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Australasian Centre for Rail Innovation

REVIEW REPORT

FREIGHT TRAIN VISIBILITY

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Freight Train Visibility Review

Final Report

Australasian Centre for Rail Innovation

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Craig Skicko

Originator : .... **Date:** 31.01.2022

Craig Skicko
Senior Consultant
Craig.Skicko@atkinsglobal.com

Checked By : .... **Date:** 31.01.2022

Alan Braithwaite
Technical Services Lead (Victoria)
Alan.Braithwaite@atkinsglobal.com

Approved By : .... **Date:** 31.01.2022

James Claxton
Director, Rail Director, Rail
James.Claxton@atkinsglobal.com

Distribution : **Paul Murray, Ryan Williams, Robert Moffat**
ACRI

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Definitions and Abbreviations

Term	Definition
Active Level Crossing	A level crossing with infrastructure controls that react to the presence of a train on approach (such as those fitted with lights and boom barriers)
ACRI	Australasian Centre for Rail Innovation
ALCAM	Australian Level Crossing Assessment Model
ARA	Australian Railway Association
ATSB	Australian Transport Safety Bureau
Conspicuity	The ability to attract attention or be noticeable
FORG	Freight On Rail Group
Freight Consist	The full freight train, consisting of both locomotives and wagons
Freight Locomotive	Powered rolling stock locomotive used to haul freight wagons
Lighting	In the context of this report, lighting refers to lights fitted to the exterior of the vehicle, unless specified otherwise
ONRSR	Office of the National Rail Safety Regulator
Passive Level Crossing	A level crossing with controls that do not react to the presence of a train (such as those fitted with only stop signs or give way signs)
RISSB	Rail Industry Safety and Standards Board

Executive Summary

Level crossing safety is contributed to by various factors including rail vehicle conspicuity, road and rail alignment, infrastructure controls, surrounding environmental conditions, weather (and other visibility impairing factors), and road user behaviour.

Level crossing safety is holistically being assessed within Australia, with a number of initiatives currently ongoing to improve the level of safety being achieved, such as upgrades to level crossing protection, and level crossing removals (e.g. grade separations).

Currently, the number of passive level crossings in Australia greatly outweighs the number of operating freight locomotives. Therefore, should there be opportunity to improve level crossing safety through enhancements to rolling stock technology, changes in design or educational initiatives and campaigns, safety benefits may be achievable ahead of future level crossing infrastructure upgrades throughout the network. However, this is contingent on proposed rolling stock controls being proven effective and feasible for implementation.

Previous research conducted by the Australasian Centre for Rail Innovation (ACRI) has identified that **level crossing safety may be improved if steps are made to make freight vehicles more conspicuous** (LC13 - Better Stimulus Around Level Crossing Control - Initial Project), i.e. more noticeable to road users and pedestrians.

SNC-Lavalin has worked with ACRI, the Office of the National Rail Safety Regulator (ONRSR), Freight On Rail Group (FORG), Australian Railway Association (ARA), Rail Industry Safety and Standards Board (RISSB) and TrackSAFE to identify potential opportunities that may improve freight vehicle conspicuity and driver awareness when interacting with passive level crossings.

The assessment has been limited to freight vehicle mounted systems and educational initiatives for road users.

To understand the potential opportunities available and to develop informed conclusions on control efficacy, SNC-Lavalin has conducted literature reviews of publicly available documentation, stakeholder engagement workshops, reviews of Australian standards and data analysis of previous collisions and near-misses.

SNC-Lavalin has also conducted a comparative study with international documentation to determine where Australian best practices differ from those adopted overseas and identify potential improvement areas.

Of particular note is the contribution of daylight collisions to the overall statistics.

As reported in the 2009 update to the Train Illumination Report, **daytime collisions contribute between 75% and 94% of all collisions**, depending on the data source. This can be considered largely attributable to the higher traffic levels experienced during daytime operation.

A number of Australian Standards exist to support a range of rail issues, including AS7531 – Lighting and Visibility. Although standards are not legally mandated, under the Rail Safety National Law all rail operators have to demonstrate that they are managing risks to safety so far as is reasonably practicable (SFAIRP). The adoption of a relevant standard is often the means of being able to demonstrate this SFAIRP requirement.

There is a clear downward trend in night time collisions since the introduction of AS 7531 - Lighting and Visibility, however **daylight collision levels have seen negligible change.**

In assessing previous research papers and the controls mandated by AS 7531, reasonable assumptions regarding the cause for daylight collision levels remaining stagnant can be formed.

Previous research papers highlight that **conspicuity improvements gained through the use of white lights are limited for daylight operation**. Suggestions are made to use coloured lighting, such as coloured strobes.

Currently, the majority of controls implemented on freight rolling stock operating in Australia use white lights only. Daytime specific controls that are adopted are currently limited to the use of high visibility paint on the front of the locomotive.

Other **limitations** currently exist:

- Where road and rail alignments cross at an acute angle, the ability for the reflective delineators to return light to its source is significantly reduced, therefore impeding the road user’s ability to detect the presence of the freight locomotive or wagons.
- The variable environment that a rail vehicle operates in means that there is no single optimum colour to achieve adequate contrast with its surroundings, meaning that the efficacy of high visibility paint is

limited. This is further compromised when dirt and oil, for example, accumulates on the vehicle exterior, covering the high visibility colours and blending the vehicle into its surroundings.

SNC-Lavalin has considered the key causes of level crossing incidents while assessing potential controls. These include:

- Failure to drive according to the conditions, such as driving too fast in wet weather
- Driver fatigue
- Driver over familiarity with the level crossing location and the resulting habituation that this incurs
- Driver distraction
- Sight lines and visibility of the rail corridor and/or level crossing
- Operational aspects of heavy road vehicles use and a reluctance to fully stop at a crossing to view the rail corridor
- Driver impairment, such as drug or alcohol consumption

SNC-Lavalin and the wider stakeholder group has successfully **identified and assessed thirty controls** that may improve vehicle conspicuity. These are categorised as follows:

- Immediate Opportunities (**15**)
- Medium-Term Opportunities (**11**)
- Long-Term Opportunities (**2**)
- Other (**2**)

Sixteen controls were identified throughout the course of the project that were deemed out of scope. As the team involved in developing the list of controls were not qualified infrastructure SMEs, more detailed assessment of these controls was not appropriate. It is recommended, as per section 10, that controls falling outside the scope of this assessment are explored by suitably qualified personnel to ensure that level crossing safety is assessed holistically.

It should be noted that the categorisation pertains only to the perceived timeframe of implementation and does not guarantee control efficacy. The speed of implementation may also be subject to specific train configurations for certain opportunities (i.e. some vehicles may have spare capacity in components such as conduits and junction boxes, whereas others may not).

The freight train visibility review project findings have been extensively and collaboratively analysed by the various stakeholder rail industry bodies whom commissioned this work. Several near to medium term trial opportunities and next steps are now being considered by many of the FORG member organisations.

1. Introduction

1.1. Project Background

Level crossing safety is contributed to by various factors including rail vehicle conspicuity (i.e. how easily the train can be identified by a road user or pedestrian), road and rail alignment, infrastructure controls, surrounding environmental conditions, weather (and other visibility impairing factors), and road user behaviour.

A number of initiatives are currently ongoing to improve the level of safety being achieved, such as upgrades to level crossing protection, and level crossing removals (e.g. grade separations).

Currently, the number of passive level crossings in Australia, being 16,563 at the time of writing, greatly outweighs the number of operating freight locomotives. Therefore, should adaptations to the train be effective in improving level crossing safety, safety benefits may be achievable prior to implementing any additional infrastructure controls throughout the network. It is expected that these safety improvements will be most noticeable in areas where infrastructure controls are limited, such as regional locations.

This project focuses on the potential opportunities that may improve rail freight vehicle conspicuity and road user awareness, associated with upgrades to train systems, introducing new technology or adapting current educational programs. It should be noted that the project has aimed only to identify those opportunities that should be explored further and appropriate assessments to determine control efficacy are recommended to be completed prior to implementation.

The focus on freight vehicles taken throughout this project is further supported by the frequent operation of freight rail through regional locations, where the majority of level crossings include passive protection only.

The Australasian Centre for Rail Innovation (ACRI) has engaged SNC-Lavalin to conduct research into freight train conspicuity to determine:

- The current freight train conspicuity and educational controls adopted in Australia.
- Challenges and issues currently encountered at passive level crossings in Australia.
- International approaches to improving vehicle conspicuity in the rail industry, that could be locally adopted.
- Approaches to improving conspicuity within other industries, that could be implemented on freight vehicles.
- New and emerging technology that may benefit conspicuity.

The scope of this assessment is described in further detail in Section 1.2 below.

1.2. Project Scope

The following objectives were established at project inception and agreed with ACRI:

- Establish a baseline understanding of train conspicuity solutions in Australia by conducting a review of Australian train visibility standards, data and statistics on level crossing incidents, existing locomotive and wagon conspicuity technology and current education and training.
- Conduct a literature review to investigate previous local and international level crossing projects, train conspicuity projects, and conspicuity solutions in other industries, such as emergency services.
- Engage with international resources to understand best practice mitigation measures and new and emerging technological solutions adopted or considered overseas.
- Prepare and conduct stakeholder workshops and review data to reflect on and evaluate the effectiveness of current risk management strategies, such as locomotive and wagon conspicuity technology, education, and human factors.
- Provide an overview of solution feasibility and recommendations regarding immediate-, medium- and long-term opportunities.

In line with these objectives, SNC-Lavalin has conducted literature reviews, engaged with stakeholders, and utilised its digital platforms to engage international resources.

This has allowed for an understanding of the current Australian freight conspicuity approach to be established and potential improvement opportunities identified. The assessment has considered new and emerging technology and approaches adopted overseas and within other industries.

The assessment has been limited to freight vehicles. Consideration has been given to both day and night operation, and the array of environmental and weather conditions that may be experienced across Australia throughout each year.

SNC-Lavalin has gathered evidence and data, as allowed within the project programme, to identify potential solutions and provide informed conclusions and recommendations associated with each.

It should be noted that additional research, whether previously conducted or ongoing at the time of writing, may provide further insight into conspicuity initiatives or challenges, and assessment of other research papers should not be discounted based on the provision of this document.

1.3. Assumptions

The following assumptions have been made:

- The collision and near miss data provided by ONRSR is the best available as of 18 October 2021 and provides collision and near miss data that is suitably accurate to form conclusions on current incident trends experienced across the network from 2014 onwards (see section 5 for further details).
- Unless stated otherwise, previous tests and trials that have informed the referenced research papers have been performed in a manner which reasonably represents a working rail level crossing environment.
- As reported in the 2009 update to the Train Illumination Report [6], freight locomotives operating in Australia are largely compliant with the current version of AS 7531, and **non-compliance** with AS 7531 is not a key contributor to level crossing collisions occurring in the past year.
- Due to COVID-19 pandemic, the frequency of freight locomotives is expected to have decreased in 2020 due to complications surrounding importing goods and shortages of freight containers. This assumption is driven by articles such as ABC News – 'What is the great shipping container shortage, and could it ruin your Christmas?' (https://www.abc.net.au/news/2021-10-29/what-is-the-great-shipping-container-shortage-covid-christmas/100550198). It is also expected that road traffic levels were reduced due to state lockdowns and "stay at home" awareness campaigns. Any conclusions surrounding collision and near-miss data have taken this into account.

1.4. Exclusions

The following items identify exclusions from the project scope:

- Passenger and track maintenance vehicles have only been considered where they present additional conspicuity controls that are not yet adopted for freight locomotives. No recommendations for passenger or track maintenance conspicuity enhancements have been made.
- Focus has not been given to level crossings with active protection, however it is expected that conspicuity improvements that are effective at passive level crossings will produce similar advantages at locations where active controls are present.
- Testing of current or potential controls has not been conducted as part of the assessment. Any determination of efficacy is based upon engineering judgement and conclusions provided in previous research papers, and therefore may not be supported by quantitative analysis.
- Solutions identified throughout the project that are associated with rail infrastructure amendments or reconfiguration are considered out of scope and have not been fully assessed.
- Consideration of effectiveness of conspicuity on behaviour change only relates to increasing the ability to notice and respond to train and does not consider other behavioural issues which may result from early detection of the train such as attempting to beat the train or the complacency which can occur from regular interactions with trains.

1.5. Reference Documents

The documentation listed in the table below has been reviewed and has informed that conclusions provided in this report.

Table 1-1 - Reference Documents

Ref.	Document Number	Document Title
1	AS 7531, 2015	Lighting and Visibility
2	AS 7658, 2020	Level Crossings – Rail Industry Requirements
3	EN 15153-1, 2020	Railway Applications – External Visible and Audible Warning Devices Part 1: Head, Marker, and Tail Lamps for Heavy Rail
4	EN 15153-2, 2020	Railway Applications - External Visible and Audible Warning Devices Part 2: Warning Horns for Heavy Rail
5	GM/RT 2131, 2015	Audibility and Visibility of Trains
6	Nil	House of Representatives Standing Committee on Infrastructure, Transport, Regional Development and Local Government Level Crossing Safety: an Update to the 2004 Train Illumination Report
7	CR 217, 2003	Prospects for improving the conspicuity of trains at passive railway crossings
8	AP-R208, 2002	Reducing collisions at passive railway level crossings in Australia
9	49 CFR Part 224, 2010	Code of Federal regulations (US) – Retro-reflectorization of Rail Freight Rolling Stock
10	T HR RS 00890 ST v1.0, 2014	RSU Appendix 1 - Reflective delineators
11	LC13	Better Stimulus Around Level Crossing Control - Initial Project
12	LC13B	Better Stimuli for Level Crossing Control
13	LC11B	Retro-reflective Screens: Evaluating retro-reflective screens to aid conspicuity of tabletop carriages at passive level crossings
14	Nil	Motorist Behaviour at Railway Level Crossings: The Present Context in Australia, Angela Wallace, 2008
15	DOT/FRA/ORD-95/13	Use of Auxiliary External Alerting Devices to Improve Locomotive Conspicuity, U.S. Department of Transportation, 1995 (Caroll et al.)
16	RO-2016-009	Level Crossing Collision Between Truck and Passenger Train 8753, 2016
17	2006/014	Collision Between Rigid Tipper Truck/Tri-Axle Trailer and The Overland Passenger Train, 4AM8, Wingeel, Victoria
18	Nil	Wertheim, Alexander. (2010). Visual conspicuity: A new simple standard, its reliability, validity and applicability. Ergonomics
19	Nil	Wickens, C. D. (1980). The structure of attentional resources In: Nickerson R. S. (Ed.), Attention & Performance,
20	Nil	Hypoxia and Dark Adaptation in Diabetic Retinopathy: Interactions, Consequences, and Therapy - Scientific Figure on ResearchGate.
21	Nil	Hole, Graham & Tyrrell, Lisa & Langham, Martin. (2007). Some factors affecting motorcyclists' conspicuity. Ergonomics.
22	Nil	Hsiao, H., Chang, J., & Simeonov, P. (2018). Preventing Emergency Vehicle Crashes: Status and Challenges of Human Factors Issues. Human Factors
23	Nil	Rossion, B., & Pourtois, G. (2001). Revisiting Snodgrass and Vanderwart's object database: Color and texture improve object recognition.

24	Nil	S. Poret, R. D. Dony and S. Gregori, "Image processing for colour blindness correction," 2009 IEEE Toronto International Conference Science and Technology for Humanity (TIC-STH), 2009
25	Nil	Rigden, C. (1999). 'The Eye of the Beholder'-Designing for Colour-Blind Users. British Telecommunications Engineering
26	Nil	Jenny, B., & Kelso, N. V. (2007). Designing maps for the colour-vision impaired. Bulletin of the Society of Cartographers
27	Nil	Jefferson, L., & Harvey, R. (2006, October). Accommodating color blind computer users.
28	Nil	Lidestam, B., et al. (2020). In-Car Warnings of Emergency Vehicles Approaching: Effects on Car Drivers' Propensity to Give Way. Frontiers in Sustainable Cities
29	Nil	Pinto, M., Cavallo, V., & Saint-Pierre, G. (2014). Influence of front light configuration on the visual conspicuity of motorcycles. Accident; analysis and prevention
30	Nil	Blackman, R., & Haworth, N. (2012). Desktop Review of Conspicuity Markings for Heavy Vehicles. The Centre of Accident Research and Road Safety – Queensland
31	Nil	Devney, J. (2011). Changing Perceptions of the Bus with Branded Services.\
32	Nil	Scott-Samuel NE, Baddeley R, Palmer CE, Cuthill IC (2011) Dazzle Camouflage Affects Speed Perception.
33	Nil	Abdur, R., Kato Teppei, K., & Hisashi, K. (2021). A mechanism to enhance bicycle conspicuity and visibility and increase detection distances
34	Nil	Yong, Z., & Hsieh, P. (2017). Speed-size illusion correlates with retinal-level motion statistics.
35	Nil	Wojtach, W., Sung, K., & Purves, D. (2009). An Empirical Explanation of the Speed-Distance Effect. PLoS ONE, 4.
36	Nil	Clark, H. E., Perrone, J. A., Isler, R. B., & Charlton, S. G. (2017). Fixating on the size-speed illusion of approaching railway trains: What we can learn from our eye movements. Accident; analysis and prevention, 99(Pt A)
37	Nil	Ashida, H., Ho, A., Kitaoka, A., & Anstis, S. (2017). The “Spinner” Illusion: More Dots, More Speed? I-Perception.
38	Nil	Carpenter, S. (2001, April). Sights unseen. Monitor on Psychology, 32(4).
39	Nil	Rizzo, M., Sparks, J., McEvoy, S., Viamonte, S., Kellison, I., & Vecera, S. P. (2009). Change blindness, aging, and cognition
40	Nil	Gunnell, D.O.A., Kunar, M.A., Norman, D.G. et al. The hazards of perception: evaluating a change blindness demonstration within a real-world driver education course.
41	Nil	Crundall, D., & Underwood, G. (1998). Effects of experience and processing demands on visual information acquisition in drivers
42	980319	SAE International. (1998). The Influence of the Light Distribution of Headlamps on Drivers Fixation Behaviour at Nighttime.
43	Nil	Larue, G. S., Watling, C. N., Black, A. A., Wood, J. M., & Khakzar, M. (2020). Pedestrians distracted by their smartphone: Are in-ground flashing lights catching their attention? A laboratory study.
44	Nil	Larue, G. S., Watling, C. N., Black, A., & Wood, J. M. (2021). Improving the safety of distracted pedestrians with in-ground flashing lights. A railway crossing field study.

