Crossing, vehicle and environmental characteristics influence on crash likelihood in Australia and New Zealand

Simon Meiers, Hai Guo and Michael Levasseur

GHD, Transport for NSW, Australian Road Research Board Group

SUMMARY

In order to better understand level crossing risk in Australia and New Zealand 10 years of state road crash data, railway incident data and crossing survey data have been compiled and linked. This has provided the basis for conducting analyses of key crash causation factors, the results of which included a series of findings pertaining to the impact of crossing, vehicle and environmental characteristics on crash likelihood.

Road crash data revealed many factors relating to crash likelihood of trains and road vehicles at crossings were also similarly represented in road vehicle crashes near crossings and in general. In only a few areas did factors for crashes between trains and road vehicles at crossings show different patterns to road vehicle crashes in the proximity to level crossings crashes, and road vehicle crashes in general.

An investigation was performed on how road and rail traffic influences crash likelihood, and how existing models perform in this respect. Results showed that some established formulations performed well, but less support was found for others.

Analyses also investigated how surveyed characteristics of crossings influence crash likelihood. For the inventory of surveyed crossings thirty three characteristics have been measured in a consistent manner. Linking crash data to the inventory revealed which characteristics drive crash likelihood. In some cases the expected relationship between a particular crossing characteristic, for example the presence of queuing, did correlate to higher crash likelihoods. Some counter-intuitive results, however, were also found.

INTRODUCTION

Australia has around 8,000 public level crossings of which 22% are protected by flashing light controls and 17% have half booms [1]. There are an even greater number of private crossings of which a lower proportion have active controls. Consequently collisions between road vehicles and trains at level crossings remain one of the biggest safety risks for rail operations in Australia, accounting for about 67% of rail related fatalities when suicides and trespassers are removed. Some of these fatalities are related to high consequence accidents involving heavy vehicles which have occurred in recent years.

In the wake of these accidents the demand for better information on factors that influence crash risk at crossings led the peak Australasian crossing safety policy group to conduct a project assembling all available inventory and crash data from rail authorities, road authorities and rail safety regulators. Data was collected from 16 agencies over seven Australian states and territories and New Zealand, producing a collection of more than 9,000 crossings.

This data was analysed for factors influencing crash likelihood.

ROAD CRASH, RAIL COLLISION AND RAIL INVENTORY DATA

Data Sources and Integration

As Australia is a federation of states and territories and transport services are largely provided by state governments road and rail crash data is collected on a state by state basis. New Zealand also works closely with Australian transport authorities and often participates in research projects such as this one. Therefore in order to create combined Australian/New Zealand road and rail crash dataset, data was collected from rail regulators in seven Australian states and territories plus Kiwirail as well as road crash data from road authorities in seven states and territories and the New Zealand road authority. Level crossing survey and management data was also collected from transport authorities in the five largest Australian states plus Kiwirail. This meant interfacing with 20 different organisations.

Data for the period 2000 to 2009 was sourced from these organisations.

The projects objectives was to integrate the different forms of level crossing data so that all available data could be used for analysis. In order to achieve this links between the various datasets was necessary, namely:

- A link between rail regulator crash data and road authority crash data;
- A link between rail regulator crash data and crossing survey and management data; and
- A link between road authority crash data and crossing survey and management data.

This was largely facilitated by use of a common identifier for each crossing.

Where a road authority records was found to match a rail regulator record of a crash between a train and road vehicle at a level crossing, such data is referred to as a “matched level crossing crash record”. In total, it was possible to match more than 600 road crash records with the rail data based on the information obtained.

Another objective was to compare crashes between road vehicles and trains at level crossings to road vehicle crashes in general, to provide a comparison set of data. General road crash data from the eight Australian and New Zealand road authorities was sourced, as well as a subset of road vehicle crashes (not with trains) in a “zone of influence” about the crossing, that is within the sighting distance of the crossing on the road approaches.

The size of the dataset is presented as Table 1 and Datasets and linkages collated for the study are illustrated as Figure 1.

