less than 90 degree angles to the crossing, or curvature of the road or track (NTSB 1998b).

Males are over-represented in level crossing accidents, being involved in 71% of collisions from 1998 to 2007 (Raub 2009). Drivers aged under 25 years are over-represented in level crossing accidents, compared to their representation in the US population (FRA 2006; Raub 2009). Additionally, drivers aged over 65 years were 50% more likely to be involved in a fatal collision (Raub 2009).

It is consistently found that cars are the most common motor vehicles involved in level crossing accidents, followed by trucks. For example, cars were involved in 46% of US level crossing collisions in 2005, and 39% of fatalities (FRA 2006). The next highest road user group was truck/trailer combinations, representing 17% of collisions. In Canada, cars represented 53% of fatal level crossing vehicle–train collisions between 1983 and 2001, followed by light trucks (27%), heavy trucks (5%) and tractor trailers (4%) (Caird et al. 2002). Finally, 64% of UK vehicle–train collisions involved cars, followed by 17% involving lorries (Rail Safety and Standards Board 2004).

Although pedestrians represent a minority of level crossing accidents, the consequences of pedestrian–train collisions are much more severe. In the US, for example, pedestrians were only involved in 4% of collisions during 2005, but they represented 16% of fatalities (FRA 2006). Pedestrians also represent the vast majority of fatalities at UK level crossings (Evans 2011; Nelson 2008).

In 2005, 82% of all US level crossing accidents could be attributed to the road user. Specifically, 41% of all accidents were attributed to driver inattentiveness, 20% to violations, 13% to misjudgment, and 7% to road users deliberately ignoring warning devices (FRA 2006). Half of the vehicle incidents at passive level crossings during 1996 involved the driver not stopping. Driver distraction was a contributing factor in 20% of accidents (FRA, 1998). When driver behaviour in Canada was considered to be intentional, the most common reasons were ‘failed to stop’ and ‘drove around gates’ (Caird et al. 2002).

2.2 Australia

2.2.1 Level crossing occurrence data

There are no national databases that catalogue the circumstances of occurrences at Australian level crossings. This is partly due to the fact that the reporting and classification of level crossing incidents is managed separately by the rail regulators in each jurisdiction. As the reporting and categorisation methods differ between jurisdictions, aggregating this data at a national level has proved quite difficult. The ATSB only requests limited...
data from the jurisdictions. Thus, the data remain distinct at a jurisdictional level, meaning Australian level crossing occurrences cannot be examined in a holistic manner. None of these individual databases is available to the public. Consequently, for industry outsiders without access to the data, information on Australian level crossing occurrences can only be obtained from reports generated by government and industry organisations. As a result, the accuracy of these reports cannot be subject to critical peer review, and researchers are unable to use the information to test their own specific hypotheses.

The ATSB has published basic occurrence data on vehicle–train and vehicle–person collisions in each jurisdiction since 2008, which is updated biannually. The frequency of incidents is also normalised by million train kilometres. But beyond this, this source provides no detail on the characteristics of these crashes, including the number of serious injuries or fatalities, the type of crossing control (e.g. boom gates, stop sign), or the likely incident precursors, including human factors. In contrast, the Australian Level Crossing Assessment Model (ALCAM) database (discussed in more detail in section 3) provides the characteristics of each Australian level crossing, such as sight distance and type of crossing control. However, this information is not linked with occurrence data.

Additionally, detailed level crossing safety investigations conducted by the ATSB only include those that occur on the Defined Interstate Rail Network (DIRN), which comprises the standard gauge lines that link the mainland capital cities. Each jurisdiction is responsible for investigating occurrences on its own intrastate rail networks (ATSB 2009). Even then, the ATSB does not investigate all accidents occurring on the DIRN; due to its limited resources, it does not investigate those that are highly similar to previous accidents, and the findings of which will not necessarily contribute to improving rail safety (ATSB 2009). Thus, readers will not get a representative view of level crossing accidents from these reports, with level crossing accidents occurring on ‘local’ intrastate tracks likely to be under-represented.

Without detailed statistics on level crossing accidents and near-misses, the main causes of these occurrences cannot be determined, and any countermeasures adopted may not be effective in preventing them. Thus, such a database is critical for improving level crossing safety. For this reason, industry experts and researchers have been calling for a comprehensive national database for many years (see ATSB 2004b; Cairney 2003; Cairney, Gunatillake & Wigglesworth 2002), but to date, there has been relatively little progress on this front. Level crossing research cannot progress until this task is accomplished.

In 1999, the Australian Transport Council decided that the ATSB should assist in the development of national rail safety statistics (ATSB 2004b). Since then, the ATSB has endeavoured to obtain quality safety data from state and territory rail regulators. However, in its 2006 annual review, it expressed disappointment that even the limited safety data provided thus far was likely to be misleading, and the broader safety data promised by regulators would be significantly delayed (ATSB 2006). In an attempt to remedy this, the ATSB provided $80,000 to rail regulators to audit and improve their data issues.

Currently, rail transport operators are required to collect data on level crossing occurrences using the standards Occurrence Notification Standard One (ON-S1) and Occurrence Classification Guideline One (OC-G1) (Rail Safety Regulators’ Panel 2008a; 2008b). These two standards provide frameworks for reporting the circumstances of level crossing occurrences, but do not have the scope for reporting information on possible occurrence precursors. However, in the past year, rail industry members have also been reporting rail occurrences in accordance with the Contributing Factors Framework (CFF) (Rail Safety Regulators’ Panel 2009), which is complementary to ON-S1 and OC-G1 (Rob Burrows, personal communication). The CFF includes systemic factors that contributed or led to the occurrence. It is anticipated that use of this framework should provide greater detail on level crossing occurrences (Rail Safety Regulators’ Panel 2009). However, this cannot be confirmed until the data collected using the CFF are made available.

A notable example of current data collection comes from the NSW Independent Transport Safety Regulator (ITSR), which has recently developed a checklist to capture greater detail on the human factors precursors to level crossing accidents (2010a). It is based on a UK toolkit and the US FRA reporting framework, but has been adapted for the Australian context. Numerous precursors are included, such as time of day, weather and environmental...
conditions, including adjacent intersections, crossing characteristics such as controls, sight distances, vehicle and train volumes, multiple tracks, and several human factor precursors, like road user age, gender, locality and driving experience, the presence of distractions such as child passengers or mobile phones, and road user behaviour such as 'drove around gates', poor scanning and misjudging train speed or distance. Although this tool is designed primarily for use by the ITSR, train drivers are also encouraged to use it to enhance their reporting. The level of detail that can be obtained from this checklist is promising, but such frameworks need to be used consistently between jurisdictions, and made mandatory for train operators to use.

The advent of a single national rail safety regulator by January 2013 should hopefully lead to greater consistency in data reporting and categorisation across Australia (National Rail Safety Regulator Project Office 2011). Although industry negotiations are ongoing, it appears that the ATSB will host a national rail safety database that includes all Australian level crossing occurrences (Kevin Taylor, personal communication). Furthermore, the ATSB is attempting to establish a single national rail safety investigator. Consequently, having a single investigator may provide a more holistic approach to systematically determining and recording precursors of level crossing occurrences. These two major changes provide a great opportunity to improve current knowledge on Australian level crossing occurrences. It is our hope that this potential is fully realised.

2.2.2 Prevalence and nature of level crossing accidents

It is difficult to determine the predominant causes of occurrences at Australian level crossings, given there are relatively few level crossing occurrences each year, and there is a lack of detailed data on level crossing occurrences. Current knowledge on Australian level crossing occurrences has been pieced together from several different reports, using different data sources that cover different time periods. These data sources are often limited by missing data and differences in reporting guidelines by jurisdiction, and are not always normalised using appropriate metrics, if at all. For example, normalising information, including the number of crossings, daily road–rail traffic, the proportion of the population or of licensed drivers, or the distance travelled by the particular user group (e.g. older drivers) is often not included, making it difficult to determine what particular crossings or circumstances are inherently more risky. Additionally, these reports may only detail occurrences in single jurisdictions, or on interstate (and not intrastate) rail networks. In this way, the data may not necessarily be representative of national trends. It is then also difficult to synthesise the data from different jurisdictions. Finally, as many particular statistics (e.g. proportion of each age group) have only been listed in one report, there is little opportunity to verify these findings using other data sources. Nonetheless, the information available provides a description of some of the circumstances that appear to be prevalent in collisions at Australian level crossings.

Considering that Australian level crossing statistics are so limited, it is not surprising that most academic and industry reports rely on only two particular reports when discussing the number and type of Australian crossings, collisions, and their possible human factor precursors (see ATSB 2002; Ford & Matthews 2002). These reports are now outdated, containing data that is at least 11 years old, and they have numerous limitations, including large amounts of missing data. Updated inventories of Australian level crossings and associated occurrences have only been relatively recently released, and consequently are not yet widely reported (ATSBI 2010a; Rail Industry Safety and Standards Board 2009).

The most recent occurrence data provided by the ATSB shows that there were 643 collisions between trains and motor vehicles at level crossings between January 2001 and June 2010 (ATSBI 2010a). This translates to an average of 68 collisions per year. Queensland, then Victoria, recorded the highest number of collisions, but when data were normalised by million train kilometres, Tasmania, the Northern Territory, and then Victoria recorded the highest rates of collisions. In addition, there were 91 train–person collisions over the same period, equating to an average of 10 collisions per year. The greatest number of train–person collisions occurred in Victoria, then South Australia, regardless of whether data were normalised. However, no mention was made within this document about whether these data included attempted or actual suicides. Additionally, normalising information on the number of level crossings in each jurisdiction would have been useful, to gain a more detailed picture of which jurisdictions had the highest number of collisions, these things being equal. Another report listed 695 collisions over a similar period (2000–2009), but also included collisions on private roads, which may not have been included in the ATSB report (ITSR 2010b).
Another ATSB analysis covering the period 1997–2002 found an average of 37 fatalities at Australian public level crossings per year (ATSB 2004a). A Rail Safety Regulators’ Panel report puts this figure for the same period as closer to 15 (Rail Safety Regulators’ Panel 2008c). However, this difference may be partly definitional, as the latter report excluded any deaths that were ‘suspected suicides’, whereas the former only excluded suicides that were ruled as such by the coroner. Thus, it is possible that some of the 37 fatalities in the former report were actually suicides.

Furthermore, an Australian Health and Welfare report shows that, from 2002–2003 to 2006–2007, an average of 51 people per year were seriously injured (i.e. requiring a hospital stay) at Australian road vehicle and pedestrian level crossings (Henley & Harrison 2009). These serious injury rates remained stable across the five-year analysis period. Hospital stays lasted 11.9 days on average, which was approximately three times as long as stays for all non-rail-related injuries. These data excluded attempted suicides.

These three sources of data provide the most recent information on occurrences, fatalities and serious injuries at Australian level crossings. However, it would be much more useful for this information to come from one data source, so that data did not have to be synthesised across different time periods, and from reports that may have differentially excluded suicides. As these reports also differed on the normalising data they used (if at all), it is particularly difficult to synthesise these results. Such information would provide more detailed information regarding the likelihood of particular outcomes resulting from level crossing collisions. These reports also do not provide much detail on the specific characteristics of these occurrences, including the type of crossing control and human factor precursors.

A promising new approach was taken in a recent ARRB study, where characteristics of train–vehicle level crossing collisions for the period 2000–2009 were studied using linked road crash and rail incident data (Levasseur & Mitchell 2011). Data linkage analysis of level crossing collisions had not been previously undertaken, and enabled greater detail on collision circumstances to be examined, including time of day, weather conditions, number of tracks, vehicle type, and driver age, sex and postcode (see the following paragraphs for more detail). Some of this information was also normalised by factors like population of registered drivers, and train and road vehicle traffic. Although data were obtained from New South Wales, Queensland (excluding 2009), Victoria, South Australia and New Zealand, collisions in the Northern Territory and Tasmania were not examined (which would have excluded approximately 34 collisions (see ATSB 2010b). Furthermore, not all level crossing collisions were included, as they could not all be matched with road crash data; the 307 collisions from the five states examined represent only ~50% of collisions recorded by the ATSB during 2000–2009 (ATSB 2010b). And as not all state databases included the same collision characteristics, numbers differed between each analysis. Thus, while the results are current and informative, they cannot be considered representative of all Australian level crossing collisions. And while several high-risk groups could be identified from the data (see below), the data provided no information as to what behaviours contributed to these groups’ high-risk status.

The number of fatalities from train–vehicle level crossing collisions has reduced by about 70% since 1970 (ATSB 2008b; Victorian Auditor-General 2010; Wigglesworth 2008a; Wigglesworth 2007). Several factors may have contributed to this decline, including upgrading passive to active crossings, and upgrading ‘flashing light’ crossings to boom barrier controls, as well as more general road safety initiatives such as enforcement of speed and seat belt use (Wigglesworth, Graham & Routley 2005; Wigglesworth 2001). However, declines over the last few years have been much more modest (Wigglesworth 2008a). Recent trends show little decline in collisions and fatalities overall in Australia, with only two jurisdictions showing significant decreases in vehicle–train collisions (Rail Safety Regulators’ Panel 2008c). However, these jurisdictions were not explicitly named, and possible reasons as to why they experienced decreases in accidents were not discussed.

A majority of vehicle–train collisions occur at crossings with active controls (ATSB 2002; Ford & Matthews 2002; Han et al. 2010; ITSR 2011b). For example, an ATSB monograph (2002) examining fatal level crossing accidents from 1988 to 1998 found that 51% of fatalities were at actively controlled sites. However, this report only examined accidents in ‘even number’ years, and with only partial data for 1998, so statistics generated from this
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Chapter 2 – Accidents and statistics

Report cannot be considered as entirely representative of Australian trends. More recent data of Australian and New Zealand level crossing crashes from 2003 to 2007 show that 50% occurred at active crossings, 29% occurred at passive crossings, and a further 22% occurred at crossings with unknown or unspecified controls (Han et al. 2010). Importantly, neither of these reports used any normalising data, including train or road traffic activity. Thus, it is likely that the higher proportion of collisions at active crossings is a result of higher exposure. In fact, once train and road traffic are controlled for, passively controlled crossings (i.e. stop and give way signs) have much higher collision rates than actively controlled crossings (ITSR 2011b). For example, an analysis of Victorian casualty crashes during 2007–2008 showed that the rate of casualties at passive crossings controlled by stop signs was up to 16 times higher than for crossings controlled by boom barriers (Public Transport Safety Victoria 2008). Unfortunately, such crossing control type information is not available for pedestrian-train collisions.

Few crashes occur at crossings with multiple tracks (21.5%), but these types of accidents are over-represented, considering only 12.2% of level crossings have multiple tracks (Levasseur & Mitchell 2011). Additionally, crashes at crossings with adjacent side roads represented 40% of all crashes during 2000–2009, despite side roads only being present at 16.6% of level crossing locations (Levasseur & Mitchell 2011).

A breakdown by road user type shows pedestrians (excluding suicides) comprise 66% of fatalities at level crossings (ATSB 2004a). In contrast, pedestrians only represent 30% of seriously injured people (Henley & Harrison 2009), and 12% of occurrences overall (ATSB 2010a). It must be noted that these three figures come from different reports covering different (although overlapping) time periods. And as previously mentioned, suicides are treated differently across reports. This is an important omission, given the high proportion of pedestrian-train collisions that are (at least suspected) suicides (Wigglesworth, Graham & Routley 2005). Nonetheless, it is clear that, although there are fewer train-pedestrian level crossing occurrences, the consequences of these incidents are much more likely to be severe.

Over the past decade, accidents involving road vehicles comprised 88% of level crossing occurrences (ATSB 2010a). Most road vehicle fatalities at level crossings involve cars, utilities, vans and 4WDs, which represented 72% of the vehicle-train collisions examined within the ARRB report (ATSB 2002; Levasseur & Mitchell 2011). A smaller proportion of accidents involve heavy vehicles. For example, 15% of the fatalities investigated between 1988 and 1998 involved heavy vehicles, as did 5% of the fatalities investigated during 1997–2002 (ATSB 2004a). The ARRB report found that heavy vehicles were involved in 18–20% of the vehicle-train collisions examined, yet they constituted only 2.5% of vehicles registered in that period, and drove only 6% of the kilometres travelled by Australian road vehicles. Heavy vehicle collisions were more than twice as common at level crossings than in all road crashes (ITSR 2010b; Levasseur & Mitchell 2011). Of all Australian and New Zealand level crossing collisions occurring between 2003 and 2007, 20% involved heavy vehicles. However, heavy vehicles comprised only 4% of all registered vehicles during 2007 (Han et al. 2010). Furthermore, heavy vehicle collisions now represent a greater proportion of accidents at level crossings than in previous years. Specifically, during the period 1999–2006, eight of the 23 incidents involved heavy vehicles, in contrast with only three of the 85 consecutive fatalities at Victorian level crossings during the period 1973–1977. This represents a tenfold increase in heavy vehicle accidents over a 30-year period (Wigglesworth 2007). However, these figures do not account for the fact that yearly distance travelled by heavy vehicles has increased in recent years, and is higher than travelling distance for the general population. Thus, it is possible that the over-representation of heavy vehicles is at least partly due to the greater among of driving that they do.

Males represent the majority of people involved in level crossing accidents. Of the level crossing road vehicle fatalities analysed from 1988 to 1998, 76% were male (ATSB 2002). Similarly, of the level crossing fatalities between 1997 and 2002, 70% of the vehicle drivers and 84% of the pedestrians were male (ATSB 2004a). However, this male predominance is also evident in all road accidents (at 80%, as reported in ATSB 2002). In the ARRB report, males were consistently over-represented in level crossing crashes for all age groups, and when compared with the proportion of all registered drivers. This was especially pronounced for 17–24 year old males, who represented more than double the proportion of registered drivers of this age group and gender (Levasseur & Mitchell 2011). Only from 30 years and older did males have a higher proportion of level crossing crashes than road crashes. In contrast, females were consistently under-represented in level crossing collisions compared with
all road collisions, and all registered drivers. Only after age 50 did they have a greater proportion of level crossing crashes than road crashes (Levasseur & Mitchell 2011).

There is also some evidence to suggest that both younger and older drivers are involved in a disproportionate number of level crossing accidents. Drivers aged 60 and over represented 26% of the level crossing fatalities examined from 1988 to 1998. This is significantly higher than the proportion of older people represented in all road crash fatalities, at 10% (ATSB 2002). This does not necessarily mean older people are more likely to be involved in collisions; instead, they may simply be at increased risk of dying when they do crash, given that their bodies may be frailer, and less able to recover from trauma (Li, Braver & Chen 2003; Oxley et al. 1997). This possibility cannot currently be addressed, as level crossing occurrence data are not currently broken down into age groups. However, the broader road crash data show that, when involved in crashes, older drivers are more likely to suffer more serious, and often fatal, consequences than younger drivers (Fildes 2008; Langford & Koppel 2006; Li, Braver & Chen 2003).

In contrast, young adults in the 20–24 year age group represented the highest rates of serious injury at Australian level crossings from 2002–2003 to 2006–2007, on a population basis (Henley & Harrison 2009). The highest rate for males was also the 20–24 year age group, with rates generally elevated across the broader 15–34 year span. For females, the peak serious injury rate was at 70–74 years, with generally high rates across 70–79 years. However, a second smaller peak was also evident at 20–24 years (Henley & Harrison 2009). This interaction between age and gender is also seen in pedestrian data. Specifically, 60% of pedestrian fatalities between 1997 and 2002 were males aged 15–49 (ATSB 2004a). As males in this age range comprised just under 30% of the Australian population during this period, they are clearly over-represented in level crossing statistics (ATSB 2004a). Normalising data on the distances travelled by each age group would be useful here, as it is possible that younger drivers are over-represented at least partly because they spend more time driving than many older age groups.

Most vehicle–train collisions (and fatalities) occur during daylight hours (ATSB 2002; Cairney 2003; Levasseur & Mitchell 2011; Wigglesworth 2001). The ATSB reports that 83% of fatalities occurred in daylight (excluding dawn and dusk) (ATSB 2002). The ARRB report found that 76% of the collisions analysed occurred in daylight (Levasseur & Mitchell 2011). Additionally, 73% of the collisions at Victorian passive crossings in the periods 1973–1976 and 1977–1991 occurred between 6 am and 6 pm (Wigglesworth 2001). However, if exposure data had been considered when analysing these data, it may have emerged that the higher likelihood of daytime accidents was simply due to the greater amount of road traffic during daytime hours (as suggested by Caird et al. 2002; Wallace 2008). Given that it is much harder to visually detect both crossings and trains at night, and to distinguish between (inactivated) active and passive warning signs, level crossings may be inherently more risky during nighttime hours. There is currently no evidence to support this possibility.

For most fatalities resulting from vehicle–train collisions (66%), the point of impact was the front of the train (ATSB 2002). This suggests that more fatalities (and perhaps also collisions) result from not noticing or misjudging the arrival time of an approaching train, rather than not noticing a train that is already on the crossing.

According to the ATSB’s analysis of Australian level crossing fatalities, weather and road conditions do not appear to be terribly important contributing factors, with 85% of fatalities from vehicle–train collisions occurring in good weather conditions, 84% on a dry road, 89% on a straight road, and 77% on a level road (ATSB 2002). The ARRB report found that 75% of the collisions investigated occurred on straight flat roads, 89% occurred on sealed roads, and 85% occurred in clear weather conditions (Levasseur & Mitchell 2011). It appears that level crossing crashes are more likely to occur on sealed roads, as only 54% of roads approaching level crossings have sealed surfaces (Levasseur & Mitchell 2011). Other factors less relevant to level crossing collisions are excessive speed (7% of fatalities), and drugs or alcohol consumption (9% of fatalities), both of which featured significantly less often than in other road crashes (ATSB 2002). Finally, fatigue does not appear to be a significant contributor, being present in only 3% of the level crossing fatalities. This estimate was only slightly lower than that for all road crashes (at 8% of fatalities) (ATSB 2002). However, fatigue may be difficult to assess validly using fatality data, as the road users
One of the major contributing factors in level crossing accidents is unintentional road user error. In the ATSB analysis of fatalities during 1988–1998, 46% appeared to be due to unintended driver error, compared with 22% at other fatal road crashes (ATSBI 2002). The driver did not see the train, or did not observe or was unable to heed the warning system, or for some other reason was unable to avoid the train. Although it was not reported how this information was obtained, it had to have come from somewhat subjective external informants, such as the train drivers. And as these data were not broken down any further, it could not be determined whether one particular type of road user error (e.g. familiarity with the crossing) was most prevalent. Additionally, Wigglesworth (2001) analysed data from detailed police reports of Victorian level crossing fatalities during 1973–1977, and concluded that the majority of accidents were due to driver distraction, inattention, and cognitive or perceptual overload, rather than a deliberate breach of regulations.

At this point, it is important to properly acknowledge that a high proportion of level crossing accidents are suicides (or attempted suicides), and that this issue presents a significant, but somewhat distinct, problem for Australian level crossing safety. As mentioned, most (though not all) Australian reports and statistics exclude suicides at level crossings, given that they are not accidental, and stem from very different causes (ATSBI 2004a; Rail Safety Regulators’ Panel 2008a; 2008c). There is also little that any countermeasure may do to prevent people from trespassing on the tracks if they are set on ‘death by train’. While this reasoning is sensible, none of these reports then analyse suicides as a separate entity, but instead exclude them from analysis altogether. Consequently, we know very little about suicides at level crossings (for the most detailed report, see Routley et al. 2007). Additionally, as it can be difficult in some circumstances to determine whether a level crossing fatality involved suicide, it is likely that some level crossing statistics contain cases that were actually suicides. This effectively adds error to the data, making it more difficult to determine human factor precursors to level crossing accidents.