45	RR07-17	Alerting Lights on Locomotives, U.S. Department of Transportation, Federal Railroad Administration, 2007

Several online resources have also been utilised to gather information associated with road user education. The respective links are provided below:

1. https://newcastletransport.info/newcastle-be-aware-of-the-rhino/
2. https://yarratrams.com.au/media-centre/news/articles/2011/positive-results-following-beware-the-rhino-campaign/
3. https://yarratrams.com.au/news/rhino-takes-on-the-world-and-wins
4. https://oli.org/
5. https://oli.org/sites/default/files/2021-02/2019-OLI-Annual-Report-Final-PDF-version.pdf
6. https://www.transport.nsw.gov.au/sydneytrains/education
7. https://tracksafefoundation.com.au/about/about-tracksafe/
8. https://www.mylicence.sa.gov.au/safe-driving-tips/level_crossings
9. https://www.nsw.gov.au/topics/roads-safety-and-rules/safety-updates-for-nsw-road-users/road-user-handbook
10. https://www.nsw.gov.au/topics/driver-and-rider-licences/driver-licences/driver-licence-tests/hazard-perception-test
11. https://www.vicroads.vic.gov.au/licences/your-ps/get-your-ps/hazard-perception-test

2. Methodology

The methodology adopted to deliver the project was agreed with ACRI at project inception and captured within the Offer of Service, SN0243974 (Client Ref. LC35). This section expands upon this methodology to discuss the activities conducted throughout the project in greater detail.

As described within the Offer of Service, the project was split into six work packages. These have been extracted and listed below:

Table 2-1 - Project Work Packages

Package Number	Description
Work Package #1	Project Inception/Kick-Off meeting to review the project scope and approach with key proponents and available working group members.
Work Package #2	Establish a baseline understanding of existing train conspicuity solutions in Australia through review of standards, data and statistics, technology and education and training.
Work Package #3	Literature review and workshops to identify and evaluate conspicuity solutions and visibility risk management strategies currently adopted in Australia and overseas for rail and other industries, as well as potential emerging solutions.
Work Package #4	Determination of indicative time and cost for implementation, associated risks and issues and the perceived feasibility of each solution identified in Work Package #3.
Work Package #5	Further discussion and debate on the available and emerging train conspicuity solutions, applications, apparent risks, issues and opportunities, business cases and other considerations.
Work Package #6	Preparation of a report (this document) that collates the findings from the assessment and workshops.

The project activities and their relationship with each work package are described in sequence in Sections 2.1 to 2.6.

2.1. Project Inception & Kick-Off Meeting (WP#1)

The Project was commenced via a Project Inception & Kick-Off meeting held on 1st October 2021, with representation from ONRSR, ACRI, TrackSAFE and SNC-Lavalin.

The meeting established an agreed approach to achieve the project objectives and allowed for the wider stakeholder group to be agreed.

2.2. Current Solutions and Best Practice (WP#2, WP#3)

SNC-Lavalin conducted literature reviews and engaged project stakeholders to determine the current requirements governing freight train conspicuity, and the research that drove the adoption of various design best practices and technologies.

The literature review covered existing Australian standards, research papers and educational documentation (such as road driver hazard perception training, awareness campaigns etc.), as referenced in Section 1.5, to establish a baseline understanding of mandated controls.

This baseline understanding was later supplemented by project stakeholders during the initial stakeholder workshop conducted on 19th October.

This workshop consisted of members from FORG, TrackSAFE, ARA, RISSB, ACRI and ONRSR, who provided insight into controls currently adopted by the freight operators and educational organisations, and the key issues associated with level crossing safety.

This included the identification of additional controls adopted that improve the level of safety over and above the prescribed controls of AS 7531.

The governing standards and current controls have been documented in Sections 4 and 7 of this report, respectively.

The previous research that has driven the adoption of current conspicuity methods is discussed in Section 3.

2.3. Data Analysis (WP#2)

A data request was provided to project stakeholders following the Project Inception & Kick-Off meeting to determine:

- Level crossing locations and protection levels.
- Recent level crossing incidents and near misses, split into three date ranges as follows:
    - 2015 to Present (representing the period of currency of AS 7531, 2015).
    - 2007 to 2015 (representing the period of currency of AS 7531, 2007).
    - Pre-2007 (representing the period prior to the introduction of AS 7531).
- Freight vehicle cleaning procedures and frequency.
- Train timetables and freight train frequency on each line.
- The freight vehicle types operating in Australia and their level of compliance to AS 7531, 2015.

Of the above items, two data sets were not able to be provided within the course of the project programme. These were:

- Train timetables and freight train frequency – A holistic data set, covering all regular freight and passenger rail movements was not readily available, and could not be generated within suitable timescales. Some publicly available data did exist, however this data set provided information for passenger vehicles only, and hence did not provide the requisite information to form robust and informed conclusions surrounding driver habituation, for example.
  It should also be noted that the level of accuracy of this data has not been validated by a recognised rail organisation.
- Freight vehicle types and level of compliance to AS 7531 – This information has not yet been collated, and hence is not available. However, as discussed in Section 1.3, the 2009 update to the Train Illumination Report [6] indicates that the level of compliance to the standard is high.

It should also be noted that procedural documentation describing freight vehicle cleaning methods was not provided. Instead, only an overview of cleaning frequency was provided by the project stakeholders. This is discussed further in Section 7.2.

SNC-Lavalin has conducted data analysis, utilising the information received regarding level crossing locations, protection levels, collisions and near misses to determine trends in accident levels and the perceived efficacy of current controls.

The data analysis methodology and conclusions are further discussed in Section 5 of this report.

2.4. Potential Solution Identification (WP#3)

Once the baseline understanding of the current approach was established, SNC-Lavalin developed a list of potential options that may be considered to improve the conspicuity of freight rolling stock.

This list was initially populated internally, utilising the team’s knowledge of technology and rolling stock systems, and through review of publicly available documentation.

The list of potential options was later expanded during Workshop 1, with contributions from the wider stakeholder group. This workshop was primarily aimed at the identification of potential, and discussion regarding feasibility, financial implications etc. did not occur.

Research into the implications of each option and available technology was conducted later in the project programme (see Section 2.5 below).

2.5. Research of Potential Solutions (WP#3, WP#4, WP#5)

Following Workshop 1, SNC-Lavalin assessed the identified options to determine:

- Whether the options were considered in scope.
- Implications associated with each option, categorised into:
    - Data, Stats & Standards.
    - Technology.
    - Education.
- Human Factors (as further described in Section 6).
- Risks, Issues and Opportunities associated with each option.
- The perceived efficacy of each option in improving level crossing safety (note that this was via qualitative assessment only).
- The perceived financial implications associated with each option.
- Option categorisations, being one of either:
    - Immediate Opportunities.
    - Medium-Term Opportunities.
    - Long-Term Opportunities.

This assessment utilised documentation available in the public realm and consisted of a literature review and stakeholder engagement, conducted in Workshop 2. The findings of this assessment are presented in Section 8 and Appendix A of this report.

It should be noted that the categorisation of each option pertains only to the timeframe associated with its implementation and does not necessarily guarantee the efficacy of the control. Commentary on control efficacy is provided alongside each option in Appendix A.

2.6. Documentation and Reporting (WP#6)

Throughout the project, SNC-Lavalin has documented and consolidated their findings and observations within a centralised workbook. Extracts of this workbook can be found in the appendices of this report.

Each workshop has utilised Miro™ software for its preparation and conduct, with all stakeholder inputs captured within the associated Miro™ Board. Stakeholder input has since been transferred to the SNC-Lavalin workbook and validated against the literature review activities conducted.

All findings and observations made throughout the project are presented in this report.

It should be noted that certain controls identified were deemed out of scope and have not undergone the same level of assessment.

3. Previous Research

SNC-Lavalin has conducted a literature review of documentation available in the public realm, and as provided by ACRI, to determine the previous research activities conducted and the conclusions and recommendations drawn regarding freight train conspicuity. Documentation reviewed throughout this process are listed in Section 1.5.

The following sections discuss the key observations associated with the reviewed documentation and highlight where the conclusions and recommendations of each research piece have informed the development of the current mitigation approach adopted in Australia.

3.1. The Train Illumination Report

The 2009 update to the Train Illumination Report, and the original 2004 publication produced by the House of Representatives Standing Committee on Infrastructure, Transport, Regional Development and Local Government, discuss the connection between train visibility (i.e. conspicuity) and level crossing incidents.

Since the original publication, a new standard, AS 7531, has been introduced to govern train visibility in Australia. This standard provides requirements for vehicle external lighting, high contrast paint colours and reflective delineators to ensure vehicles are visible to road users, pedestrians, and any other public or professional personnel that may conduct activities close to the rail corridor. The requirements of this standard are further described in Section 4.1.

Since the introduction of this standard, collision rates have reduced during night time operation, and this conclusion is supported by SNC-Lavalin’s data analysis conducted throughout the course of the project, as described in Section 5.

The previous research and resulting requirements of AS 7531 propose a variety of lighting systems to aid in vehicle conspicuity. Such systems introduce lighting arrangements, utilising white light, that have found to be effective during previous research. These include crossed visibility lights, a triangular arrangement of lights on the front of the vehicle, and flashing headlights that are interlocked with the vehicle horn.

The report [6] highlights that there now exists a high level of compliance to AS 7531 across Australian rolling stock, and this is expected to rise further as existing rolling stock undergoes routine servicing, and new rolling stock is procured.

As reported in the 2009 update to the Train Illumination Report, however, the number of level crossing incidents occurring during daylight hours, where the use of white light becomes less effective, greatly outweighs those occurring at night. Depending on the data source, the daylight hours incidents were reportedly as high as 94% of all level crossing incidents.

Daylight incidents remain a key concern associated with level crossing safety and there is no clear downward trend in collision levels for daylight operation.

The Train Illumination Report suggests that train lighting may be less significant when assessing the cause of level crossing incidents, and that a rising level of compliance to the current revision of AS 7531 may only result in minor improvements.

To aid in understanding why the current visibility controls may be failing to significantly improve level crossing safety during daylight operation, the ATSB conducted various investigations to determine how the actions of road drivers were contributing to level crossing incidents.

It was found that motorists failed to give way to an oncoming train because of a variety of issues, as follows:

- Failure to drive according to the conditions, such as driving too fast in wet weather.
- Driver fatigue.
- Driver over familiarity with the level crossing location and the resulting habituation that this incurs.
- Driver distraction.
- Sight lines and visibility of the rail corridor and/or level crossing.
- Operational aspects of heavy road vehicles use and a reluctance to fully stop at a crossing to view the rail corridor.
- Driver impairment, such as drug or alcohol consumption.

It should also be noted that the above issues may be considered to act in isolation or in combination, leading to level crossing incidents or near misses.

The report concludes by providing 10 recommendations, as summarised in the table below.

Table 3-1 - Train Illumination Report Recommendations

No.	Description	Comments
01	AS 7531 to be adapted to include maintenance requirements for reflective materials	Recommendation was supported in principle and has since been incorporated into AS 7531 under Clause 15
02	Rigorous scientific research to be conducted into the efficacy of auxiliary lighting in improving conspicuity	Recommendation was not supported as, in 2009, it was not deemed warranted. Further justification can be found in the 2009 documentation
03	Consistent penalties to be set for motor vehicle driving offences at level crossings	Recommendation was not supported as neither the Australian Government or NRSC had the authority to set traffic penalties. Further justification can be found in the 2009 documentation
04	Road speed limits to be reduced to 80km/h at level crossings on all major highways with a speed limit of 100km/h or more	Recommendation was supported in principle. However, assessment of the incorporation of this control is not within the scope of this project.
05	Further trials of passive rumble strips to be conducted at selected level crossings	Recommendation was supported in principle. However, assessment of the incorporation of this control is not within the scope of this project.
06	Initiate a programme of active rumble strip trials at the most dangerous level crossings	Recommendation was not supported as the efficacy of passive rumble strips was still being assessed. Reviewing the progress of such assessments is deemed outside the scope of this project.
07	Ongoing research into intelligent transport systems to be supported by government to speed the implementation of such technology	Recommendation was supported. Potential intelligent transport solutions are discussed within Section 8 and Appendix A of this report.
08	Further research into cut-in warning systems to warn vehicle users of oncoming trains upon approach to a level crossing is to be encouraged	Recommendation was supported in principle. Similar potential solutions are discussed within Section 8 and Appendix A of this report.
09	A national database is established which aggregates data from level crossing crashes and fatalities in all Australian States and Territories	Recommendation was supported in principle. Such a database has now been established, with relevant data accessible through ALCAM and the level crossing data portal. The improvement in data capture can also be observed within the data analysis conducted as part of this project and described in Section 5. The dataset is noticeably more robust/complete from 2014 onwards.
10	Revision of the National Railway Safety Strategy as part of the new National Transport Policy	Recommendation was initially not supported as justified in the 2009 documentation. Since release of the report, the National Level Crossing Safety Committee and the National Level Crossing Safety Strategy have been

	established to govern and address issues surrounding level crossing safety.

3.2. Other Research Documentation

A series of other publicly available research documents, collision reports, and project documentation provided by ACRI have been reviewed to aid in establishing a baseline understanding of freight vehicle conspicuity and supplement the observations taken from the Train Illumination Report.

The documentation reviewed includes:

- Motorist Behaviour at Railway Level Crossings: The Present Context in Australia, Angela Wallace, 2008.
- Prospects for improving the conspicuity of trains at passive railway crossings, ATSB 2003.
- Reducing collisions at passive railway level crossings in Australia, AustRoads 2002.
- Better Stimulus Around Level Crossing Control - Initial Project, ACRI 2015.
- Better Stimuli for Level Crossing Control, ACRI 2018.
- Retro-reflective Screens: Evaluating retro-reflective screens to aid conspicuity of tabletop carriages at passive level crossings, ACRI 2020.
- Use of Auxiliary External Alerting Devices to Improve Locomotive Conspicuity, U.S. Department of Transportation, 1995.
- Hunter Valley News, Turnaville Level Crossing Collision Report, 2021.
- Level Crossing Collision Between Truck and Passenger Train 8753, 2016.
- Collision Between Rigid Tipper Truck/Tri-Axle Trailer and The Overland Passenger Train, 4AM8, Wingeel, Victoria.
- Alerting Lights on Locomotives, U.S. Department of Transportation, Federal Railroad Administration, 2007.

The key observations and statistics pertaining to freight train conspicuity have been extracted and summarised below to provide a basis of understanding prior to exploring the freight conspicuity options provided in Section 8 and Appendix A. For further information, please refer to the source documentation listed in Section 1.5.

- Level crossing protection across Australia predominantly consists of passive level crossings, where no active controls such as lights or boom barriers are utilised. The latest data at the time of writing shows the following apportionment:
    - Passive Protection: 16563 (~80%).
    - Active Protection: 4176 (~20%).
    - Unknown: 6 (<1%).
- Incident occurrence is primarily during daylight hours and contributable to the higher traffic levels experienced during these hours. Data suggests that the proportion of daylight hour crashes is between 75% and 94%.
- Collision types between road and rail vehicles can be categorised into 2 general groups: where the road vehicle is hit by the front of the train; and where the road vehicle hits the side of the train. Higher occurrence of the former scenario is currently experienced, however when approaching conspicuity improvements, both scenarios must be considered.
- Causes of incidents can be attributable to several road driver issues, as described in Section 3.1. These can be categorised into two key groups:
    - The driver's inability to identify the oncoming train.
    - The driver's inability to determine the approaching trains speed and resulting time before the train will arrive at the level crossing.

  The human factors issues associated with each of these categories are further discussed in Section 6. It should be noted that a consolidated data set does not currently exist that differentiates between each of these collision causes.

- It has been found that the minimum sighting distances from the crossing required to allow a road user to identify the train and decelerate to a stop are as follows:
    - At 60km/h, 134m.
    - At 80km/h, 178m.
    - At 100km/h, 222m.

  However greater sighting distances are desirable to further improve safety.
- Trials conducted by VTT in Finland and Singapore, where strobe lights have been fitted to the front of the vehicles, suggest that the addition of such a lighting system can aid in the road user's ability to identify an oncoming train.
  This is supported by "Prospects for Improving the Conspicuity of Trains at Passive Railway Crossings", which indicates that roof-mounted xenon strobes received the most attention as a potential control, as the trials conducted suggest it is detectable from larger viewing angles and greater distances than a standard headlight.
  However, this is contradicted by recent trials conducted in WA which argue that the presence of a strobe light in addition to the current lighting systems has negligible effect to the road user's ability to identify the oncoming train (see "Reducing Collisions at Passive Railway Level Crossings in Australia").
  These contradictory conclusions cloud the perceived efficacy of the control; however strobe lighting continues to be considered as a viable option to improve conspicuity.
- It should also be noted that previous testing of strobe lights has focused solely on white light emitted at a given frequency. Investigations have concluded that this control has seen greater improvements during night, where visibility is poor.
  To achieve greater improvements during daylight hours, coloured strobes, which contrast more effectively with the surrounding environment during the day should be considered.
  It should be noted that the reduction in light intensity when coloured filters are applied will reduce the effectiveness during night hours or poor visibility conditions (e.g. fog) and night time operation must also be assessed for such systems.
- Of the previous controls assessed, the optimum lighting arrangement included a combination of headlights and auxiliary lights fitted to the front of the train.
  Specifically, optimum results were obtained when the lights were positioned in a triangular arrangement (see "Reducing Collisions at Passive Railway Level Crossings in Australia"), with the headlight located at the top of the triangle and in the centreline of the vehicle.
  Subsequently, crossing the beams of the bottom marker lights was found to improve the road user's ability to not only identify the oncoming train, but also judge the vehicle's speed.
  This lighting configuration has been incorporated into AS 7531 and is, by extension, currently in use in Australia.
- Previous research proposed the adoption of reflective strips fitted to the sides of the vehicle to reduce the occurrence of road users colliding with the side of the train during low light conditions.
  This control has since been incorporated into AS 7531, however further assessments have shown that the success of the reflective delineators in improving safety is directly influenced by the road and rail geometry.
  For crossings that are skewed (i.e. where there is a tight angle between the road and rail alignment), the efficiency of retroreflective materials in returning light to its source is greatly reduced, therefore failing to provide adequate warning to the road user that a train is present on the tracks.
- It is noted in "Prospects for Improving the Conspicuity of Trains at Passive Railway Crossings" that, despite Caroll et al. concluding that flashing lights was an effective way of improving vehicle conspicuity above standard headlights (by a factor of ~10%), flashing lights were not incorporated in AS 7531 as a mandatory requirement.
  This has since been amended, with AS 7531 requiring visibility lights to flash when the vehicle horn is sounded and on change of direction.
  The report specifies that many rail operators have now incorporated flashing lights as a control mechanism to improve level crossing safety. In some cases, headlight control is already interlocked with vehicle, causing the headlight to flash when the horn is sounded.
  The exact breadth of adoption of this control, however, is not known at the time of writing. It should be noted that requirements do not mandate flashing of the vehicle headlight.
- It has long since been understood that, due to the varying environmental conditions and surrounding infrastructure along the rail corridor, no single colour provides consistent contrast against all

backgrounds that will occur during operation (established by Aurelius and Korobow in 1971 and summarised by Caroll et al. in 1995).
A yellow vehicle face has been adopted for many fleets across Australia as this has been found to contrast well, however AS 7531 also allows for the adoption of orange, orange-red or red colours (see Clause 10 of the standard).
Although these paint schemes provide a good level of contrast, there is significant risk associated with vehicle cleanliness, whereby dirt can cover the high contrast paint and generate a vehicle colour that is comparable to the surrounding environment (see incident examples below).