Table 1 Data used in crash analysis

Data set	Records included	Locations included	Number of records	Years included	State / country included
Rail regulator level crossing crashes	Vehicle–train crashes only	Level crossing crash locations	899	2000–2009	NSW, NZ, QLD, SA, VIC , NT, Tas and WA
Matched train/road vehicle crashes	Vehicle–train crashes only	Level crossing crash locations	602	2000–2009	NSW, NZ, QLD, SA, VIC and WA
Road crashes in area of influence of level crossings	All types of road crashes	Crashes within area of influence of level crossings	2 963	2000–2009	SA, VIC and WA
Five state road crash data	All types of road crashes	All crash locations	594 994	2004–2008	NSW, QLD, SA, VIC and WA
Level crossing inventory (LXM) data	All available records	All level crossing locations	12 237	–	NSW, SA, VIC, WA and NZ

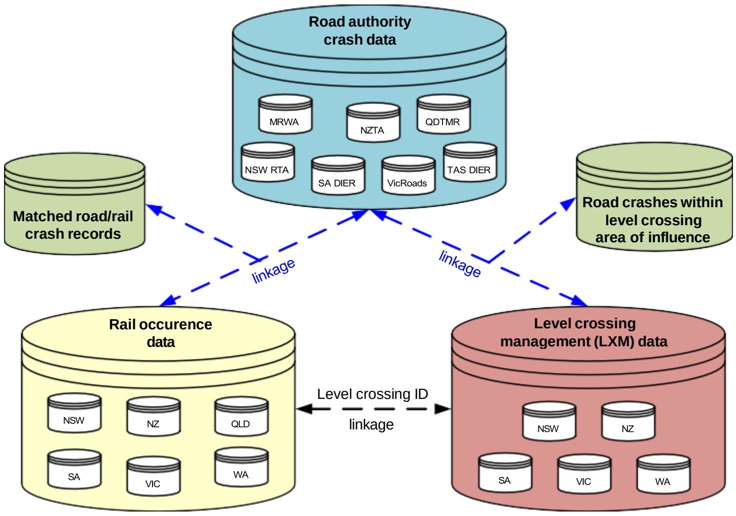


Figure 1 Data Sets and Linkages

Nature of common road crash data parameters

For many road crash data parameters collected in Australia, road authorities categorise parameters differently. Therefore, a process of creating consistent data parameters across all authorities was required. Some authorities use a coarser definition for crash parameters. For example, most road authorities provided a classification of articulated and rigid heavy vehicles. However, for New Zealand data, it was only possible to distinguish a heavy vehicle from other types of vehicles. Additionally, not all road authorities collect certain types of data. For example, vertical curvature is not collected by New South Wales or Victoria. For some crash records, there were also gaps in the data available for some of the crash factors.

Table 2 lists the road crash database fields that were included for analysis. The road authorities for which the data was obtained and the number and proportion of the total records obtained are also noted.

Table 2 Road crash fields included in analysis

Road crash field	Jurisdictions from which crash fields were obtained	Matched records containing road crash field	
		Number of records	Proportion of matched records
Posted speed limit	All	590	98%
Horizontal alignment	All	585	97%
Vertical alignment	QLD, SA and WA	142	24%
Road surface type	All	427	71%
Road surface condition	All	582	97%
Weather	All	582	97%
Lighting	All	599	99%
Traffic control	All	531	88%
Vehicle type	All	552	92%
Driver age	All except NZ	275	46%
Driver sex	All except NZ	273	45%
Type of driver licence	All except NZ	247	41%
Alcohol involved	All except NZ	187	31%
Speeding involved	All except NZ and VIC	154	26%
Fatigue involved	All except NZ and VIC	142	24%
Driver post code	NSW, SA and VIC	117	19%
Crash severity	All	598	99%

COMPARISON OF FACTORS IN LEVEL CROSSING CRASHES WITH ROAD CRASHES

Method

Using the rail and road level crossing crashes which were matched and linked, crash analysis was conducted to investigate the key crash causation factors related to road characteristics and vehicle and occupant details.

Two types of analysis were performed:

- a comparison of matched train/road vehicle crashes with other types of road crashes to determine the similarities or differences between key crash causation factors
- a comparison of matched train/road vehicle crashes with level crossing inventory (LXM) data to identify whether any crash causation factors were over-represented in the level crossing crash data.

Not all of the road crash attributes readily correlated with an attribute of the crossing inventory data. Therefore, the latter comparison (i.e. matched train/road vehicle crashes and inventory data) was not possible for all of the road crash factors identified.