The few reports that provide statistics on suicides estimate suicides to represent 40–65% of rail-related deaths (Bureau of Transport and Regional Economics 2002; Wigglesworth, Graham & Routley 2005). A smaller proportion of suicides occur at level crossings (15–30%), and they tend to be more restricted to pedestrian crossings, to males, and among the 15–40 year age group (Routley et al. 2007; Wigglesworth, Graham & Routley 2005). It also appears that the incidence of psychiatric disorders among rail-related suicides is quite high (Routley et al. 2007). The Bureau of Transport and Regional Economics (2002) estimated the cost of rail-related suicides and attempted suicides during 1999 at $53 million. However, these estimates do not address the almost immeasurable psychological cost to train drivers (Bureau of Transport and Regional Economics 2002; Davey, Ibrahim & Wallace 2005; Wigglesworth, Graham & Routley 2005). A significant proportion of Queensland train drivers surveyed within focus groups reported experiencing suicides during their career, which were associated with considerable psychological trauma (Davey, Ibrahim & Wallace 2005). Thus, suicides are a significant area of concern at Australian level crossings, and are worthy of separate and detailed examination. Research into rail-related suicides is currently being conducted within Victorian government, industry and university partnerships (Routley et al. 2007).

2.2.3 Prevalence and nature of level crossing near-misses
It is also important to examine near-miss occurrences, as these incidents could have easily resulted in serious injuries or fatalities. Additionally, as near-miss incidents at level crossings far outnumber actual collisions, they provide a much greater opportunity to develop a detailed picture of human factor precursors. The greater sample size would allow data to be broken down into greater detail, such as according to crossing control type, without a substantial loss of statistical power. Yet there is even less data available regarding these occurrences. This omission represents a missed opportunity, which needs to be rectified.

The definition of a ‘near-miss’ provided in the current reporting guidelines is ‘any occurrence where the driver of a moving train takes emergency action, or would have if there was sufficient time, to avoid impact with a person, vehicle or other obstruction and no collision occurred’ (Rail Safety Regulators’ Panel 2008a, p. 15). This definition is quite broad, and may be interpreted in various ways by train drivers. Focus groups of Queensland train drivers
felt that the definition of near-miss was unclear and subjective, and there was no consistent definition agreed on by this group (Davey, Ibrahim & Wallace 2005). Factors that influenced the drivers’ perceptions of what constituted a near-miss included their perceived likelihood of impact, and also the level of emotional distress involved — as one driver reported, ‘everybody’s made differently ... what could upset (name), might not upset me’ (Davey, Ibrahim & Wallace 2005, p. 4). Near-misses with heavy vehicles were a source of great distress (Wallace 2008). Train speed was also a consideration, suggesting that near-miss definitions might differ between drivers of coal and freight trains. Thus, these issues are likely to have resulted in inconsistent reporting of near-miss incidents.

Figures showing the frequency of near-miss incidents from 1995 to 2007 for each jurisdiction were presented in a recent report (Rail Safety Regulators’ Panel 2008c). The number of near-miss incidents ranged widely between jurisdictions, from approximately 15 to 150 during 2006–2007. These numbers had to be visually estimated from the graphs in this report, as actual numbers were not provided. These data were also limited by definitional errors and limitations in systematically recording near-miss incidents. For example, data for Western Australia were considered too inconsistent to be made available, and other jurisdictions began recording near-miss incidents as late as 2002. Furthermore, as the definition of ‘near-miss’ varied between jurisdictions during the period of data collection, the jurisdictional data could not be validly compared or aggregated. And although there was a statistically significant increase in near-miss occurrences over time, this was likely to be due to improved reporting practices over this period, rather than an actual increase in occurrences. Finally, these data were not normalised by train or road user traffic.

During 2009, 702 near-misses involving motorists and pedestrians occurred at level crossings in Queensland (Queensland Rail 2010). This figure was reported by the CEO of Queensland Rail for the launch of the level crossing safety campaign “What would you miss?”. At the launch, train drivers discussed their experiences of regular near-misses, including motorists driving through flashing lights and around boom gates, and pedestrians pushing through closed gates and walking in front of oncoming trains (Calligeros 2010). Descriptive information for particular near-miss events was discussed, suggesting that more detailed data were available regarding possible precursors. Unfortunately, this information has not yet been made public.

Recently, TasRail reported that 22 near-miss incidents at Tasmanian level crossings occurred over a one-month period in 2011 (ABC News 2011).

Rail operators are required by law to report all near-miss occurrences. However, anecdotal evidence suggests that near-misses at level crossings are far more frequent than what is currently reported. Within focus groups of Queensland train drivers, participants discussed the almost daily regularity of near-miss occurrences (Davey, Ibrahim & Wallace 2005; Wallace 2008). Common reasons for not reporting near-miss occurrences related to ambiguities in the definition of ‘near-miss’, the perceived lack of outcomes resulting from reporting incidents, personal feelings such as not wanting to dwell on the incident, and workplace norms such as not wanting to be perceived as a ‘whinger’ (Davey, Ibrahim & Wallace 2005; Wallace 2008). New South Wales train drivers reported frustration at the lack of response to their ongoing pleas for industry action, and suggested that many drivers no longer see reporting of near-miss occurrences as an effective means of preventing further accidents from occurring (STAYSAFE Committee 2004).
3. The Australian Level Crossing Assessment Model

The Australian Level Crossing Assessment Model (ALCAM) is a mathematical tool used to assess the degree of risk at level crossings. The degree of risk generated from the ALCAM is used to prioritise crossings that need upgrading. It began as the Queensland Risk Based Scoring System for passive crossings in 1999. In 2003, the Australian Transport Council sanctioned the adoption of the ALCAM as the national standard. Currently, the ALCAM is implemented in all Australian states and territories. In the history of Australian level crossing safety improvements, the ALCAM is still relatively new, and is in a process of continual development in response to industry input (Spicer 2007). Thus, the ALCAM provides information regarding what factors are considered ‘risky’ at Australian level crossings according to industry experts.

The ALCAM considers the physical characteristics of level crossings, and level crossing controls, such as train speed, track curvature, visibility, the number of tracks, heavy vehicle use, and the possibility of short-stacking or queuing. It also considers a handful of common behavioural factors, such as fatigue and skylarking (Department of Infrastructure/VicRoads 2007). Both road and pedestrian level crossings can be assessed using the ALCAM. Each risk is weighted according to its likely contribution to accident mechanisms, such as misjudgment of train speed, and inability to see an approaching train. Weightings were determined through a series of workshops with level crossing industry experts. The weighted risk factors are summed to produce a total risk score. This score can then be multiplied by the site’s train, vehicle and pedestrian volume to compute a total risk exposure score, which enables the comparison and ranking of level crossing sites within a jurisdiction. Although the type of accident risk posed by each crossing (i.e. heavy vehicle collision, pedestrian collision, fatigue-related collision) is often factored into the final ALCAM risk score, this information cannot be readily determined from the resulting score.

The ALCAM is only one of the tools used in the safety assessment of Australian level crossings. However, it is considered to be the best available level crossing risk assessment tool (Spicer 2007). Risk scores calculated from the original ALCAM algorithm have been shown to correlate strongly with crash history (Hughes, 2002, as cited in Wallace, McCusker & Hirsch 2008). But as the risk weightings used in this algorithm are based solely on industry expert opinion, it is not clear if the relative importance of the factors considered is consistent with reality (ARRB 2009, as cited in Government of Victoria 2009). Without documented statistical associations between these factors and crash likelihood, the actual weights assigned are subjective, and likely to be incorrect (Levasseur & Mitchell 2011). However, as there is a paucity of representative and detailed Australian level crossing statistics, there is currently little else on which to base these weightings. To industry outsiders, it is not apparent what weightings are assigned to each particular precursor. Thus, what industry experts consider as ‘risky’ is not obvious. As an example, the ALCAM gives higher weighting for crossings with unsealed roads on the approach, whereas recent data shows an over-representation of crashes on sealed roads (Levasseur & Mitchell 2011). However, these data represent only around 50% of the level crossing collisions that occurred during the study period (2000–2009), which suggests it may not be beneficial to adapt ALCAM weightings on this evidence (ATSB 2010b; Levasseur & Mitchell 2011).

The ALCAM does not include all possible factors that may lead to a level crossing collision. As a case in point, prior to the fatal truck–train collision, the Kerang level crossing site was rated by the ALCAM as ‘needing no attention’ (Office of the Chief Investigator Transport and Marine Safety Investigations 2008; Ross 2008). As the coronial inquest into this collision is ongoing, possible human factor contributors have not yet been determined. Additionally, as highlighted by Wigglesworth (2007), the ALCAM did not identify that the crossing of the fatal Lismore collision was unnecessary and could be closed, as another crossing existed just 249 metres away, on a connecting road.

In particular, the ALCAM cannot account for all possible human factors that, in interaction with crossing characteristics, may lead to a collision. As an example, Australian level crossing safety expert Eric Wigglesworth (2007) suggested that, because the passively controlled Lismore crash site followed a succession of actively controlled crossings, the heavy vehicle driver may have been conditioned to expect to be warned of an approaching train, and thus did not exercise appropriate scanning behaviour. So although the ALCAM was able to
examine the specifics of the Lismore crossing, it was not able to conduct a more holistic analysis by considering this particular crossing within the broader local level crossing context (Wigglesworth 2007). Of course, several major causal factors that were specific to this collision, including the heavy fog conditions and the excessive speed of the truck, would never be able to be anticipated. However, it is possible that expectation factors may have exacerbated their unsafe effects.

It is important to note that the ALCAM was never designed to identify these and other human factors. However, there is no reason why it could not be expanded to do this. Although the ALCAM will never be able to account for all human factors, it may still be possible to include some other human factors that are as yet unaccounted for. An example of one such factor is the proportion of road traffic that is local, consisting of people who use the crossing on a regular basis. For crossings with a high proportion of local traffic, especially in combination with passive crossings with low train volumes, the behavioural precursor of familiarity or complacency could perhaps be accounted for (see section 4.4.1 for more detail on familiarity and complacency).

Knowledge of previous road user behaviour at each crossing would be helpful in this regard. However, the ALCAM database is not linked with crash history, so there is currently no potential to identify the likely human factor precursors at each site (Edquist et al. 2009).

The only high-risk vehicle user group to be identified within the ALCAM is heavy vehicle drivers. As for pedestrians, the risk algorithm takes into account whether young children and schoolchildren, cyclists and mobility impaired people frequent the crossing.
4. General human factors relating to level crossing accidents

Most level crossing users inadvertently engage in risky behaviour. Level crossing occurrences generally result from road users not detecting crossings or approaching trains, or ignoring or misjudging the risk that approaching trains pose (Abraham, Datta & Datta 1998; ATSB 2002; Caird et al. 2002; Cairney 2003; Edquist et al. 2009; Leibowitz 1985; Parliament of Victoria 2008; Wallace, McCusker & Hirsch 2008; Wigglesworth 2001; Yeh & Multer 2008). According to several comprehensive reviews of driver behaviour at level crossings, occurrences are generally a result of limited crossing/train visibility, inattention, distraction, lack of knowledge regarding level crossings, and misjudgment of train speed or distance (Caird et al. 2002; Edquist et al. 2009; Wallace, McCusker & Hirsch 2008; Wigglesworth 2001; Yeh & Multer 2008). However, a smaller, but unknown, proportion of level crossing occurrences are due to deliberate violations of crossing rules.

Many unintentional errors can be partially explained by Signal Detection Theory (Raslear 1996), which has previously been applied to level crossing collision investigations. This theory describes how the road user must detect the ‘signal’ of the approaching train among the ‘noise’ of the surrounding environment. In many instances, it can be difficult to detect the signal from competing noise such as in-car distractions or visually complex road traffic environments, and the driver must make the decision whether to cross the level crossing in uncertain circumstances.

Whatever the underlying cause, successful negotiation of level crossings, despite (intentional or unintentional) risky behaviour, makes it more likely that road users will continue this risky behaviour in future. Specifically, risky behaviour is reinforced when road users are able to continue over the crossing with no interruption to their journey, and no negative consequence of collision. This could be considered somewhat of a learning effect. Furthermore, with a lack of negative consequences, road users may come to view this behaviour as safe (Davey et al. 2008b; Yeh & Multer 2008).

The human factors discussed here apply generally to all road users of level crossings. However, different combinations of these factors combine to influence the behaviour of specific high-risk user groups. And certain human factors may be more prevalent in one particular road user group. Thus, we have chosen to first discuss these factors at a general level, before applying them to high-risk user groups in section 5.

4.1 Conspicuousness of crossings and trains

To be able to abide by level crossing controls, road users must first detect the presence of a crossing or a train. There are numerous reasons as to why road users may fail to do this.

First, detecting crossings and trains depends greatly on the visual contrast of these objects against their broader environment. There are several instances in which this contrast may be reduced. For example, it becomes much harder to detect crossings and trains in weather conditions that reduce visibility, such as snow, fog or rain. Contrast is also heavily reduced at night-time. This is exacerbated when there is little or no retro-reflective material on crossings for road vehicle headlights to catch, or no lighting at rural crossings. Additionally, during the day, the sun may reflect off of the road surface or vehicle windshield and temporarily blind road users. Sun glare may also occur in low-sun conditions, such as just after dawn, and just before sunset (Caird et al. 2002; Gou, Bellavigna-Ladoux & Dumont-MacKay 2003). Under low contrast conditions, it becomes much harder to detect motion in depth (Gray & Regan 1996). This may explain why, among 24 driving simulator participants, safety margins for executing left turns in front of oncoming traffic (equivalent to right turns in Australia) were significantly smaller under glare conditions designed to emulate low sun (Gray & Regan 2007). As a result, significantly more simulator collisions occurred under the glare than the no-glare condition.

Second, the sight lines along the track or the road approach may be inadequate for road users to determine if a train is approaching at passive crossings. Sight distance must allow road users not only to detect a train, but also
to also be able to stop safely before the crossing, if necessary. Inadequate sight distances may be due to vegetation or buildings located alongside the track, curvature in the road or track, or the road and railway tracks intersecting at an acute angle (Caird et al. 2002; Gou, Bellavigna-Ladoux & Dumont-MacKay 2003).

Third, less than perpendicular road–rail intersections can be problematic, as road users must look over their shoulders and take their eyes off the road to determine if a train is approaching. This may be difficult for people with limited physical mobility or blind spots associated with vehicle design, and may detrimentally affect driving.

A focus group of regional Queensland train drivers felt that about 60% of near-miss incidents were due to poor visibility, with only 30–40% estimated to be due to road user error (Davey, Ibrahim & Wallace 2005). Additionally, the ATSB investigated 16 fatal level crossing collisions occurring between 2002 and 2008, which were further analysed by the Australasian Railway Association (2009). Of these fatal accidents, five (30%) occurred at crossings with sighting issues. Although this was a small sample, and these cases cannot be considered representative of all Australian level crossing accidents, they illustrate that sighting is an important issue.

4.2 Distraction and inattention

In a recent survey of 4402 Australian drivers from both metropolitan and rural areas of each state and territory, and who had reported crossing a railway level crossing (excluding as a passenger) in the last six months, 22% reported that they had not noticed a level crossing until they had driven through it (Roy Morgan Research 2008). Within this survey, driver inattentiveness and impatience were collectively rated as the factors most likely to increase risk at railway level crossings.

Active crossings are often a part of visually and mentally complex traffic systems. The level crossing itself may occur near road intersections with accompanying traffic control devices like traffic lights or give way signs, pedestrian traffic, shops and advertising billboards, among other stimuli. All of these aspects of the broader road environment must be simultaneously processed and negotiated by the road user. Such ‘external distractions’ may divert road users’ attention from level crossings (Caird et al. 2002; NTSB 1998b; Wigglesworth 2001; Yeh & Multer 2008). An FRA investigation, discussed by Raslear (1996), supports this possibility. Of the 56 US level crossings investigated that averaged more than one accident per year, 95% of these crossings had a large number of driveways and intersecting roadways, and 80% had ‘visual clutter’ on the approach.

Road users may also be presented with internal distractions, which include, but are not limited to, the use of media devices such as mobile phones, stereo systems and MP3 players, conversations with passengers or fellow pedestrians, attending to children, or distracting mental processes like daydreaming or worrying (Creaser et al. 2002; NTSB 1998b; Wigglesworth 1979; Yeh & Multer 2008).

Approaching trains may also function as distractions. First, pedestrians may be focused on catching a train that is approaching a train station, and in doing so, run into the path of a second approaching train (FRA 2008; Illinois Commerce Commission 2005; Spicer 2008). Second, motorists may similarly have their attention focused on a train that is either approaching, stopped at an adjacent station, or just passed, and presume that it is safe to cross, when in fact a second unseen train is approaching (Caird et al. 2002; Creaser et al. 2002; Wallace, McCusker & Hirsch 2008). At active crossings, drivers must violate activated warning signals to do this, perhaps assuming that the signals are still activated only for the first train.

For these reasons, road users may be overloaded with other stimuli, their situational awareness may be reduced, and their attention resources may be diverted from the level crossing. In these circumstances, it is quite possible that stimuli such as trains or flashing lights may be fully visible, but unnoticed. This phenomenon is termed ‘attentional blindness’, or ‘looked but failed to see’. Research has demonstrated that many people (in one instance, a quarter of participants) can fail to detect the presentation of an object while engaged in an absorbing task, even when they are looking directly at it (Mack & Rock 1998).
In contrast, passive crossings are often located on isolated rural roads with low train and road traffic. In these instances, drivers may be in low states of arousal and inattentive to the broader environment, and may fail to notice either crossings or approaching trains (Edquist et al. 2009).

4.3 Lack of knowledge

4.3.1 Not knowing rules for level crossings
There is evidence that many drivers do not understand the road rules that apply to level crossings, and particularly those that apply to passive crossings.

First, drivers may not fully understand that due to their large weight and high speed, trains have an extremely long stopping distance, and thus are unable to stop or slow down to avoid collisions. In a study of 176 Tennessee drivers, many felt that train drivers held partial responsibility for avoiding level crossing collisions by stopping or slowing the train (Richards & Heathington 1988). This was a commonly discussed point among focus groups of Queensland train drivers, with one driver reporting ‘people say that to me, why don’t we stop for them?’ (Wallace 2008, p. 124).

Second, drivers may not appear to fully understand the correct action that is required of them at level crossings, as indicated by warning devices. Less than 1 in 3 Australian licensed drivers participating in a driving simulator study reported that the correct thing to do at level crossings controlled by stop signs was to completely stop and look before proceeding (Rudin-Brown et al. 2010). The majority of participants reported only needing to slow down and look. Several US studies have also shown that a significant minority of drivers do not fully understand level crossing controls. For example, 13% of surveyed road users wrongly reported that the crossbuck was an advance warning sign (Richards & Heathington 1988). Furthermore, other road users did not know the meaning of the crossbuck, other than indicating the presence of a level crossing (Lerner et al. 2002).

Finally, many road users may not be aware that their behaviour is a violation of level crossing rules, is illegal and can incur penalties. In the National Rail Level Crossing Road User Behavioural Study, approximately one-fifth of the licensed driver respondents were not aware of any type of penalties for violating level crossing rules (Roy Morgan Research 2008). Furthermore, two-thirds of respondents felt that they were less likely to be penalised for violating level crossing rules than for speeding (Roy Morgan Research 2008). Additionally, there was generally a poor level of knowledge about penalties and fines for level crossing violations among many of the Queensland vehicle drivers participating in focus groups (Wallace 2008). Finally, almost one-half of pedestrians surveyed at seven Melbourne crossings thought it was not illegal to cross when a train was approaching, or did not know it was illegal (Lloyd’s Register Rail 2007).

4.3.2 Failing to distinguish passive crossings
It is commonly reported that many drivers do not look for trains at passive crossings, despite the fact that there are no warnings to inform them of an approaching train. Only one-third of the drivers observed at a Victorian passive level crossing looked for the presence of a train (Wigglesworth 2001).

It has been hypothesised that drivers engage in this risky behaviour because they expect to be informed of an approaching train. Wigglesworth (2001) tested this supposition by observing 92 drivers’ scanning behaviour at one passive and one active Victorian level crossing. Observers were parked in an unmarked car to the side of the crossing. As 57% of the drivers showed identical head movements at both active and passive level crossings, this suggested that many drivers do not distinguish between the two types of crossings. Even when this study was replicated with a larger sample, and with obvious police presence at the crossings to prompt drivers to behave in a manner they thought was legal, a smaller though sizeable number (44%) of people demonstrated identical head movements at the two types of crossings (Wigglesworth 2001).

Two Australian studies have provided evidence to support this notion. First, in a Victorian rail simulator study, most participants thought that all, or almost all, Victorian level crossings were equipped with active controls. In
actuality, less than 50% of Victorian crossings were actively controlled (Misopoulos et al. 2002, as cited in Wallace, McCusker & Hirsch 2008). Second, many of the urban Queensland drivers participating in focus groups reported being unfamiliar with passive level crossings, as they mostly drove in metropolitan areas. Furthermore, several of the drivers were unaware that crossings without active controls even existed (Davey, Ibrahim & Wallace 2006; Wallace 2008). US studies have also demonstrated that a significant minority of road users (approximately 15–25%) believe that all crossings are equipped with active controls, or that passive crossings are not located on public roads (Fambro et al. 1995; Lerner et al. 2002; Sanders 1976). Thus, some road users may expect to be informed of an approaching train at all crossings, and may wrongly assume that it is safe to cross when there are no lights flashing, even at crossings that are not equipped with lights (Staplin et al. 2001; Wigglesworth 2008b).

4.4 Inaccurate risk perception

Some people simply do not understand the risks posed by level crossings. A Canadian survey of 1209 drivers revealed that level crossings were not considered to pose serious road safety issues, and were rated as less serious than numerous general driving issues, including vehicle defects and distracted drivers (Beirness, Desmond & Simpson 2003). Only 17% of the respondents considered level crossing safety to be a serious problem. Additionally, a telephone survey of 500 Minnesotan drivers revealed that, overall, respondents did not consider traversing level crossings to be dangerous (Dolan 1996). This misperception of risk may arise from a lack of knowledge (as discussed above), but also familiarity with crossings and low expectations of encountering a train, misjudging train speed and distance, and overconfidence in one’s ability to ‘beat the train’, among other factors.

4.4.1 Familiarity and expectation

It is a consistent finding that familiarity with level crossings is associated with violations and accidents. An analysis of coroner records for motor vehicle fatalities at Victorian level crossings found that 86% of the fatalities occurred within one mile of their home address (Wigglesworth 2001). More recently, 57% of vehicle–train collisions in NSW during 2000–2010 occurred within 10 km of the drivers’ home postcodes (ITSR 2011a). These are imperfect measures of familiarity, as drivers may not have frequently used that crossing, despite living locally. However, it is difficult to operationalise familiarity when using fatality data, as the drivers could not be questioned regarding how often they actually used the crossing.