- ACRI report LC13, Better Stimulus Around Level Crossing Control, explored a number of level crossing incidents and concluded that approximately half of the incidents may have been avoided if efforts were made to make the vehicle considerably more conspicuous, supporting the implementation of additional train mounted controls. It additionally indicates that inattentional blindness is a key contributor to driver error and the resulting collisions and near misses experienced on the network.
  Inattentional blindness has been addressed and explored as part of the Human Factors element of this project, as reported in Section 6.
- Review of road driver training content and example tests, as sourced on the driver education websites for each state, highlights that hazard perception training and testing across Australian States does not include any scenarios to ensure appropriate interaction with level crossings.
  It is therefore likely that a lack of awareness regarding the warning signs for level crossings, and the appropriate approach to interacting with a level crossing exists, particularly with new road drivers.
- Free level crossing training and educational content is available and provided by multiple organisations, such as TrackSAFE and Transport for New South Wales (TfNSW). This covers safety around trains and level crossings, however the level of uptake of the course appears to be minimal. Actual figures representing uptake have not been determined at the time of writing.
- Variations in road driver education currently exist from state to state, highlighting a risk of inconsistent approaches to safe level crossing interaction. The driver educational system does not appear to have taken steps to harmonise communications regarding level crossing interaction and safety between each State.
- Operation Lifesaver is an initiative adopted within the U.S. to raise awareness regarding safe level crossing/rail interaction. It provides a wide range of level crossing and rail safety campaigns and education programs and provides a useful model for adoption in Australia.
  Such initiatives do not appear to be widely distributed within Australia.

For Human Factors specific research, refer to Section 6.

3.3. Incident Examples

The below examples discuss level crossing incidents where vehicle conspicuity may have contributed to the occurrence of the collision. Notably, other rail corridor sighting issues and driver behaviour are also key contributing factors.

The data captured for each of these collisions does not allow for accurate confirmation of the key cause of each incident.

3.3.1. Scone, NSW: 29 September 2021

https://www.huntervalleynews.net.au/story/7449333/truck-and-train-collision-at-level-crossing-near-scone/

Infrastructure and Environmental Conditions

At the time of the collision (7am), skies were clear and there was good visibility of the surrounding environment.

However, the road layout and surrounding vegetation provided challenges in viewing the rail corridor to identify an oncoming train.

Notably, thick vegetation blocks the road user's view of the rail corridor when approaching from the east, reducing the time available to identify the train.

Subsequently, when approaching from the east, the proximity of the rail crossing to the road junction over New England highway presents additional challenges for the road driver to navigate, which may impede their ability to notice the rail crossing and identify the train.

Description and Train Condition

In this example, a truck collided with a freight train (carrying coal) under the environmental conditions described above.

Conclusions on the precise incident cause have not yet been reported, however stakeholder discussions have highlighted that this is expected to be a result of the road user attempting to "beat the train" and not accurately determining the speed of the train.

As seen in the image to the right, the vehicle was painted with high contrast colours in accordance with AS 7531. However, the dirty condition of the vehicle caused it to appear in a state that closely matched the surrounding vegetation, which may have contributed to the driver's inability to correctly judge the train speed. Nonetheless, the appropriate action upon identifying the presence of the train would have been to give way at the level crossing.

3.3.2. Phalps Road, VIC: 13 July 2016

Level Crossing Collision Between Truck and Passenger Train 8753, 2016

Infrastructure and Environmental Conditions

At the time of the collision, weather conditions allowed for good visibility of the surrounding environment. It was also reported that the sun was positioned behind the truck and hence did not affect the truck driver's observation of the rail corridor (e.g. due to glare).

The rail corridor and road approach to the level crossing are both straight, with good visibility of the crossing. However, the sight lines between the road and rail are obstructed by thick vegetation on the east side of the road to the north of the crossing. The existence of this vegetation contributed to the driver's inability to see the oncoming train.

This sighting issue is exacerbated by the acute angle between the road and rail geometry, which present further challenges for road users to identify an oncoming train. It is noted in the collision report that the angle is non-compliant with level crossing design standards.

Description and Train Condition

In this example, a truck and train collided at Phalps Road, despite good environmental conditions, a clean train and compliant road driver actions.

It has been reported that the train involved in the collision departed from Southern Cross Station on schedule, and it can therefore be assumed that the time at which the train entered the crossing would be a similar time to usual operation, potentially ruling out road driver habituation as a collision cause.

At the time of the collision, the road vehicle was travelling in compliance with the road rules, approaching the crossing at a reduced speed between 40 and 50km/h. It is reported that the truck driver stopped at the crossing, but failed to identify the oncoming train, despite the train being in a clean condition and sounding its horn upon approach (as required by operational safety controls).

The front loco included high visibility paint, with both red and yellow colours applied. However, the lighting controls adopted on the vehicle were not reported and compliance with the lighting controls prescribed by AS 7531 cannot be determined for the time of the collision.

3.3.3. Wingeel, VIC: 15 November 2006

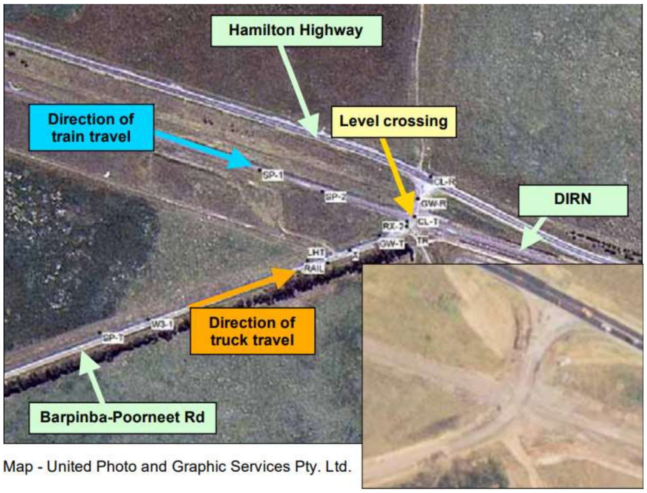
Collision Between Rigid Tipper Truck/Tri-Axle Trailer and The Overland Passenger Train, 4AM8, Wingeel, Victoria

Infrastructure and Environmental Conditions

At the time of the collision, the Barpinba-Poorneet Road level crossing included only passive protection (stop sign) and was situated on a road where the geometry did not allow for easy viewing of the rail corridor on approach to the crossing.

Multiple junctions existed in close proximity, giving rise to the potential for driver distraction and/or inattentional blindness. It was also found that the road signage and markings did not comply with industry standards, however given the road user's familiarity with the route, it was argued that this did not contribute to the accident.

It was reported that, at the time of the incident the sky was overcast and dull in colour.



Map - United Photo and Graphic Services Pty. Ltd.

Description and Train Condition

In this example, a truck and train collided at Barpinba-Poorneet Road Level crossing, where only passive protection existed in the form of a stop sign. The collision resulted from the road user failing to initially identify the oncoming train and stop at the stop sign.

The visibility/conspicuity controls of the overland passenger train involved in the collision, and as depicted, include some controls currently mandated by AS 7531. Specifically, the vehicle incorporated external lights in a triangular pattern and high visibility paint (orange-red) on the front of the locomotive. However, noting the overcast weather conditions at the time of the collision and the road and rail geometries, it is reasonable to assume that the effectiveness of these controls was reduced, i.e. the incorporation of the grey colours of the vehicle were expected to be less visible against the dull sky, and white lights on the front of the vehicle are known to be less effective during daylight hours. Coupling this with the accute angle between the road and rail, and the blind spots present within the cab of the truck, the ease at which the train could be identified was arguably reduced.

4. Governing Standards and Legislation

SNC-Lavalin has reviewed and decomposed local and international standards governing the visibility requirements for freight locomotives to understand current local controls and how these compare with international best practices. Key requirements and controls are described below, including comparisons with international standards.

Standards are not legally mandated, however under the Rail Safety National Law rail operators have to demonstrate that they are managing risks to safety so far as is reasonably practicable (SFAIRP). The adoption of relevant standards is often the means of demonstrating adherence to this SFAIRP requirement.

4.1. Australian Requirements

The main rolling stock lighting and visibility requirements for Australia are provided in AS 7531. The first version of AS 7531 was published in 2006 by RISSB and later updated and re-issued in 2007. A further revision was later issued in 2015.

The earlier version of the standard had four parts, which segregated the requirements for the different types of rolling stock.

The current version, published in 2015, combines all the requirements into one single document.

Changes to the standard since its original publication have been minor and implemented primarily to make it easier to measure compliance with performance requirements and to ensure that the standard is technology-agnostic.

The requirements provided in the standard are applicable to all new and existing Locomotives, Freight, Passenger, and Infrastructure Maintenance Rolling Stock.

AS 7531 provides requirements for headlights, tail and marker lights, visibility lights, number lights, flashing beacons, livery, reflective delineators, and associated maintenance activities, as well as requirements that do not contribute to vehicle conspicuity (such as interior lighting).

The key requirements of the standard are discussed below:

- The standard requires that the colour of high visibility areas on locomotives and passenger rolling stock should be one of yellow, orange, orange-red or red and prescribes specific CIE chromaticity coordinates.
  Fluorescent colours that are compliant with AS/NZS 1906.1 are also recommended for use during daytime to increase the visibility of the locomotive.
  These requirements align with the recommendations and conclusions from past research; however, it should be noted that the efficacy of the current paint colours adopted is dependent on vehicle environment, weather conditions, time of operation and vehicle cleanliness (as seen in Section 3.3 above).
- The standard prescribes a series of requirements to govern vehicle headlights, including headlight position, intensity, and the orientation of the headlights relative to the track.
  As documented in the standard, the primary purpose of the visibility lights at the front end of the locomotive is to enhance the visibility of the train from the perspective of a driver approaching a level crossing.
  Visibility lights are also required to flash when the horn is sounded, and when the vehicle changes direction, to further improve conspicuity.
- As discussed in Section 3, crossed marker lights were reported as the most effective control when it came to identifying the locomotive and determining its speed.
  The visibility lights are required to be aimed/turned cross-eyed to between a minimum of 7.5 degrees and a maximum of 15 degrees to the longitudinal centreline of the vehicle.
  The lights are also to be aimed at a point 25 meters in front of the vehicle at top of track. The figures below, as extracted from AS 7531, illustrate this lighting arrangement:

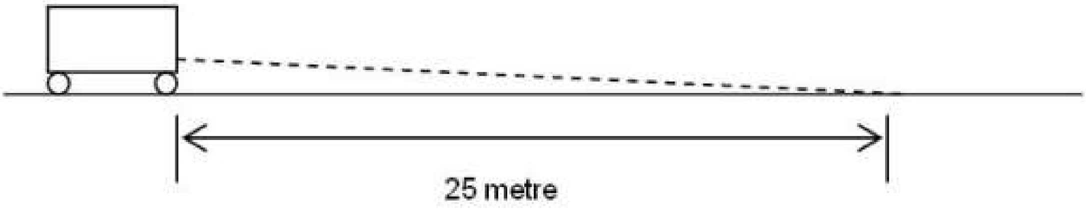


Figure 4-1 - Side View of Visibility Light Aiming (AS 7531 Figure 1)

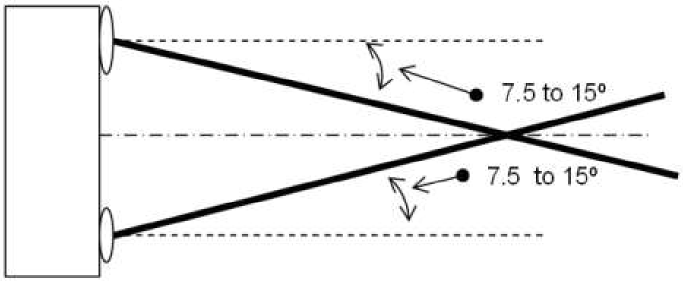


Figure 4-2 - Top View of Visibility Light Aiming (AS 7531 Figure 2)

It should be noted that additional visibility lights are required to be mounted to the front of the vehicle, as high and as wide as possible.

- Reflective delineators are required to be fitted along both sides of the vehicle and mounted at a minimum of 2.5m and maximum of 5m spacing.
  The position of the reflective delineators is to be within 800mm and 2000mm above rail to ensure that the light from road vehicle headlights is captured and reflected to the road user.
  However, as described in Section 3, the efficacy of this control is hindered by acute road and rail angles that are experienced within the network.

4.2. Overseas Requirements

SNC-Lavalin has reviewed international lighting and visibility standards that govern freight rolling stock design and maintenance to comparatively assess the Australian approach to ensuring conspicuity against international best practices.

The standards that were reviewed are:

- GM/RT 2131 (Audibility and Visibility of Trains).
- EN 15153 (External Visible and audible warning devices).
- 49 CFR Part 224 (Retroreflectorization of Rail Freight Rolling Stock).
- T-HR-RS-00600-ST-v2.0 (Minimum operating standards for Rolling stock).
- T HR RS 00890 ST v1.0 (Reflective Delineators).

Largely, the international best practices are comparable to those adopted in Australia, with standards prescribing high visibility colours, headlights (with daytime high intensity and night time low intensity), visibility lights and reflective delineators.

Discussion regarding the differences observed are provided below:

- GM/RT 2131, Section 3.10.1-4 specifies that shunting locomotives are required to be painted yellow with black diagonal stripes on the face of the vehicle.
  The stripes are applied at a nominal angle of 45 degrees from the vertical. Although this is not mandated for freight vehicles within GM/RT 2131, it highlights an additional concpicuity control that has been considered as part of this project. Further discussion on controls is capture in Appendix A.
- EN 15153. Section 5.2 prescribes frequency ranges for warning horns. This is done to differentiate horns sounded by the locomotives from similar devices used in road vehicles, emergency vehicles,

factories, or other common warning mechanisms, allowing the road user to easily identify the train. Although segregating frequency bands is a practical approach to differentiate between freight vehicles and other systems, care should be taken to ensure that the frequencies prescribed by EN 15153 are not adopted like-for like, as the frequencies of systems utilised in Australia may vary from those in Europe. Prior to adopting such a requirement, it is recommended that data is gathered to confirm the frequencies of other systems operating in the road industry or interfacing with road or rail.

Vehicle horns and their contributions to safety are being assessed as part of a separate project undertaken by ACRI and are only discussed here for completeness. Any further discussion regarding vehicle horns should be undertaken as part of the external project.

5. Collision & Near-Miss Data Analysis

5.1. Resources

SNC-Lavalin received '*ACRI – Level Crossing Collisions and Near Misses Occurrence Extract'* from ONRSR on 25 October 2021. The data captured is driven by notifiable occurrences, which are defined as "*the initial written advice of a rail safety incident that a rail transport operator (RTO) submits to ONRSR in accordance with section 121 of the Rail Safety National Law (RSNL)."*

The data extract applies only to those railways within ONRSR's area of regulatory oversight, which has expanded over the reporting period. The reporting period comprises of two types of data, depending on the jurisdiction:

- ONRSR data, that was collected by ONRSR in line with the RSNL.
- Pre-ONRSR data, that was collected by the relevant state regulator prior to transition to ONRSR.

For ONRSR data, the data is based on the incident definitions of the national occurrence classification guideline, which is date dependent.

For data up to and including 7 June 2017, incident definitions are based on those in the Occurrence Classification Guideline (OC-G1). For all other data, incident definitions are based on the Reporting Requirements for Notifiable Occurrences.

For pre-ONRSR data, the data may be based on incident definitions in use by the relevant state regulator, however this has not been clearly documented.

The geographic coverage of data is detailed in Table 5-1.