Findings

In general there was found to be only a few differences between the prevalence of road crash data factors (Table 2) for crashes between trains and road vehicles and crashes between road vehicles. Crashes between trains and road vehicles at crossings compared with road vehicle crashes in the zone of influence of level crossings and road crashes in general had similar patterns for factors such as:

- Crashes by time of day
- Horizontal and Vertical road alignment
- Weather and light conditions
- Road surface condition (dry, wet ice etc)
- Alcohol and Fatigue

The areas where train/road vehicle crashes were significantly different to road vehicle crashes near crossings or road crashes in general were:

- Severity of crashes at level crossings much higher than road crashes
- Heavy vehicles were more common at level crossing crashes than for other types of road crashes (17.6% of level crossing crashes versus 7.1% of other road crashes)
- Both train/road vehicle and road vehicle crashes are predominately on sealed roads, but a higher proportion of train/road vehicle crashes occurred on unsealed roads with train/road vehicle crashes at (11.2%) compared with the other types of road vehicle crashes (2.3% to 2.5%).
- Crashes were over-represented at passive crossings where posted speed limits were 80 km/h or greater
- Level crossing crashes were more common among drivers aged 60 or greater than for other types of road crashes

Severity of crashes

Figure 1compares the crash severity found in the three crash data sets (i.e. train/road vehicle crashes, crashes in a level crossing area of influence and crashes from the five state road crash data). Crashes at level crossings were of greater severity when compared with the other crash types. This is most dramatically shown for fatal crashes which represented 16.1% of the matched train/road vehicle crashes, but only 1.1% and 0.9% of the level crossing area of influence and five state road crash data respectively.

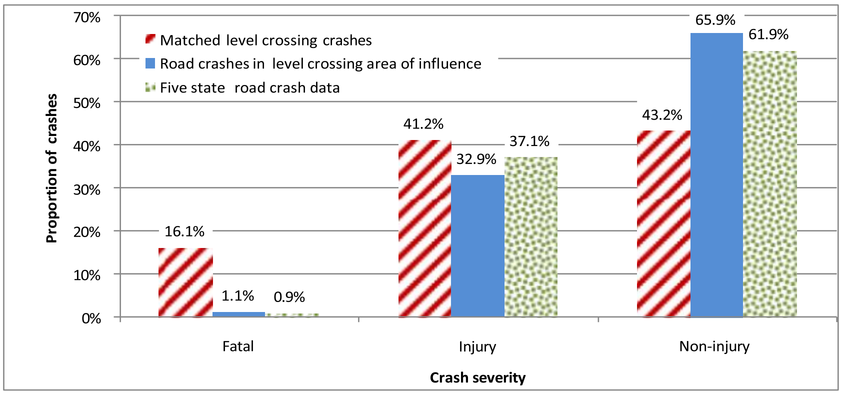


Figure 2 Proportion of crashes by severity

Type and condition of road surface

Figure 3 shows the proportion of crashes compared with the type of road surface. In general, all types of crashes occurred more frequently on sealed surfaces. Unsealed road crashes were more common for the matched train/road vehicle crashes (11.2%) compared with the other types of crashes (2.3% to 2.5%).

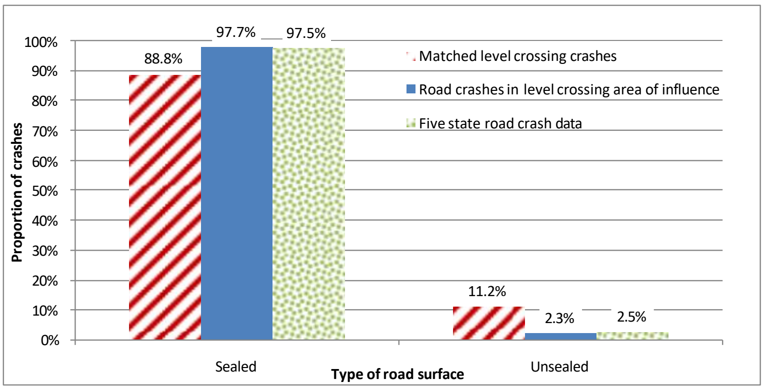


Figure 3 Proportion of crashes by type of road surface

Posted speed limit

For passive level crossings (Figure 4), matched train/road vehicle crashes most commonly occur at posted speeds of more than 80 km/h (24.4%), compared with 12.7% of crossings in the Inventory data. This suggests that for level crossings with passive protection, crashes at speed limits of more than 80 km/h were over-represented.