Similar findings have been reported in US studies (Abraham, Datta & Datta 1998; NTSB 1998b). For example, among drivers observed to commit violations at 37 level crossings in Michigan, 68% reported that they used the specific crossing at least four times a week, with another 19% using the crossing two to four times a week (Abraham, Datta & Datta 1998).

Drivers who use level crossings regularly come to develop expectations about train frequency, and the likelihood of encountering a train. In cases when drivers do not encounter a train on repeated occasions, they may come to develop low expectations about trains crossing. This can lead to complacency and reduced scanning behaviour (Wigglesworth 1978). Several reports have shown that drivers generally have low expectations about encountering trains at level crossings (Dolan 1996). Specifically, 75% of 500 Minnesotan drivers surveyed reported ‘rarely’ expecting to see a train at a crossing, even though 66% of the sample reported encountering level crossings at least five times a week (Dolan 1996).

Low expectancy is more likely to occur for drivers who frequent passive crossings, given that these crossings have low daily train volumes (Cairney 2003; Wigglesworth 1978). Drivers may even come to know train timetables for crossings with low train volumes, and may only visually search for a train at times consistent with their mental timetable (a factor which was attributed to one of the fatalities analysed in Wigglesworth, 1979). Thus, greater familiarity with level crossings can reduce the perception of risk, and encourage drivers to engage in greater risk-taking behaviour.
Motorists’ expectations of encountering trains at level crossings may also be generalised from their experiences at other crossings. For example, drivers who rarely encounter trains at crossings with low train volumes may then expect few trains at other level crossings, regardless of their actual train volume (Fambro et al. 1995). Additionally, drivers who are accustomed to being informed of approaching trains at active crossings may then expect to be similarly informed at passive crossings, and may consequently not exercise appropriate scanning behaviour (Pickett & Grayson 1996). Finally, at both the NSW and Victorian parliamentary inquiries into level crossing safety, it was argued that remaining warning signs at crossings on disused railway lines would promote inaccurate generalisation; specifically, the rural road users who regularly passed these crossings knew they were disused, and may come to ignore warning signs at other crossings, and not scan for trains (Parliament of NSW 2009; Wigglesworth 2008b). Although some Australian jurisdictions have budgeted to ‘bag’ these disused signs, this is often a slow and gradual process.

Among samples of younger, older and heavy vehicle drivers, self-reported level crossing familiarity was significantly and positively correlated with the intention to drive unsafely at level crossings in the future (Wallace 2008).

4.4.2 Misjudgment of train speed and distance

It is incredibly difficult to judge the speed and distance of approaching trains, and consequently, the time it takes for trains to arrive at level crossings. Road users tend to underestimate train speed, which can be explained by two main perceptual issues: the Leibowitz effect and the looming effect.

The Leibowitz effect describes the phenomenon where larger objects appear to be moving slower than smaller objects that are actually travelling at the same speed (Leibowitz 1985). Leibowitz initially observed this among different-sized airplanes, and consequently hypothesised that trains are perceived to move more slowly than smaller vehicles such as cars and vans.

Road users are more accustomed to negotiating road rather than rail traffic, including judging safe gaps in which to cross. Thus, when faced with an approaching train, it is possible that many road users base their judgment of train arrival time on their previous experience with cars, which appear to be travelling faster than trains, but are in most cases travelling much slower.

Three computer simulation studies using small samples have provided support for Leibowitz’s hypothesis (Barton & Cohn 2007; Clark 2010; Cohn & Nguyen 2003). First, six participants estimated that larger 2D squares started their approach significantly later than smaller squares (Cohn & Nguyen 2003). Second, five males judged smaller 3D spheres as faster moving than larger spheres, even when the larger spheres were travelling 20 miles/hour faster (Barton & Cohn 2007).

Third, the only study to use images of trains and cars within simulations was conducted quite recently in New Zealand (Clark 2010). In this study, the 10 participants tended to underestimate the speed of the computer-simulated trains, relative to the cars. The most pronounced effect occurred at a starting distance of 120 metres away, where the train and the car were perceived to be travelling at the same speed, when in fact the train was travelling 20 kilometres/hour faster.

Much more research is needed on this phenomenon, using larger and more varied samples, and using (real or computer-simulated) trains as stimuli. These findings should also be tested in the Australian context. Road–rail safety expert Eric Wigglesworth (2007; 2008a) considered further research into this phenomenon to be essential.

The main perceptual cue available to road users regarding train speed is the rate of expansion (ROE) of the train’s apparent size in their visual field. However, the looming effect describes how this ROE is not constant or linear, but instead hyperbolic, with ROE doubling every time distance is halved. This means that initially, at some distance away from the crossing, the train’s image hardly increases despite travelling great distances. In fact, virtually no change in apparent size occurs until the train is quite close by (Leibowitz 1985; NTSB 1998b). An
excellent illustration of this effect was presented by the NTSB, in a computer simulation study of a train approaching at 40 miles/hour, which started its approach from 1000 feet away (NTSB 1998a). The train only appears to be approaching at speed (determined from its more rapid rate of expansion) when it is approximately nine seconds away, at a time when it is may be too late for road users to either stop at the crossing, or to finish their passage over the crossing if they have already begun to cross.

Road users must often decide whether it is safe to traverse level crossings when trains are still some distance away. At this point, they have no accurate cues as to how fast the train is moving, and so are likely to underestimate train speed. It is likely that road users have already made their decision on whether to cross by the time that train speed can be realistically determined. One observational study of driver behaviour at two US active crossings found a positive association between train distance and the likelihood a driver would cross in front of the train, but no association between train speed and crossing likelihood (Meeker, Fox & Weber 1997). This finding suggests that drivers had trouble determining train speed, and relied on distance to determine whether it was safe to cross. However, these analyses were quite basic, and as a result it could not be determined whether a speed–crossing association emerged when controlling for distance, or as a function of distance.

Combined, these two perceptual effects suggest that road users are likely to underestimate train speeds. In fact, many of the Queensland train drivers surveyed within focus groups discussed how, in their opinion, motorists seemed unable to judge the speed and distance of approaching trains (Wallace 2008). These perceptual judgments are likely to be even harder at rural crossings and at night, given that objects in the landscape (e.g. trees, buildings) against which to judge the rate at which the train passes may not be present, or are difficult to detect under low lighting (NTSB 1998b; Trevorrow 2009; Yeh & Multer 2008).

4.5 Deliberate risk-taking behaviour

Road users who engage in deliberate risk-taking behaviour can be considered as falling into two broad categories — those that experience frustration and impatience when delayed by approaching trains, and those with risk-seeking personalities.

Several theories of behaviour at level crossings propose that the decision to violate level crossing rules is the result of a cost–benefit analysis, where the perceived benefits of committing a violation outweigh its potential costs (Fambro et al. 1995; Yeh & Multer 2008). The main benefit resulting from violating level crossing controls is reducing the potential for delays. Many road users become frustrated at the time delays presented by waiting for an approaching train. In an observational study of five Ontario crossings, higher rates of violations at level crossings were observed at crossings with longer warning times (Wilde, Hay & Brites 1987). However, this association was purely correlational, and drivers were not asked why they violated the crossing controls. In contrast, many of the 276 motorists observed to violate the controls at 37 Michigan crossings reported doing so because ‘train was stopped for an unreasonable amount of time’ (Abraham, Datta & Datta 1998). Additionally, US drivers surveyed within focus groups considered waiting for trains to pass through level crossings as an unwelcome delay, and reported that they would cross in front of approaching trains if they thought there was enough time for them to safely do so (Global Exchange 1994, as cited in Yeh & Multer, 2008).

Violations tend to increase significantly when the time between warning activation and train arrival exceeds 20–30 seconds (Coleman & Venkataraman 2001; Richards & Heathington 1990). One US study showed that there was a 10–15% increase in violations at gated crossings in Illinois for every 10 second delay beyond the initial 20 second period when gates were still descending (Coleman & Venkataraman 2001). Among a survey of 891 US drivers, greater experience of long wait times at crossings was positively associated with more self-reported ‘beat the train’ behaviours (Witte & Donohue 2000).

Impatience with delays at level crossings may arise when road users are in a hurry to reach their destination. For instance, greater rates of violations have been reported during the morning rush hour, when people are travelling
to work or school (Caird et al. 2002). As one Queensland train driver reported, ‘you can see the look on the motorist’s face ... they’re not real happy, especially when they are going to work’ (Wallace 2008, p. 123).

Road users may also deliberately violate crossing controls when they consider them to be unreliable. This may occur when crossing signals are activated for excessively long periods, or when no train is present (i.e. false alarms). There is evidence from driving simulation studies that as the reliability of active signals decreases, driver compliance decreases (Gil, Multer & Yeh 2007; Raslear & Multer 2009). The drivers were not queried regarding their actions, but the researchers supposed that they perceived little risk given the signal unreliability. The reliability of Australian active signals is unknown. However, in his submission to the Victorian Parliament’s 2008 inquiry into safety at level crossings, Charles Uber (2007) noted the near-daily incidence of lowered boom gates without the presence of a train at Melbourne level crossings. Thus, road users that experience such ‘false alarms’ may choose to violate these particular crossings, and by a process of generalisation, other crossings with active controls, regardless of their reliability.

In contrast, road users may perceive there are low costs of violating level crossing controls. For example, road users may perceive there is a low likelihood of a train arriving, or of being penalised. Additionally, road users may feel confident in being able to beat the train to the crossing (Fambro et al. 1995; Wallace, McCusker & Hirsch 2008; Yeh & Multer 2008).

Some people who wilfully violate level crossings may have risk-taking personalities, and engage in various other risky behaviours. Approximately 20% of 891 US drivers surveyed reported intentionally engaging in high-risk behaviours at level crossings, including driving around gates or through lights with a train in sight (Witte & Donohue 2000). Furthermore, 10% of these ‘risk-takers’ said they found it exciting to try and beat the train. Compared with those who exercised caution at crossings, the ‘risk-takers’ were significantly more likely to be male, and to engage in other high-risk behaviours, such as drinking alcohol, smoking, not wearing a seatbelt, getting into physical fights, and risky driving in general. They also reported more sensation-seeking tendencies such as disinhibition, susceptibility to boredom, and thrill-, adventure- and experience-seeking (e.g. using marijuana, and trying parachute jumping).
5. **Key high-risk users**

Both Australian and overseas statistics identify heavy vehicle drivers, older drivers (60+ years) and pedestrians as high-risk users of level crossings. Older drivers are over-represented in level crossing occurrence statistics. Additionally, the number of heavy vehicle occurrences has dramatically increased over the last 30 years, and these crashes have the greatest likelihood of resulting in train derailment and multiple fatalities. Furthermore, pedestrian level crossing accidents are highly likely to result in fatalities, even though the proportion of accidents is small. Thus from a cost–benefit analysis perspective, pedestrians are an important intervention target (Bureau of Transport and Regional Economics 2002).

In two Australian reports examining road user age (ATSB 2002; 2004a), younger drivers (i.e. under 25 years) were not disproportionately represented in level crossing collisions or fatalities. However, young adults (aged 20–24 years) have the highest serious injury rates at Australian vehicle and pedestrian level crossings combined (Henley & Harrison 2009). Younger drivers are disproportionately represented in Australian road crashes more generally, and are identified as high-risk users of US level crossings (ATSB 2004d; FRA 2006; Fildes et al. 2001; OECD 2006; Raub 2009). Additionally, Australian focus group and survey research has shown that younger drivers regularly engage in high-risk behaviours at level crossings (Davey et al. 2008b; Roy Morgan Research 2008; Wallace 2008). Finally, this group is often targeted within Australian level crossing safety campaigns. For these reasons, it is important to investigate this particular road user group further.

A recent open-ended survey of 24 Australian road and rail industry experts also identified younger drivers, older drivers, and heavy vehicle drivers as key high-risk groups at railway level crossings (Davey, Ibrahim & Wallace 2006; Wallace 2008).

Although there is evidence to suggest that these four road user groups are at increased risk at railway level crossings, there is little evidence available to suggest why this might be the case. Very little research has examined the behaviour of these high-risk groups at level crossings. Much of the research that is discussed in the following sections has been drawn from the broader road safety literature. This is an important omission, as without studying people’s behaviour at railway level crossings specifically, it cannot confidently be assumed that the human factors that relate to the behaviour of these high-risk groups apply to the same degree at level crossings. Nonetheless, this research provides an indication of what factors are likely to be relevant to level crossing safety.

### 5.1 Heavy vehicle drivers

As discussed in section 2.2.2., level crossing collisions between trains and heavy vehicles are often catastrophic in terms of their associated fatalities, serious injuries and infrastructure damage. Additionally, the number of these collisions has been increasing in recent years.

This trend is likely to become more pronounced for two main reasons. First, road freight traffic is forecast to double between 2008 and 2030 (Bureau of Infrastructure, Transport and Regional Economics 2010). Second, trucks are becoming longer, heavier and slower. For instance, average vehicle loads have increased by 35% between 1991 and 2005 (Bureau of Infrastructure, Transport and Regional Economics 2009a). In particular, trucks hauling three trailers (B-triples) can be over 50 metres long and 90 tonnes gross weight (Han et al. 2010; Sochon 2008). These trucks provide cheaper and more efficient freight transport than the more prevalent B-doubles. With the Australian Transport Council endorsing a national B-triple network in 2007, the number of B-triples on Australian roads will continue to grow. However, as will be discussed in the sections following, much of the existing level crossing infrastructure is inadequate for such large and heavy vehicles to traverse safely.

These concerns regarding heavy vehicles are echoed within rail and road transport industry and research. Many of the submissions to the Victorian inquiry discussed the particular risks of heavy vehicles (e.g. ARRB Group Ltd 2007; Australian Rail Track Commission 2007; ATSB 2007a; Department of Infrastructure/VicRoads 2007;...
Wigglesworth 2007). Additionally, the majority of the 24 industry experts who responded to an open-ended survey of driver behaviour at level crossings identified heavy vehicle drivers as high-risk users of level crossings (Wallace 2008). Finally, focus groups of Queensland train drivers consistently reported heavy vehicle drivers to be the main high-risk users at level crossings, with violations occurring frequently (Davey et al. 2008a; Wallace 2008).

To investigate risky driver behaviours and safety issues at railway level crossings, Queensland University of Technology (QUT) researchers conducted focus groups with train drivers and heavy vehicle drivers (Davey et al. 2008a; Wallace 2008). Both the train and heavy vehicle drivers discussed similar safety concerns with heavy vehicles at level crossings, which were broadly grouped into two categories:

- safety issues relating to heavy vehicle size and speed, slow acceleration times and long sight distances needed to clear crossings safely, and trailer overhang into the crossing
- wilful risk-taking driver behaviour, such as driving through flashing lights or around boom gates, and trying to ‘beat the train’ over the crossing.

The ATSB (2008b) identified similar factors as precursors to 12 level crossing accidents investigated between 2006 and 2007, nine of which involved heavy vehicles. These issues will now be discussed in turn.

### 5.1.1 Safety issues relating to heavy vehicle size and weight

Due to their size and weight, heavy vehicles can have trouble safely negotiating level crossings. At passive crossings, the responsibility is on the heavy vehicle driver to detect an approaching train, and make the decision to stop or proceed safely. Due to their size and mass, heavy vehicles have a long deceleration time, and so drivers must make this decision many metres in advance. An Austroads simulation and field study provides an example for a pocket road train (a moderately-sized heavy vehicle) travelling at a speed of 80 kilometres/hour on a -4% grade wet sealed road. In such a situation, this vehicle would need a sight distance of 238 metres to be able to notice the train, make the decision to stop, and safely stop at the crossing (Trevorrow 2009). For larger vehicles, including B-triples and AB-quads, which mostly drive on rural roads equipped with passive level crossings, when travelling at higher speeds, this distance may be closer to 400 metres (Trevorrow 2009).

Even if heavy vehicle drivers choose to stop at crossings to look for trains, their safety may still be compromised. This relates to the fact that heavy vehicles also take a long time to accelerate from the stopped position, traverse the tracks and safely clear level crossings. Simulation trials have estimated that B-double trucks take approximately 20 seconds to do this (ARRB Group Ltd 2007; Cairney 2003; Wigglesworth 2007). In contrast, standard freight train speeds are 115 kilometres/hour, or 32 metres/second, and fast trains can reach speeds of 126 kilometres/hour, or 35 metres/second. Therefore, in 20 seconds, trains may have travelled up to 700 metres (i.e. 20 x 35). This means that heavy vehicle drivers need a sight distance of approximately 700 metres to cross safely before an approaching train that could not be seen by the driver while stopped could reach the crossing (ARRB Group Ltd 2007; Cairney 2003; Wigglesworth 2007). The minimum sight distance is even larger again for bigger vehicle such as B-triples and AB-quads, which spend a significant proportion of their time on rural roads with passive crossings. If there is not sufficient sight distance, a previously unseen train may still reach the crossing before the truck has safely crossed. There would be few passive crossings in Australia that have unobstructed sight distances of at least 700 metres in both directions. Furthermore, it may not actually be feasible to increase sight distances to this degree at many passive crossings, but particularly with crossings used by high-speed trains (Trevorrow 2009). Thus, at crossings without active controls to indicate the presence of a train, there may be no way for heavy vehicle drivers to cross safely.

Even when sight distances are adequate, it can be extremely difficult to estimate a train’s speed at distances of around 700 metres (Trevorrow 2009). This relates to the ‘looming effect’ previously discussed in section 4.4.2, where the size of the train’s image on a driver’s retina only increases appreciably in size when it is very close by. Thus, either when approaching or waiting at the crossing, heavy vehicle drivers have no information as to how fast the train is travelling, and are not able to make an informed decision as to whether it is safe to cross.

The Australian Standards provide guidelines for sight distance requirements of heavy vehicles at passive level crossings. These sight distances are based on a ‘design vehicle’ — either a laden B-double, laden semi-trailer or...
laden road train — according to the route designation by the relevant road authority (Standards Australia 2007a). However, the longer and heavier B-triples, which are new to Australian roads, may take up to 71 seconds to clear a level crossing from a stopped position (Sochon 2008). As a result, many Australian passive crossings have not been assessed to determine if they provide adequate sight distances for B-triples (Sochon 2008).

A recent Austroads project tested the acceleration and deceleration capabilities of a number of characteristic heavy vehicles, including the B-triple (Trevorrow 2009). This involved both simulations and field tests. Results showed that generally, the sight distances allowed by the current Australian Standards were adequate under ideal conditions. However, the sight distances required by very long and heavy vehicle combinations (e.g. B-triples), when attempting to clear a crossing from the stopped position on uphill grades, were up to 15 seconds longer than that allowed by the Australian Standards. Additionally, the deceleration times and distances provided in the Standards were not sufficient for wet or gravel surfaces (Trevorrow 2009). From these findings, a review of the sight distance requirements specified within the current Australian Standards was recommended (Han et al. 2010).

The sheer length of heavy vehicles also presents safety issues at level crossings. As an example, B-triples can measure over 50 metres. If intersections located downstream and in the vicinity of level crossings are congested, truck trailers may overhang into crossings (Standards Australia 2007a). Rear trailers have even become stuck under descending boom gates (Davey, Ibrahim & Wallace 2005; Wallace 2008). This ‘short-stacking’ across tracks is more likely in areas with high traffic volume and congestion, and more complex road design. For this reason, short-stacking is particularly an issue at active crossings (Wallace 2008). Train drivers in focus groups felt that short-stacking seen among heavy vehicle drivers was unintentional, and that many drivers were simply not aware of their vehicle’s dimensions, and underestimated the space needed to safely clear a crossing (Davey et al. 2008a; Wallace 2008). A study of all vehicle–train collisions occurring in Texas during the period 1992–1994 (totalling 1328 collisions) provides support for this notion (Fambro et al. 1995). Specifically, 40% of collisions where intersection proximity was cited as the primary contributing factor involved heavy trucks or vehicles towing trailers, even though these vehicles were only involved in 11% of collisions overall.

Limited visibility has been implicated in several recent heavy vehicle–train level crossing collisions at passive crossings (ATSB 2004c; 2007b; 2007c; 2008a; 2008c). Limited visibility was a result of vegetation growing along the line, the acute angle of the road approach, sun glare, and heavy fog (in which the heavy vehicle driver was not driving to the conditions). Additionally, the design of heavy vehicle cabs can limit drivers’ field of view to just over 90 degrees from directly ahead. This limited visibility at greater viewing angles may mean drivers can only see a short stretch of train track through their side windows. This was considered as a precursor in at least two fatal level crossing collisions involving heavy vehicles (ATSB 2004c; 2007c).

Combined, these findings suggest that many Australian level crossings are not appropriately designed for use by heavy vehicles. This point is echoed by heavy vehicle drivers themselves, who commented that level crossings are not designed for their vehicles to traverse safely (Davey et al. 2008a; Wallace 2008). Design issues that were considered particularly risky included adjacent intersections and traffic congestion, limited visibility, and inadequate warning of approaching crossings. The drivers considered such design flaws to be the primary cause of their risky behaviour at level crossings (Davey et al. 2008a; Wallace 2008).

It must be emphasised that many such problematic level crossings were constructed long before the advent of modern-day heavy vehicles on Australian roads. The size and haulage of heavy vehicles has increased since these crossings were built. Thus, this problem is less to do with crossings not being designed for heavy vehicles, and more to do with crossings not being upgraded to accommodate heavy vehicles, despite heavy vehicles being allowed on these roads (Wigglesworth 2008a).

It may be partly because of the time needed to clear crossings from the stopped position (as well as causing extra wear on heavy vehicle transmissions by accelerating from rest) that many heavy vehicle drivers will instead approach and traverse crossings at a slow roll (ATSB 2007d; 2008c; 2008d; Yeh & Multer 2008). Such behaviour
represents a violation at passive crossings equipped with stop signs. Additionally, this reduces the time available for the driver to scan the tracks and determine if it is safe to proceed. However, for crossings with extremely limited sight distances, this may actually be a safer alternative (Trevorrow 2009; Wigglesworth 2008b).

5.1.2 Intentional risk-taking behaviour

The Queensland heavy vehicle drivers participating in focus groups cited overconfidence and monotony leading to complacency and lapses in concentration, fatigue and employer time pressures as contributors to their risky behaviour (Davey et al. 2008a; Wallace 2008).

Given their familiarity with level crossings and driving more generally, heavy vehicle drivers may underestimate the risk at level crossings, and may not see their behaviour as dangerous. The Queensland heavy vehicle drivers acknowledged that due to their driving experience, they felt confident in their ability to be able to identify the ‘dangerous’ crossings (Davey et al. 2006; Wallace 2008). As a related point, heavy vehicle drivers are likely to have low expectations of encountering trains at crossings, given their daily routes would take them across many passive crossings located in rural areas with low daily train volumes (Cairney et al. 2002). As discussed in section 4.3.1, repeated exposure to crossings where trains are not encountered is likely to lead to reduced scanning behaviour and increased violations. This has been considered as a possible precursor to several recent heavy vehicle collisions (ATSB 2007c; 2007d; 2008a; 2008c; 2008d; Department of Transport and Main Roads 2009). For example, expectancy was proposed as one of two possible precursors to a level crossing collision between a B-double truck and the Cairns Tilt Train at Rungoo, Queensland, which killed the two train drivers (Department of Transport and Main Roads 2009). The flashing lights mounted at the crossing were working properly at the time of the collision; however, the B-double driver reported that, although he saw the light structure, he did not see them as activated and flashing prior to the collision. The truck driver had driven this route many times before, including three return trips in the previous week. He reported that he had never seen a train on the Rungoo crossing, and had rarely encountered trains at other level crossings he used regularly. Thus, he may have had a low expectation of seeing a train, and lights being activated. This may have led the driver to not look properly for trains or flashing lights, or look but not see the activated lights, as they were not expected to be flashing (Department of Transport and Main Roads 2009).