Table 5-1 - Geographic coverage of data as defined by ONRSR

State / Territory	Date Range	Data Source
ACT	20 Nov 2014 to current	ONRSR data
	1 Jul 2014 to 19 Nov 2014	Pre-ONRSR data
	Prior to 1 Jul 2014	no data available
NSW	20 Jan 2013 to current	ONRSR data
	Prior to 20 Jan 2013	Pre-ONRSR data
NT	20 Jan 2013 to current	ONRSR data
	Prior to 20 Jan 2013	Pre-ONRSR data
Qld.	1 Jul 2017 to current	ONRSR data
	20 Jan 2013 to 30 Jun 2017	Pre-ONRSR data
	Prior to 20 Jan 2013	no data available
SA	20 Jan 2013 to current	ONRSR data
	Prior to 20 Jan 2013	Pre-ONRSR data
Tas.	20 Jan 2013 to current	ONRSR data
	Prior to 20 Jan 2013	Pre-ONRSR data
Vic.	19 May 2014 to current	ONRSR data
	Prior to 19 May 2014	no data available for commercial heavy rail operations
WA	2 Nov 2015 to current	ONRSR data
	1 Jul 2014 to 1 Nov 2015	Pre-ONRSR data
	Prior to 1 Jul 2014	no data available

It should be noted that:

- The data provided by ONRSR is the best available as of 18 October 2021.
- The data may differ from other sources. The data is subject to review and amendment as more information becomes available through investigation or inquiry, or as ONRSR refines its systems for data capture, validation, and reporting. This may result in variation between historical and future reports.
- The data is based on information provided by rail transport operators and hence, there's no guarantee against the accuracy or completeness of information provided by third parties.

5.2. Methodology

SNC-Lavalin has categorised the collision and near miss occurrences into three data ranges to align with the implementation and subsequent revision of AS 7531, as follows:

- 2015 to Present (representing the period of currency of AS 7531, 2015).
- 2007 to 2015 (representing the period of currency of AS 7531, 2007).
- Pre-2007 (representing the period prior to the introduction of AS 7531).

Further to the categorisation, SNC-Lavalin has limited their assessment to occurrences (collision and near-miss) of freight trains with road vehicles.

Other train types are beyond the scope of this study. Collisions between pedestrians and trains have not been assessed in detail as it is assumed that significant improvements around level crossing safety are expected to be attributable to the implementation of active controls around level crossings with high foot traffic (such as those in metro areas).

Assessment of the trends associated with train to pedestrian collision are therefore expected to provide conclusions that may not accurately represent the efficacy of current vehicle conspicuity controls.

The freight train incident with road vehicle data has been separated according to the level crossing protection type – active and passive; and time of occurrence – day and night. See Appendix B for the detailed data analysis results.

Given that the data before 2007 is not available for any states other than South Australia, SNC-Lavalin has discounted this data in its assessment. Instead, 2007 to 2015 data has been compared with data from 2015 to present day. This has allowed for conclusions to be drawn regarding the improvements to level crossing safety that have occurred as a result of AS 7531 (2015), and identify areas where opportunities exist to further reduce collision and near miss rates.

SNC-Lavalin has used the weighted average method to compare the 2007-2015 data to post-2015 data. This has been conducted to account for the geographic coverage of ONRSR data, as highlighted in Table 5-1 - Geographic coverage of data as defined by ONRSR The following factors should be noted:

- Due to COVID-19 pandemic, the frequency of freight locomotives is expected to have decreased in 2020 due to complications surrounding importing goods and known shortages of freight containers. It is also expected that road traffic levels were greatly reduced due to state lockdowns and "stay at home" awareness campaigns.
- Only current incidence data up to Q3 2021 was made available for comparison.

5.3. Observations

There has been approximately 35% reduction in overall near-miss incidents of freight locomotives with road vehicles in Australia since 2015 but the overall collision rate has increased. The reduction in near-miss is most notable in Queensland, with a 50% decrease in incidents since 2013.

The data highlights that the updated standard AS 7531:2015 and other contributing factors detailed below have assisted in improving the train visibility at active level crossings during daylight operation, and at passive and active level crossings during night time operation.

As daylight collision levels at passive level crossings have remained fairly consistent year to year, opportunities exist to focus on this scenario and implement new controls that specifically target daytime operation.

The near-miss incidents at active level crossing have decreased for all states except Western Australia, whereas it is constant for all states at passive level crossing.

The data analysis supports the conclusions of previous research detailed in Section 3, confirming that the majority of incidents occur during daylight hours for both active and passive level crossings.

It can be determined from Figure B-21 to Figure B-36 that, though there are more near-miss incidents recorded at active level crossings, the collisions at passive level crossings is comparatively higher, both during the day and at night.

There has been consistent decrease in near-miss and collision events in South Australia after 2010, which may be due to changes in local policy and standards to improve level crossing safety. Nonetheless, South Australia has incorporated driver education training regarding level crossing safety as explained in Section 7.3 of this report.

Factors in addition to vehicle conspicuity that contribute to improvements in level crossing safety include:

- Improvement in state policy and standards.
- Removal or closure of level crossings.
- Upgrading passive level crossing to active level crossing.
- Improvements in certain technologies such as use of LEDs instead of incandescent or fluorescent light.
- Improvement in regulatory involvements, audits, etc.

It should be noted that unprotected level crossings are captured as a separate item within the dataset provided in Appendix C. Comparisons have not been made between passive protection and unprotected crossings and the data analysis scope only included a comparative assessment between active and passive protection to align with the implementation and subsequent revision of AS 7531. As such, there is a delta between the figures provided in the ‘total’ datasets and the summation of the individual passive and active data sets.

6. Human Factors

6.1. Overview

As described in Section 3.1, the data available to-date for road vehicle and train collisions at level crossings have elucidated several contributing factors, sometimes with these factors acting in combination.

Human factors such as fatigue, familiarity and the effect of environmental conditions can lead to road vehicle users:

- Not detecting the crossing.
- Not detecting the train (e.g. from fatigue, distraction, train or crossing visibility, etc.).
- Taking action driven by habituation rather than interpreting their surroundings (i.e. due to familiarity or experience of train running).
- Misjudging train speed.

Detection of the crossing is not within the scope of this report, and environmental conditions are only considered where they present challenges in achieving adequate contrast with the train.

The Human Factors (HF) assessment has focused on the road user's ability to detect the train and includes consideration of distraction, habituation and misjudging train speed.

These areas intersect with known human-performance shaping factors (i.e. distraction, speed-size illusion, cognitive biases) as well as human information processing.

This section aims to define and describe the different aspects of train conspicuity within the information processing model, and articulate specific design considerations that can aid in addressing these key contributing factors.

6.2. Human Factors Literature Review for Train Conspicuity

6.2.1. Key Conspicuity Definitions

Visual (also referred to as sensory) conspicuity is difficult to express and is problematised further by a theoretical and applied research intersection with the literature on visual search [7].

Visual search research has focused on determining the properties of the target that must be identified by the visual system suggesting that if properties or features of an object are 'salient' enough, they cause the object to stand out from its surrounding distractors, making it conspicuous [18].

This theoretical interrelationship has confused conspicuity with visibility.

Conspicuity cannot be well defined in terms of object features or properties however, visibility can.

In this way, and throughout Section 6, **visibility** refers to 'the intensity or salience of an object's features or properties, such as its colour, luminance, form, size, etc.[18].'

By comparison, the **visual (or sensory) conspicuity** of an object refers to how well it visually stands out from its environment [18] and the ease of discrimination (i.e. from contrast, placement, layout, and patterning) the object has from its environment following a brief exposure.

The notion of visibility implies objects will have high visibility in a specific location and will be indiscernible in others (e.g. low visibility of a camouflaged vehicle situated in the jungle versus high visibility in a city street).

Whereas conspicuity describes a relationship by means of the degree to which the object is embedded in its surrounding environment or context [18].

As such, consideration for optimising locomotive conspicuity must focus on how the perceptual system manages the object, the environment, and the viewing conditions [18].

As such, conspicuity is dependent on viewing circumstances including the amount of visual clutter or noise in the environment, viewing distance, viewing angle, and ambient light—not all of which are within the project scope.

Infrastructure and environmental (i.e. vegetation, building, etc.) features at passive level crossings will play an influencing role on conspicuity and should be considered in parallel research investigations to further enhance any improvements to locomotive-only design change.

Examples of infrastructure and environmental features also playing a role in incidents has been described in Section 3.3; refer to 3.3.1 incident in Scone, NSW for vegetation impacting visual conspicuity, and 3.3.2 incident at Phalps Road highlighting the effect of visual angles for detecting a train by road vehicle users.

Another important aspect to conspicuity however, that is not always accounted for is **cognitive conspicuity**.

It is well understood that certain observer-related factors, such as their attentional state, may also affect conspicuity.

Referring to the key contributory factors described in Section 6.1, for example misjudging train speed, are closely associated with observer-related factors (i.e. cognitive biases such as confirmation bias, inattentional or change blindness) and breakdowns in information processing. Cognitive conspicuity is associated with the aspects of viewing the object and the interpretation and organisation of that information to initiate an appropriate response.

For example,

- **attention conspicuity** –which refers to the kind of conspicuity that causes an object to draw an observer’s attention or to be detected when the observer is not actively looking for it (i.e. inattentional blindness or change blindness, field of vision) –and
- **search conspicuity** – which refers to the conspicuity of objects to be detected when the observer is looking specifically for it (i.e. visual motion perception, determining speed, speed-size illusions) [18].

Therefore, to address the key contributory areas identified for collisions at level crossings, conspicuity design enhancements must aim to address the visibility, sensory conspicuity, as well as cognitive conspicuity of the locomotives.

6.2.2. Information Processing Model Framework for Conspicuity

The information processing model [18] offers a useful theoretical framework for considering train conspicuity and proposed enhancements.

Specifically, the model can identify each of the stages of psychological processing for road users upon approach to a passive level-crossing through to decision-making to cross or not cross, and areas or functions that may breakdown as part of this process that could lead to a collision.

The information processing model is shown in Figure 6-1 and illustrates how inputs (i.e. sensory information) are detected and translated to sensory memory which in turn, enable active attention to be prompted.

Information is subsequently held and recognised through working memory, before being extracted and interpreted through use of long-term memory information.

Breakdowns at any stage of this process can lead to one or more of the key contributory factors (refer to Section 6.1) occurring, which can result in a collision.

For example, a breakdown at ‘detection’ could include:

- Not detecting the crossing (i.e. input is not detected in the first place).
- Not detecting the train (i.e. sensory memory is not triggered).
- The train is not attended to due to habituation, distraction, fatigue, or other tasks performed by the observer (i.e. road vehicle user).

If the train is detected, breakdowns in recognition (e.g. due to factors such as habituation) or misjudging speed (i.e. interpretation) can also contribute to an event.

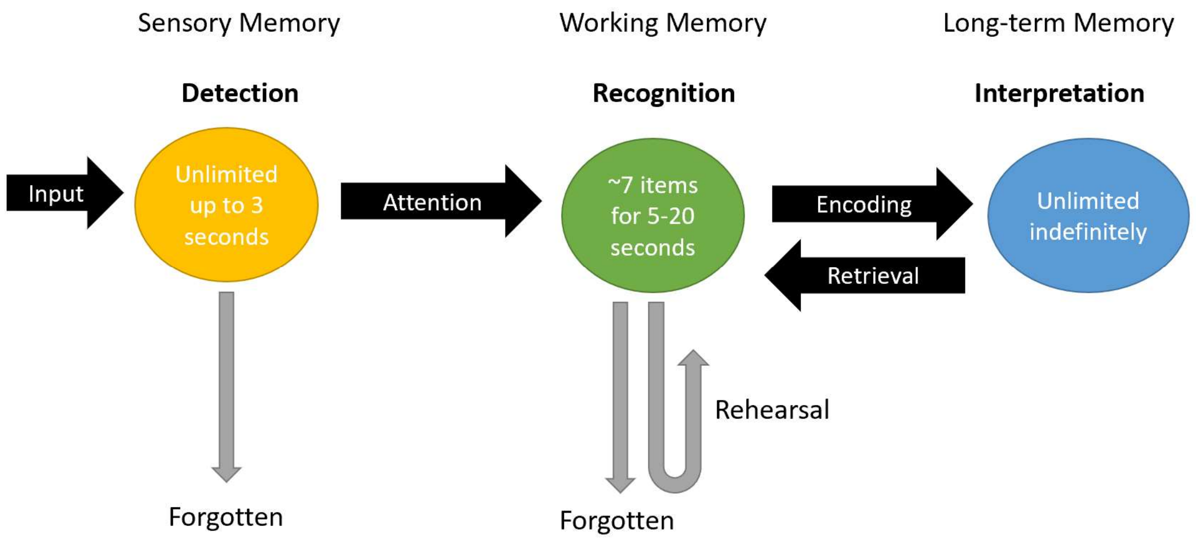


Figure 6-1 - Information Processing Model

Expanding the information processing model to align with the user tasks performed at a passive level crossing enables consideration for where the best use of conspicuity intervention could occur, and the degree by which each area of conspicuity (i.e. sensory, cognitive) influences that stage of information processing.

As shown in Figure 6-2, the three key areas associated with train conspicuity improvements (i.e. visibility, sensory conspicuity, and cognitive conspicuity) have been mapped to the phases of the model (for more information refer to Section 6.3).

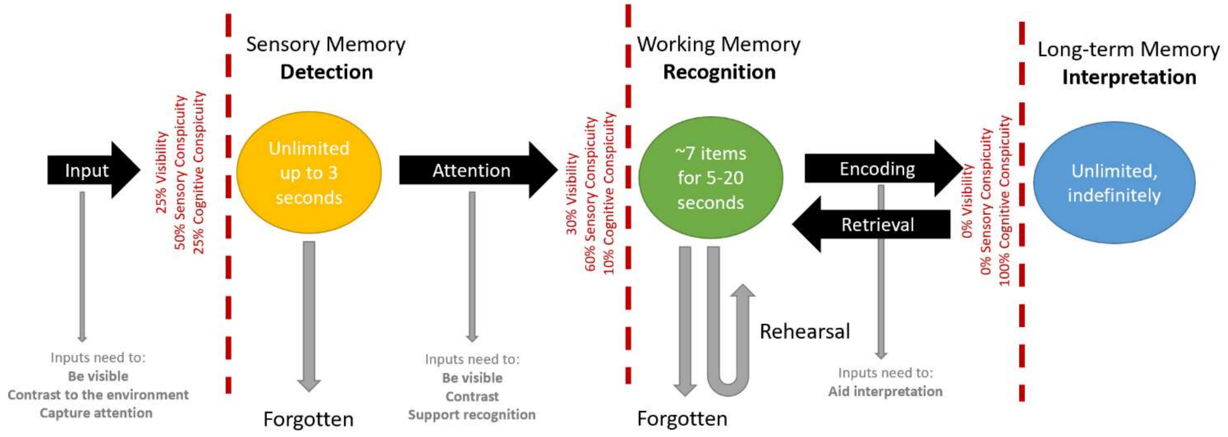


Figure 6-2 - Expanded Information Processing Model to include Conspicuity

The following section describes research associated with the relevant visibility, sensory conspicuity and cognitive conspicuity findings and recommendations that have been applied to each of the stages of information processing for optimised solution generation and assessment.

6.2.3. Key Findings from the Literature

A cross-industry literature review was conducted (using Google Scholar) spanning military, emergency services, other vehicle (e.g. heavy haul trucking, bicycles, motorcycles), and aviation for visibility, sensory conspicuity, and cognitive conspicuity to understand key findings and recommendations that address the core areas for potential implementation for heavy haul and freight locomotives.

Additionally, case study or specific industry changes through other governmental or industry body research or white papers were also reviewed and considered for the current project scope.

6.2.3.1. Visibility

Collisions at level crossings may occur due to observers not detecting the train.

Research has examined depth focus of the human eye and benefits of colour and colour contrast/discrimination as areas for improvement.

Under daylight conditions, the human eye is most sensitive to light at a wavelength of 555 nanometres (nm) which corresponds to bright yellow-green colour; while under night conditions, the human eye is more sensitive to light at a wavelength of 507nm which corresponds similarly to blue-green colour [19].

Suggestions for protective light lens covers specifically for use with lights that filter out all wavelengths of light except for 555nm (for day-time operations), and 507nm (for night-time operations) could be effective.

To-date this solution has not been implemented in the rail industry.

Although often considered for emergency warnings, red can be difficult to detect at night as it may appear black [22].

In addition, red is not permitted for use in the rail environment as it is retained solely for use for signals.

In line with colour recommendations, motorcycling research have examined the effect of hi-vis yellow clothing [20].

Research showed that the effectiveness of colour may depend on the situation in which the motorcyclist was located: bright clothing and headlight use may not be infallible. Although yellow is generally adopted as high visibility paint for trains, aspects such as the intensity of the yellow may be impacted by train wash schedules, as well as general environmental influences (i.e. surrounded by other yellow objects such as signage, infrastructure, etc.).

The authors suggested that the brightness (luminance) contrast between the object (i.e. motorcyclist) and the surroundings may be more important as a determinant of conspicuity than the motorcyclist's brightness [19].

This finding aligns with the previous definition separation between visibility and visual (sensory) conspicuity.

Additionally, research conducted at the Loughborough Design School [21] has improved international road safety by introducing a standardised design and implementation of conspicuity markings (i.e. Battenberg scheme, retroreflective markings) for emergency vehicles and trucks.

In focusing on colour, emergency vehicles are often painted with light colours (e.g. white, yellow-green) and marked with retroreflective materials and/or fluorescent colour.

These light colours are more visible during daytime under clear weather however, the influence of vehicle colour on visibility is significantly reduced in adverse light conditions.

Considerations for colour innovations will need to consider contrast across different daylight hours (dawn and dusk) that may present more reds and blues.

Furthermore, research into object recognition indicates texture, in combination with appropriate colouring, delivers additional cues to the observer, facilitating discrimination between object and environment [22].

Although maintenance vehicles within the Australian rail environment have implemented additional conspicuity markings, this recommendation has not expanded to locomotives.

Additional consideration should be given to road users who may have deficiencies in colour vision [23]. To accommodate for these deficiencies, the two main colour combinations to avoid include:

- Red–green (as this form of colour vision deficiency is the most common form).
- Blue–yellow.

However, other broader colour combinations can be challenging to discriminate [24], including:

- Green and brown.
- Blue and purple.
- Green and blue.
- Light green and yellow.
- Blue and grey.
- Green and grey.
- Green and black.

Use of colour with textures, patterns and symbols is also an alternate design strategy [26] [27] to be more inclusive of colour deficiencies in the broader population.

6.2.3.2. Sensory Conspicuity

Collisions at level crossings may occur due to observers not detecting the train, not recognising and/or interpreting that the object is a train.

6.2.3.2.1. Auditory Considerations

The role of auditory cues in detection are generally impactful by interrupting distraction and capturing attention in tasks which are heavily visual in nature.