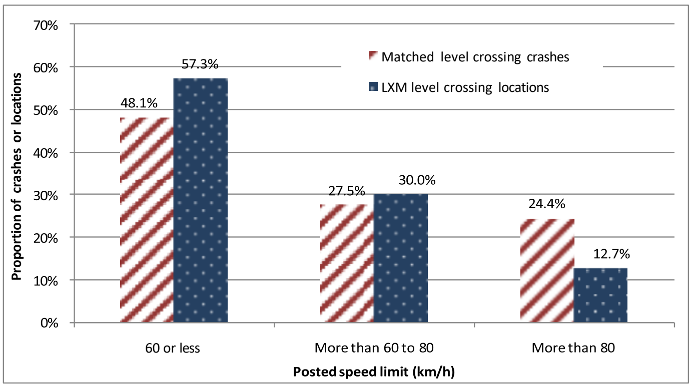


Figure 4 Posted speed for matched crashes and surveyed crossing (LXM) locations (passive protected crossings)

Road vehicle type

Crash data relating to the type of vehicles involved was available for the matched train/road vehicle crashes.

The matched train/road vehicle crashes were compared with the five state road crash data. Crashes involving light passenger vehicles were the most common among both crash data sets, representing the greatest proportion for the matched train/road vehicle crashes (72.83%) and the five state road crash data (85.2%). However, a lower proportion of light passenger vehicle crashes were found at the matched train/road vehicle crashes when compared against the five state data.

Data was available for articulated and rigid heavy vehicles. Both were more common for the matched train/road vehicle crashes. Crashes involving rigid heavy vehicles at level crossings were more than twice as common as those for all types of road crashes (12.0% versus 5.6%).

Articulated heavy vehicles made up a slightly smaller proportion of matched train/road vehicle crashes than rigid heavy vehicles (5.6% versus 12.0%). However, the proportion of articulated heavy vehicles in the matched train/road vehicle crashes was substantially larger (5.6%) than the proportion for the five state road crash data (1.5%).

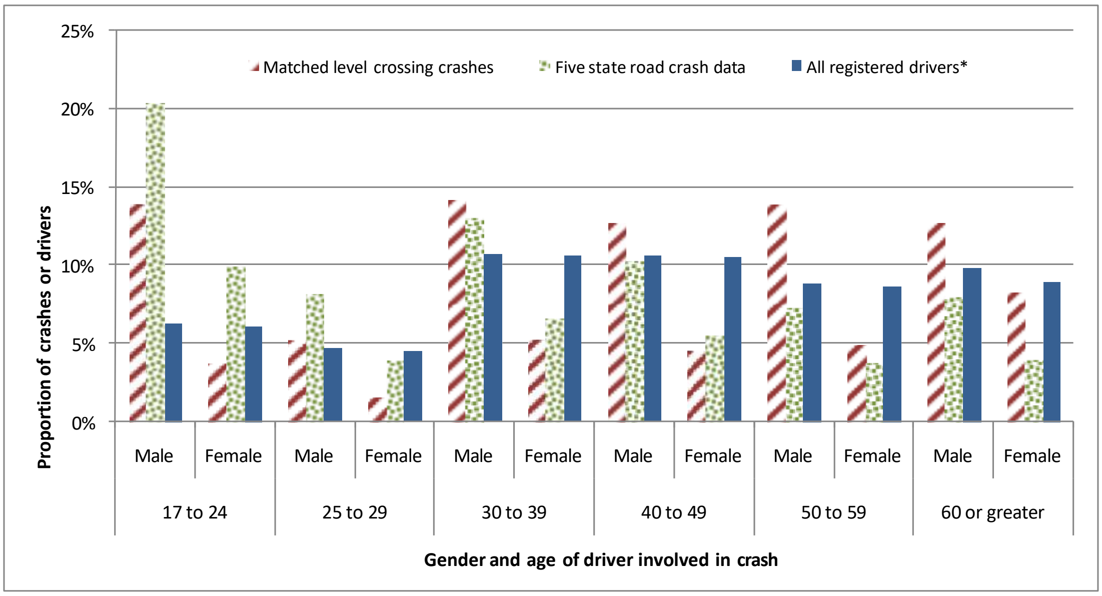
Drivers

Gender and age of drivers

Figure 5 compares the gender and age of drivers at the matched train/road vehicle crashes against all types of road crashes. Registered driver data from the Austroads RoadFacts 2005 report [2] is included in the comparison. Young male drivers (i.e. aged 17 to 24) were over-represented in level crossing crashes. This was supported by both the matched crash (13.5%) and the five state (20.3%) data sets.