Level crossing familiarity was also considered to be one of the potential precursors in the heavy vehicle–train collision at Ban Ban Springs, NT (ATSB 2008d). The driver was highly familiar with this crossing, having traversed it 800 times in the past month, and only seeing four freight trains. Combined with the routine (and perhaps monotonous) driving task, the driver involved may have had a low expectancy of seeing a train. This low expectancy may at least partially explain why the driver did not stop at the crossing, or even look for an approaching train.

In addition, heavy vehicle drivers may have low expectations of the reliability of active warning signals. At the Rungoo collision, the B-double driver had encountered a level crossing only minutes before the collision site where flashing lights were activated despite no train being present. Due to this recent encounter, the B-double driver may have actually seen the lights flashing at the Rungoo crossing, but did not perceive them to be reliable (Department of Transport and Main Roads 2009).

Familiarity with driving routes may also lead to inaccurate generalisation. Wigglesworth (2008b) considered this to be a potential precursor to the fatal Lismore heavy vehicle–train accident. Specifically, prior to arriving at the fatal crossing site, the truck driver had travelled a route where he passed through four level crossings that were all equipped with active controls. By the time the driver reached the Lismore crossing, which was passively controlled, he may have become accustomed to not having to look for trains, and expected to be actively warned of approaching trains. Unfortunately this hypothesis could not be verified, as the heavy vehicle driver was killed.

Both expectancy and distraction may contribute to the phenomenon of ‘looked but failed to see’, or ‘attentional blindness’, which has been implicated in at least two recent heavy vehicle level crossing accidents (ATSB 2007c; 2007d). In one instance, the heavy vehicle driver did not notice the approaching train, even though he claimed to...
have looked along the tracks, which may have resulted from his very low expectancy of actually seeing a train approaching. In the other case, the heavy vehicle driver’s gaze was directed towards the crossing, and the approaching train would have likely registered in his peripheral visual field. However, as his attention was captured by the merging traffic at the adjacent road intersection, he may have failed to process the competing information of the approaching train.

Second, wilful risk-taking behaviour has been attributed to frustration at having to wait for extended periods of time, and the desire to avoid lengthy delays (Davey et al. 2008a). Such frustration may in part result from the time pressures imposed on drivers by their road transport employers (Davey et al. 2008a). This notion was supported by train drivers, who reported that heavy vehicle violations were most commonly observed among drivers from two particular trucking companies (Davey et al. 2008a).

5.1.3 Fatigue
The limited research on the contribution of fatigue to level crossing accidents may at least partially explain why it is not considered to be a major contributor to level crossing accidents in general. It is quite possible that fatigue plays a larger influence on level crossing user behaviour than currently thought, but especially on the behaviour of heavy vehicle drivers at level crossings. This is because driver fatigue is a well-recognised problem in the road transport industry.

In the context of human performance, fatigue is a physical and psychological condition that is primarily caused by prolonged wakefulness, or insufficient or disturbed sleep (House of Representatives Standing Committee on Communication, Transport and the Arts 2000). Fatigue can result from factors such as time on task, time since awake, sleep debt and disruptions to circadian rhythms (i.e. the internal 24-hour ‘body clock’ which programs us to sleep at night and be awake during the day) (House of Representatives Standing Committee on Communication, Transport and the Arts 2000).

Considering this, the work of heavy vehicle drivers makes them vulnerable to the effects of fatigue. Specifically, heavy vehicle drivers work long hours, possibly while sleep-deprived. In a survey of 638 Australian truck drivers in states that were not subject to driving hours regulations, 38% reported exceeding 14 hours of driving in a 24-hour period. Additionally, 20% of drivers reported getting less than six hours sleep prior to their last journey (Arnold et al. 1997). Heavy vehicle drivers also engage in monotonous driving tasks on long stretches of lonely rural roads, and drive at times when their circadian rhythms are not at high alertness (such as between midnight and 6 am). Familiarity with the driving task may also make these drivers more likely to succumb to fatigue (Arnold et al. 1997; House of Representatives Standing Committee on Communication, Transport and the Arts 2000; Swann 2000). All of these factors may be exacerbated by workplace practices such as poor rostering and scheduling, and time pressures (House of Representatives Standing Committee on Communication, Transport and the Arts 2000).

Surveys of Australian heavy vehicle drivers have documented the high levels of fatigue in this population. In a large survey of over 3500 heavy vehicle drivers, 16% reported symptoms of excessive daytime sleepiness, and 33% suffered from medically detectable fatigue symptoms (Swann 2000). Among 638 heavy vehicle drivers, 14% reported nodding off at least occasionally while driving (Arnold et al. 1997).

Fatigue has a number of performance consequences that are relevant to driving behaviour at level crossings. Fatigue can result in reduced vigilance, awareness and motivational drive, slower reaction times, memory lapses, inattention, complacency, lack of judgment, and falling asleep (Dawson & Reid 1997; House of Representatives Standing Committee on Communication, Transport and the Arts 2000). Moderate levels of fatigue (17 hours of sustained wakefulness) produced performance decrements on a tracking task equivalent to the impairment associated with a 0.05% blood alcohol concentration (Dawson & Reid 1997). Thus, if heavy vehicle drivers are suffering one or more effects of fatigue, they may be less likely to look for a train, detect a train if they do look, or take timely action to avoid a collision, even if they do see a train approaching (Yeh & Multer 2008).
Importantly, people generally underestimate their level of fatigue, and are not aware of how it may be affecting their performance. A study of 15 truck drivers tested across a 24-hour period showed that the drivers chose to continue driving during 75% of driving simulator sessions where they were having 50–100 seconds of ‘microsleeps’ (i.e. short ‘sleep attacks’) each hour (Howard & Pierce 2002, cited in Swann 2002).

It is possible that the heavy vehicle drivers involved in several recent level crossing collisions may have been experiencing a degree of fatigue that could have affected their driving performance (ATSB 2007b; 2008c; Department of Transport and Main Roads 2009). For example, although the driver involved in the Rungoo collision reported not to have felt fatigued, he had worked more than the regulated 12 hours on the day prior to the collision, and obtained a broken sleep in his non-air-conditioned cab the night prior (Department of Transport and Main Roads 2009). The driver involved in the Lismore collision was not in breach of work hours regulations, but had worked long hours in the days before the accident, often with early-morning starts (ATSB 2007b).

Additionally, many of the Queensland heavy vehicle drivers surveyed within focus groups listed fatigue as a factor that would increase their likelihood of a level crossing collision (Wallace 2008).

5.2 Younger drivers (under 25 years)

In the recent National Rail Level Crossing Road User Behavioural Study, which surveyed 4402 qualified drivers, 15–25-year-old drivers were considered to be the most at-risk group at railway level crossings (Roy Morgan Research 2008). This young driver group also agreed with their high-risk status (Roy Morgan Research 2008). Additionally, young drivers were considered to be a high-risk level crossing user group by focus groups of Queensland train drivers (Davey, Ibrahim & Wallace 2006; Davey et al. 2008b; Wallace 2008).

There are two possible reasons why younger drivers are at increased risk at railway level crossings. First, younger drivers are likely to have lower levels of driving skill, as a result of their limited driving experience. Second, the driving style of younger drivers is subject to distorted perceptions of risk and driving ability, and involves elevated levels of (intentional and unintentional) risk-taking behaviour (Caird et al. 2002; Deery 1999; Edquist et al. 2009; Wallace, McCusker & Hirsch 2008; Yeh & Multer 2008). These two factors place younger drivers at a higher risk of road crashes in general, but they may also apply to driving behaviour at level crossings more specifically.

The fact that there is little research on the behaviour of younger drivers at level crossings specifically is a major limitation of current research. As most of the current knowledge has to be inferred from the more general driving literature, these factors may not apply to the same degree at level crossings.

5.2.1 Inexperience

There is evidence that younger drivers have poor knowledge of the road rules at level crossings, as well as the existence of fines and penalties for violating crossing rules. Among 149 younger drivers completing a questionnaire, only 15% could correctly answer all five questions on level crossing rules. The young drivers had substantially worse knowledge on level crossing rules than did the two other high-risk user groups surveyed, being older drivers and heavy vehicle drivers (Wallace 2008). Level crossing knowledge was also poor among focus groups of regional and urban younger drivers. In particular, the urban young drivers only had good knowledge of active crossings equipped with boom gates. Their awareness of active crossings with lights only, and of passive crossings, was very limited, as they did most of their driving in urban areas. The urban drivers also had poor knowledge of the yellow ‘keep clear’ hatching painted across level crossings, with very few participants being able to explain its meaning. Many participants were also not aware that they could be fined for driving through flashing lights, or queuing across level crossings (Wallace 2008).

Younger drivers may also lack specific skills for driving more generally, which are typically acquired with greater driving experience. Although novice drivers learn vehicle-control skills quickly, it takes much longer to learn the more complex cognitive and perceptual processing skills that are essential for safe navigation of the broader driving environment (Deery 1999). Hazard perception (the ability to recognise and anticipate dangerous traffic situations) is one of the few aspects of driving skill that has shown significant associations with accident
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involvement (Horswill & McKenna 2004). Several studies have found that more inexperienced drivers perform worse in hazard perception tasks (e.g. Borowsky, Shinar & Oron-Gilad 2010; Deery 1999; Horswill & McKenna 2004). For example, compared with more experienced drivers, 29 novice drivers with less than six months experience missed significantly more hazards, and were significantly slower to respond to hazards presented in short video sequences. These effects remained even when controlling for both age and reaction time (Scialfa et al. 2011). Another study found that, although there was little effect of driving experience on the detection of actual hazards (e.g. a lead car braking suddenly), 21 young novice drivers (aged 17–18) were less likely to detect potential hazards (e.g. following too close to a lead car) (Borowsky, Shinar & Oron-Gilad 2010). This suggests that novice drivers may have more of a problem with reading the driving environment and anticipating potential hazards. As an example, when watching traffic merging at a T-intersection, compared with more experienced drivers, the younger drivers tended to look straight ahead, and not to the right, in the direction of the oncoming traffic.

By examining hazard detection abilities in more detail, it appears that young novice drivers are less efficient in searching for and processing the visual information needed to drive safely. There is evidence that novice drivers tend to focus on single dimensions of the driving environment, rather than taking a holistic perspective. They fixate on fewer objects and glance at them less frequently, and also check mirrors less frequently (Crundall & Underwood 1998; Deery 1999). In one study, 16 novice drivers (mean age = 17.9 years, mean experience = 0.2 years) varied the direction of their gaze less often than did more experienced drivers, and tended to focus on a small area directly in front of the simulated windscreen, either at the road or on a lead vehicle (Crundall & Underwood 1998). Additionally, compared with more experienced drivers, 24 novice drivers (aged 16–17 years) were less likely to fix their gaze on risk-relevant elements of a computer-simulated driving environment for all of the 16 risk scenarios presented (Pradhan et al. 2005).

These visual attention deficits are commonly cited as key contributing factors in the young driver road crash statistics, referred to as ‘looked but did not see’, ‘inattention’, or ‘inadequate surveillance’ (Braitman et al. 2008; Clarke, Ward & Truman 2005; Curry et al. 2011; Mayhew, Simpson & Pak 2003). For example, in 198 non-fatal crashes where a 16-year old driver was at fault, the most common contributing factor was search and detection errors (38%), such as distraction, inattention, or not looking thoroughly (Braitman et al. 2008).

Hazard detection and visual attention skills often improve with increasing age and experience. It is consistently found that the likelihood of being involved in a car crash declines significantly within the first year of driving. For example, in a sample of over 44,000 Canadian novice drivers, the crash risk of 16–19 year old drivers declined by just under 50% over the first seven months of licensing, and then decreased much more gradually through to two years post-licence (Mayhew, Simpson & Pak 2003). Older novice drivers (aged 20+ years) showed a similar, although slightly smaller, decrease, but at all times were at a lower risk than the 16–19-year-old drivers. Thus, both driving experience and age-related factors (e.g. impulsivity, sensation seeking) had independent effects on crash risk.

Given the consistency of these findings, it seems plausible that young novice drivers would be less efficient in their visual scanning and hazard detection abilities at railway level crossings. Drivers that have little experience with driving in general may have even less experience with level crossings, and especially passive crossings, if they live in urban areas.

5.2.2 Risk perception and risk-taking behaviours

Inexperience alone cannot completely explain why younger drivers have a higher risk of collisions at level crossings, and on the road more generally. Younger drivers are also more likely to engage in deliberate risk-taking driving behaviours. In focus groups of 53 regional and urban Queensland younger drivers (aged 17–28 years), many drivers self-reported engaging in various unsafe behaviours at level crossings, including trying to beat the train across the crossing, driving through activated flashing lights, not stopping at stop signs, crossing track despite poor visibility, and driving around boom gates (Wallace 2008). Compared with groups of older drivers and heavy vehicle drivers, these younger drivers self-reported the highest level of risk-taking behaviours at level crossings.
crossings (Wallace 2008). Additionally, focus groups of Queensland train drivers reported that young drivers engage in many risk-taking behaviours at level crossings, with the chief high-risk behaviour being ‘trying to beat the train across the level crossing’ (Wallace 2008). This behaviour was rated as an ‘important/very important’ safety issue for younger drivers by 93% of the train drivers (Wallace 2008). Younger drivers may engage in these deliberate risk-taking behaviours because they underestimate the risk posed by the level crossing itself, or overestimate their ability to successfully negotiate crossings when trains are approaching (Deery 1999).

In the younger driver focus groups, both regional and urban younger drivers felt that level crossings presented only low levels of risk (Davey et al. 2008b; Wallace 2008). These young drivers felt that the risky behaviours they engaged in at level crossings were less risky than speeding or drink-driving. Various unsafe behaviours at level crossings were considered to be ‘low-risk’, including traversing active crossings while boom gates were descending, and rolling through stop signs at passive crossings when no train was visible. Compared with the opinions of industry experts, the young drivers consistently underestimated the risk of these behaviours. Rating differences were especially pronounced for the subgroup of regional young drivers; in particular, these drivers reported risky behaviours at passive crossings, such as not looking or stopping, as low risk and acceptable.

Although most of the regional young drivers knew the rules associated with level crossings, they were more influenced by community norms of driving through passive crossings without stopping. All of the younger drivers, but particularly those from regional areas, cited frustration at having to wait for trains as a reason for engaging in unsafe crossing behaviour (Davey, Ibrahim & Wallace 2006; Wallace 2008). The regional drivers discussed freight trains with wagons as having extremely long wait times. Consequently, these young drivers reported trying to ‘beat the train’ to the crossing in a desire to avoid delays. Those who reported engaging in this risky behaviour also reported having done it many times before, and having never had a near-miss. Thus, it appeared that the lack of negative consequences experienced by these drivers acted as reinforcement for their repeated risky behaviour. The group of young drivers felt that they were able to safely estimate the risk posed by each crossing, and judge whether it was safe to cross. Specifically, they were confident in their ability to judge the distance from an approaching train to the level crossing accurately, and that in doing so, they had sufficient time to cross in front of the train. Additionally, they felt that there was a low likelihood of being caught and punished for violating level crossing controls (Davey, Ibrahim & Wallace 2006).

The younger drivers also felt that there was a low likelihood of encountering trains at passive crossings. Furthermore, the subgroup of urban drivers perceived level crossing accidents as extremely rare events, and some of these drivers stated that trains would slow down if the train driver saw cars on the crossing (Davey, Ibrahim & Wallace 2006).

These findings are consistent with studies examining the risky behaviour of young drivers more generally. Younger drivers are more likely to perceive less risk in driving situations, feel more confident in their driving abilities, and subsequently engage in more risky driving behaviour (Deery 1999). In fact, one study found that deliberate risk-taking behaviours such as speeding, drink-driving and risky overtaking were the primary contributors of almost 50% of the 3437 at-fault accidents of young UK drivers (aged 17–25 years) (Clarke, Ward & Truman 2005). Additionally, younger drivers report engaging in significantly more risky driving behaviours than their adult counterparts (Parker et al. 1992; Rhodes & Pivik 2011).

The perception of risk involved in driving appears to be underestimated by younger drivers, relative to older drivers (Deery 1999; Groeger & Chapman 1996; Hatfield & Fernandes 2009; Parker et al. 1992; Rhodes & Pivik 2011). Additionally, compared to older drivers, younger drivers report being less likely to avoid risk in general, experiencing greater enjoyment from risky driving behaviours, and focus on their positive rather than negative consequences, such as ‘blowing off steam’, getting to a destination quicker, and thrill-seeking. They also consider these risky driving behaviours as more accepted by their peers (Hatfield & Fernandes 2009; Parker et al. 1992; Rhodes & Pivik 2011). Considering this, it is not surprising that the younger drivers reported a greater likelihood of engaging in such risky behaviours again in future (Hatfield & Fernandes 2009; Parker et al. 1992). In a study of 504 teen and adult US drivers, positive affect for risk-taking and perceived risk of driving situations completely
explained the association between age and self-reported frequency of risky driving behaviours, including speeding, driving while influenced by fatigue or alcohol, running red lights, and fast acceleration and braking (Rhodes & Pivik 2011).

Younger drivers also appear to have a high confidence in their ability to avoid a driving accident; younger drivers consistently rate their likelihood of an accident as lower than that of their age-mates, and of older drivers (Finn & Bragg 1986; Harré, Foster & O'Neill 2005; Hatfield & Fernandes 2009). Although they understand that certain driving behaviours are associated with higher likelihood of accidents, and consider drivers their age as more at-risk than older drivers, they do not seem to apply this logic to themselves personally (Finn & Bragg 1986; Harré, Foster & O'Neill 2005; Hatfield & Fernandes 2009).

Among the younger driver population, males are consistently more likely to be involved in risky driving behaviour, to find it more enjoyable, and to underestimate the level of risk it poses (Clarke, Ward & Truman 2005; Deery 1999; Deery & Fildes 1999; Hatfield & Fernandes 2009; Parker et al. 1992; Rhodes & Pivik 2011).

One explanation for the overconfidence and visual scanning deficits of younger drivers (and particularly males) may be due to factors such as impulsiveness and sensation-seeking, which are more prevalent in adolescence. For example, in a sample of 198 teenaged drivers (aged 16–19), two small subgroups reported relatively high levels of sensation-seeking, including in relation to drugs and alcohol, driving-related aggression, verbal hostility and competitive speed. Compared with the rest of the sample, these drivers reported a more risky driving style, and were less likely to change their driving behaviour on a simulator in response to hazards, in terms of speed, deceleration, and position on the road (Deery & Fildes 1999). Overall, their driving behaviour was characterised by a relative lack of caution. It is important to note that these predominantly male ‘sensation-seekers’ comprised less than a quarter of the total sample. The majority of the teenage drivers sampled displayed good attitudes, did not report having a risky driving style or more general risk-taking tendencies, and showed low levels of crash involvement and responsibility. Thus, it is more likely that only certain subgroups of younger drivers are likely to display this risky sensation-seeking behaviour.

Such sensation-seeking behaviour may be partly a matter of personality. However, it may also reflect the still-developing brains of adolescents. Relatively recent research has shown that the brain, but especially the pre-frontal cortex, may not be fully developed until the third decade of life, at around 25 years of age. The pre-frontal region is associated with higher order cognitive attention and regulation tasks, including planning, inhibitory control, reasoning and decision-making, and sustained, selective and divided attention. Thus, some young drivers may not be developmentally capable of managing certain driving tasks, especially under complex conditions such as high speeds or heavy traffic. Due to their under-developed brains, their driving behaviour may involve higher levels of sensation- and novelty-seeking, risk-taking, and less well-reasoned decisions (Keating 2007; Steinberg 2008).

Although, based on the above research, it seems plausible that younger drivers may exhibit these particular risk-taking behaviours at level crossings, there is very little evidence to support this. There is currently no evidence to suggest that the young drivers who violate level crossing controls have sensation-seeking tendencies. Although the QUT focus group research (Davey, Ibrahim & Wallace 2006; Davey et al. 2008b; Wallace 2008) suggests that younger drivers’ perceived levels of risk at level crossings are lower than those of industry professionals, these opinions have not been compared with the opinions of other ‘lay’ road users. This research also provides some evidence to suggest that a significant proportion of younger drivers may be overconfident in their abilities to ‘beat trains’, and that their risky behaviour may be motivated by frustration at delays. Notably, it also demonstrated important differences between regional and urban drivers, who are likely to be exposed to different types of crossing control. This research is a promising start into exploring why younger drivers may be at heightened risk at level crossings. However, as it represents an exploratory and qualitative first step, these results need to be supported in other samples, and using other techniques such as questionnaires and performance on driving simulator tasks. Additionally, as these groups of younger drivers constituted a relatively small sample, these results may not necessarily be representative of the broader younger driver population. As a related
consequence, the small sample precluded a more detailed investigation of possible subgroups of younger drivers (e.g. those with provisional licences), who may be particularly at risk.

5.3 Older drivers (over 60 years)

Older drivers are not only over-represented in level crossing collisions, but in road crashes more generally. In absolute terms, only a small proportion of road users involved in both level crossing and general road accidents are older drivers. However, when accounting for the fact that older people represent only a small proportion of the Australian population, and a relatively small proportion of this age group still hold driving licences, they are much more likely to be involved in collisions (Fildes et al. 2001; Langford & Koppel 2006). In fact, when driving distance is taken into account, older drivers’ crash risk is the same as that of novice drivers (Daigneault, Joly & Frigon 2002; Strutts, Martel & Staplin 2009). Older drivers are also more likely to be at fault in their crash involvements (Clarke et al. 2010; Langford et al. 2006; Mayhew, Simpson & Ferguson 2006; Preusser et al. 1998).

As the ‘baby boomer’ generation is now entering their mid-60s, and will live and remain mobile for longer as a result of medical advances, the proportion of older drivers is expected to increase in future. As a result, it has been predicted that, without any intervention, there will be an approximately three-fold increase in the risk of fatal crashes in older people in the 30 years spanning 1995–2025 (Fildes et al. 2001).

For these reasons, the majority of research into older drivers examines their driving abilities and crash risk in general, rather than at level crossings specifically. The level crossing reports that discuss older drivers have had to rely on this broader research base (e.g. Staplin et al. 2001; Wallace, McCusker & Hirsch 2008; Yeh & Multer 2008). Consequently, there is little evidence that the potential human factor contributors discussed here apply to the same degree at level crossings. However, all of the functional declines discussed relate to tasks involved in successfully negotiating level crossings (e.g. selecting appropriate traffic gaps in which to cross).