Research has examined auditory interventions to enhance conspicuity in association with visual interventions such as combined warning lights and sirens.

Most research conducted has examined emergency vehicles and indicates warning lights and sirens and while they can effectively alert drivers, they can also adversely affect both emergency vehicle drivers and nearby drivers depending on how the flashing and sounds are implemented.

Warning lights and sirens have a strong influence on drivers' vision, hearing, and physical and physiological systems, which could disturb driving performance.

Strobe lights can impede vision (particularly at night), induce driver distraction, and trigger rare seizures due to photosensitive epilepsy (triggering range of 10 to 20 hertz frequency).

Other studies [13] have cautioned against extended use of warning lights for such reasons.

Although alternative lighting solutions have been considered and implemented in the international rail environment (i.e. US). Such solutions have yet to be explored within the Australian context.

Auditory cues are likely to be most effective when combined with visual cues as auditory information can enhance understanding of the motion and proximity of an object, as well as provide an additional cue for further visual scan if not initially seen. It should be noted that auditory cues, such as vehicle horns, are explored in further detail as part of a separate ACRI project.

6.2.3.2.2. Visual Considerations

Visual conspicuity can relate to a number of factors including contrast elements within a background, motion, and disruptive visual stimuli such as flashing.

Visual conspicuity solutions have typically focused on ways in which object contrast can be enhanced for the array of environments in which it is likely to be situated.

Research has demonstrated the effectiveness of motorcycle conspicuity aids depends upon the situation in which the motorcyclist was located [20].

However, certain light arrays may assist human information processing by providing more information for the observer to calculate distance, speed, and direction [20].

Research has shown a 'triangle of conspicuity' 'whereby light array formation consists of a central headlight and two lights located on rear-view mirrors, provides cues and sufficient contrast even in cluttered environments [20].

This recommendation is also described in Section 3.2 within the rail environment and has been incorporated into AS 7531.

Importantly, research cites benefits in defining a visual signature [29] for an object (such as a train) to aid in identification and interpretation.

Another aspect of conspicuity of light arrays is how it might reflect biological motion.

Human detection is typically enhanced for biological type movements (movements which are constrained and patterned by a skeletal system such as a person walking) over other types (such as a simple pendulum), and this has been shown to equate to light arrays which show a facsimile of the joints and movement of biological objects.

This preference for biological motion, and other types which elicit a "causal perception" can potentially be leveraged to improve conspicuity and indications of motion. While this has been studied for pedestrians and cyclists and shown to improve detection, it may provide an opportunity on conspicuity of trains.

Research for emergency vehicle conspicuity highlights that the success of reflective markings is dependent on the patterns deployed and the ability of the marking to catch external light sources (Battenberg markings, crosshatch chevron designs).

For instance, low placement of reflective material on vehicles optimises approaching vehicles headlight reflectorisation.

However, it is important to note that the use of retroreflective markings is only effective at night and relies on an external light source.

The efficiency with which reflection is achieved (luminance) and the angle from which a material reflects depends on the design and composition of the material, which has generally improved over time through research and development.

Classes of retroreflective materials are specified in the Australian Standard covering road signage (AS 1906), wherein the classes of materials specified are the same as used for vehicle conspicuity markings in Australia.

Importantly, it is theoretically possible to "over-do" the use of retroreflective materials, which can interfere with drivers' ability to recognize other roadway hazards.

Alternatively, or in combination with retroreflective markings, fluorescent materials enhance the conspicuity of an object during the daytime but offers no additional benefits under dark conditions as fluorescent colours only interact with ultraviolet radiation.

The use of fluorescent materials combined in retroreflective sheeting is reported to enhance daytime visibility [30].

Fluorescent colours, especially fluorescent yellow-green and orange, provide higher visibility during daylight hours. Also, the use of contrasting colours can assist civilian drivers in recognizing a hazard amid the visual clutter of the roadway.

The literature review and review of the wider Australian automotive, emergency services, and military contexts, identified several other proposed or implemented interventions including:

- The trucking industry has demonstrated benefits in applying contour markings outlining the surface profile of the object (i.e. indicating vehicle height, length, and width).
  This design implementation has shown to be effective in signalling to other road users the location of the vehicle and supports recognition of vehicle type.
- Public transportation (i.e. bus) [31] conspicuity improvements such as full body bus livery branding can change perceptions of services and aid immediate recognition (key examples include the Perth Cat bus and Brisbane CityGlider).
- ‘Dazzle’ patterns on military vehicles have been shown to distort speed perception [32].
  Painting units in high contrast geometric patterns (i.e. ‘dazzle patterns’) can distort speed perception (i.e. reducing perceived speed of the object) and trajectory estimates, and the effect is greatest at high speeds. This research suggests extreme patterns should be avoided on locomotives.
- Research into bicycle conspicuity [33] shows that implementing additional livery (on the rear tyre) that is white stripes overlaid on red increases the signal detection for the presence of a bicycle and improves detection distance.

6.2.3.3. Cognitive Conspicuity

Cognitive conspicuity research considers how elements can improve the understanding and interpretation of the incoming perceptual information.

For example, collisions at level crossings may occur due to observers identifying the train but miscalculating the approach speed and time-to-arrival (speed-distance effect).

This issue is known as the ‘speed size illusion’ which is a common visual motion perceptual experience whereby the size of an object affects the estimation of its speed with smaller objects appearing to move faster than larger ones, despite their physical speeds being the same.

Additionally, the speed-size illusion is correlated with retinal image speed distribution bias—distant objects generate smaller retinal image size and speed [34]—and that speed-distance effects are determined from accumulated experience, compounding the phenomenon of the illusion between image speeds (and their size), and moving objects [35].

The literature review and review of the wider Australian rail industry context, identified several proposed or implemented interventions including:

- Training interventions showing large objects moving faster (counterintuitive to the illusion) compared to small objects moving slower.
  Training showed some effect in counteracting the illusion[20] based on lab studies. Further investigation into real-life application is required for suitability in the rail context.
- Yarra Trams in Victoria implemented a community wide ‘Beware the Rhino’ Campaign. The campaign sought to highlight the difficulty of the tram in braking quickly and likened it to “a rhino on a skateboard”. A initial survey of 1087 people post-campaign suggested there was significant campaign recognition. Results reported by Yarra Trams indicate that the total number of incidents of pedestrian knockdown had declined by 26% in comparison to the previous year however, further exploration into the duration of these effects may be warranted for long-term solution approaches. For more detail refer to Section 7.3.
- Research suggests that speed-size illusion is associated with eye movements, and that people tend to make initial fixations to locations around the visual centroid of a moving vehicle.
  Manipulation of eye movement behaviour has been explored as means to reduce the magnitude of the size-speed illusion [36].
  A static fixation square was placed in the foreground at one of two locations on a train (front and centroid). Results showed that with the square placed around the front location of a vehicle, participants do still underestimate the speed of the train relative to a car, however this estimation was better than when the square was placed around the visual centroid of the train.
- Design interventions (i.e. through lighting or livery) could incorporate other illusions that create speed perceptions that could counteract the speed-size illusion.
  The spinner illusion [37] is shown using two circular formations of dots. For one, there are four yellow dots and for the other, there are eight yellow dots. Both sets of dots revolve at the same rate, yet all observers consistently report seeing the dots for the eight-dot composition as rotating faster.
  This effect is enhanced further with inclusion of additional dots (i.e. 12 compared to 8). Further investigation into real-life application of this illusion and its suitability in the rail context is required.

Another key consideration for cognitive conspicuity is the ‘look but fail to see’ effect (also referred to as inattentional blindness and/or change blindness).

Research shows a third of people exhibit inattentional blindness even to objects that are distinctive in colour, shape, and path of motion [38].

Inattentional blindness is an effect whereby people paying attention to a primary task (i.e. driving) often fail to notice an unexpected object (i.e. train), or a change in the visual scene (i.e. change blindness), even when it appears in the centre of their field of vision.

This effect has been demonstrated consistently in the scientific literature and affects highly skilled and highly trained operators including pilots using advanced supportive technologies (i.e. heads up displays).

Change blindness may also increase with age, indicating a group that may be of higher risk at level crossings [39] and can occur when a driver is regularly exposed to the crossing with no train present and has begun to passively perform the checks.

To mitigate this effect, research has considered several interventions:

- Implementation of a Driver Awareness Course that was based around the phenomenon of change blindness showed that participants’ self-reported ability to spot important visual changes was reduced after the change blindness demonstration (across conditions of training being police-led or a laboratory-based trainer) [40].
  This research suggests training interventions may be helpful to remind the community of safety awareness at level crossings.
- Research of Driver eye tracking indicates Drivers tend to use a horizontal search window—external driver fixations tend to fall in a horizontal movement pattern (i.e. people look left and right laterally much more than up and down whilst driving).
  This tendency may be useful in considering pattern and/or conspicuity marking locations and orientations to align with this search window [41].

- Additionally, industry studies show that drivers fixate on bright areas that are in their field of vision [42] which may reduce situational awareness at night.
  This finding may be of key consideration for conspicuity solutions that include arrays of light or create bright areas of focus in that it may present adverse or unexpected impacts under dark lighting conditions.
- Pedestrian road [43] and level crossing [44] research shows flashing lights located in the pavement of crossings in the periphery of pedestrian's vision, are effective at attracting the attention of distracted pedestrians (such as those on mobile phones etc.).
  Train based flashing light solutions that apply a similar approach may therefore successful; however, this would require further testing and validation.

In summary, train conspicuity improvements should consider design enhancements that address visibility, sensory conspicuity, and cognitive conspicuity factors.

Some key recommendations for implementation based on the literature include:

- Use of colour that is salient for daytime (550 nm, yellow-green) and night-time (507 nm, blue-green).
- Implementation of light colours for livery and vehicle painting.
- Patterns that enhance contrast to surrounding environment (i.e. Battenberg markings) that are within the central field of view.
- Light arrays that create a triangle of conspicuity.
- Contour markings that are reflectorised to delineate vehicle height, length, and width and that create a vehicle signature for ease of identification.
- Reflectorised and/or fluorescent materials for night and daytime conspicuity.
- Lighting that induces visual perception of greater speed for approach to mitigate speed-size illusions.
- Implementation of design changes within a horizontal search window.
- Community awareness and training for cognitive biases, and inattentional and change blindness.

6.3. Human Factors Evaluation Criteria for Train Conspicuity Improvement Options

As outlined in Section 6.2.2, there is a need to assess train conspicuity options for effectiveness. To do this, the expanded information processing model shows the degree by which each area of conspicuity (i.e. sensory, cognitive) influences that stage of information processing as shown in Figure 6-3.

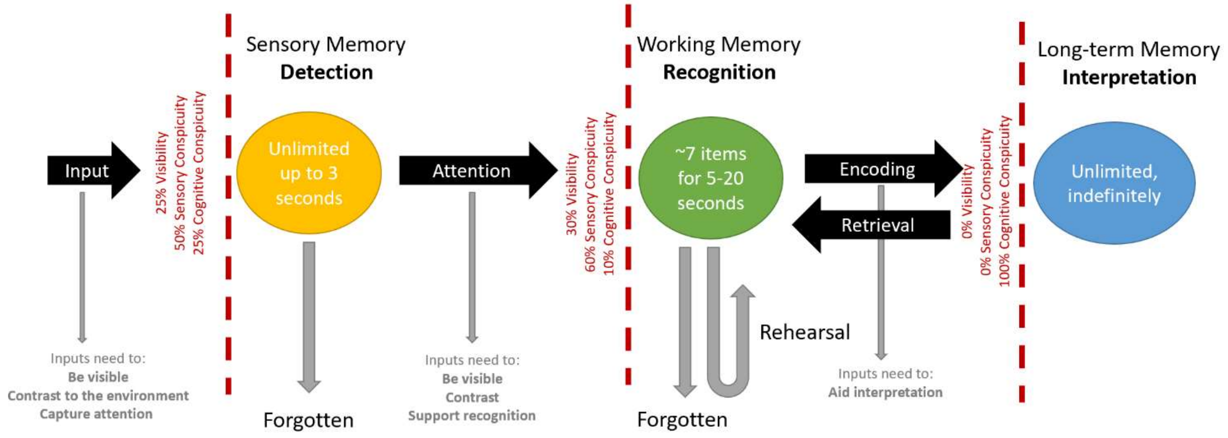


Figure 6-3 - Expanded Information Processing Model to include Conspicuity

To map the conspicuity type to the phases of the model, a task analysis approach was used as it enables identification of task failure and error potential to be mapped for further mitigation strategy consideration (i.e. train conspicuity design intervention). Mitigation strategies can be further informed by the literature review conducted in Section 6.2.3.

As shown in Table 6-1 to Table 6-3 below, the high-level task sequences of road users align to each phase of the model and can be weighted accordingly based on the potential impact of visibility, visual (or sensory) conspicuity, and cognitive conspicuity.

Weightings have been assigned as a function of frequency for each phase as an indicator of importance (also depicted in Figure 6-3).

Exploratory areas for intervention and conspicuity improvements have also been captured as illustrative examples for each task and phase of processing.

Table 6-1 - Tasks associated with Train Detection at Passive Level Crossing

Goal	Tasks	Sub Task	Aids to Task	Error/ Influencing factors	Criterion – visibility, sensory, cognitive conspicuity	Methods to protect against error
	Identify passive level crossing	OUT OF SCOPE				
	Stop at crossing (stop sign/give way sign)	OUT OF SCOPE				
	Observe other driver behaviours	OUT OF SCOPE				
	Scan for train	OUT OF SCOPE				
	Observe Train	Alerted by features of visual appearance	-Train colour contrast/salience -Lighting -Decal/Livery -Proximity -Clear sightlines	-Look but did not see (inattentional blindness, complacency) -Look but confirm 'no train' (confirmation bias) -Omit check -Distraction -Adverse weather -Day/night conditions -Angle of approach/stop -Vegetation/sightlines -Vehicle type	1/4 Visibility 2/4 Sensory conspicuity 1/4 Cognitive conspicuity	-Conspicuity: Draw attention, not just see; contrast to surrounding environment; novel/attention grabbing
		Alerted by sound	-Horn -Clack of wheels	-Does not hear -Windows closed - Loud music - Phone call or other tasks	--Sensory conspicuity (2/4)	-Conspicuity: Differentiation of horn sound or train sound to surrounding environment accounting for vehicle buffering

Table 6-2 - Tasks associated with Train Recognition at Passive Level Crossing

Goal	Tasks	Sub Task	Aids to Task	Error/ Influencing factors	Criterion – visibility, sensory, cognitive conspicuity	Methods to protect against error
🟩	Identify as train	Scene and feature recognition	-Shape and features of train -Visibility of track -Visibility of level crossing	Identification too slow or incorrect Misinterpretation of vehicle type and its characteristics (i.e. large = slow) Weather/time of day conditions	2/6 Visibility 3/6 Sensory conspicuity	-Arrangement of lights -Front of train appearance (aid identification (train) -Delineating side of train at night
	Identify train approaching	Recognise movement of train towards or away from crossing	-Angle of view to train -Binocular disparity	Identification too slow or incorrect Misinterpretation of vehicle type and its characteristics (i.e. large = slow)	--Sensory conspicuity (3/6) 1/6 Cognitive conspicuity	-Front of train appearance (aid identification (train) -Delineating side of train at night Conspicuity: Draw attention, not just see; contrast to surrounding environment; novel/attention grabbing
		Observe distance of train from crossing	-Sightlines to train -Visual effects (i.e. angles versus straight line)	Identification too slow or incorrect Misinterpretation of vehicle type and its characteristics (i.e. large = slow)	---Visibility (2/6) --Sensory conspicuity (3/6)	
	Consider road rules in place	Understanding of familiar signs	OUT OF SCOPE			
	Recognise traffic slowing/ stopping	Brake lights indicate change in conditions	OUT OF SCOPE			

Table 6-3 - Tasks associated with Train Interpretation at Passive Level Crossings

Goal	Tasks	Sub Task	Aids to Task	Error/ Influencing factors	Criterion – visibility, sensory, cognitive conspicuity	Methods to protect against error
	Understand/ interpret speed	Determine time available to cross	Aspects improving salience/detection of train features and motion	Misinterpret information (size-speed illusion) Misinterpretation of vehicle type and its characteristics Amount of information perceived about train	1/2 Cognitive conspicuity	-Interpreting speed when oncoming (as above) -Aids to increase sense of speed/power
	Choose to stop or go	Reassess information available	Time of approach to track and first detection of train	-Insufficient time/failure to reassess Misinterpret information (size-speed illusion) Misinterpretation of vehicle type and its characteristics -Incorrect interpretation of information	1/2 Cognitive conspicuity	Feedback

Appendix A provides detailed description of each proposed train conspicuity improvement option and the associated human factors considerations, visibility, and conspicuity improvement potential—as aligned with the information processing model and task sequences for each phase.

Each solution has been considered from an information processing model perspective, as well as the degree to which visibility, sensory and/or cognitive conspicuity play a role in mitigating or influencing the solution proposed.

7. Existing Conspicuity Controls

The following section discusses the existing freight train conspicuity controls adopted within Australia.

Some controls, such as strobe lights, are adopted in the rail industry internationally, however these are considered under the proposed controls (Section 8 and Appendix A) as these have not been introduced by Australian rolling stock operators, maintainers, or suppliers.