Comparing the matched level crossing data with that for other types of road crashes, less crashes involving young male drivers were found in the matched level crossings (13.8%) compared with the five state road crash data (20.3%). However, males in the 50 to 59 and 60 or older age groups represented greater proportions of the matched train/road vehicle crashes when compared with the five state road crash data.

Female drivers aged 60 or older represented the greatest proportion of matched train/road vehicle crashes (8.2%) for any female age groups. This was similar to the proportion of all registered female drivers making up this age group, but was more than twice as large as the proportion of crashes for the five state crash data (3.9%).



Source: *All registered drivers from Austroads [2]

Figure 5 Gender and age of drivers versus all registered drivers

ROAD AND RAIL TRAFFIC RELATIONSHIP TO CRASH LIKELIHOOD

An analysis was performed to determine how Australian level crossing crash data compared with formulations of road and rail traffic for predicting crash likelihood. Four different formulations were investigated:

- Basic product of trains per day and road vehicles per day
- Stott relationship [3,4]
- U.S. Department of Transportation Accident Prediction Model (base model) [5]
- The Peabody Dimmick formulation used for many years in the US [5]

The analysis was performed by forming broad categories of road and rail traffic and determining the number of crashes per crossing year for the categories (total crashes divided by total years in service). This produced a historical crash rate for each crossing group and made allowance for crossings with different service lives in the 10 year period of analysis, such as when a crossing is upgraded. Then each of the formulations for predicting crash likelihood was used to determine a predicted number of crashes for each category for the years in service of the crossings. As the predictions over-predict they were adjusted by dividing by a constant so that the sum of predicted crashes in each category came to the total actual number of crashes. The adjusted predicted crashes were then divided by the total years in service to produce a predicted crash rate per crossing year, allowing a direct comparison with the historical crash rate for each of the categories.

The results of the analysis are displayed as Figure 6. The results show very good correlations between the US DOT and Peabody Dimmick models (when adjusted to match the actual total number of collisions) and the actual crash rate for the categories of road and rail traffic for crossings with booms, flashing lights and stop signs but less of a match for give way signs. The performance of both the Peabody Dimmick formulation and the US DOT was very similar with both showing close correlation with the actual crash rates. The close correlation between the US models and Australian data suggests an underlying consistency in level crossing crash likelihood between countries.

The prediction based on the basic product of the road and rail traffic does not perform well, with it clearly under-predicting at low levels of rail traffic and over-predicting at high levels. This suggests it is not suitable for forming the basis of a crash prediction model. The Stott has theoretical basis is that at high traffic levels the traffic forms a barrier to prevent errant motorists entering the crossing and so reducing the probability of crashes. The actual crash rates doesn't show this lower crash rate at high road traffic levels.

The method produced two useful outcomes, the ability to compare the performance of crash prediction models and the results forming a coarse model in itself, eg for a combination of road and rail traffic a crash rate can be determined.