The elevated crash risk of older drivers is thought to be in a large part due to age-related functional declines in areas of perception (e.g. vision, hearing), cognition, and physical health and mobility. These declines share considerable overlap — for example, the cognitive tasks of information processing and reaction time depend greatly on drivers’ abilities to visually detect hazards. Of course, it must be noted that there are vast individual differences in the ageing process, in relation to both the emergence and rate of these declines. However, even healthy older adults are likely to experience at least some degree of functional decline (Charlton et al. 2003; Fildes 1997; Hakamies-Blomqvist 1998). It has been suggested that no single decline in function, but rather several simultaneous declines, put older drivers at increased risk of collisions (Charlton et al. 2003; Decina & Staplin 1993). Thus, it is more likely that there are distinct subgroups of older drivers that have increased crash risk (Hakamies-Blomqvist 1998).

As a result of these functional declines, many older drivers report exercising self-regulating driving behaviours in an attempt to mitigate this risk. Such behaviours include driving slowly, and avoiding busy traffic high speed roads and night driving (Ball et al. 1998; Charlton et al. 2003; Hakamies-Blomqvist 1994). However, it is unlikely that these self-regulatory driving behaviours are completely successful at preventing crashes (Strutts, Stewart & Martel 1998). Furthermore, not all older drivers are likely to self-regulate their driving. For example, of the 656 Victorian older drivers surveyed (aged 55 to 75+ years) who reported having low confidence in some driving task, only half also reported avoiding this task (Charlton et al. 2003). The older drivers who did avoid certain driving situations (like night driving, or driving in heavy traffic) were more likely to be female, not the principal driver in the household, and aged over 75 (Charlton et al. 2003). Thus, it is possible that earlier functional declines occurring during the fifth or sixth decades of life may not be pronounced enough for drivers to detect them, and self-regulate accordingly. Furthermore, as these participants actively volunteered for the study, they may have had a particular interest in ageing-related driving research, and thus may also have had relatively high levels of self-awareness in regards to their functional declines. Consequently, other older drivers may not have the self-awareness to regulate their driving behaviour.
In fact, there is evidence that many older drivers consider themselves to be ‘better than average’ drivers, and may lack awareness of their limitations. One study found that, among 49 older drivers who were referred for an evaluation of their fitness to drive, 65% thought they would perform better than other drivers of their age (Freund, Colgrove & Burke 2005). As self-reported driving confidence increased, there was a significantly increased risk of unsafe driving on the evaluation test. Notably, all of the drivers who were subsequently deemed ‘unsafe’ rated their expected driving performance as the same or better than that of their age-mates.

There is evidence that older drivers are also not self-aware of their own high-risk status at level crossings, in part due to their strong safety attitudes and generally cautious driving behaviour, and that they consider themselves as better drivers than younger people (Roy Morgan Research 2008; Wallace 2008). Although 43 Queensland older drivers (aged over 60 years) surveyed within focus groups acknowledged their driving-related functional limitations, they felt that their compensatory behaviours essentially negated this risk (Wallace 2008). Self-regulating behaviours used at level crossings included driving slower on approach to the crossing, exercising greater scanning behaviour, taking a longer time to scan and make the decision to cross, and avoiding what they considered to be ‘bad’ crossings (Davey, Ibrahim & Wallace 2006; Wallace 2008). However, as these participants were recruited from social and charity organisations, they may have been more physically and cognitively active, and thus engaged in greater self-regulatory level crossing behaviour than other older drivers.

As older drivers tend to exhibit more cautious and self-regulated driving behaviour, their road accidents are less likely to be the result of intentional risk-taking behaviour, such as excessive speed, or consumption of alcohol or illicit drugs (Hakamies-Blomqvist 1994; Langford & Koppel 2006; Mayhew, Simpson & Ferguson 2006; Rakotonirainy & Steinhardt 2009; Strutts, Martel & Staplin 2009; Zhang et al. 1998)

The Queensland older drivers who were surveyed within focus groups reported experiencing age-related impairments in negotiating level crossings, which mostly related to perceptual and cognitive declines, and included decreased visual acuity, especially at night, difficulties with glare, slower reflexes and reaction time, reduced awareness or alertness, poor hearing, confusion at unfamiliar crossings or crossings in complex road traffic environments, and distraction (Davey, Ibrahim & Wallace 2006; Wallace 2008). These factors are consistent with research into general age-related driving impairments, which will now be discussed in more detail.

5.3.1 Perceptual declines

Vision is arguably the most important sense at level crossings — road users predominantly rely on visual cues to detect level crossings, warning signs and instructions, and approaching trains. Furthermore, vision is the sense that shows the largest age-related decline. The most commonly reported medical condition among 656 Victorian older drivers was poor vision (75% of respondents, Charlton et al. 2003). Furthermore, almost one-quarter of participants rated their night driving vision as fair or poor (Charlton et al. 2003).

As a part of the normal ageing process, the eye muscles weaken, the lens becomes more yellow and opaque, less elastic, and thicker, and the pupil size becomes smaller. These declines may also occur as a result of ageing-related diseases such as glaucoma and macular degeneration. As a result, older people are more likely to experience reduced visual acuity, lower contrast sensitivity, longer dark adaptation and glare recovery, and visual field loss including reduced peripheral vision (for reviews, see Ball et al. 1998; Charlton et al. 2003; Fildes 1997; Shaheen & Niemeier 2001; Staplin et al. 2001; Wood 2002; Yeh & Multer 2008).

Visual acuity, contrast sensitivity and horizontal visual field scores have shown negative correlations with age in over 1000 licensed drivers aged from 15 to over 75 years (Decina & Staplin 1993). However, associations with drivers’ crash history were only significant when these vision variables were combined together, and not in isolation. The group of drivers aged 66 and over and who had poor vision were over-represented in previous crash involvement. Among 384 older drivers aged between 55–85 years, decreased visual acuity and contrast sensitivity were significantly associated with self-reported driving difficulty on all of the driving tasks assessed (e.g. night driving, driving during rush hour, and turning across oncoming traffic) (McGwin, Chapman & Owsley 2000).
Increased glare sensitivity becomes more common with increasing age (Gray & Regan 2007; Staplin et al. 2001; Theeuwes, Alferdinck & Perel 2002; Yeh & Multer 2008). Glare levels designed to simulate bright headlights and low sun have been shown to affect both driving simulator and controlled track driving performance of older drivers more so than younger drivers (Gray & Regan 2007; Shaheen & Niemeier 2001; Theeuwes, Alferdinck & Perel 2002). However, the evidence is equivocal as to whether increased glare sensitivity puts older drivers at increased risk of crashes during their normal daily driving. Several studies that examined several visual performance measures — including glare sensitivity, visual acuity, contrast sensitivity and useful field of view (UFOV) — found that, when analysed simultaneously, glare sensitivity was not uniquely related to crash risk (e.g. McGwin, Chapman & Owlsley 2000; Owlsley et al. 1998). This may be because drivers with increased glare susceptibility limit driving in such conditions (Ball et al. 1998; Gray & Regan 2007).

There is also evidence to suggest that older drivers may suffer from inefficient visual information processing. In one study, the eye movements of 10 participants were examined as they viewed pictures of traffic scenes (Maltz & Shinar 1999). Compared with the younger drivers (aged 20–30), the older drivers (aged 62–80) engaged in more visual fixations, took longer to complete the traffic processing task, and spent a longer amount of time dwelling on only a few of the critical traffic aspects. In contrast, the younger drivers spent a shorter, and more even, amount of time surveying all of the traffic aspects.

UFOV is related to peripheral vision, and refers to the visual field area from which information can be acquired in a brief glance (Fildes 1997; Owlsley et al. 1998). However, it also taps cognitive constructs, such as speed of visual processing and divided attention. This ability is important for detecting potential hazards outside one’s direct line of sight, and thus may be crucial for detecting approaching trains at passive level crossings, given that approaching trains will first appear in one’s peripheral vision. Restrictions to UFOV may lead to ‘looked but didn’t see’ crashes, where approaching trains are detected, but are not recognised or understood so that a driver can safely decide whether to stop or proceed (McGwin, Owlsley & Ball 1998). UFOV has consistently been found to predict older drivers’ crash risk, often showing the only significant association among a raft of visual and cognitive assessments. For example, UFOV was the only variable to distinguish between crash-involved vs. non crash-involved older drivers (aged 56–90 years), regardless of whether crashes were self- or government-reported (McGwin, Owlsley & Ball 1998). Additionally, Owlsley and colleagues (1998) found that, among 294 older drivers (aged over 55 years), those who experienced at least a 40% reduction to their UFOV (which may occur to approximately one-third of older adults) were more than twice as likely to have been involved in a crash in the three years following testing. Finally, in a large sample of 600 Queensland older drivers (aged over 60 years), UFOV and slightly lower levels of cognitive functioning were the only variables to predict the prospective risk of driving incidents in the 12 months following testing (Stavrou 2006).

Older drivers with visual deficits, including those outlined here, may delay seeing elements of the level crossing, such as advance warning signs, crossbucks or flashing lights, or even an approaching train, perhaps until the point at which a collision is unavoidable (Staplin et al. 2001). However, as age-related visual declines occur slowly, older drivers may be unaware of their visual limitations until they are involved in an accident (Wood 2002). Perhaps for this reason, not all older drivers self-regulate their driving, even though many are likely to suffer poor vision to some degree. For example, in the survey of Victorian older drivers, only 30% of those who rated their night vision as low reported that they intentionally avoided night driving as a result (Charlton et al. 2003).

Although less crucial than visual functions, hearing declines documented among older drivers may interfere with the ability to successfully negotiate level crossings. If, for whatever reason, the road user has failed to detect an approaching train, train horns are the last remaining signals to alert road users to the presence of the train (Yeh & Multer 2008). Hearing loss becomes more common with age. For example, in the Australian Blue Mountains Eye Study of 2379 current older drivers (aged 49–80s), 38% reported having hearing loss. Furthermore, the drivers’ hearing impairment (especially in the right ear) was significantly associated with self-reported car accidents over the last 12 months (Ivers, Mitchell & Cumming 1999).
Exactly which combination of these perceptual deficits is likely to increase older drivers’ risk of level crossing accidents is purely speculative. Although intuitively one would assume that any perceptual decrement that reduced drivers’ ability to detect level crossing hazards would place them at risk, there is currently no evidence available to confirm this.

5.3.2 Cognitive declines
Alongside the age-related vision declines of older drivers, a general slowing of cognitive function occurs as people age. Thus, older drivers are more likely to suffer from slowed information processing and reaction time, reduced selective or divided attention, and reduced ability to integrate speed and distance information.

It is a consistent finding that older drivers are most likely to be involved in collisions when negotiating intersections in complex traffic environments, especially uncontrolled turns across oncoming traffic (i.e. right-hand turns in Australia) (e.g. Clarke et al. 2010; Daigneault, Joly & Frigon 2002; Di Stefano & Macdonald 2003; Langford & Koppel 2006; Mayhew, Simpson & Ferguson 2006; Owsley et al. 1998; Preusser et al. 1998; Strutts, Martel & Staplin 2009; Zhang et al. 1998). For example, over half of the fatal two-vehicle accidents involving older drivers (i.e. over 70 years) occurred at intersections, with the most common reason being ‘failure to yield’ (Strutts, Martel & Staplin 2009). Similar findings were obtained using 1996–1999 Australian fatality crash data; specifically, 50% of older driver (i.e. over 75 years) fatal crashes were found to occur at intersections, compared to 21% of middle-aged drivers (aged 40–55 years) (Langford & Koppel 2006). Furthermore, the strongest predictor of pass/fail outcomes of older drivers referred for driving testing was negotiating intersections (Di Stefano & Macdonald 2003).

Intersections are complex traffic environments: they involve a great deal of competing visual information and associated points of conflict. To negotiate intersections successfully, drivers must integrate visual information, detect hazards in the presence of distractions, and make decisions, all in a short amount of time, and often at high speeds. All of these tasks are likely to be harder for older drivers, given that their divided attention, mental processing and reaction time, and ability to integrate speed and distance info are more limited (Oxley et al. 2004; Staplin et al. 2001). By extrapolation, this suggests that older drivers may be particularly at risk of collisions at passive railway level crossings, given that they are also uncontrolled intersections, and often require quick decision-making, including estimation of train arrival time, while driving at high speeds.

Older drivers have been shown to have slower reaction and decision-making times, compared to younger drivers, especially when tested in more complex traffic environments (Charlton et al. 2009; Hong, Kurihara & Iwasaki 2008; Horswill et al. 2009; Martin et al. 2010; Ranney & Pulling 1990; Staplin 1995). For example, a recent Australian driving simulator study of 216 drivers found that the older drivers (aged over 65 years) showed significantly longer brake times for unexpected events than younger drivers (Charlton et al. 2009). However, it could not be determined whether this difference was due to more limited physical mobility, or longer cognitive processing time among the older drivers. However, one study that did examine these influences separately found the decreased braking abilities of older drivers were due to longer reaction times rather than longer movement times (Martin et al. 2010). Additionally, the hazard perception latencies of 34 old-old drivers (i.e. 75–84 years) were significantly longer than those of mid-aged (35–55 years) and young-old (65–74 years) drivers (Horswill et al. 2009). Furthermore, these hazard detection age differences were mediated by drivers’ visual abilities of contrast sensitivity and peripheral vision (Horswill et al. 2009).

Among 129 Australian older drivers (aged 60–88 years) who were tested on a driving simulator, the cognitive abilities of working memory, decision-making under time pressure, and confidence in high-speed driving were significantly associated with self-reported crashes that had occurred within the past year (Lee et al. 2003).

Additionally, there is evidence that older drivers have difficulty with motion perception, and in particular, in integrating speed and distance information. A study of over 1200 older driver (60+ years) crashes in three UK counties during 1994–2007, where the drivers were at least partially to blame, found that one in five cross-flow
right turn crashes were due to the older driver misjudging the speed of the approaching vehicle (Clarke et al. 2010).

Several studies have shown that older drivers rely more on distance estimations in choosing acceptable traffic gaps in which to cross. Thus, they are more likely to choose unacceptable gaps as the speed of approaching vehicles increase (Scialfa et al. 1991; Spek, Wieringa & Janssen 2006; Staplin 1995; Yan, Radwan & Guo 2007). First, 29 regular drivers observed an approaching vehicle on a test track, which was travelling from 24 to 88 kilometres per hour. The older drivers (aged 55 to 74 years) were found to overestimate vehicle speed at the lower speeds, but underestimate vehicle speed at higher speeds (Scialfa et al. 1991). Second, in both field and simulator trials with 79 drivers aged 20 to 91 years, Staplin (1995) asked the drivers to indicate the last possible safe moment to turn in front of an approaching vehicle. As the speed of the approaching vehicle increased from 48 to 96 kilometres an hour, the older drivers (55–91 years) chose shorter gaps, whereas the gap judgments of younger drivers remained more or less the same. Third, Spek and colleagues (2006) examined the responses of 40 younger drivers (with a mean age of 24 years) and 40 older drivers (with a mean age of 67 years) on a driving simulator. They found that when drivers were executing cross-traffic turns, the tendency to accept shorter gaps as the speed of the vehicle approaching increased was greater for older drivers. Finally, Yan and colleagues (2007) tested the ability of 63 drivers aged 20 to 83 to conduct uncontrolled left-turns across oncoming traffic on a driving simulator. Overall, the older drivers (56 to 83 years old) chose larger gaps. However, when analysed in more detail, the older drivers only chose larger gaps than the younger drivers at low speeds, and did not increase their chosen gap size at higher speeds, which did not significantly differ from that of the younger drivers. This was especially problematic as the older drivers accelerated and turned more slowly than the younger drivers, and so they were more likely to be involved in collisions.

Furthermore, it seems likely that older drivers’ distorted judgments of speed may also be exacerbated by their visual declines. It has been found that when visual contrast is reduced, the speed of approaching vehicles is harder to estimate, and consistently seems slower (Horswill & Plooy 2008). However, this was not examined as a function of driver age.

The tendency of older drivers to underestimate vehicle speed as velocity increases quite obviously has large implications for their ability to negotiate passive level crossings when trains are approaching. Trains are the fastest vehicles that drivers will encounter, travelling at very high speeds of up to 130 km/hour. Underestimating their speed could have deadly consequences. In fact, a panel of 24 Australian level crossing industry experts considered the most important older driver level crossing risk behaviour to be errors in judgment for the time needed to safely traverse crossings, rated as ‘important/very important’ by 79% of the experts (Wallace 2008). However, to our knowledge, no empirical research has investigated older drivers’ perception for vehicle speeds higher than 100 kilometres per hour, or when using (real or computer-simulated) trains. It may be the case that older drivers’ speed judgment errors are even greater for approaching trains, but this possibility has not yet been tested. Additionally, it is possible that, given the difficulties integrating speed and distance information, perceptual errors explained by the Leibowitz and looming effects may be more common or pronounced in older drivers (Staplin et al. 2001). However, the little research that has examined these effects has not looked at the influence of driver age (Barton & Cohn 2007; Clark 2010; Cohn & Nguyen 2003; Leibowitz 1985; NTSB 1998b).

5.3.3 Physical declines
As part of the ageing process, the muscles, bones and joints in the body decline. Muscle loss occurs, and joints become less flexible, which may also be compounded by medical conditions such as Parkinson’s disease and arthritis. These physical declines may make general driving tasks, as well as negotiating level crossings, more difficult for older drivers (Shaheen & Niemeier 2001; Staplin et al. 2001; Yeh & Multer 2008).

Muscle strength and flexibility, as well as range of motion, are needed for braking and accelerating, as well as more complex steering for manoeuvring around obstacles. Head, neck and torso flexibility are important for searching for hazards, especially looking over one’s shoulder when roads approach railway level crossings at an acute angle. Among 656 Victorian older drivers (aged 55–75+), 12% rated their head/neck mobility as fair or poor.
Reflexes are needed for reacting quickly to hazards, such as approaching trains (Shaheen & Niemeier 2001; Staplin et al. 2001; Yeh & Multer 2008). Thus, it is plausible that older drivers who experience such physical declines may be less likely to notice approaching trains, or to act quickly enough to avoid a collision. However, there is limited research addressing the contribution of physical mobility to driving performance or crash history.

5.4 Pedestrians

There is even less research on pedestrian behaviour at level crossings than the limited literature on driver behaviour at level crossings. This is a significant omission, given that for all road users involved in level crossing collisions, the likelihood of being killed is much higher for pedestrians than for vehicle drivers or passengers (Illinois Commerce Commission 2005; Lobb 2006; Parliament of Victoria 2008). To illustrate, the literature review by Lobb (2006) identified only 14 articles on train–pedestrian accidents. Furthermore, most of these were broad, and considered illegal level crossing users together with trespassers — those who crossed at illegal places, other than the level crossing.

As pedestrian road crashes are considered to be more of an urban problem (Oxley et al. 2004), it is also likely that pedestrian level crossing accidents are more likely to occur at active crossings, which are located in more built-up areas with a higher flow of pedestrian traffic (Cairney et al. 2002). However, the current Australian statistics are not detailed enough to confirm this possibility.

A number of human factors are relevant to pedestrian violations at level crossings, including, but not limited to, time of day, age, gender, inattention, time pressures, the number of pedestrians present, the influence of alcohol or drugs, mental illness, and thrill-seeking behaviour. Many, but not all, of these human factors are similar to those that apply to vehicle drivers at railway level crossings.

The ATSB conducted a preliminary investigation of the first 18 pedestrian fatalities between 2002 and 2004 to be included on the National Coronial Information System database (ATSB 2004a). In all cases, the crossing signals were working properly, and there was no trace of alcohol or drugs in the train crew’s system. Of these 18 fatalities, eight cases involved misjudgment, in six cases the pedestrians were under the influence of alcohol or drugs, and four cases showed a history of mental illness. These fatalities constituted only a small sample, and did not represent the total number of deaths occurring in that period, but only the number that had been processed and loaded onto the coronial database. Thus, the characteristics of these fatalities cannot be considered as representative of all Australian fatalities at level crossings.

Several studies have shown elevated blood alcohol levels in a high proportion of pedestrians killed or injured at level crossings (e.g. Lerer & Matzopoulos 1996; Lobb 2006; Nixon et al. 1985). However, most of these studies included all pedestrian rail accidents, including falls and trespassing, and not just those occurring at level crossings. The presence of drugs or alcohol seems to be more specific to pedestrian–train collisions, as they are not a prominent feature of vehicle–train collisions (ATSB 2002).

In many cases, pedestrians may be aware of an approaching train, and thus may knowingly violate crossing controls. One US study of pedestrian–train collisions in north-eastern Illinois from 2000 to 2004 found that 66% of cases were likely to have resulted from pedestrians ignoring active warning devices (FRA 2008; Illinois Commerce Commission 2005). In many instances, the pedestrian crossings were fitted with pedestrian gates. The researchers concluded that pedestrian warning devices are ‘commonly ignored, and easy to circumvent’ (FRA 2008; Illinois Commerce Commission 2005). Additionally, a Public Transport Safety Victoria (PTSV) study found that 31% of pedestrians reported crossing the tracks when they knew a train was approaching (Lloyd’s Register Rail 2007). Pedestrians may also illegally traverse crossings by going the wrong way through emergency escape gates (designed to let people out who have gotten trapped on the tracks). This behaviour has been documented in observational studies of several Victorian crossings, including Bentleigh, where several pedestrians have been killed (Dickinson, Maddock & Majernik 2010).
Males are more likely to violate pedestrian level crossings. As previously mentioned, males are clearly over-represented in level crossing pedestrian fatalities (ATSB 2004a). Furthermore, 40% of the males surveyed reported they would at least sometimes cross at pedestrian crossings when lights, bells or gates were activated, but no train was visible, compared with 12% of females (Lloyd’s Register Rail 2007).

Pedestrian level crossing accidents more often occur in daytime hours. Moreover, the rate of both violations and incidents at Victorian crossings was found to be much higher during the morning ‘rush hour’ (Lloyd’s Register Rail 2007; Spicer 2008). This may suggest that hurrying to catch trains or to get to work or school on time may play a part in deciding to cross illegally. Additionally, among pedestrians surveyed at seven Melbourne metropolitan level crossings, the most common reason given for violating level crossing controls was being in a hurry (Lloyd’s Register Rail 2007). Several studies have found that most pedestrians’ behaviour, when violating road traffic or level crossing controls, or trespassing on train tracks, seeks to maximise convenience, and minimise delays (Daff & Cramphorn 2006; FRA 2008; Lobb 2006).

Inattention may also be a factor in pedestrian accidents. Almost one in five pedestrians (18%) surveyed at Melbourne level crossings reported they had become unintentionally caught on the tracks when a train was approaching (Lloyd’s Register Rail 2007). The most common reasons reported by these pedestrians were being unaware of a train, or a second train approaching, often due to headphone use. Use of mobile phones or MP3 players may divert pedestrians’ attention from the crossing, and use of headphones that block out environmental noise may prevent pedestrians from hearing train engine noises and warning horns.

Incidents may also occur at crossings with multiple train tracks, when a pedestrian crosses following the passage of one train, and into the path of a second unseen train that is approaching from the opposite direction. Of the people surveyed at the seven Melbourne level crossings, 16% reported they would at least sometimes cross at level crossings after one train had passed, but controls were still activated (Lloyd’s Register Rail 2007). In the Illinois study, the second main contributing factor to pedestrian accidents occurring between 2000 and 2004 was the presence of a second train, which contributed to 18% of accidents (FRA 2008; Illinois Commerce Commission 2005). Additionally, the three fatal pedestrian accidents that occurred at the Bentleigh, Victoria, crossing between 1998 and 2004 all involved the presence of a second train, as well as illegal access to the crossing (Spicer 2008). An analysis of Victorian coroner reports of pedestrian level crossing fatalities found that the ‘second train’ scenario was often mentioned (Lloyd’s Register Rail 2007).