7.1. Current Technical Solutions

The following solutions identified throughout the course of the project are currently implemented on Australian freight vehicles:

- The current AS 7531 standard requires the use of headlights, marker lights, reflective delineators, high contrasting colours, tail lights, visibility lights, number lights and livery on trains.
  It should be noted that AS 7531 is not a mandated standard in law and as such implementation of the controls identified is not necessary for all rolling stock. AS 7531 is, however, commonly implemented within organisations Safety Management Systems (SMS) and the 2009 update to the Train Illumination Report highlights that compliance was widely adopted at the time in which it was published.
- LED lights are gradually displacing filament lights for use in headlights, tail lights, marker lights and ditch lights, both in ‘new build’ and retrofitted locomotives.
  Although the use of LED lights is not mandated by any Australian standard, many operators are seeking to adopt the technology. For example, one operator has refitted their 120 main intermodal locomotives with full LED lighting at their 15-year overhaul as LED lights have been proven to boost train visibility while being energy and cost efficient.
- Current practice regarding the use of locomotive horns recommends sounding the horn on approaching a level crossing. Current health and environmental considerations rule out the prospect of increasing the sound pressure level of the horns.
- On some trains the ditch lights are configured to flash automatically when the train horn is sounded. The SDA-1 type locomotives operated by SCT also flash the ditch lights when they are powered up and when the brakes are released.
- Freight trains switch between low and high beam intensity during different times. Low intensity light is used during night time operation, whereas high beam intensity is utilised during the daylight operating hours to improve conspicuity in high light environments.
- As per the current AS 7531 standard, flashing or rotating beacons are only required for infrastructure maintenance vehicles. The solution has been known to extend to other rolling stock, however, such as sugar rail in Queensland.
- Although requirements regarding vehicle gauge, and static and kinematic envelopes are not intended on ensuring vehicle conspicuity, they do contribute to ensuring that freight vehicles are generally similar in appearance. This recognisable train shape and configuration aids in road users and pedestrians identifying the presence of a train and differentiating between road and rail vehicles.

7.2. Current Operational Solutions

The following solutions identified throughout the course of the project are currently implemented by freight operators and/or maintainers:

- Locomotive cleaning is reportedly conducted during routine servicing of the vehicles. This is generally at consistent intervals across multiple operators, at an average of every 180 days. The freshly serviced locomotive is then placed at the front of the train to ensure that the road drivers have a view of the vehicle where the conspicuity controls are most noticeable.
  It should be noted, however, that the duration between cleaning activities may not be sufficient to ensure that conspicuity controls remain effective throughout operation.
- As confirmed by vehicle operators, reflective delineators are cleaned on a more regular basis when compared to the overall locomotive. At the time of writing, cleaning procedures have not been provided and an accurate frequency for reflector cleaning has not been determined. It is observed that this frequency may vary between operators.

- Operators and Maintainers adopt a safety management system that is informed by local standards and best practices.
  Safety management systems will allow the organisation to track faults and issues with systems and verify their adequate resolution. This includes conspicuity related controls, such as ensuring that lights are working and achieve adequate luminous intensity, reflective delineators are present and fully intact, vehicle paint is not unacceptably degraded etc.
  It should be noted, however, that standards adopted to inform each organisations SMS can vary, and harmonisation of safety management systems may be beneficial in tackling issues associated with freight vehicle conspicuity.

7.3. Current Educational Solutions

Education systems, available training and prior information campaigns have been reviewed to determine the current approach across Australia. Notably, education provided to road users varies state to state, but there is a consistent omission of level crossing interaction as part of the hazard perception testing adopted.

Some information regarding level crossing interaction is captured by road driver education organisations and is publicly available, however this appears to be limited to South Australia only.

Multiple organisations have adopted a rail safety educational programs to provide free education to schools and communities and improve safe travel around trains, stations, and level crossings.

Although such educational sources and awareness programs are available to the community, high level surveys conducted by SNC-Lavalin have highlighted that there is a risk that community uptake may be low, resulting in the full benefit of these courses not being realised.

However, it should be noted that insufficient data was gathered throughout the project programme to make any robust or complete conclusions around the current efficacy of these initiatives.

7.4. Key Issues and Observations

As seen in Section 5, the current conspicuity controls required by AS 7531 and its wide adoption across Australian freight locomotives appear to have been effective in lowering the number of collisions and near misses at passive level crossings during night time operation since its introduction in 2007. However, the trend for daylight hours shows relatively consistent collision and near miss rates.

It should be noted that the data does not necessarily confirm that current controls to improve daylight conspicuity are ineffective, as minor improvements may be offset by increases in traffic levels from year to year.

It does, however, highlight that there is significant opportunity to improve the level of safety at level crossing should improvements to daylight conspicuity be achieved (to a similar degree as the efficacy of the external lighting systems on night time operation, for example).

Currently, the main control to ensure daylight conspicuity is the adoption of high visibility colours on the face of the cab.

Although this provides a level of contrast between the vehicle and its surroundings, the variations in operating environment and the accumulation of dirt, graffiti, and other foreign substances on the vehicle exterior limit the impact that this control has upon level crossing safety.

The latter is currently addressed through cleaning of freight locomotives, however this is currently conducted at an approximate frequency of 180 days, giving rise to the potential for conspicuity controls being hidden, and therefore rendered ineffective, for an extended period of time.

Another significant factor to be considered is the road user's ability to determine the train speed in azimuth (i.e. when looking down the rail corridor).

Previous studies [7] have assessed various controls to improve determination of speed and the resulting time remaining to cross the crossing. These studies have found that crossed ditch/marker lights below the vehicle headlight were most effective, and this has been implemented in AS 7531 as a mandatory requirement.

However, road user ability to determine train speed is still a key issue that may lead to level crossing incidents and near misses, and should be given due consideration when assessing the controls proposed in Section 8 and Appendix A.

Another key contributor to incidents and near misses is road user habituation, error, non-compliance with road rules and inattentional blindness. Notably, mandated road driver educational programmes currently adopted in Australia do not adequately address safe level crossing interaction, and do not appear to assess a driver's ability to successfully navigate a level crossing (whether passive or active) as part of the hazard perception test.

Community awareness initiatives should be considered to combat unsafe level crossing interaction. It is noted that these do currently exist, however it is recommended that the breadth of reach of these initiatives is assessed, and steps are taken to widen the audience of these programmes should a lack of uptake be identified.

8. Considered Conspicuity Controls

Appendix A presents information on the potential controls that have been assessed throughout the project programme. Consideration to the implications, risks, and opportunities of each should be given due consideration prior to implementation.

The solutions have been categorised into immediate-, medium- and long-term opportunities, identifying how quickly solutions may be trialled by the industry, to either support implementation or justify that the control does not produce a practicable safety benefit.

The efficacy and financial implications of each have been assessed qualitatively, based on SNC-Lavalin's engineering knowledge, stakeholder input and the literature review conducted as part of this assessment.

To confirm the efficacy of the controls, it is recommended that trials are conducted for those controls where a reasonable body of evidence does not exist. For all controls that are implemented, adequate data capture should occur following their introduction to confirm or deny their success in reducing level crossing incidents and near misses.

The following table summarises each solution and their categorisations. It should be noted that, at the time of writing these simply identify opportunities to be explored further and do not present controls where efficacy and positive contributions to level crossing safety are guaranteed.

The IDs represent the order in which they were captured within SNC-Lavalin's internal systems, and that these systems also captured existing controls and those deemed out of scope. As such, the IDs are not sequential throughout the table.

The breakdown of solution categorisations are as follows:

- Immediate Opportunities: **15.**
- Medium-Term Opportunities: **11.**
- Long-Term Opportunities: **2.**
- Other: **2.**

As indicated above, these categorisations identify the timeframe associated with trialling the controls, and are not associated with fleet-wide implementation times. Implementation of each control will be subject to the trials providing evidence of control efficacy. The implementation time for controls proven to be effective will be dependent on several factors such as fleet sizes, wider vehicle configuration changes required to facilitate implementation, and vehicle life cycle/planned maintenance activities.

For a detailed description of each option, please refer to Appendix A, which captures:

- Categorisation Rationale.
- Implications & Considerations associated with:
    - Data, Stats & Standards.
    - Technology.
    - Education.
    - Human Factors.
- Risks, Issues & Opportunities.
- Solution Efficacy.
- Financial Implications.

Table 8-1 - Considered Conspicuity Controls for Trial - Summary Table

ID	Title	Description	Timeline for Trials
01	Higher Efficiency Lighting	New higher efficiency lighting technology, such as LEDs, to allow for greater light intensity to be achieved for headlights, marker lights etc. with lower energy consumption.	Immediate Opportunity
02	Coloured Strobe lights	Use of coloured strobe lights to improve conspicuity during daylight hours	Immediate Opportunity
03	Attention Grabbing Textures	Adoption of attention-grabbing textures and patterns on the front of the locomotive to improve contrast with the vehicle's surrounding environment	Immediate Opportunity
04	Dirt repellent paint/coating	Adopt dirt repellent paint or coatings from other industries for more frequent and easier cleaning.	Immediate Opportunity
05	Dirt repellent reflectors	Dirt repellent reflective delineators that can be cleaned more easily and remain in a clean condition for longer.	Medium-Term Opportunity
06	Road Driver Education Improvements	Incorporation of level crossing safety into road driver education, including appropriate scenarios for hazard perception training and testing.	Medium-Term Opportunity
07	In-Situ Cleaning	Cleaning of the locos while they are coupled to the wagons, utilising technology such as train washes, to ensure that the vehicles remain clean while operating in service and that dirt does not prevent the efficacy of the conspicuity controls.	Medium-Term Opportunity
08	Auxiliary strobe lighting	Fitment of white strobe lights to the front of the locomotive to capture the attention of road users and pedestrians	Immediate Opportunity
09	Other Industry Solutions	Adoption of conspicuity solutions adopted in other industries.	N/A – Captured in other items, see Appendix A for detail
10	LED Wobbly Headlights	Implementation of headlights which oscillate, rather than remaining in a fixed position, to attract the attention of road users and pedestrians.	Immediate Opportunity
11	Light Projections	Light projections from the train to the level crossing to provide early warning to road users, particularly in scenarios where sightlines of the rail corridor are poor (e.g. where thick vegetation exists).	Long-Term Opportunity
12	Lighting Arrays	Patterns in which arrays of single or multi-coloured lighting can be used to improve train visibility.	Medium-Term Opportunity
13	Flashing Headlights	Incorporation of flashing headlights on approach to a level crossing to better capture road user and pedestrian attention.	Immediate Opportunity

14	Vehicle Side Lighting	Dynamo lighting along the side of the train to increase the visibility of the wagons while crossing through a level crossing, particularly at night	Medium-Term Opportunity
15	Vertical Scrolling Lights	Vertical LED lights that are programmable to be attached on the front of the locomotive and display certain moving or stationary patterns and/or messages.	Medium-Term Opportunity
16	Variable Timing LED Lights	Alterations to the control mechanisms of flashing lights to produce flashes at varying frequencies to capture road user and pedestrian attention more successfully. Similarly, to existing controls, this could be interlocked with the vehicle horn to produce a variable flashing light when the horn is sounded.	Immediate Opportunity
17	Low Frequency Sound	Incorporation of horns with lower frequency sound to enable better penetration of materials and aid in road user's ability to hear an oncoming train.	Medium-Term Opportunity
18	Varying Light Wavelengths	Use of different wavelengths of lighting i.e. different coloured lights to reach further out in front of the locomotive.	Immediate Opportunity
20	Exterior Edge Lighting	Additional exterior 'edge' lighting to be added to increase the visibility of the train by illuminating its outline.	Medium-Term Opportunity
21	Recognisable device/ face	Standardising locomotive cab design and/or paint regimes to allow for more immediate differentiation between road and rail vehicles	Immediate Opportunity
22	Intelligent Transport Systems	Integrating GPS tracking and warning systems in the form of intelligent transport system between road traffic and rolling stock to provide a channel of communication between the vehicles.	Long-Term Opportunity
23	Targeted Awareness Campaigns	Include targeted campaigns for road users, heavy vehicle drivers, and pedestrians to improve behaviour around, and interaction with level crossings.	Immediate Opportunity
24	Increased Cleaning Schedules	Increased frequency of locomotive cleaning, with consideration to smart monitoring devices to conduct reactive cleaning.	Immediate Opportunity
25	UHF/CB Automated Radio Broadcast	Ultra-High Frequency Citizen Band radio broadcast to be used by the train driver to communicate to road vehicles upon approaching level crossings.	Medium-Term Opportunity
31	Count Down Timer	Implementation of a countdown timer mounted to the front of the vehicle to signal to road users the time in which it will take the train to reach the level crossing.	Not expected to be implemented due to risks highlighted in Appendix A
32	Operation Life Saver Equivalent	Operation life saver (OLI) is a leader in rail safety education and is adopted in North America. OLI has been running public education programs across the U.S. preventing collisions, injuries, and fatalities on and around railroad tracks and highway-rail grade crossings.	Medium-Term Opportunity

56	Self-cleaning photocatalyst based agents / coatings	Applying a clear agent or coating that is dirt repellent on train surface for more frequent and easier cleaning.	Immediate Opportunity
57	Driver Conducted Localised Cleaning	Localised cleaning of dirt/oil/etc. conducted by the train driver to remedy instances where conspicuity controls are covered or impaired.	Immediate Opportunity
58	Solar Powered Lane Markers	Fitment of solar powered lane markers, as used on roads, along the side of the wagons to illuminate the train and clearly show its length during night time operation.	Immediate Opportunity
66	Alterations to Existing Paint Schemes	Alter existing train colour/livery to colour schemes to allow for better contrast between the locomotive and its background, including the adoption of fluorescent and photo reflective paint	Medium-Term Opportunity

9. Conclusions

Level crossing safety is contributed to by various factors including rail vehicle conspicuity, road and rail alignment, infrastructure controls, surrounding environmental conditions, weather (and other visibility impairing factors), and road user behaviour.

With the data currently captured, it is difficult to accurately determine the extent to which each factor controls the outcome of level crossing interaction. Examples exist, however, where collisions have occurred with rail vehicles in a condition of low conspicuity, supporting initiatives to improve current controls and incorporate new technology to increase the train's visibility to road users and pedestrians.

The Australian rail industry currently implements a series of design requirements, through the adoption of AS 7531, aimed at improving vehicle conspicuity.

Notably, the controls identified within this standard are generally aimed at ensuring contrast between the vehicle and its surroundings through the use of high visibility paint; illuminating the exterior of the vehicle using headlights, marker lights etc. and providing reflective materials on the sides of the vehicles to reflect road user headlights during night time operation.

With the exception of the high contrast paint, these controls mainly improve vehicle conspicuity during low visibility or night time operation, which is reflected in the downward trend of incidents and near misses that can be seen within the data set discussed in Section 5.

However, as the surrounding environment changes throughout the rail corridor, the contrast achieved by incorporating a solid high visibility paint colour varies as the vehicle progresses through its route.

The improvement to level crossing safety at passive level crossings during daylight operation therefore appears to be negligible and there is significant room for improvement for daytime conspicuity.

SNC-Lavalin, working closely with ACRI, ONRSR and other stakeholders, have successfully identified 30 opportunities that have potential to improve freight vehicle conspicuity and, in turn, level crossing safety, that may be implemented into the Australian rail industry.

Each of these potential controls have been qualitatively assessed to determine the associated implications, risks, issues and opportunities to inform decisions on their implementation as level crossing safety initiatives progress.

Evidence to support the efficacy of each control is variable, as described further within Appendix A.

It should be noted that certain controls are more effective under specific conditions, such as night time operation, and given that most incidents occur during daylight hours (between 75% and 95%), these controls may be less effective overall in reducing level crossing incidents and near misses.

In accordance with the project scope, SNC-Lavalin has identified and assessed each potential solution without bias and has not provided any recommendations to pursue any controls as higher priority. It is however recommended that daytime operation is given focus as this contributes to the majority of incidents and is currently a key area of concern.

Further recommendations are included in Section 10.

10. Recommendations

The following recommendations are made in association with the conclusions provided:

- Evidence of control efficacy should be considered prior to implementation, with additional simulations or tests conducted for instances where supporting data is lacking to ensure that controls will improve level crossing safety without introducing additional hazards into the rail corridor. It is recommended that relevant data is captured following implementation to determine the effectiveness of each control in improving the level of safety at passive level crossings.
- Consideration should be given to testing controls prior to wide scale implementation and the associated investment. Decisions surrounding the inclusion and scope of testing activities should consider the body of evidence supporting the efficacy of the controls in the context of the rail corridor. This should consider the array of environmental conditions that may be experienced when compared to other industries that may already implement the proposed solution.
- Other controls not associated with rolling stock conspicuity should be considered to assess and improve mitigation strategies holistically for the full level crossing system and its interfaces. This may include assessment of rail infrastructure, road infrastructure and environmental management.
- Consideration is to be given to working with drivers and driver unions to communicate the scale of the issue surrounding level crossing safety and vehicle conspicuity and discuss the potential solutions that may be adopted (i.e. such as driver conducted cleaning etc.).