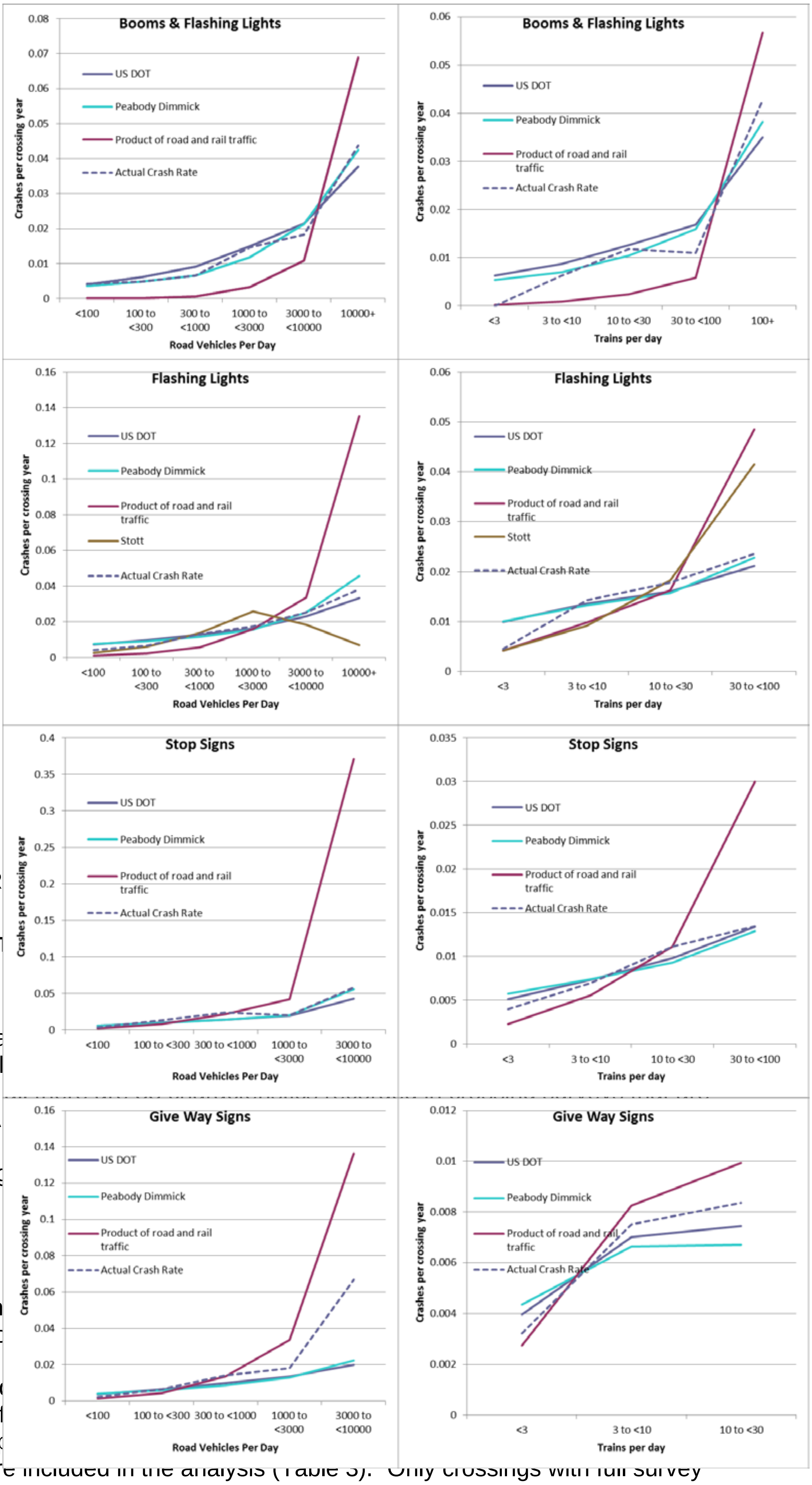


Figure 6 Historical Crash R

CROSSING CHARACTERIST

Introduction

Level crossings in Australia
requirements of the Austral
be related to crash risk. In
then available to the ALCA
Australia surveyed against
influence of the 33 crossing

Method

To explore the relationship
conducted to determine wh
the categories used for eac

For the analyses conducted
compared against the risk f
considered each control typ
In total 4875 crossings were included in the analysis (Table 3). Only crossings with full survey data could be used

Table 3 Crossings included in the analysis

Control type	Crossings with no crashes	Crossings where crashes occurred	Total crossings analysed
Boom gates	709	164	873
Flashing lights only	1091	151	1242
Stop signs	1318	70	1388
Give way signs	1311	61	1372
All control types	4429	446	4875

The analysis assessed the impact of locations where the control type changed during the ten-year analysis period. This was conducted by assigning a crossing location to the analysis for multiple control types representing the years in which a crossing was operating under each control type.

Due to the challenges associated with the non-numeric categories of the data available for most of the Characteristics, non-parametric tests were chosen to conduct statistical analysis. The Mann-Whitney and Kruskal-Wallace tests were used as part of the analysis. A literature review identified that similar analysis was conducted by Raub [6] in order to investigate the relationship between crashes and crossing characteristics.