Pedestrian level crossing violations and accidents may be more likely to occur as the number of people present at the crossing increases. Thus, pairs or groups of pedestrians, including school children, or those who have just alighted from a train at a station, are more likely to violate crossing controls. In an observation of a suburban Melbourne level crossing, pedestrians in a group were observed to scan for trains less often than when they were by themselves (McPherson & Daff 2005). The authors supposed this may have been due to pedestrians’ reliance on the collective scanning of the group. Additionally, the presence of a greater number of pedestrians was associated with increases in pedestrian level crossing violations at one Nebraska crossing (Khattak & Luo, in press). This effect was observed for both young children (approximately eight years or younger) as well as older pedestrians. A number of Victorian coroner reports from pedestrian level crossing fatalities discussed the fact that people travelling in pairs or groups were more at risk of being involved in an accident — possibly due to diffusion of responsibility, or distraction. In one instance, a child on the crossing failed to notice the train coming while he was turned around to talk to his friend (Lloyd’s Register Rail 2007).

Although misjudging train speed may also be an important factor in pedestrian level crossing accidents, no evidence exists to support this possibility. However, there is some evidence to suggest that most pedestrians have a tendency to underestimate road vehicle speed as approaching vehicles are travelling at higher speeds (Dommes & Cavallo 2011; Oxley et al. 2005). Thus, it is possible that the speed of approaching trains, which often travel at higher speeds than road vehicles, is underestimated by pedestrians at level crossings.
Several more specific high-risk groups of pedestrians have also been identified. These include school children and youth, people with disabilities, and the elderly (Lloyd's Register Rail 2007). Detailed information regarding why these user groups are at increased risk at railway level crossings is limited. Instead, the majority of evidence is extrapolated from the literature on pedestrians in general. For example, a recent literature review and report commissioned by the Victorian Government on at-risk level crossing pedestrian groups mostly relied on general pedestrian research to identify high-risk groups (Lloyd’s Register Rail 2007). Thus, we cannot be completely confident that these pedestrian user groups are indeed at-risk of being involved in collisions with trains specifically. As a related consequence, there may also be equally or more at-risk pedestrian groups which are as yet unidentified.

5.4.1 School children

Several studies have shown the increased risk of school-age children at railway level crossings. New Zealand data have demonstrated the high proportion of pedestrian occurrences involving school-aged children: during 1996–1997, 50% of train-related fatalities and 40% of injuries involved children aged between 10 and 19 years (New Zealand Health Information Service 1999, in Lobb, Harré & Terry 2003). Additionally, children aged approximately 8 years or less were involved in 25% more pedestrian level crossing violations than older pedestrians at one Nebraska crossing, observed on three occasions over a three-year period (Khattak & Luo, in press). Finally, school children and youth were involved in almost half of the crossing violations at the crossing observed in Bentleigh, Melbourne (Spicer 2008).

There is limited research to suggest why school children may be at increased risk at railway level crossings. However, possible reasons include reduced scanning behaviour, underdeveloped perceptual or cognitive skills, peer influence, impulsivity, and convenience maximising. Much of this information has been gleaned from the broader pedestrian literature, and research on railway trespassers.

From a survey and camera footage of 208 people at a Victorian level crossing, pedestrians in the 12–17-year-old age group showed the worst scanning behaviour, where only just over half looked in both directions, and 11% did not look at all (McPherson & Daff 2005). However, exactly why these children showed such poor scanning (e.g. distraction, low risk perception) was not examined.

It has been hypothesised that primary school children pedestrians (e.g. 5–12 years) are the age group at highest risk of collisions in general (i.e. not specifically at railway level crossings) due to their relatively recently acquired walking independence, coupled with their underdeveloped perceptual, attention and cognitive skills (Congiu et al. 2008). As has been demonstrated with older people, young children are more likely to rely on the distance of approaching traffic, and not the speed, in deciding when it is safe to cross (Congiu et al. 2008; Connelly et al. 1998). This risk is even more evident at younger ages (e.g. 5–8 years) (Congiu et al. 2008; Connelly et al. 1998).

Additionally, underdeveloped attention skills may also contribute to the poor crossing decisions of young pedestrians. Among 44 children aged 4–10 years, younger children were shown to have worse selective and divided attention skills. Furthermore, higher divided attention skill levels were associated with looking for traffic prior to stepping onto the road, and higher selective attention skills were associated with more controlled crossing (e.g. not running) (Dunbar, Lewis & Hill 2001). Similar findings were demonstrated among 83 children aged 6–9 years, where both increasing age and better executive function skills (i.e. selective attention, working memory, and behavioural monitoring and inhibition) were associated with increased scanning behaviour of approaching traffic before initiating crossing of a suburban road (Barton & Morrongiello 2011). Once these executive function skills were controlled for, the age effect became non-significant. Additionally, among 71 children aged 6–10, poorer executive function skills, including working memory and sustained attention, were significantly associated with choosing an unsafe gap in which to cross in front of a computer-simulated approaching vehicle (Congiu et al. 2008).

Thus, it is possible that the cognitive function needed to cross safely may exceed young children’s developmental capacity (Connelly et al. 1998). However, it is also possible that age-related factors such as height, and experience
with (road or rail) crossings may also play a part in increased risk (Congiu et al. 2008; Connelly et al. 1998). Importantly, none of these developmental capacities have been tested when using approaching trains as stimuli.

### 5.4.2 Youth

From an analysis of ATSB pedestrian fatality data from 1997 to 2002, 15–19 year old males were found to have the highest proportion of fatalities. As with vehicle driver accidents, males represented a much greater proportion of accidents; over 90% of the fatalities in this age group were male, and more than one-third of all pedestrian fatalities involved 15–29 year old males. Unfortunately, these data were not normalised on a per population basis.

It is likely that a significant proportion of level crossing violations committed by this age group represent intentional risk-taking behaviour. In the PTSV survey, 18-25 year olds and 26–35 year olds were most likely to report intentionally crossing when a train was approaching (Lloyd’s Register Rail 2007).

Additionally, the results of one study suggest that youth exercise poor scanning behaviour at pedestrian crossings. In the Victorian level crossing observation, the age group with the second-worst level of scanning behaviour was the 18–30 year old group; only 60% looked both ways along the tracks, and 5% did not look at all (McPherson & Daff 2005).

However, there is little evidence available to suggest why youth are more likely to take risks at pedestrian level crossings. In both studies mentioned above, underlying reasons behind the youth displaying poor scanning and knowingly crossing in front of trains was not examined. Similar influences as those for younger drivers may be at play, including risk-seeking tendencies, an increased confidence in the ability to beat the train, low knowledge of road rules, a low perception of risk or of consequences, and peer influences (Davey, Ibrahim & Wallace 2006; Davey et al. 2008b; Wallace 2008). Unfortunately, there is currently no evidence to either support or refute these possibilities.

### 5.4.3 People with physical disabilities or mobility aids

Pedestrian rail level crossings can present a significant safety issue for people with physical disabilities or mobility issues, for two main reasons. First, wheels on mobility aids, including wheelchairs and prams, can easily become stuck in the flange gap between the track and the bitumen crossing path (McPherson & Daff 2004). This is especially likely if the bitumen path does not cross the tracks at a 90 degree angle. Second, the bitumen surfaces of the crossing that span the width of the tracks may be cracked, broken or uneven, causing additional tripping points for those who may be already unsteady on their feet (or wheels) (McPherson & Daff 2004). In 2001, two fatal level crossing accidents involving people in wheelchairs occurred in Melbourne within weeks of one another. In both cases, the wheelchair-bound level crossing users were unable to free their chairs from the tracks before the approaching trains arrived.

In the Victorian level crossing survey, the second-most common reason reported for becoming unintentionally caught on the tracks when a train was approaching was requiring earlier warning of an approaching train due to mobility impairment issues (Lloyd’s Register Rail 2007). During this survey, several mobility-impaired pedestrians were observed to take up to 30 seconds to complete their crossing, even though it typically took only 25 seconds for the train to reach the crossing after the active warning bells had started (Lloyd’s Register Rail 2007).

A distinguishing feature of this high-risk user group is that infrastructure factors (i.e. crossing surfaces), rather than human factors (i.e. inattention), are the primary reason behind their high-risk status (Lloyd’s Register Rail 2007). However, it is possible that slower crossing speeds may partly contribute to the infrastructure risk these crossings impose. Additionally, it seems plausible that if level crossings are a particular source of concern for mobility-limited crossing users, they may cross in an anxious or hurried manner, which may only exacerbate their risk of becoming stuck on the tracks. Sadly, this was the case for one of the wheelchair-bound fatalities mentioned above; when the cerebral palsy sufferer’s wheelchair became stuck on the crossing, he panicked and lost all muscle control, preventing attempts to free himself (Lloyd’s Register Rail 2007; Silkstone 2005).
Following the two fatal pedestrian accidents in 2001, the Victorian Minister for Transport subsequently established a taskforce to examine pedestrian level crossings in relation to disability access, and subsequently published the findings in a 2002 report (Wheelchair Safety at Rail Level Crossings Taskforce 2002). During the consultation process, focus groups of people with mobility issues emphasised the need for regular maintenance to improve degraded crossing surfaces, as well as increased manoeuvring space and easier access to crossing emergency exit gates, and realignment of some pedestrian crossings so that paths were at right angles to tracks, and the entry and exit gates were aligned (Lloyd’s Register Rail 2007; McPherson & Daff 2004). This investigation generated 25 recommendations for the safety of pedestrians with mobility issues, which have since been implemented by the Department of Infrastructure (Wheelchair Safety at Rail Level Crossings Taskforce 2002). A particular area of concern was that the then-current level crossing standards, which predated the Disability Discrimination Act 1992, did not specifically address disability access. The standards have since been updated to address such issues, including crossing surfaces and flange way gaps.

5.4.4 The elderly (over 60 years)
To our knowledge, there is only one study that has examined the behaviour of older pedestrians at railway level crossings (Lloyd’s Register Rail 2007). Thus, there is very limited evidence to demonstrate that older people are at increased risk at level crossings, and examine why this is so. However, on a per population basis, older pedestrians are over-represented in pedestrian–road vehicle collisions resulting in serious injuries and fatalities (Oxley et al. 2004). Thus, it is plausible that older pedestrians may also be at increased risk at railway level crossings. However, the following discussion of precursors to older pedestrians’ accidents is severely limited in that it largely draws from the broader older pedestrian literature.

The Victorian study of pedestrian behaviour determined that older pedestrians were less likely than younger pedestrians to report crossing when they knew a train was approaching (Lloyd’s Register Rail 2007). This would suggest that older pedestrians’ risky crossing behaviour is less likely to be intentional. However, the authors’ subsequent analysis of Victorian pedestrian level crossing incidents using the PTSV database suggested that ‘visual and hearing impairment is linked to a number of incidents and could potentially be one of the reasons why elderly pedestrians may be at greater risk of being unintentionally caught on crossings when a train is approaching’ (Lloyd’s Register Rail 2007, p. 19). However, examples of these cases, and the specific nature of their perceptual impairments (e.g. cataracts, poor peripheral vision) were not provided.

As already discussed in relation to older drivers (see section 5.3), there are numerous age-related functional declines that may affect the ability to successfully negotiate traffic situations. The research on general age-related declines and the performance of older drivers will not be revisited here. However, research that is specific to older pedestrians, although similar in some respects, will now be discussed. This literature is more limited than the older driver literature base, and there is no evidence to suggest that the cognitive, perceptual and physical age-related declines that are related to older driver safety apply to the same degree for older pedestrians (Oxley et al. 2004).

To begin with, older pedestrians are likely to have greater mobility issues, including physical impairments such as arthritis and slower walking speeds. These issues mean that older pedestrians will take a longer time to cross roads, and may have a reduced ability to adapt their walking pace or direction so as to move out of the way of oncoming vehicles once they have already started to cross (Oxley et al. 2004). Studies on pedestrian crossing behaviour have demonstrated that older pedestrians take significantly longer than younger pedestrians to cross roads (Dommes & Cavallo 2011; Lobjois & Cavallo 2009; Oxley et al. 2004; Oxley et al. 1997; Oxley et al. 2005). Mobility issues are likely to play a larger part in old people’s pedestrian, rather than driving, behaviour, as driving speed is less likely to suffer than walking speed as a result of reduced mobility. Additionally, as people age, they have poorer balance control and postural stability mechanisms, rendering them less steady on their feet while walking, and more susceptible to stumbling or falling if the road surface is cracked or broken (Oxley et al. 2004). Furthermore, there is evidence that older pedestrians have difficulty integrating information regarding the speed and distance of oncoming traffic, so as to determine safe gaps in which to cross (Dommes & Cavallo 2011; Lobjois & Cavallo 2009; Oxley et al. 1997; Oxley et al. 2005). This is consistent with the research on older drivers, as
previously discussed in section 5.3.2. Specifically, it seems that older pedestrians rely primarily on the distance of
the approaching vehicle, and not its speed, in determining whether it is safe to cross in front of it. Thus, as vehicle
approach speed increases, older pedestrians are likely to underestimate vehicle speed and make more unsafe
crossing decisions, relative to younger pedestrians.

In one of these studies, the 18 ‘old-old’ pedestrians (aged 75 and over) were better able to integrate speed and
distance information when they were given more time in which to make their crossing decisions while watching
simulated road traffic sequences (e.g. five seconds compared to one second) (Oxley et al. 2005). But despite this
greater decision-making time, the older pedestrians still made a greater proportion of unsafe crossing decisions
than the 36 younger pedestrians. This appeared to be, in part, due to their increased walking times; the older
pedestrians seemed to be either unaware of their physical limitations, or simply unable to compensate
accordingly.

In a study examining the crossing behaviour of 20 young (20–30 years), 21 young-old (61–71 years) and 19 old-old
(72–83 years) pedestrians, the cognitive skills of processing speed visual attention and time-to-arrival estimates
were found to significantly decline with age (Dommes & Cavallo 2011). Additionally, the older pedestrians made a
greater number of unsafe crossing decisions at approach speeds of 50 kilometres/hour or above. Importantly, all
of these cognitive variables significantly predicted the pedestrians’ unsafe crossing decisions, and once these
variables were accounted for, the unique association of age was reduced considerably (although it remained
significant).

Thus, it seems that older pedestrians have less cognitive resources available to process several sources of
information, especially while under time pressure and in complex traffic environments, and to compensate
successfully for their age-related limitations.
6. Summary

6.1 Australian level crossing occurrence data

In summary, the statistics available to date provide an initial, but incomplete, picture of the nature of Australian level crossing occurrences. As a result, many more questions than answers are generated from these data. To begin with, the majority of detailed information regarding the human factors associated with level crossing occurrences is at least 13 years old, so recent data is greatly needed. Additionally, much of this information is more descriptive rather than empirically driven, meaning that little is provided in the way of actual numbers, or statistical indications of significance or effect sizes. The existing information is also quite general, and lacks important detail, such as the type of crossing control (i.e. passive or active), as well as subcategories (e.g. ‘flashing lights only’ or ‘give way sign’), road user age, and the types of road user error involved (e.g. distracted by passenger, attempting to ‘beat the train’).

Furthermore, this information has numerous data quality issues, including a lack of uniform reporting and definitions between jurisdictions, especially in relation to near-miss events and deaths classified as suicides, and sizeable amounts of missing data. As a result, we cannot be entirely confident in the results obtained. It is then also difficult to synthesise information from different sources. To address some of these data quality issues, data collection and categorisation must be made consistent across jurisdictions, and definitions must be clearer. Only then can data be aggregated within one large database.

Additionally, few reports are accompanied by normalising data that would allow researchers to determine whether certain factors are more prevalent in level crossing occurrence statistics purely due to higher exposure, or whether they are inherently more risky. Both train and road user exposure data (e.g. per million crossing vehicles) are needed to determine which crossings are the most risky. To obtain a detailed picture of high-risk user groups, multiple exposure indices are needed. Not only do we need to know the rate of accidents on a population basis, but also on a per licence basis, per distance travelled, broken down by suburban, urban and rural driving, and per hours spent driving each week, for example. Normalising data using these different indices may produce a different picture of level crossing occurrences; for example, we know that heavy vehicle drivers are over-represented in crashes in relation to all registered heavy vehicles, but this may be at least in part due to the fact that heavy vehicle drivers spend more hours driving each week, and travel greater distances. Finally, there is limited access to raw occurrence data such as frequency tables. As a result, it is more difficult for researchers to test their own specific hypotheses, and instead they must rely on the statistics generated and released by investigation and regulatory bodies.

In risk management perspectives, risk is calculated as the product of the likelihood of the occurrence and its associated costs (e.g. money, life). In Australian level crossing research, we have a fairly good idea of the cost of level crossing accidents, as applied to road vehicles, heavy vehicles specifically, and pedestrians. However, as a result of the limited Australian statistics and exposure data, we have little idea of the likelihood of specific types of accidents occurring. Without this information, it becomes difficult to prioritise high-risk areas for intervention.

6.2 Human factor precursors and high-risk user research

Currently, there is very little information available regarding the behaviour of high-risk users at level crossings. This is not terribly surprising, given that the limited statistics prevent researchers from developing a detailed picture of exactly who is at high risk. Nonetheless, much of the research into high-risk users at level crossings (both Australian and international) has had to draw from the broader road safety literature. For example, although there is evidence that human factors, including hazard detection and scanning errors, contribute to young drivers’ risky driving in general, there is no evidence to confirm that they also contribute to level crossing occurrences to the same degree, if at all. Although these are very plausible hypotheses, without empirical research, they remain as speculation.
7. Recommendations

To advance knowledge on level crossing safety and develop effective countermeasures and interventions, we need to know much more about high-risk users and the associated human factors contributing to their risky behaviour, and how these interact with crossing characteristics.

As the current research and statistics are limited, this literature review has generated many more questions than answers. What follows are several recommendations for future level crossing research.

It is important to place these recommendations within a risk management framework, so as to best allocate funding, researchers and resources to investigate and ‘treat’ the circumstances which have the greatest likelihood of precipitating a level crossing accident, the greatest associated costs, and the greatest likelihood of responding to intervention. Currently, we need to use better logic as to how and why we upgrade Australian crossings. As put aptly by Reason: a lot of organisations spend a lot of money on preventing accidents that have already happened (retirement speech by J Reason to the Federal Aviation Administration, personal communication from Drew Dawson). In other words, there is little point in upgrading a crossing where a crash has occurred if it is unlikely to happen again, or if the upgrade does not counter the specific risk posed.

For these reasons, Wigglesworth (2007; 2008b) was particularly scathing of the recent upgrade to the Lismore heavy vehicle fatal crossing site. The rural crossing was equipped with passive signage at the time of the accident, and was subsequently upgraded to boom barrier control. Wigglesworth pointed out that boom barriers are an expensive treatment, and are mostly suited for urban crossings with high visual clutter, where drivers are likely to be cognitively overloaded and commit ‘looked but did not see’ violations. Upgrading the Lismore crossing to flashing lights and bells would have been cheaper, and would provide more than enough visual stimulation to drivers on the straight stretch of rural road. In this particular accident, the heavy driver was travelling too fast for the extremely foggy conditions, and may not have seen the approaching train. Flashing lights may have been the best option for these conditions, as boom barriers would not have added any additional visual stimulation in the heavy fog, and may not have prevented a collision if they were driven into. Even sealing the road and diverting traffic to the adjacent level crossing several hundred metres up the road would have been cheaper and more effective at preventing accidents. The additional cost of this inappropriate treatment could have instead been allocated to the upgrade of another crossing.

The point of this example is that decisions regarding how best to upgrade crossings must be based on solid research evidence and cost–benefit analyses; however, both of these are lacking from the literature. Also, as level crossing accidents are already rare events, with reductions in accidents almost reaching an asymptote in recent years, it is important to consider the proportion of effort put into implementing a particular countermeasure in relation to the relatively small proportion of accidents it may prevent. This does not mean that endeavouring to prevent further accidents is immaterial, but rather that it is especially pertinent to keep these cost–benefit trade-offs in mind while doing so.

It is important to note that each jurisdiction has recently amended their rail safety legislation to assess rail safety from a risk management perspective, and to have shared responsibility between road and rail authorities for level crossing safety (Spicer 2010). Hopefully these changes will result in better management of level crossing safety, including uptake of at least some of the following recommendations.

7.1 Occurrence data

To determine exactly who is at risk at Australian level crossings, and why, we greatly need more detailed statistics. The extensive data collection and dissemination by the FRA provides an excellent model of what we should be striving for. Detailed information on US level crossing occurrences is readily available on the FRA website. Yearbooks containing tables of frequency data provide information on the time, day and month of occurrences, as well as weather and road conditions, the type of crossing control, and road user type (e.g. heavy
vehicle driver), age and gender. The FRA also categorises these occurrences according to potential precursors, such as ‘did not look’, ‘misjudged train speed’, ‘inadequate sight distance’, ‘influence of alcohol/drugs’, or ‘fatigue’. All of this detail is provided for both collisions and near-misses. Australian level crossing occurrence data collection and research would be greatly improved simply by following the FRA’s example (Cairney 2003; FRA 2006). It is essential that Australian data be categorised at this level of detail, including the same environmental, level crossing, and road user characteristics as the FRA. Any possible precursors to the occurrence, as perceived by the train driver, road user or witnesses, should also be recorded, such as ‘drove around gates’, ‘on mobile phone’ or ‘gaze focused on nearby intersection’. The ITSR checklist discussed earlier is a promising start, but such detailed data collection and categorisation needs to be implemented nationally, and used consistently by train operators.

Given that rail safety regulation and investigation is still being established at a national level, this is an excellent time to be setting up a detailed framework for collecting this type of occurrence data. The changes currently being implemented should be reviewed with these considerations in mind. If needed, the CFF should be expanded to ensure there is scope for recording and categorising the data according to all of these factors. To ensure data accuracy, clear definitions of all categories must be used. Many of the issues plaguing the currently available statistics will continue if clear and uniform national standards and definitions are not put in place, and if a widely accessible national database is not developed.

It must be acknowledged that it can be extremely difficult to determine the possible human factor precursors associated with Australian level crossing occurrences, given that investigators must rely heavily on ‘external’ judgments to determine the mental state of road users, especially when the road users involved are either dead, or untraceable (as is generally the case with near-misses). For this reason, it may be especially helpful to:

- follow-up vehicle near-misses by tracing number plates
- conduct detailed interviews with injured road users
- obtain reports from witnesses closer to the road user than the train driver, including vehicle passengers and fellow pedestrians.

Although doing this would undoubtedly be logistically difficult, the information obtained would be incredibly valuable, and arguably worth the effort.

Near-misses represent an excellent opportunity to gather detailed data on potential precursors of a large number of level crossing occurrences. Thus, it is vital that the definition of a ‘near-miss’ is not only standardised across jurisdictions, but also defined in enough detail so that train drivers are able to determine easily what does and does not constitute a near-miss occurrence. Additionally, train drivers’ reporting of near-miss occurrences must increase. These two issues are clearly symbiotic — if train drivers have greater faith and understanding in the system, they are more likely to engage with it. But only with detailed occurrence information can the definition of what does and does not constitute a near-miss be made clearer.