Appendices

Appendix A. Potential Controls

A.1. Immediate Opportunities

<table>
<tr><td>Title</td><td colspan="4">Higher Efficiency Lighting</td><td>ID</td><td>01</td></tr>
<tr><td>Description</td><td colspan="6">New higher efficiency lighting technology, such as LEDs, to allow for greater light intensity to be achieved for headlights, marker lights etc. with lower energy consumption.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="6">Higher efficiency lighting, such as LEDs, can directly replace existing light bulbs with minimal changes to the wider vehicle configuration. It is expected that existing cable routes and lighting controls can be utilised.</td></tr>
<tr><td colspan="7">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="6">LED lighting technology, such as the Model 8770 Locomotive produced by JW Speaker, can readily achieve light intensity levels that exceed the minimum requirements of AS 7531. With the adoption of these systems, standards may be adapted to prescribe a greater light intensity level during daylight hours, which may improve conspicuity. It is expected that night time light intensity would remain consistent with current requirements as an increased light intensity would introduce adverse effects.</td></tr>
<tr><td>Technology</td><td colspan="6">LED technology, such as the Model 8770 Locomotive produced by JW Speaker, is currently in production and proven as a rail industry solution. Suppliers for this technology appear to exist in Australia currently, for example, Transit Supplies provide a train LED headlight (PAR56 SCT013) manufactured by Teknoware.
Currently, new locos procured within the Australian market are fitted with LED headlights. It is anticipated that the retrofit activities required to upgrade existing locos with LED technology would be relatively straight forward requiring minimal changes to other items such as cable routes/conduits and controls.
However, at the time of writing, it has not been confirmed which locos are not fitted with LED lights.</td></tr>
<tr><td>Education</td><td colspan="6">Higher light intensities may require minor alterations to driver training to ensure that high intensity light levels are used at the correct times during network operation.</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td colspan="2">Visibility</td><td colspan="3">Sensory Conspicuity</td></tr>
<tr><td>Static light may not be as effective at grabbing attention</td><td colspan="2">Brightness contrast/luminance should be enhanced through implementation</td><td colspan="3">Lighting needs to consider sunlight (rise and sunset) for potential obscurity and/or glare effects. Consideration needs to be given to both the brightness contrast and colour contrast of the light with the train and ambient conditions.</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td colspan="4">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="2">Lighting needs to consider headlight distribution. Larger/wider spread may reduce speed estimation ability</td><td colspan="4">Higher light intensity is associated with an improved time interval (i.e. less time) between appearance of the visual signal and conscious perception in the brain.</td></tr>
<tr><td colspan="7">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="6">• White light is not as visible during daylight hours
• Any lights applied at roof level are very hard to clean and improvements in intensity may therefore have negligible results
• Implementation of new powered treatments will require adaptation to maintenance procedures, including any parts and spares held by operators</td></tr>
</table>

	• Implementation of new LED lighting would generate a level of obsolescence in parts and spares held by rolling stock maintainers
Opportunities	• Improved light intensity during daylight hours may result in improvements to train conspicuity
Conclusions	
Efficacy	The adoption of LEDs will allow for higher light intensities to be achieved, potentially improving conspicuity during daylight hours, where higher light intensity levels are generally used. However, noting that previous studies have raised concerns regarding the efficacy of white light during daylight hours, improvements are likely to be limited.
Financial Implications	Expected to be a low-cost solution. Existing cable routes and lighting controls can be retained; however, it should be noted that this will generate a level of obsolescence in the parts and spares held by the maintainers. Careful consideration will need to be given to who the responsible party is for costs associated with this obsolescence.
Further Comments	Nil

Title	Coloured Strobe lights	ID	02
Description	Use of coloured strobe lights to improve conspicuity during daylight hours		
Categorisation Rationale	Mounting of the strobe lights onto locomotives may utilise existing conduits and power supply. Ease of implementation would be driven by specific rolling stock configuration and spare capacity.		
Implications & Considerations			
Data, Stats & Standards	Testing was conducted by VTT in Finland with auxiliary strobe lighting systems installed in trains in addition to existing headlights to increase the visibility of the vehicle. It was concluded that strobe lights were successful in enhancing the detection of trains at level crossings. Warning lights with 3 consecutive blinks followed by a 3s break was found to be highly effective. Standards, including AS 7531, may have to be adapted to place controls on coloured strobe lighting. Currently no guidance on the application of strobe lights exists within Australian rolling stock standards.		
Technology	Coloured strobe lights are not currently applied in the Australian rolling stock industry. Subsequently, at the time of writing, no global rail industry coloured strobe lighting suppliers have been found. Although this technology exists in other industries, such as the emergency services, a supply chain would have to be established for rail suitable strobe lights prior to implementing this solution. This would include, for example, design of coloured strobe lighting and associated attachments able to withstand the shock and vibration levels experienced within the rail corridor. As strobe lighting is an additional system fitted to the front of the locomotive, new conduits and power supply may be required to facilitate its implementation.		
Education	Community awareness and education for road users of colour lights for freight trains to avoid 'startle' or 'surprise' effects. There may be a period of initial implementation and rollout where the public need to adjust and become familiar.		
	General	Visibility	Sensory Conspicuity
Human Factors	Strobe lights carry the risk of distracting vehicle operators and hindering visibility of other objects, particularly during the night. Strobe lights could impede a person’s vision (particularly at night), induce driver distraction, and trigger rare bodily reactions such as an unusual feeling, involuntary twitch, or full-blown seizure due to photosensitive epilepsy. There may be limitations to the effectiveness of a strobe light, as a single strobe light may not improve detection when added to locomotives already fitted with both headlights and crossing lights. The colour of the light will also impact the distance at which it can be perceived. FRA research shows that a triangle of white flashing light (headlight and ditch lights) is far more effective.	There will be a need to consider colour use and contrast with train livery and surrounding environment. There will be a need to consider the crew/driver and whether this option impedes or affects driver visibility and/or contributes to distraction, difficulty achieving depth perception or seeing track-based information.	Lighting solutions need to consider sunlight (rise and sunset) for potential obscurity and/or glare effects. Considerations for the brightness contrast and colour contrast of the light and how it contrasts with the train and ambient conditions. An extended use of warning lights is likely to contribute to adjacent vehicle crashes. There is a need to consider the frequency of use and when the strobe lights commence - the distance from the level crossing (for activation) will be affected by angles and unique aspects for each one, unless these are permanently strobing (which presents its own risks). There may be an effect on Driver behaviour where the strobe is no longer salient because the

	Flashing lights in periphery may improve chance of detection. Strobe lights could cause serious issue with 'weld spots' in eyes, plus light pollution. Coloured lighting associated with emergency vehicles - coloured lighting shown to decrease vehicle speeds in the vicinity of the flashing lights.		wait time is so long for some locations or the strobe is not detected until a short distance due level crossing characteristic (i.e. angle). The placement of lighting on the locomotive and the different locomotive fronts and doing so a) consistently and b) for each consist design will need to be evaluated for a position of prominence/benefit.

	Cognitive Conspicuity - *Search*	Cognitive Conspicuity - *Attentional*
	Red invokes the strongest emotions of any colour and is associated with observers perceiving higher speeds. However, red is banned on the rail corridor and is harder to spot at a distance as well as under dark conditions. Evidence shows that yellow-green (daytime) and blue-green (night time) colours are best for general detection. There is a phenomenon for red and blue lights whereby red strobing lights can cause the perception a vehicle moving away, and blue can result in the perception of vehicle moving towards. Also, of note, blue is most visible at night, while red is most visible during the day.	There is potential that strobe lights cause confusion whereby the RMV thinks that it is an emergency vehicle. This could lead to response delays as the interpretation time takes longer and the train needs to be closer to determine what the object is.

Risks, Issues & Opportunities	
Risks & Issues	• Any lights applied at roof level are very hard to clean. The effectiveness of strobe lights mounted at the top of the vehicle may therefore reduce. • Strobe lighting may have an adverse effect on the drivers, track workers, community and environment. • Implementation of new powered treatments will require adaptation to maintenance procedures, including parts and spares held by the operator. • Optimal colours for the front of a loco, to ensure high contrast with its surroundings, may vary throughout a journey. For example, drought affected land, lush green vegetation and desert will all have varying contrasting colours. • Epilepsy considerations for rate of strobe and the effect induced. • Colour combinations to account for colour-blind individuals. Approx. 7-9% of male population is colour deficient. • Considerations for the crew/driver and whether this option impedes or affects driver visibility and/or contributes to distraction, difficulty achieving depth perception or seeing track-based information. • A recent study for Western Australian Government Railways indicated that a single strobe light did not improve detection when added to locomotives already fitted with both headlights and crossing lights. • Error risk and infrastructure needed for Belize/GPS based to automate flashing for the right time on approach to the Level crossing.
Opportunities	• Adoption of coloured strobes is likely to significantly improve conspicuity during daylight hours when compared to white strobes and other lighting currently adopted. • Strobe lights could be interlocked with the vehicle horn to ensure that strobes only activate on approach to a level crossing, however the implementation of this would need to consider any risks associated with human error.

	• If strobe lighting is interlocked with the horn and horn is not sounded due to driver error/degraded systems, both signals will not be presented to road user. Consider automation. Possibility to lead to inaccurate judgement of safety to cross. Additionally, possibility for desensitisation of strobe lighting (false positives) and risk taking.
Conclusions	
Efficacy	'Strobe lights have been proven to be effective in increasing the visibility of trains at level crossing. Coloured lights have been used as warning signs in ambulances and other emergency vehicles and are successful in improving conspicuity during daylight hours.
Financial Implications	This is expected to be a low to moderate cost solution. Existing off-the-shelf products may be suitable for rail operation, however careful consideration should be given to the casing and mounting solutions to ensure they are suitable for rail operation. Implementation of the solution may also require changes to vehicle conduits, power supply etc. depending on lighting design, which will increase cost.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="2">Attention Grabbing Textures</td><td>ID</td><td>03</td></tr>
<tr><td>Description</td><td colspan="4">Adoption of attention-grabbing textures and patterns on the front of the locomotive to improve contrast with the vehicle’s surrounding environment</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="4">Textures and patterns can quickly be applied to the front of the vehicle using decals.</td></tr>
<tr><td colspan="5">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="4">For this option, it should be noted that previous research concludes that maintaining the outline of the vehicle face as a solid colour is a key contributor to vehicle conspicuity. As such, in adopting certain patterns on the vehicle face, care should be taken to maintain this outline (perhaps in yellow high visibility colour currently adopted, for example).
Known attention grabbing textures should be identified and provided in standards to ensure adequate control across Australia. Appropriate paint and livery materials will also have to be identified and will need to comply with other applicable AS standards.
Colours incorporated into any texture or pattern will need to comply with AS 2700.</td></tr>
<tr><td>Technology</td><td colspan="4">Technological implications are expected to be dependent upon the method of applying textures and patterns to the front of the freight locomotives. Exterior livery is widely applied to passenger rolling stock within Australia, and it is expected that similar methods of application could be adopted for the front and sides of freight locomotives. However, applying patterns using paint may require new methods or technology to be adopted by suppliers/maintainers to ensure that attention grabbing patterns can be accurately drawn on the front and sides of the vehicle.</td></tr>
<tr><td>Education</td><td colspan="4">Nil</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td>Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td>Further detail required on possible solutions, possibly referring to surface patterns of vehicle livery.
Maintaining outline of vehicle is important for conspicuity.
Attention grabbing patterns may be more effective.
Effective only in high light conditions (day).
Optimal colour of locomotive can vary throughout the journey. An example would be a train going from Sydney to Perth would travel through night and day, green vegetation, red soil, and little vegetation, etc.</td><td>Research indicates texture may improve visibility by providing an additional cue
Certain types of textures may cause the vehicle to be camouflaged or interfere with detection of the lines/shape. Smaller textures, or textures which only cover a section of the vehicle are typically preferable.</td><td colspan="2">Battenberg/chevron markings have been used successfully for emergency services vehicles (UK).
There will need to be consideration given to the chosen colour and/or combination(s) and their contrast against surrounds.
Research shows white strips overlaid on red colour for bicycles increases detection distance.
Research shows two colour stripes (black and white) is more effective than single colour for spatial awareness and collision avoidance (police vehicles)</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td colspan="2">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="2">Dazzle patterns can distort speed perception (i.e. make it appear to move slower), and the effect is greatest at high speeds. Finding suggests extreme patterns should be avoided as it may compound the already-known speed-size bias.</td><td colspan="2">Nil</td></tr>
<tr><td colspan="5">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="4">• High contrasting colours and patterns may be ineffective when the vehicle is dirty
• Graffiti on wagons can cover safety features such as patterns and livery, and may render these conspicuity controls ineffective
• Lack of empirical evidence for textures effect on conspicuity</td></tr>
</table>

	• Solution is expected to be ineffective during night operation, unless certain reflective materials are incorporated in the pattern/texture applied.
Opportunities	• Adoption of textures may improve contrast for a greater range of environmental conditions and surrounding infrastructure when compared to solid colours. Textures will allow for the adoption of multiple colours on the front of the vehicle that may contrast with, for example, drought affected land, lush green vegetation, and desert in varying weather conditions • Opportunity to also incorporate reflective materials into the texture or pattern on the front of the vehicle, however the effectiveness of this would be limited by the road and rail geometry
Conclusions	
Efficacy	The body of evidence supporting the efficacy of this solution is somewhat limited. Efficacy will be dependent on the colours and patterns utilised; however, it should be noted that certain patterns can distort a person's ability to judge speed successfully, which may further contribute to issues in judging train speed when looking down the rail corridor. Further investigation will be required to confirm optimum patterns and their influence on level crossing safety.
Financial Implications	This is expected to be a very low-cost solution as it can be attained through application of decals.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="4">Dirt repellent paint/coating</td><td>ID</td><td>04</td></tr>
<tr><td>Description</td><td colspan="6">Adopt dirt repellent paint or coatings from other industries for more frequent and easier cleaning.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="6">Dirt repellent paint/coating can be applied directly on the existing paint without any changes to the vehicle and is expected to be a low-cost solution.</td></tr>
<tr><td colspan="7">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="6">Dirt repellent paint/coating is already in use for some fleets, and particular in new passenger fleets. However assessments have not been conducted into the effects of this on vehicle conspicuity. Instead, this is generally to assist in cleaning of graffiti and for aesthetic purposes.
Options for new paint or coating materials that provide dirt/oil etc. repellent properties should be specified within the relevant standards.
Any coatings will be required to comply with environmental requirements and legislation.</td></tr>
<tr><td>Technology</td><td colspan="6">Unipart Rail provides a dirt, grime and chemical repellent paint coating that is also proven to withstand graffiti (Aqueous Guard). The coating can be applied on top of the vehicle paint and is removable using a formulated gel. The adoption of this product could improve the vehicle's ability to remain clean in service, or may be used in conjunction with operational controls, such as the removal and reapplication of the coating to remedy any significant graffiti or other markings experienced on the vehicle during operation.
Another viable product is ecotio2 Ultra C which is a clear topcoat and is easy to clean. This product has been used inside tunnels in Japan to reduce build up on the painted tunnel walls due to easy clean. It utilises an ion exchange catalyst or redox catalyst that uses resin as a binder.
Other environment friendly product is Nanoecogroup’s 3D nano technology paint to prevent adhesion of graffiti and dirt.
The application of the coating may require new technology and/or methods to be adopted by suppliers/maintainers.</td></tr>
<tr><td>Education</td><td colspan="6">There will be a need for training maintenance personnel in the use of correct cleaning materials (including management of non-approved cleaning products by accident).
Training to also cover procedures for the MSDS of new materials</td></tr>
<tr><td rowspan="4">Human Factors</td><td colspan="2">General</td><td colspan="2">Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td colspan="2">The roughness of the paint surface can affect reflectance and should be considered for selection of product.</td><td colspan="2">Dirt repellent would improve the visibility of existing train livery.</td><td colspan="2">Paint or coating solution relies on the effectiveness of the existing paint/colour in providing sensory conspicuity (i.e. contrast)</td></tr>
<tr><td colspan="3">Cognitive Conspicuity - <i>Search</i></td><td colspan="3">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="3">Nil</td><td colspan="3">Nil</td></tr>
<tr><td colspan="7">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="6">• Dirt/oil etc. repellent paint or coatings may have adverse environmental effects.
• Application of coatings or dirt repellent paint may increase procurement and maintenance costs.
• Cleaning gel for Aqueous Guard would need to be incorporated into supply chain for maintainers/operators and procedures would have to be updated accordingly.
• The effectiveness of the dirt repellent paint or coating may be reduced by using train wash.</td></tr>
<tr><td>Opportunities</td><td colspan="6">• Any materials such as paint or coatings that aid in repelling dirt, oil, coal etc. will present advantages in ensuring high contrast between the vehicle and its environment for a greater proportion of time in operation. This is a result of keeping the vehicle in a cleaner condition, allowing the high visibility paint to remain visible.</td></tr>
</table>

	Similarly, any improvements to graffiti repellent materials may also improve vehicle visibility.
Conclusions	
Efficacy	Dirt repellent paint or coatings alone is unlikely to be an effective control to improve the vehicle conspicuity. Instead, this must be coupled with adequate cleaning procedures to ensure that the vehicle maintains its visibility throughout operation. However, dirt repellent paint/coatings will improve efficiencies regarding vehicle cleaning and may facilitate an increase in cleaning frequency due to shorter required periods.
Financial Implications	Dirt repellent paint/coating is expected to be a low-cost solution; however, price will be driven by the coating/paint type utilised.
Further Comments	Nil

Title	Auxiliary strobe lighting	ID	08
Description	Fitment of white strobe lights to the front of the locomotive to capture the attention of road users and pedestrians		
Categorisation Rationale	Mounting of the strobe lights onto locomotives may utilise existing conduits and power supply. Ease of implementation would be driven by specific rolling stock configuration and spare capacity.		
Implications & Considerations			
Data, Stats & Standards	Testing was conducted by VTT in Finland with auxiliary strobe lighting systems installed in trains in addition to existing headlights to increase the visibility of the vehicle. It was found that strobe lights were successful in enhancing the detection of trains at level crossings. Warning lights with 3 consecutive blinks followed by a 3s break was found to be highly effective. Standards, including AS 7531, may have to be adapted to place controls on strobe lighting, such as light intensity and frequency. Currently no guidance on the application of strobe lights exists within Australian rolling stock standards.		
Technology	Strobe lights are not currently applied in the Australian rolling stock industry. Strobe light suppliers exist within the Australian market; however it does not appear that these have been applied to rail applications or assessed against the criteria applicable to a railway environment (e.g. shock & vibration limits etc.). However, strobe lighting has been successfully trialled on rolling stock by VTT in Singapore (including implementing into vehicle simulators) and Finland. This demonstrates that the application of strobe lights is feasible. As strobe lighting is an additional system fitted to the front of the locomotive, new conduits and power supply may be required to facilitate its implementation.		
Education	Community awareness and education for road users of strobe lights for freight trains to avoid 'startle' or 'surprise' effects. There may be a period of initial implementation and rollout where the public need to adjust and become familiar.		
Human Factors	General	Visibility	Sensory Conspicuity
	Strobe lights carry the risk of distracting vehicle operators and hindering visibility of other objects, particularly during the night. Strobe lights could impede a person's vision (particularly at night), induce driver distraction, and trigger rare bodily reactions such as an unusual feeling, involuntary twitch, or full-blown seizure due to photosensitive epilepsy. There may be limitations to the effectiveness of a strobe light, as a single strobe light may not improve detection when added to locomotives already fitted with both headlights and crossing lights. FRA research shows that a triangle of white flashing light (headlight and ditch lights) is far more effective.	There will be a need to consider colour use and contrast with train livery and surrounding environment. There will be a need to consider the crew/driver and whether this option impedes or affects driver visibility and/or contributes to distraction, difficulty achieving depth perception or seeing track-based information.	Lighting solutions need to consider sunlight (rise and sunset) for potential obscurity and/or glare effects. Considerations for the brightness contrast and colour contrast of the light and how it contrasts with the train and ambient conditions. An extended use of warning lights is likely to contribute to adjacent vehicle crashes. There is a need to consider the frequency of use and when the strobe lights commence - the distance from the level crossing (for activation) will be affected by angles and unique aspects for each one, unless these are permanently strobing (which presents its own risks). There may be an effect on Driver behaviour where the strobe is no longer salient because the