The Mann-Whitney test was used to analyse crossing characteristics which had two categorisations (e.g. yes or no), whilst the Kruskal-Wallace test was applied to characteristics with more than two categorisations. A two-tailed probability was used to determine statistical significance based on a 95% confidence level. Additionally a logistic regression was performed with the 33 categories plus road and rail traffic as explanatory variables and crashes as the dependent variable. This was to explore how characteristics affected crash risk in combination.

Results

Results of the analysis is shown as Table 4. The table lists each of the 33 crossing characteristics and what change to the characteristic is expected to produce an increase in crash likelihood, derived from the studies literature review.

The results are shown as light and dark green and light and dark orange. Dark green is where both the Mann-Whitney/Kruskal-Wallace category comparisons and the logistic regression supported the expected relationship of the characteristics influence on crash likelihood with statistical significance. The light green results were where only the Mann-Whitney/Kruskal-Wallace category comparisons supported the expected relationship. Dark orange is where both the Mann-Whitney/Kruskal-Wallace category comparisons and the logistic regression did not support the expected relationship of the characteristics influence on crash likelihood with statistical significance. The light orange results were where the Mann-Whitney/Kruskal-Wallace category comparisons only did not support the expected relationship.

The analysis shows three key themes, one that a number of the characteristics did have the expected influence on crash likelihood, two that a number of characteristics appear to have no discernible influence on crash risk, and three that a few characteristics have the opposite influence on crash risk to what is expected.

Table 4: Crossing Characteristics Captured with ALCAM Survey

No	Crossing Characteristic	Expected change to increase crash risk	Boom	Lights	Stop	Give Way
1	Effectiveness of equipment inspection and maintenance	less effective			(light green)	
2	Longest approach warning time	shorter	(light green)			
3	Proximity to intersection/control point	closer	(light green)	(light green)		

No	Crossing Characteristic	Expected change to increase crash risk	Boom	Lights	Stop	Give Way
4	Proximity to siding/shunting yard	closer				
5	Proximity to station	closer				
6	Possibility of short stacking	increasing				
7	Number of lanes (highest number of lanes in any one approach)	increasing				
9	Presence of adjacent distractions	increasing				
10	Condition of traffic control at Crossing	worse condition				
11	Visibility of Traffic Control at Crossing	less visibility				
12	Distance from advance warning to crossing	increased distance				
13	Conformance with standard AS 1742.7	less compliant				
14	Heavy vehicle proportion	greater proportion				
15	Level of Service (Vehicle Congestion)	increased congestion				
16	Queuing from adjacent intersections	increased queuing				
17	Road traffic speed (approach speed 85%ile)	increasing speed				
18	Train volume - two way (high is bad)	increasingly high 2 way traffic				
19	Train volume - two way (low is bad)	decreasingly lower 2 way traffic				
20	Seasonal/infrequent train patterns	less frequent				
21	Slowest train speed at crossing (typical)	slower train speed				
22	Longest train length (typical)	longer				
23	High Train Speed	faster				
24	Number of operational rail tracks	more tracks				
25	Road surface on immediate approach/departure (not Xing panel)	decreasing condition				
27	S1 - advance visibility of crossing from road	increasing sighting distance				
28	S2 - approach visibility to train (vehicle approaching crossing)	Increasing sighting distance				
29	S3 - visibility to train (vehicle stopped at crossing)	Increasing sighting distance				
30	Possible sun glare sighting crossing on road approach	Glare an issue				
31	Possible sun glare sighting train	Glare an issue				
32	Temporary visual impediments - sighting of crossing	Increasing impediments				
33	Temporary visual impediments - sighting of train	Increasing impediments				

Key

- Mann-Whitney/Kruskal-Wallace category comparisons and the logistic regression support expected relationship to crash risk
- Mann-Whitney/Kruskal-Wallace category comparisons only support expected relationship to crash risk
- Mann-Whitney/Kruskal-Wallace category comparisons and the logistic regression did not support expected relationship to crash risk
- Mann-Whitney/Kruskal-Wallace category comparisons only did not support expected relationship to crash risk

Characteristics that showed no statistical correlation with crashes for all four crossing control types were "Proximity to siding/shunting yard", "Proximity to station", "Condition of traffic control at

Crossing", "Conformance with standard AS 1742.7" and "Number of operational rail tracks". The number of operational rail tracks did, however, have a positive correlation with crashes in the logistical regression, for Booms, Lights and Stop Signs.