Headway is being made into improving the definition of near-miss occurrences by QUT, CQU and UQ researchers, who have recently commenced a Rail CRC project that collects occurrence information from locomotive-mounted video surveillance cameras (Wullems & Toft 2011). Specifically, cameras that are mounted on several trains on lines with a high number of occurrences are triggered on approach to the crossing, and take high-speed sampling to enable a detailed picture of occurrences to be analysed. This method circumvents the need to rely on train driver reports, and provides greater detail and more objective information. This information will enable a clearer definition of near-miss occurrences to be developed. By comparing this video information to occurrence reports, factors that may influence a driver’s decision to report particular occurrences as near-miss incidents can be determined. Furthermore, a Safety Data Guidelines Project for the Rail Industry Safety and Standards Board is currently developing guidelines for classifying, recording and reporting near-misses using the existing ON-S1 and OC-G1 frameworks (Naomi Frauenfelder, personal communication). Innovative approaches such as these will enable more high-quality data to be collected.
To improve near-miss incident reporting, definition and categorisation, it may also be worthwhile to work in partnership with train drivers. Obtaining train driver input into improving the reporting framework will ensure that reporting categories are consistent with train drivers’ daily experience, easier to understand, and subsequently more likely to be used. By explaining in greater detail exactly what the occurrence data is used for, and how it can benefit rail safety, and in particular the safety of train drivers, it is more likely that train drivers will consider reporting to be important and useful, and do it more often.

Both near-miss and collision data must be accompanied by various types of normalising data, including, but not limited to, per million train kilometres, million crossing vehicles, population, licensed driver, distance travelled, and hours driven. It is incredibly important to know what characteristics are associated with occurrences when controlling for exposure rates, as the currently available Australian statistics do not provide this information. As an example, it has already been determined that a greater proportion of collisions occur during daylight hours. However, there is also greater road vehicle and train traffic during the day, and the available statistics have not taking into account this greater exposure. It is possible that, when exposure is controlled, it may be inherently more risky for road users to traverse level crossings during the night. If this were true, this would have important implications for the use of countermeasures that improve train and crossing conspicuousness at night-time, such as crossing lighting, and reflectors on trains and at crossings. Furthermore, younger drivers spend much more time driving than older drivers. If the exact figures could be controlled for within analyses, it may emerge that younger drivers’ higher risk status is simply a result of their greater time spent driving, and so greater opportunity to be involved in an accident (see Caird et al. 2002 for a thorough discussion).

Additionally, separate occurrence statistics need to be generated for specific high-risk user groups. It has often proved difficult to do this simply because the already small sample sizes used meant the loss of statistical power when splitting the sample further. However, if near-miss data were better reported and categorised, this would provide a much larger sample size to split into data groups, without losing appreciable statistical power. Analysing the characteristics of level crossing occurrences among key high-risk user groups may reveal new and important information. For example, there is evidence to suggest that overall, fatigue and drugs or alcohol are not considered important contributors to level crossing accidents. However, it is possible that these factors may play a larger role in occurrences involving heavy vehicles, as discussed in section 5.1.3. By determining which road user groups have collisions at level crossings, and exactly when and where these occur, we may be able to identify and target potential level crossing ‘black spots’, perhaps better termed as ‘black circumstances’ (e.g. passive crossings at night-time for younger drivers) (Summala 1996).

These improvements would allow researchers to generate more accurate and detailed information on human factors implicated in Australian level crossing occurrences.

### 7.2 The ALCAM

The ALCAM is one of the main tools used to identify the risk level of each Australian level crossing, and prioritise them for upgrades. Thus, it is essential that the risk algorithm within the ALCAM is expanded to include more human factor precursors of level crossing occurrences.

Of course, to be able to do this, greater information is needed on the human factors of level crossing occurrences. Once more detailed occurrence data are collected, these should be linked to the ALCAM database, so that the interaction between crossing characteristics and human factors can be examined in relation to level crossing occurrences. In this way, the ALCAM algorithms can be based on evidence, and not just on expert opinion.

Additionally, it would be advantageous for the ALCAM to be able to predict the likelihood of specific outcomes (e.g. night-time collision, heavy vehicle collision), rather than just a collision. This information would enable countermeasures and interventions to be tailored to the specific risk that each crossing presents. By meeting the above two recommendations, this may be achievable.
7.3 Research

The current research on human behaviour at railway level crossings is limited in two important ways. First, very little research has been conducted on road user behaviour at level crossings, and on the effectiveness of potential countermeasures. Second, the scope and quality of much of this research is limited. For example, studies of road user crossing behaviour often only encompass a short time period, which means that only a limited number of violations can be assessed. Furthermore, many intervention studies only assess a short time period following countermeasure implementation, which does not allow their long-term effectiveness to be determined, and may not include appropriate ‘control’ crossings. Many studies are affected by small sample sizes — either in terms of the number of road users, or the number of crossings assessed. Finally, very little research has been conducted in the Australian context. There is an abundance of research that still needs to be conducted in this area.

There are many ways that this research could be conducted (see Edquist et al. 2009 for a review). For example, researchers could conduct observations at crossings, either by using trained observers, or crossing- or locomotive-mounted video surveillance cameras. An advantage of using trained observers is that members of high-risk user groups (either all members, or those who are seen to violate crossing controls) could be stopped after they have traversed the crossing and questioned regarding their attitudes and behaviour. However, it is time-consuming, and observers may miss important details. Surveillance cameras have the ability to collect a large amount of data that is objective, and can be re-analysed and coded numerous times by different people. However, this kind of technology is expensive, and complex computer algorithms are needed to reduce the large amount of data to a smaller amount that can then be processed by researchers. In both methods, the internal thoughts, attitudes and motivations of the road users must be inferred from their behaviour or facial expressions, and so are likely to carry some degree of error (Edquist et al. 2009).

Additionally, specific road user groups could be surveyed regarding their attitudes, knowledge, intentions and behaviour regarding level crossings. Focus groups with specific high-risk user groups, such as those conducted by QUT researchers, provide an efficient way of doing this (e.g. Davey, Ibrahim & Wallace 2005; 2006; Davey et al. 2008a; 2008b; Wallace 2008). A large number of road users can be accessed through mail or internet surveys. This type of methodology would be ideal for examining whether sensation-seeking tendencies are significantly related to level crossing violations in younger drivers, compared to the wider driving population. However, surveys of attitudes and intentions do not necessarily equate to future behaviour; for example, people may respond in a socially desirable manner, or may never engage in risky level crossing behaviour, despite showing the intention to (Edquist et al. 2009).

In contrast, computer simulator exercises are able to assess the actual behaviour of road users, be it when driving or walking. Such studies would be able to examine factors such as scanning behaviour, hazard perception, gap selection, and reaction and decision-making time of high-risk level crossing users, and how they are associated with the likelihood of being involved in a level crossing collision — either real, derived from crash statistics or self-reports, or computer-simulated. However, these results may also be subject to social desirability bias, where participants behave in the manner in which they think the experimenters are expecting. Additionally, as the consequences of ‘crashing’ on a simulator are trivial compared with level crossing collisions in reality, there may be less motivation for drivers to exercise completely safe behaviour, such as appropriate scanning. Thus, though computer simulators provide the potential to gain a great deal of information from within highly controlled conditions, it still may not be a completely valid method of assessing road user behaviour.

Crash case control studies that are more commonly used by epidemiologists may also provide important information on the human factor precursors to level crossing incidents (as an example, see Connor et al. 2002). Specifically, all victims of level crossing occurrences in a given population (e.g. Victorian drivers injured at passive crossings in the years 2012–2014) are matched with control drivers who are recruited from the same level crossing sites, and at the same time of day. These two groups (crash victims versus controls) can then be compared in an attempt to determine what precursor factors may significantly discriminate between those involved in level crossing collisions and those who weren’t.

Given that all methods have their strengths and limitations, researchers must use several methods to obtain the most detailed and valid picture of behaviour at level crossings as possible. This research must also be
multidisciplinary in nature, combining the expertise of human factor scientists, psychologists, epidemiologists, engineers, optometrists and neuroscientists, to name a few. Research generated from such partnerships will provide a more integrated and holistic view of the precursors to level crossing occurrences.

### 7.3.1 High-risk users

Greater and more detailed research is needed on the behaviour of high-risk user groups at level crossings specifically, rather than on roads in general. Currently, there is a paucity of research examining how the high-risk groups discussed here behave at level crossings. Consequently, any interventions that are based solely on evidence from road users more generally may well be unsuccessful at reducing level crossing collisions.

By taking a risk management perspective, and from examination of the Australian statistics reviewed here, we feel the first research priority is to focus on the behaviour of heavy vehicle drivers. This is because:

- the proportion of heavy vehicle accidents has increased in recent years, and heavy vehicle drivers are disproportionately represented in level crossing accidents given their proportion of all licensed road vehicles
- their accidents are associated with much higher costs
- their driving behaviour may be more easily modifiable and enforced.

One particular area that needs research is the degree to which fatigue may influence driver behaviour at level crossings. Additionally, it is important to determine how heavy vehicle drivers behave at crossings equipped with different levels of control, and if behaviour differs between drivers from transport companies that are subject to different regulatory procedures. This is not to ‘point the finger’ at particular companies, but to determine which industry-used regulations appear to be more effective at curbing risk-taking behaviour. It is also important to determine the prevalence of perceptual errors in misjudging train speed and distance in heavy vehicle drivers; given that they must decide to cross at passive crossings at great distances from approaching trains, it seems plausible that these types of collisions may be more prevalent in heavy vehicle drivers.

We consider the second research priority group to be pedestrians, given that:

- of all road users involved in level crossing accidents, pedestrians are much more likely to die
- as a result, their accidents are associated with higher costs in relation to lost productivity and medical costs
- there is evidence that pedestrian education campaigns have a higher likelihood of success.

Pedestrians have been neglected in level crossing research, perhaps partly because they represent only a small proportion of level crossing occurrences. Consequently, any research on the behaviour of this high-risk group at level crossings is sorely needed. Observational studies may determine what risky behaviours are most prevalent, and under what conditions (e.g. in groups, in rush hour). It is also important that pedestrians are questioned about their behaviour once they have crossed, as well as about their knowledge of and attitudes towards level crossings, to determine the more distal precursors of their risky behaviour. Detailed demographics should be collected to enable examination of pedestrian subgroups. Furthermore, studies could test pedestrians’ cognitive and perceptual skills in areas that are important for safely navigating level crossings, including being able to ignore distracting stimuli and inhibit dominant impulses, and accurate judgment of the speed and distance of approaching trains (either real, or computer-simulated).

Research is needed on many possible human factor precursors. However, as one particular example, there is limited, but promising evidence to suggest that road users may make fundamental perceptual errors in judging the speed of oncoming trains. Thus, much more research is needed on the Leibowitz and looming effects, as this possibility compromises the safety of all road users at passive level crossings. It is also important to determine if these effects are more pronounced among specific groups, such as older drivers (who have greater difficulty in estimating time-to-arrival) and heavy vehicle drivers (who must make crossing decisions when there is greater distance between them and the approaching train). By determining under what conditions, and for which road users, these errors are more likely, we can begin to target these circumstances for intervention. This research
should be quite feasible for Australian researchers to conduct with the appropriate computer simulation and eye-tracking equipment.

Additionally, research must examine the more distal precursors of level crossing occurrences. For example, there is evidence that young pedestrians have the worst scanning behaviour of all age groups. However, there is no evidence as to why this might be the case. Interventions that target these groups are unlikely to be successful unless we know why they do what they do.

Researchers at MUARC have recently been awarded a five-year Australian Research Council Linkage grant, part-sponsored by the Victorian Railway Crossing Safety Steering Committee, to study older drivers, which will include driver simulator research. This represents a promising opportunity to include driving behaviour at railway level crossings. It would be relatively easy to include level crossings within the simulated drives, which has already been done using the same simulator by other MUARC researchers in more general driving populations (Lenné et al. 2011; Rudin-Brown et al. 2010). The researchers could examine the ability of older drivers, relative to the general driving population, to detect and react quickly to approaching trains at passive crossings, by assessing reaction time, looking behaviour, time-to-arrival judgments, for example. This research would be the first to test the driving behaviour of older people at level crossings.

The research examining high-risk user behaviour at level crossings that was conducted by QUT researchers (Davey, Ibrahim & Wallace 2005; 2006; Davey et al. 2007; 2008b; Wallace 2008) represents a promising start in determining exactly who is high-risk at Australian level crossings, and tapping the knowledge and attitudes of these high-risk user groups. The use of focus groups was especially good for exploring emerging themes, seeing as there was little research on which to base hypotheses, and ask specific questions. Their findings provide a solid base on which to build further research using larger samples, not only to replicate their findings, but also to ask more detailed questions generated from the knowledge obtained.

As greater research is conducted, more high-risk user groups other than those discussed here are likely to emerge. Furthermore, the high-risk groups identified here need to be broken down into more homogenous subsamples, to determine exactly which level crossing users in these broad groups are at increased risk. For example, the broader road safety research suggests that not all older drivers are at increased risk of being involved in a road accident. Instead, older drivers with specific levels of decline in their UFOV are much more vulnerable, and could be targeted for interventions, such as driver training, or restricted licences. With large samples, this possibility could also be examined in relation to risk at level crossings. In this way, any countermeasures implemented are less likely to stigmatisate and penalise all people within a particular group.
8. **Conclusion**

Examination of the particular combination of human factor precursors that place certain road users at greater risk of level crossing occurrences is an incredibly important area of research, but one that has received little attention. Because of this, there is a great deal of potential for discovering more and improving the safety of these groups, and by association, all level crossing users.

This review represents only the first step to improving level crossing safety by identifying high-risk groups. At the end of this review, there is still little understanding of why the level crossing user groups identified here are at high risk of being involved in collisions. Thus, the next critical step forward is to move beyond identifying particular groups, and towards uncovering their specific risky level crossing behaviours. Further to this, we need to know why high-risk groups behave in such risky ways.

Greater research, be it in the form of field observations, focus groups and questionnaires, or driving simulation tests, for example, must be conducted with large and representative groups of heavy vehicle drivers, older drivers, younger drivers and pedestrians. Many pertinent research questions have been suggested here, but these represent only the start of the detailed enquiry that is needed.

Until we do this, we will have little success of targeting these groups, and reducing their high-risk behaviour, and likelihood of injury or death.
An investigation of risk-takers at railway level crossings

References


An investigation of risk-takers at railway level crossings

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Bureau of Infrastructure, Transport and Regional Economics. (2010). Road freight estimates and forecasts in Australia: Interstate, capital cities and rest of state (report no. 121). Canberra, Australia: Department of Infrastructure and Transport.

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Rakotonirainy, A & Steinhardt, DA. (2009). In-vehicle technology functional requirements for older drivers. Paper presented at the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Essen, Germany.


References


### Appendix 1 – Annotated bibliography

Key references that discuss human factor precursors associated with high-risk users and level crossing collisions

<table>
<thead>
<tr>
<th>Reference</th>
<th>Importance</th>
<th>What was done</th>
<th>What was found</th>
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<tr>
<td><strong>Human factors precursors relevant to level crossing accidents</strong></td>
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<tr>
<td>Clark 2010</td>
<td>***</td>
<td>Tested 10 males’ speed estimates of computer-simulated cars and trains, which varied in approach speed</td>
<td>Participants underestimated the speed of the computer-simulated trains, relative to the cars. The most pronounced effect occurred at a starting distance of 120 metres away, where the train and the car were perceived to be travelling at the same speed, when in fact the train was travelling 20 kilometres/hour faster.</td>
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<tr>
<td>Wigglesworth 2001</td>
<td>**</td>
<td>A review of Wigglesworth’s human factors level crossing research</td>
<td>Most collisions at passive level crossings occur during daylight hours. Most fatal accidents were attributable to human overload rather than a deliberate breach of regulations. Crossings located near complex intersections with much visual clutter may divert road users’ attention from level crossings. 57% of drivers showed identical head movements at both active and passive level crossings, suggesting that many drivers do not distinguish between the two types of crossings. 86% of Victorian level crossing fatalities occurred within one mile of the drivers’ home addresses.</td>
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<tr>
<td>Dommes &amp; Cavallo 2011</td>
<td>**</td>
<td>Examined the crossing decisions of 20 young (20–30 years), 21 young-old (61–71 years) and 19 old-old (72–83 years) pedestrians at a computer-simulated road, and correlated these with cognitive and visual abilities</td>
<td>The old-old pedestrians took significantly longer than the other pedestrians to cross the simulated road. Old-old pedestrians made a greater number of unsafe crossing decisions at approach speeds of ≥ 50 kilometres/hour. Processing speed visual attention and time-to-arrival estimates significantly declined with age. All of these cognitive variables significantly predicted unsafe crossing decisions, and considerably reduced the independent effect of age.</td>
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<tr>
<td>Arnold et al. 1997</td>
<td>**</td>
<td>Surveyed 638 Australian heavy vehicle drivers in states that were not subject to driving hours regulations</td>
<td>38% of drivers reported exceeding 14 hours of driving in a 24-hour period; 20% reported getting less than six hours sleep prior to their last journey; and 14% reported nodding off at least occasionally while driving.</td>
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<td>Borowsky, Shinar &amp; Oron-Gilad 2010</td>
<td>**</td>
<td>Tested the hazard perception skills of 21 young-inexperienced (17–18 years), 19 experienced (22–30 years),</td>
<td>Driving experience had little effect on the detection of actual hazards (e.g. a lead car braking suddenly). Instead, the inexperienced drivers were less likely to detect potential hazards (e.g. following too close to a lead car).</td>
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</table>
An investigation of risk-takers at railway level crossings

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<th>Study</th>
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<tr>
<td>Hatfield &amp; Fernandes 2009</td>
<td>Surveyed 89 young (16–25 years) and 110 more experienced (35+ years) drivers outside of NSW motor registries, regarding their driving attitudes, motivations and behaviour. Compared with the older drivers, younger drivers underestimated their risk of driving accidents. Additionally, they reported being less likely to avoid risk in general and experiencing greater enjoyment from risky driving behaviours. Younger drivers tended to focus on the positive rather than negative consequences of these risky behaviours, such as 'blowing off steam', getting to a destination quicker, and thrill-seeking. They also considered these behaviours as more accepted by their peers. Finally, the younger drivers reported a greater likelihood of engaging in such risky behaviours again in future.</td>
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<tr>
<td>Horswill et al. 2009</td>
<td>Studied the hazard perception latencies of 22 mid-aged (35–55 years), 34 young-old (65–74 years), and 23 old-old drivers (75–84 years) in response to road traffic videos, and in relation to UFOV, contrast sensitivity and reaction time. The hazard perception latencies of the old-old drivers were significantly longer than those of the other drivers. Furthermore, these hazard detection age differences were mediated by drivers' visual abilities of contrast sensitivity and peripheral vision.</td>
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<tr>
<td>Staplin 1995</td>
<td>Conducted field and simulator trials of gap selection in front of oncoming vehicles with 79 drivers aged 20 to 91 years. The 24 older drivers (55–71 years) had slower reaction times than younger drivers. As the speed of the approaching vehicle increased from 48 to 96 kilometres an hour, the older drivers chose shorter gaps, whereas the gap judgments of younger drivers remained more or less the same.</td>
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<td>Lee et al. 2003</td>
<td>Tested the cognitive abilities of 129 older Australian drivers (60+ years) using a driving simulator, and correlated results with self-reported retrospective crash history. The cognitive abilities of working memory and decision-making under time pressure, and confidence in high-speed driving, were significantly associated with the drivers’ self-reported crashes that had occurred within the past year.</td>
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<td>Barton &amp; Morrongiello 2011</td>
<td>Assessed the executive function skills and crossing behaviour, next to an actual road, of 83 child pedestrians (6–9 years). Age and executive function skills (i.e. selective attention, working memory, and behavioural monitoring and inhibition) were positively associated with increased scanning behaviour of approaching traffic before initiating crossing of a suburban road. The effect of age was no longer significant once these executive function skills were controlled for.</td>
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**High-risk user groups in relation to level crossings specifically**

<table>
<thead>
<tr>
<th>Authors</th>
<th>Methodology</th>
<th>Findings</th>
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<tr>
<td>Davey, Ibrahim &amp; Wallace 2005; 2006; Davey et al. 2007; 2008a; 2008b</td>
<td>Conducted focus groups with three key high-risk level crossing user groups: older drivers ($n = 43$); younger drivers ($n = 53$); and heavy vehicle drivers ($n = 26$)</td>
<td>Train drivers considered heavy vehicle drivers to show the greatest amount of risky behaviour at level crossings. They also felt that younger drivers regularly engage in high-risk behaviours at level crossings. Train drivers and heavy vehicle drivers considered that factors relating to heavy vehicle size and speed jeopardised their safety at level crossings. Both of these groups considered that some heavy vehicle drivers engaged in wilful risk-taking behaviour. Younger drivers often had poor knowledge of level crossing rules, and a low perception of risk or consequence for violating controls.</td>
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<td>Lloyd’s Register Rail 2007</td>
<td>Interviewed 216 pedestrians at seven Melbourne level crossings, and identified high-risk groups at pedestrian crossings from an analysis of existing literature, and Victorian coroner reports</td>
<td>Identified school children and youth, the elderly, and people with mobility issues as high-risk users. <strong>Survey results:</strong> 31% of pedestrians reported crossing the tracks when they knew a train was approaching. 16% reported they would at least sometimes cross at level crossings after one train had passed, but controls were still activated. 40% of the males surveyed reported they would at least sometimes cross at pedestrian crossings when lights, bells or gates were activated, but no train was visible, compared with 12% of females. The rate of both violations and incidents at Victorian crossings was found to be much higher during the morning ‘rush hour’. The most common reason given for violating level crossing controls was being in a hurry. 18% of pedestrians reported they had become unintentionally caught on the tracks when a train was approaching.</td>
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<td>McPherson &amp; Daff 2005</td>
<td>Observed the scanning behaviour of 208 pedestrians at a Melbourne level crossing. The age-brackets that pedestrians belonged to were estimated by observers</td>
<td>Pedestrians in a group were observed to scan for trains less often than when they were by themselves. Pedestrians in the 12–17 year age group showed the worst scanning behaviour, where only just over half looked in both directions, and 11% did not look at all. The 18–30 year old group showed the second-worst level of scanning behaviour; only 60% looked both ways along the tracks, and 5% did not look at all.</td>
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<tr>
<td>Author</td>
<td>Importance</td>
<td>Summary</td>
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<tr>
<td>Han et al. 2010</td>
<td>***</td>
<td>Reviewed literature on safety of heavy vehicles at level crossings, including a recent field study of acceleration/deceleration capabilities of Australian heavy vehicles (Trevorrow 2009)</td>
</tr>
<tr>
<td>Staplin 2001</td>
<td>**</td>
<td>Reviewed older driver functional declines, and applied these to driving behaviour at level crossings</td>
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</table>

*Note.* *** = essential to read; ** = quite important; * = not essential.
Appendix 2 – Potential countermeasures

Discussion of potential countermeasures for high-risk users of level crossings has been deliberately relegated to the appendix section. This is because much more research must be conducted on why certain high-risk groups (e.g. young pedestrians) violate level crossing controls before specific countermeasures that address their risky behaviours may be proposed. Additionally, at a more general level, numerous reports and articles are available that review several potential level crossing countermeasures in great detail (e.g. Caird et al. 2002; Cairney 2003; Cairney, Gunatillake & Wigglesworth 2002; Coleman & Venkataraman 2001; Edquist et al. 2009; Fambro et al. 1995; FRA 2008; Larue, Soole & Rakotonirainy 2010; Parliament of Victoria 2008; Rudin-Brown et al. 2010; STAYSAFE Committee 2004; Wallace, McCusker & Hirsch 2008; Yeh & Multer 2008).

Instead, the following discussion highlights only a small selection of countermeasures that may have particular relevance to the high-risk user groups identified in this review. Many of these countermeasures have little evidence regarding their effectiveness, mostly because they have not been properly evaluated. In fact, there is limited or mixed evidence regarding the effectiveness of most countermeasures at Australian level crossings (see Edquist et al. 2009 for a more detailed discussion). Thus, these countermeasures are not presented here as necessarily having a high likelihood of success, but only as options that warrant further research and evaluation.

Before discussing specific countermeasures, it is important to consider level crossing safety from a risk management perspective. The primary goal of risk management is to completely eliminate the risk by removing it (Hopkin 2010). In the case of level crossing accidents, this would involve grade separation (i.e. installing under/overpasses) or crossing closure. However, the former option is very costly, and the latter is unlikely to be possible for all crossings.

If elimination of the risk is unable to be achieved, then the risk must instead be minimised using the most effective options available within the risk management ‘hierarchy of control’, such as restricting access, engineering safety devices or warning systems, and administrative controls (e.g. procedures, education) (Hopkin 2010). Given that passive crossings are inherently more risky, as they provide no indication of an approaching train, a third effective option would be to upgrade passive crossings to active control. Most Australian jurisdictions are undergoing a continual process of upgrading passive crossings to active control, with the highest risk crossings (according to various risk indices including ALCAM, as discussed in section 3) prioritised for upgrades. However, it is too expensive to upgrade all Australian passive level crossings in this manner (Cairney 2003; Cairney, Gunatillake & Wigglesworth 2002; Parliament of Victoria 2008).

While the best available control countermeasures should be implemented when possible, such as upgrades to active controls, it may be quicker, cheaper and easier to implement lower order control measures in the meantime (Hopkin 2010). Thus, in relation to level crossing safety, it is also important to consider low-cost warning devices. Although low-cost treatments may significantly reduce accidents, they are unable to completely prevent them, and may not be ‘fail-safe’. But there is a compelling argument for providing some level of control at a greater number of crossings, rather than complete control at fewer crossings.

Furthermore, active controls are not fool-proof, and will never be able to prevent all level crossing accidents. Specifically, users that deliberately choose to violate level crossing controls find ways around active controls, such as driving or walking around boom barriers, jumping over locking pedestrian barriers, and illegally accessing the pedestrian emergency escape gates. Therefore, such higher order active control countermeasures must be used in conjunction with other lower order countermeasures, such as education and enforcement.

Short of closure or grade separation, no combination of countermeasures can be completely effective at preventing level crossing accidents. Level crossing accidents generally result from the combination of a number of different factors occurring at a particular point in time, and these particular circumstances can never be entirely predicted or controlled for. Two sad examples are the recent deaths of a family in a vehicle at a Victorian crossing that had just been upgraded with rumble strips one month prior (ABC News 2008; Ross 2008; Wigglesworth
According to media reports, the driver reported not to have seen the warning signs or noticed going over the rumble strips, and did not notice the approaching train until his wife yelled out. Although speculative, and not able to be confirmed until the impending coronial inquest, perhaps other factors such as fatigue, internal distractions and visibility may have limited the effectiveness of the rumble strips. Additionally, a pedestrian fatality recently occurred in 2010 at the Bentleigh crossing in Victoria, after it had been upgraded with ‘second train coming’ signs, and locking gates following the death of a pedestrian there in 2004 (Carey 2011; Harris 2011). According to police accounts, the elderly female pedestrian ignored the fully operational active warning signs in order to catch an approaching train, and walked into the path of a second train approaching from the opposite direction.

Increasing the conspicuousness of crossings and trains

Improving the ability of the road user to detect both level crossings and approaching trains at passive crossings may especially benefit older road users with limited perceptual abilities. Several reports are dedicated to improving the conspicuousness of trains and infrastructure at passive crossings, and their specific findings will not be repeated here (interested readers are referred to Cairney 2003; Cairney, Gunatillake & Wigglesworth 2002; Lerner et al. 2002). Some methods of improving the contrast, and so detectability, of crossings and trains include increased crossing lighting, and additional retro-reflective material (which reflects the light from a vehicle’s headlights back at the road user) on both train carriages and crossings. There is evidence that the addition of street lights reduces night-time accidents at passive crossings, even when controlling for traffic volume (Walker & Roberts 1975, as cited in Caird et al. 2002). Although Australian standards require level crossing signs to be reflectorised, not all crossings have been upgraded to meet these (Edquist et al. 2009). Reflectorising crossings and trains is relatively low-cost to install, but the retro-reflective material must be especially carefully maintained on train carriages, as dirt accumulates quickly, rendering them much less effective (Caird et al. 2002; Edquist et al. 2009; Yeh & Multer 2008).

Several studies have also examined train lighting, and found little evidence to recommend increasing the train lighting beyond what is already provided on Australian trains, especially as they do little to improve conspicuousness during daylight hours (Cairney 2003; Cairney, Gunatillake & Wigglesworth 2002). According to the 2007 Australian Standard, trains are already required to have powerful ditch and train-mounted lights, so increasing lighting would probably do little to improve conspicuousness (Australasian Railway Association 2009; Standards Australia 2007b). As an additional source of lighting, Wigglesworth (2007) advocated for the use of flashing or rotating lights to be trialled as potential countermeasures for increasing train conspicuousness in his submission to the Victorian inquiry into level crossing safety (Parliament of Victoria 2008). However, several committees have recommended against beacons being fitted, and concluded that given the limited evidence available, more trials of increased train lighting are needed (Parliament of Victoria 2008; STAYSAFE Committee 2004).

However, train conspicuousness and detectability have not been tested for specific high-risk groups, such as older drivers. Thus, it is not known whether increased lighting would increase train conspicuousness for this road user group.

Additionally, a countermeasure that may circumvent the visual deficits of older drivers is rumble strips, or tactile strips fixed to the road surface that provide kinaesthetic and auditory stimuli to the road user as they are driven over. Rumble strips are designed to call a distracted road user’s attention to the presence of a level crossing. Rumble strips may also be useful for alerting fatigued drivers. However, the limited evidence available on the effectiveness of rumble strips is mixed. As discussed by Raslear (1996), if drivers do not understand the meaning of the stimuli, the rumble strips may actually distract the road user’s attention from the direction of the crossing. Some studies have shown that rumble strips are associated with a reduction in collisions at road intersections, but are limited by extremely small sample sizes and problematic methodologies (Harwood 1993, as cited in Wallace, McCusker & Hirsch 2008). Additionally, there is evidence that rumble strips at level crossings reduce the approach speeds of drivers (Radalj & Kidd 2006; Yeh & Multer 2008). However, although this was taken as evidence that the rumble strips prompted an increase in drivers’ alertness, it was not known whether the drivers were actually
alerted to the level crossing specifically, and thus undertook greater scanning behaviour. Additionally, for rumble strips that are only installed on the crossing approach sides of two-lane roads, there is evidence that drivers will engage in unsafe behaviour to actively avoid them by swerving into the oncoming traffic lane (Wallace, McCusker & Hirsch 2008; Yeh & Multer 2008). Wigglesworth (2008b) specifically advocated for the use of active (pneumatic) rumble strips that only inflate when a train is approaching. The evaluation of rumbles strips at Australian level crossings is ongoing in several states, including Victoria and Western Australia (Victorian Government Department of Transport 2011).

**Alerting road users to approaching trains**

Arguably, the most important task for level crossing users is determining when a train is approaching. For this reason, passive crossings are inherently more risky, as the onus is on the road user to detect an approaching train, and to then decide whether it is safe to cross (Edquist et al. 2009; Wigglesworth 2008b). A number of warning devices represent promising approaches to this problem, and are currently being trialled in Australia (Larue et al. 2010; Wullems, in press).

For example, intelligent transport systems (ITS) technologies transfer information between trains, road vehicles and crossing infrastructure regarding the presence of approaching trains. ITS technologies may be particularly useful at crossings where visibility is an issue. They may also be especially useful for heavy vehicle drivers, not only because they are especially vulnerable at crossings with limited visibility due to their slow acceleration and deceleration times, but also because their cabs are more likely to be equipped with the technology needed to receive this information. As one example, Vic Roads, along with industry partners, is currently trialling ‘radio break-in’ technology that involves transmitters that are fitted to level crossing infrastructure. When a train approaches, the device emits a radio signal that can ‘break in’ to road vehicle radios within a certain vicinity of the crossing, and warn them of the approaching train (Larue et al. 2010; Victorian Government Department of Transport 2011). The Victorian Department of Transport, together with La Trobe University, QUT and others, has won a grant from the AutoCRC on a three-stage project investigating vehicle-to-vehicle and vehicle-to-infrastructure dedicated short range communication ITS. This project is valued at almost $5 million, which includes a 100 vehicle trial of the technology in 2012 (Spicer 2010).

An important warning device for pedestrian crossings is the ‘second train coming’ active warning sign, which flashes to alert pedestrians to the presence of a second train approaching on another track. Several versions of these signs have shown significant reductions in illegal pedestrian crossing behaviours in several US studies, including bypassing lowered gates, and attempting to cross between the first and second trains (see Yeh & Multer 2008). They have also been installed and trialled at several crossings in Victoria and South Australia (Daff et al. 2007). However, these signs are not being adopted at other crossings, given that cost–benefit analyses showed that this treatment would not produce savings within the 30-year period estimated (Dickinson et al. 2010). Instead, the authors of this analysis suggested that these signs may be more beneficial to adopt at crossings that are undergoing other upgrades, as the extra infrastructure costs may then be reduced.

**Improving the ability to judge time-to-arrival**

It stands to reason that if all road users tend to underestimate an approaching train’s speed, and therefore underestimate its time of arrival, then interventions are sorely needed that improve their ability to make safe crossings decisions. Interventions that improve people’s ability to judge train speed may be particularly helpful for older drivers and pedestrians, given their ability to overestimate vehicle arrival time at high speeds, and also perhaps heavy vehicle drivers, who must make the decision to cross while the train is still some distance away, and appears to be moving slowly.

Recently, Mumbai’s Central Railway, together with Final Mile Consulting, implemented and evaluated an intervention designed to counter the Leibowitz and looming effects at a Mumbai railway station that averaged one track death or injury per day, mostly due to trespassing (Dominic 2011; Subramanian 2011). Researchers painted sets of several adjacent railway sleepers yellow, at regular intervals. Thus, the rate at which the yellow
sleepers disappeared under the approaching train allowed people at the tracks to make a more accurate judgment of the train’s speed. In the year following the intervention, the number of deaths at this crossing decreased by 75%. These interventions have since been trialled simultaneously at seven other Mumbai stations, with similar degrees of success. However, as the researchers also simultaneously implemented two other countermeasures (placing graphic photos by the tracks, and changing the timing and pattern of train horns), it cannot be determined how much of this decrease in deaths was due to the yellow sleepers. Additionally, it is unclear whether this intervention would have such great success in the Australian context, where there are significantly fewer rail accidents, and most occur at level crossings rather than as a result of trespassing. Nonetheless, this countermeasure represents a promising and innovative approach to improving people’s ability to judge train speed, and is worthy of further research and evaluation.

It may even be possible to counter a perceptual illusion with another illusion — rather than making road users’ decisions more accurate, interventions may instead make them overly cautious, by making the road user perceive the train is approaching faster than is actually the case. This might be achieved by spacing the painted sleepers successively closer and closer together, to give the illusion that the train is speeding up. As an alternative for vehicle drivers who are not afforded as close a view of the tracks as pedestrians, perhaps painted poles or other similar stimuli could be spaced along the track approach. Some rumble strips are designed in this manner, so that even when travelling at constant speed, road users feel as if they are speeding up, and hopefully slow down as a result. Leibowitz (1985) proposed that the perceptual illusions responsible for level crossing occurrences could be used as interventions, but to our knowledge, this possibility has not been tested.

Physically preventing access to level crossings

The half boom barriers that are currently used as active controls in Australia can still be driven around by impatient or sensation-seeking drivers. However, several devices can physically prevent drivers from entering the crossing: four-quadrant gates, extended arm gates and vehicle-arresting barriers block the approach and departure lanes to the crossing, and median and centreline barriers installed along the roadway centreline prevent drivers from crossing lanes to manoeuvre around gates. These devices effectively seal off the level crossing to road users, making them almost impossible to circumvent. Additionally, the development of obstacle detection technology may make it possible for approaching trains to be alerted and even halted if drivers become trapped on the tracks after gates have descended (Khoudour et al. 2009; Larue et al. 2010).

Several US studies have demonstrated the effectiveness of these devices at preventing crossing violations (Coleman, Eck & Russell 2000; Coleman & Venkataraman 2001; Heathington, Fambro & Richards 1989; Hellman, Carroll & Chappell 2007; Khattak 2007; Ko et al. 2007; Saccomano, Park & Fu 2007; US Department of Transportation 2001). For example, initial trials of these devices at one North Carolina crossing found that four-quadrant gates alone reduced crossing violations by 86%, median barriers alone reduced violations by 77%, and when these controls were used in combination, violations reduced by 98% (US Department of Transportation 2001). Additionally, use of longer gate arms at one crossing reduced crossing violations by 84% one year after installation.

The results of these studies seem promising. However, several of these studies were limited by methodological issues: the majority studied only a small number of crossings, some using only single sites, no control sites were used, and many used only a short-term follow-up period. Additionally, it is not known how Australian drivers would respond to these controls. Median barriers are currently used in Australia, and four-quadrant gates are installed at selected crossings in NSW and Qld, but there is no research to suggest the effectiveness of these devices in the Australian context.

Upgrading crossings to this level of control is costly, and they are installed in very few sites internationally for this reason (Caird et al. 2002; Cooper & Ragland 2009). Thus, these types of countermeasures may be better suited for high-volume crossings controlled by two-quadrant gates that have a high rate of violations. These devices are also a cheaper alternative to grade separation, and so could possibly be used in instances where this is being
considered (Coleman et al. 2000). Due to the large proportion of accidents that they prevent, cost–benefit analyses demonstrate that they deliver a considerable economic return (US Department of Transportation 2001).

Recently, the emergency gates at two busy Victorian pedestrian crossings were upgraded to further prevent pedestrians from illegally accessing crossings when trains are approaching. The emergency gates close when trains approach, and can be released from the track side to provide an emergency exit for people caught on the tracks. However, these gates were easy to unlock from the wrong side by reaching over the fence, meaning pedestrians could and did open these gates illegally to gain access to the crossing. Mechanical and electromagnetic emergency escape gate latches were installed at Bentleigh and Yarraville stations, respectively, which made it more difficult for people to open the emergency gate from the wrong side. The installation of both gate latches resulted in a significant decrease in pedestrian crossing violations. More specifically, CCTV analysis of over 5000 pedestrians at the Yarraville site showed that gate violations significantly reduced from 30 at pre-installation, to one at post-installation (Dickinson et al. 2010). However, the time period of the post-installation assessment was not specified, so it is not known whether these results represent long-term change. Despite such promising results, cost–benefit analyses showed that the gates do not produce savings within the 30-year period specified by VicTrack, and so there is not a compelling reason for installing them at other sites (Dickinson et al. 2010). However, the latches may possibly prove cost-effective at sites that are already undergoing upgrades, rather than as than when used as a stand-alone upgrade.

Restricting access to crossings

Given that some passive level crossings with limited sight distances are not safe for use by heavy vehicles, all jurisdictions have enforced some form of heavy vehicle restricted access. For example, in Victoria, Queensland, South Australia and Western Australia, road and rail authorities have established permits that certain heavy vehicles (such as B-doubles, or vehicles longer than 26 metres) must obtain before they may traverse crossings, and gazetted routes on which they are allowed to travel (Han et al. 2010).

Preventing queuing and short-stacking

Yellow box markings — yellow grid lines painted across level crossing tracks — were designed to prevent queuing across crossings. These markings have been trialled at crossings in South Australia, Victoria and Western Australia with high incidences of queuing, usually at locations with controlled road intersections nearby, and relatedly, active crossing controls. There is some limited evidence from before and after trials to suggest that the yellow box markings have reduced the incidence of drivers queuing on the crossings, which initially had a high number of queuing vehicles pre-intervention (CPG Australia 2009; Traffix Group 2010). Although these initial reports are promising, greater research is needed to determine the effectiveness of these markings.

Education

Given that many drivers may lack knowledge of the dangers posed by level crossings, and of associated rules and regulations, all of the high-risk user groups discussed here could benefit from greater information on these issues. However, such information has already been offered within state-wide and national advertising campaigns, with limited success (Parliament of Victoria 2008; Wallace, McCusker & Hirsch 2008). More success has been found among targeted education campaigns aimed at pedestrians at level crossings (Lobb, Harré & Suddendorf 2001; Lobb et al. 2003; Sposato, Bien-Aime & Chaudhary 2006). To our knowledge, no Australian advertising campaigns have been conducted that raise awareness of perceptual errors, including the Leibowitz and looming effects. The US-founded Operation Lifesaver has included information regarding these illusions into their written educational material (Biederman 2003; Operation Lifesaver 2011b), but no reports have been found that document its evaluation. Simple but effective computer simulations of these effects (for a good example, see National Transportation Safety Board 1998a), along with information describing these errors, may be worth trialling in Australia.
Additionally, more specific education campaigns that are tailored to particular road users, and that teach safer behaviour, may be more promising options (Wallace 2008). For example, older drivers and pedestrians could be made more aware of their age-related limitations, and trained to self-regulate their driving and crossing behaviour. Such interventions have shown reasonable success for older drivers more generally (Owsley, Stalvey & Phillips 2003). Education programs targeted towards younger drivers could train them to scan level crossings and train tracks, and better recognise the hazard that approaching trains pose.

**Enforcement**

Enforcement of the safe behaviour of all road users at level crossings could be achieved with the use of surveillance cameras. Akin to the red-light camera technology currently used at many road intersections, cameras are activated at the same time as the active crossing control devices. Drivers in violation of controls can then be issued with fines or demerit points. Enforcement cameras have been very effective at reducing level crossing violations and collisions in the US: a meta-analysis of three studies estimated that enforcement cameras reduced collisions by 75%, and were the most effective of the 18 countermeasures studied, short of grade separation (Park 2007; Saccomano et al. 2007).

However, it becomes difficult to determine exactly what constitutes an offence; the ‘dilemma zone’, or the point immediately following signal activation where drivers are unable to stop safely and so must continue through the crossing, must be fully defined for the level crossing context. Such cameras are currently being trialled and introduced in Australia, including Victoria and Queensland (Department of Transport and Main Roads 2009; Victorian Government Department of Transport 2011).

Additionally, there are several options for enforcing safe driving behaviour among heavy vehicle drivers specifically, which are centred on fatigue management and curbing deliberate violations like not stopping or slowing at passive level crossings, and driving around gates at active crossings.

First, there is the potential for enforcement for heavy vehicle drivers to come from within the road transport industry. A ‘best-practice’ transport company has systems in place to ensure that rosters allocate appropriate work and rest hours, employees are subject to regular medical checks and random drug and alcohol testing, sufficient accommodation is provided for overnight rest stops, and GPS navigation systems are installed within cabs, for example. Companies that do this have greater accountability over heavy vehicle driver behaviour, including their driving log book records (Department of Transport and Main Roads 2009). Companies that put these systems in place can then be accredited under national Heavy Vehicle Accredited Scheme. Apart from the obvious incentive to transport companies of a lower crash risk, they may also receive lower insurance rates as a result. However, at the time of the Rungoo investigation, it was noted that many road transport companies were not accredited under this scheme (Department of Transport and Main Roads 2009). Perhaps legislating mandatory accreditation of road transport companies would lead to greater accountability, and safer heavy vehicle driver behaviour subsequently.

The Ban Ban Springs case study provides an excellent example of road transport company enforcement of heavy vehicle driver behaviour at level crossings specifically (ARRB Group 2008; Cairney 2008). Following the heavy vehicle level crossing accident at this site in 2006, the driver’s mining company implemented a rule whereby all drivers had to stop their vehicles at the crossing for at least three seconds before proceeding. This was enforced by security guard monitoring, and the need to alight from the cab and sign a book located at the crossing. Non-compliant drivers were subject to instant dismissal, or were sent off site if they were contractors. This was a very effective strategy; over a period of three months, non-compliance dropped dramatically from about 30% to virtually zero (ARRB Group 2008; Cairney 2008). Similar procedures could be put in place by other road transport companies, or even government regulators.

Other enforcement options for heavy vehicle drivers include camera monitoring, and GPS satellite navigation (Department of Transport and Main Roads 2009). Several states currently use ‘Safe T Cams’ that are located on designated heavy vehicle routes, and record the front number plates of heavy vehicles. This information is used to
detect violations of speed limits and driving hours, and since implementation, has reportedly resulted in reductions in violations (Department of Transport and Main Roads 2009). Also, in-vehicle satellite navigation monitoring GPS has been trialled and implemented in some jurisdictions (Department of Transport and Main Roads 2009). The in-vehicle units monitor the vehicle’s position in time, speed and self-declaration of information. Any violations detected by the system can be sent directly to the relevant road authority. However, this system is currently optional, and not all heavy vehicles are fitted with them (Department of Transport and Main Roads 2009). As a GPS map of all Australian level crossing locations exists, this could be used with GPS tracking equipment to examine violations at level crossings specifically. However, this has not yet been done.

Recommendations

All promising countermeasures need much more thorough research and evaluation to determine their effectiveness at improving scanning behaviour, reducing speed, complying with crossing controls, and improving level crossing safety generally. Researchers should strive to include a number of crossings in their evaluations, including matched control crossings that are not treated with the particular countermeasure. It may perhaps be more advantageous to initially study crossings that are known to have a high level of violations; although findings generated from these crossings may not generalise to all Australian level crossings, the greater number of initial violations will allow a greater ‘sample size’, and thus greater statistical power with which to detect any significant effects. Furthermore, it may be the case that certain countermeasures are more appropriate for use at ‘black spot’ crossings. Longer pre- and post-intervention crossing observation periods will also provide a greater ‘sample size’ of potential occurrences, and will provide a better understanding of the longer term effectiveness of these measures. As with all countermeasure research, very little high-quality research has been conducted in the Australian context. Such research is essential for developing countermeasures that are effective at reducing level crossing violations.

However, there are several particularly important areas of countermeasure research, including further research into perceptual interventions that lessen the Leibowitz and looming effects, further trials and development of various ITS technologies that are able to alert road users to the presence of an approaching train at passive crossings, and enforcement technologies for use within the road transport industry, including GPS monitoring, fatigue countermeasures and enforcement cameras. There is also potential for the ‘second train coming’ warning signs to be trialled in other jurisdictions. These represent only some of the many promising areas of countermeasure research.