Characteristics that showed the opposite relationship to crashes than expected were "Seasonal/infrequent train patterns", "Longest train length (typical)" for boom crossings, "Road surface on immediate approach/departure (not Xing panel)" for flashing light and stop sign crossings, "S1 - advance visibility of crossing from road" for boom crossings, as well as possible sun glare sighting crossing control or train and temporary visual impediments for boom crossings. Of note is how many of the opposite correlations were for boom crossings – perhaps indicating a different dynamic to crashes than the other "open" control types.

The negative correlation for both the Mann-Whitney/Kruskal-Wallace category comparisons and the logistic regression for road surface on immediate approach/departure for both flashing light crossings and stop sign crossings is interesting. A possible explanation is that the road surface is acting like speed humps and causing the motorist to slow down.

For the positive correlations an interesting result is how for heavy vehicles both the Mann-Whitney/Kruskal-Wallace category comparisons and the logistic regression showed the expected correlation with crashes for both passive types of crossings (stop sign and give way). This and the finding looking at crash data factors showing high proportions of heavy vehicles involved in crashes at level crossings suggests that large vehicles have some difficulties crossing passive crossings safely. Queuing, short stacking, distance of advance warning to crossing and adjacent distractions also provided positive correlations, particularly for boom crossings.

The information gained from the analysis has allowed improvements to the ALCAM model to be made, where it has been able to be de-weighted in areas where no correlation or negative correlation have been observed. In this was the model has become a hybrid of engineering judgement and statistics.

CONCLUSIONS

The compilation of road crash data, rail incident data and level crossing survey data has produced a rich dataset that through analysis has provided some insights to the level crossing problem in Australia.

An investigation of crash factors for train/road vehicle crashes compared to road vehicle crashes in the "zone of influence" of level crossings and road crashes in general showed that in general the patterns are very similar, but some differences were apparent for train/road vehicle crashes. These differences were with factors such as severity, heavy vehicle involvement, road seal, speed limit for passive crossings and driver ages.

Analysis investigated how road and rail traffic influence crash likelihood, and how existing models perform in this respect. Results showed that some established formulations used in the US performed well, but the product of train and road traffic performed poorly.

The dataset of surveyed crossing characteristics proved useful for determining which characteristics influence crash risk. The analysis found that some surveyed characteristics had the expected influence on crash risk, but others had no discernible influence or had the reverse effect to what was expected.

The challenge now in Australia and NZ is to keep the process of compiling and analysing data from all the various data sets going on a regular basis and to form better links between datasets. The data gathered during level crossing surveys is very detailed, and has proven to be very useful for analysis. The links between crash data and crossing survey data needs to be maintained and analysed periodically, in order to maintain the validity of models such as ALCAM, but also inform level crossing safety strategy development.

REFERENCES

[1] Railway Safety Regulators' Panel, Review of National Level Crossing Statistics, September 2008,

[2] Austroads 2005, Roadfacts 2005, An overview of the Australian and New Zealand road systems, AP-G18/05, Austroads, Sydney, NSW.

[3] Stott, PF, 'Automatic Open Level Crossings A Review of Safety', paper to the Department of Transport, 1987

[4] Heavisides, J & Barker, Dr J 2008, 'Impact of traffic flow on level crossing risk', *World Level Crossing Symposium, 10th, Paris, France*

[5] Railroad-Highway Grade Crossing Handbook - Revised Second Edition August 2007

[6] Raub, RA 2006, 'Examination of highway-rail grade crossing collisions over 10 years in seven midwestern states', ITE Journal, April 2006, pp. 16-26.

APPENDIX 1:

APPROVAL TO PUBLISH PAPER

I/We ....

of Company (if applicable) ....

hereby give permission to the Global Level Crossing and Trespass Symposium 2012 (GLXS 2012) to publish the paper titled:

Insert Title ....

To be presented at the GLXS 2012 conference to be held at the Pullman London St Pancras Hotel, London, England on 8 - 10 October 2012.

In the following media (tick as appropriate):

□ Copied to memory stick for distribution to conference delegates

□ Publish on the GLXS 2012 website

Signed: ....

Date: ....

Please return this form when submitting the final version of the paper.