<table>
<tr><td rowspan="3"></td><td>Flashing lights in periphery may improve chance of detection.
Strobe lights could cause serious issue with 'weld spots' in eyes, plus light pollution.</td><td colspan="2"></td><td>wait time is so long for some locations or the strobe is not detected until a short distance due level crossing characteristics (i.e. angle).
The placement of lighting on the locomotive and the different locomotive fronts and doing so a) consistently and b) for each consist design will need to be evaluated for a position of prominence/benefit.</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - Search</td><td colspan="2">Cognitive Conspicuity - Attentional</td></tr>
<tr><td colspan="2">Car driver behaviour research suggests effectiveness of flashing warning lights on other vehicles aid identification of vehicle direction when lights flash in a sequential pattern.
Issues for further investigation: What reaction might road users have to seeing a flashing light? Can they perceive speed effectively?</td><td colspan="2">There is potential that strobe lights cause confusion whereby the RMV thinks that it is an emergency vehicle. This could lead to response delays as the interpretation time takes longer and the train needs to be closer to determine what the object is.</td></tr>
<tr><td colspan="5">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="4">• White light is not as visible during daylight hours, meaning that non-coloured strobes may be sub-optimal.
• Roof level lighting is very hard to clean, so strobes fitted in this position may become dirty, reducing their effectiveness.
• Strobe lighting may have an adverse effect on the drivers, track workers, community and environment.
• Implementation of new powered treatments will require adaptation to maintenance procedures, including parts and spares held by the operator.
• Epilepsy considerations for rate of strobe and the effect induced.
• Considerations for the crew/driver and whether this option impedes or affects driver visibility and/or contributes to distraction, difficulty achieving depth perception or seeing track-based information.
• Strobes may be masked by more powerful crossing ditch lights and rendered ineffective.</td></tr>
<tr><td>Opportunities</td><td colspan="4">• Adoption of strobes will improve vehicle conspicuity during day, and research previously conducted suggests strobes are visible from greater distances and wider angles when compared to vehicle headlights.</td></tr>
<tr><td colspan="5">Conclusions</td></tr>
<tr><td>Efficacy</td><td colspan="4">Strobe lights have been proven to be effective in increasing the visibility of trains at level crossing. However, previous research has demonstrated that white light is not particularly effective during daylight hours, raising concerns that this control may only be effective under certain environmental circumstances.</td></tr>
<tr><td>Financial Implications</td><td colspan="4">This is expected to be a low to moderate cost solution. Existing off-the-shelf products may be suitable for rail operation, however careful consideration should be given to the casing and mounting solutions to ensure they are suitable for rail operation.
Implementation of the solution may also require changes to vehicle conduits, power supply etc. depending on lighting design, which will increase cost.</td></tr>
<tr><td>Further Comments</td><td colspan="4">Nil</td></tr>
</table>

<table>
<tr><td>Title</td><td colspan="4">LED Wobbly Headlights</td><td>ID</td><td>10</td></tr>
<tr><td>Description</td><td colspan="6">Implementation of headlights which oscillate, rather than remaining in a fixed position, to attract the attention of road users and pedestrians.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="6">LED wobbly headlight technology already exists and has previously been implemented as a rolling stock system overseas. It is expected that only minimal configuration changes would be required to existing freight locomotives.</td></tr>
<tr><td colspan="7">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="6">Standards, including AS 7531, may have to be adapted to place controls on "wobbly" lights. Currently no guidance on the application of such lighting solutions exists within Australian rolling stock standards.</td></tr>
<tr><td>Technology</td><td colspan="6">Oscillating beacons have previously been utilised in the rail industry, dating back as far as 1936. The historical technology has been adapted over time and is now provided by TriLite under the Mars "888" product. The Mars "888", termed traffic breaker, provides light in a "triple eight" pattern to alert surrounding personnel of the presence of emergency equipment. The product is available as a pedestal mounted beacon and a flush mount beacon and can utilise either halogen or LED lighting technology. It is expected that this type of solution could be implemented fairly simply, with minimal changes to the wider vehicle configuration.
An alternative solution exists in the automotive industry, whereby intelligent headlight control, provided by companies such as Bosch, is beginning to be implemented to provide automatic control of car headlights. This technology controls the width and intensity of the light beam using a multi-purpose camera, which determines the current light conditions on the road.
Similar technology could be implemented on freight rolling stock, however adaptations to the artificial intelligence methods would likely be required. In adopting a multi-purpose camera, as per the automotive industry, a visual queue would be required on approach to each level crossing. For this application, it would not be as simple as determining the current light levels surrounding the train. Instead, infrastructure systems may be used to trigger the headlight control to pulse. The control systems adopted in the automotive industry may be utilised to achieve this function, whereby the width of the beam expands and contracts at a given frequency on approach. This could be coupled with changes in light intensity to further improve the "wobble" or pulsating effect and grab the attention of the road user.</td></tr>
<tr><td>Education</td><td colspan="6">Community awareness and education for road users of wobbly lights for freight trains to avoid 'startle' or 'surprise' effects. There may be a period of initial implementation and rollout where the public need to adjust and become familiar.</td></tr>
<tr><td rowspan="4">Human Factors</td><td colspan="2">General</td><td colspan="2">Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td colspan="2">Nil</td><td colspan="2">For crew/driver, this solution may impede or affect their visibility and/or contribute to distraction, difficulty achieving depth perception or seeing track-based information</td><td colspan="2">Nil</td></tr>
<tr><td colspan="3">Cognitive Conspicuity - <i>Search</i></td><td colspan="3">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="3">Lighting that moves in a vertical direction may not be as easy to interpret for speed assessments by RVM. Consideration for frequency/timing of lighting</td><td colspan="3">Nil</td></tr>
<tr><td colspan="7">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="6">• White light is not as visible during daylight hours, and red not allowed within the rail corridor (see Mars "888" product options)
• Wobbly lighting may have adverse effects to drivers, such as causing nausea
• Implementation of new powered treatments will require significant adaptation to maintenance procedures
• Solution requires more parts (i.e. those to control lighting movement), potentially resulting in higher maintenance costs
• Wobbly light may result in greater adverse impacts to the surrounding environment</td></tr>
</table>

Opportunities	• Wobbly lights have potential to grab the attention of road drivers more successfully
Conclusions	
Efficacy	Wobbly headlights have historically been found to successfully capture the attention of persons near to the vehicle. However, adverse effects on the driver may incur additional hazards or hazard causes that should be considered further.
Financial Implications	This is considered as a low-cost solution as the Mars "888" product can be easily procured and implemented
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="4">Flashing Headlights</td><td>ID</td><td>13</td></tr>
<tr><td>Description</td><td colspan="6">Incorporation of flashing headlights on approach to a level crossing to better capture road user and pedestrian attention.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="6">Flashing headlights are currently adopted in some capacity in Australia and the configuration changes associated with implementing the control are fairly simple (e.g. utilising a pressure switch linked to the train horn to initiate headlight flashing on approach).</td></tr>
<tr><td colspan="7">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="6">Requirements provided in T-HR-RS-00600-ST-V2.0 - 9.7.3. Visibility lights.</td></tr>
<tr><td>Technology</td><td colspan="6">Additional technology not required. Software updates can change the headlights so they flash instead of staying on as a beam of light.
Trials have been conducted by SSR using pressure switch connected to the horn.</td></tr>
<tr><td>Education</td><td colspan="6">There may be a need for crew training depending on whether the headlight solution is automatic or not (i.e. if auto only awareness training, if manual there will need to be procedures, timings, etc., covered).
Community education/awareness for what the flashing headlights indicate. There may be a period of initial implementation and rollout where the public need to adjust and become familiar. Precautionary approaches to train handling may be appropriate during this rollout phase.</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td colspan="2">Visibility</td><td colspan="3">Sensory Conspicuity</td></tr>
<tr><td>Initial pedestrian road crossing and level crossing research suggests flashing lights in the periphery of vision in the crossing pavement are effective at attracting the attention of distracted pedestrians (i.e. on smart phones). Potential for train based solutions that apply a similar approach; however this requires further testing and confirmation
Flashing lights in school zones associated with a decrease in driver speeds
Different types of flashing, and flashing vs a rotating late will have different advantages. For example faster flashing indicates urgency, whereas slower flashing rates will minimise glare effects at night. There are also indications that multiple flashing beacons may be more effective, and are most effective when flashing simultaneously rather than alternately.</td><td colspan="2">Considerations for the crew/driver and whether this option impedes or affects driver visibility and/or contributes to distraction, difficulty achieving depth perception or seeing track-based information.</td><td colspan="3">Studies have warned that an extended use of warning lights is likely to contribute to adjacent vehicle crashes.</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td colspan="4">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="2">Car driver behaviour research suggests effectiveness of flashing warning lights on other vehicles aid identification of vehicle direction when lights flash in a sequential pattern.</td><td colspan="4">Nil</td></tr>
<tr><td colspan="7">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="6">• White light is not as visible during daylight hours.
• Flashing lights may have an adverse effect on train drivers/ track workers/ community/ environment.
• Implementation of new powered treatments may require significant adaptation to maintenance procedures.
• Issues with driver error (sounding horns and initiating flashing lights on approach).</td></tr>
</table>

Opportunities	• Flashing lights may capture the attention of pedestrian and road users more successfully.
Conclusions	
Efficacy	There is evidence to support that flashing headlights are effective in grabbing the attention of road users and pedestrians. However, utilising a white light is expected to be sub-optimal for daylight conditions and this does not provide a large contrast due to the low level of contrast with the surrounding environment.
Financial Implications	Financial implications are expected to be low as this solution incurs minimal configuration changes.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="2">Variable Timing LED Lights</td><td>ID</td><td>16</td></tr>
<tr><td>Description</td><td colspan="4">Alterations to the control mechanisms of flashing lights to produce flashes at varying frequencies to capture road user and pedestrian attention more successfully. Similarly to existing controls, this could be interlocked with the vehicle horn to produce a variable flashing light when the horn is sounded.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="4">Many freight vehicles are already fitted with a flashing headlight that flashes at a given frequency when the vehicle horn is sounded. Adaptation of this control to a variable flash would therefore be achievable through minor configuration changes.</td></tr>
<tr><td colspan="5">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="4">Minor changes could be made to Australian standards (e.g. AS 7531) to control variable timing light design.
For further information on flashing lights, see ACRI report LC13C, which provides information regarding a literature review conducted to assess emergency services flashing rates/frequencies.</td></tr>
<tr><td>Technology</td><td colspan="4">Past research has shown that it is easier to capture the visual attention of drivers and pedestrians using variable timings and patterns of LED's. This included either the illumination of single LED's or sequentially illuminating LED's generating the illusion of movement towards the target. The research concluded that the participant reacted 200-450ms faster than with constant illumination.
Suitable technology already exists for road vehicles, such as emergency services and construction vehicles. This technology could be utilised for application in the rail corridor and is not expected to require significant changes to the wider vehicle configuration (i.e. many vehicle lights already flash upon sounding the horn, and the control systems of these lights would likely only require minimal adaptation to achieve this function).</td></tr>
<tr><td>Education</td><td colspan="4">Community awareness to aid identification and interpretation of variable light frequencies indicating a train is present.</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td colspan="2">Visibility</td><td>Sensory Conspicuity</td></tr>
<tr><td>Assumption is that this solution proposes marker lights/ditch lights do flashing whereas headlights do not. There is a need to understand when the driver needs ditch/marker lights, so any flashing effect doesn’t interfere with tasks/activities.
This solution may work like wayside horns to get better motorist response as more difficult to perceive (i.e. not able to habituate).
Habituation of the road users and the control.</td><td colspan="2">Visibility will be dependent on the LED light intensity.</td><td>Alternating/variable timing can capture attention by contrasting with other lighting in the environment. This effect may depend on wider environment review (i.e. level crossings near other flashing lights such as billboards, traffic lights, construction works, etc.).</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td colspan="2">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="2">It may be hard to judge speed of train if there are variable timings presented as this conflicts with the train moving forward at a consistent speed. Perceptual effect/features would need assessment of the solution such that some frequencies are not used that may induce a 'slower approach' effect.</td><td colspan="2">Variability may hinder identification of train as it is inconsistent.</td></tr>
<tr><td colspan="5">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="4">• If white lights are utilised, these are not as visible during daylight hours.
• Strobe light effect may adversely impact the drivers/ track workers/ community/ environment.
• Implementation of new powered treatments will require significant adaptation to maintenance procedures.
• Driver distraction risk.</td></tr>
</table>

Opportunities	• Variable timing LEDs may be successful in grabbing the attention of road users while approaching a level crossing.
Conclusions	
Efficacy	It is expected that a variable flash would capture the attention of road users and pedestrians more successfully than that of a constant frequency. Similar approaches have already been adopted within the emergency services industry as a measure to improve vehicle conspicuity. As such, this control can be somewhat considered as proven in service, however it should be noted that application in the rail environment has not yet been thoroughly tested. Consideration should also be given to the limitation of white light effectiveness during daylight hours, which may in turn limit the effectiveness of this control.
Financial Implications	Financial implications are expected to be minor as only small configuration changes would be required.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="2">Varying Light Wavelengths</td><td>ID 18</td></tr>
<tr><td>Description</td><td colspan="3">Use of different wavelengths of lighting i.e. different coloured lights to reach further out in front of the locomotive.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="3">Different coloured lights are readily available in the market and can directly be used to replace existing lights with minimal changes to the wider vehicle configuration. It is expected that existing cable routes and lighting controls can be utilised.</td></tr>
<tr><td colspan="4">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="3">Varying wavelength of light, i.e. different colours are used by Emergency vehicles as visual warning to indicate urgency and have proven to be effective for years.
In Australia, colours are generally regulated at the state level. The significance of different colours of lights are described below:
• Red and blue is used by Law enforcement officers and emergency vehicles.
• Red signifies risk to life situations.
• Amber or yellow are used by roadside breakdown vehicle, tow trucks, etc.
• Green is used to denote stationary ambulance, fire or police command motor vehicle.
• Blue is reserved for emergency motor vehicles only.
• Magenta or purple are used by heavy vehicle enforcement/escort officers of Transport for NSW, Victorian VicRoads and South Australian Transport Safety Inspectors.
• Magenta or purple in combination with amber or yellow is used by some council rangers.
A combination or colour different to the ones mentioned above can be used to improve train visibility on level crossing without startling the road vehicle drivers.
There’s a requirement to update rail design standards so the lighting colours used don’t coincide with the colours designated for Emergency vehicles in each Australian state.</td></tr>
<tr><td>Technology</td><td colspan="3">In other words, different wavelength of light means different colours of light. According to the study, high visibility coloured light such as blue/violet can be used. They'll help to increase the visibility of the train during the day. A combination of coloured lights can also be used to produce by-product of another colour. For example: pink light as a mixture of red and violet light.
It should be noted that wavelength between 380 nm and 760 nm only is detected by the human eye and perceived as visible light.
Wavelength of different coloured lights:
• Violet: 380–450 nm
• Blue: 450–495 nm.
• Green: 495–570 nm.
• Yellow: 570–590 nm.
• Orange: 590–620 nm.
• Red: 620–750 nm
Since, red and green coloured lights are prohibited from use in rail industry, they are out of scope for consideration.</td></tr>
<tr><td>Education</td><td colspan="3">Community awareness and education for road users of colour lights for freight trains to avoid 'startle' or 'surprise' effects. There may be a period of initial implementation and rollout where the public need to adjust and become familiar. Precautionary approaches to train handling may be appropriate during this rollout phase.
Train drivers will need to be trained to use the lights safely</td></tr>
<tr><td rowspan="2">Human Factors</td><td>General</td><td>Visibility</td><td>Sensory Conspicuity</td></tr>
<tr><td>There may be some road users who are colour blind. Relying solely on colour may not enhance visibility or conspicuity from some road users.</td><td>May not improve visibility if limited by colour use in the rail environment and how far away these colours can be</td><td>Lighting needs to consider sunlight (rise and sunset) for potential obscurity and/or glare effects. Considerations for the brightness contrast and colour contrast of the light and how it contrasts with the train and ambient conditions.</td></tr>
</table>

<table>
<tr><td></td><td>Angles of level crossings and parallax effects could impact effectiveness of light spill.
Different wavelengths will vary for the distance at which they can be perceived and the rate at which they will be washed out by ambient light. For example, blue lights would need to be stronger than some other colours during the day, whereas red would need to be stronger at night.</td><td>perceived (given context)
There may be a wash out of visual cues of the road if the colours are projected ahead.</td><td>Sensory conspicuity could be hindered by distance for seeing the colour used and the contextual background including day/lighting effects (i.e. for blue light). Recommendations for yellow-green (daylight) and blue-green (night).
Blinding effect of some colours for drivers.
Alternating lighting under day and night conditions would be beneficial to maximise conspicuity and linking this into train master clocks (rather than reliant on driver)</td></tr>
<tr><td></td><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td>Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td></td><td colspan="2">Some colours may confuse the freight locomotive with other vehicle types such as:
• Red/Blue use for police or emergency lights which could lead to misinterpretation or delays in interpretation.
• Orange lights might get washed out with road works or be mistaken for maintenance vehicles.
This may impact perceptions of vehicle speed as well.</td><td>Some colours may confuse the freight locomotive with other vehicle types such as:
• Red/Blue use for police or emergency lights which could lead to misinterpretation or delays in interpretation.
• Orange lights might get washed out with road works or be mistaken for maintenance vehicles.</td></tr>
<tr><td colspan="4">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="3">• Roof level lightings are hard to clean.
• Implementation of new powered treatments will require significant adaptation to maintenance procedures.
• There is a potential for driver (crew) distraction and the lights can impact crew’s visibility.
• Certain colours, such as red and green, are prohibited in the rail corridor.
• Blinding effect of some colours for drivers.
• Would be good to understand the data better for the contributory factors - attentional or not attending at the time as to whether this solution would be effective or not.
• Habituation impact - road users who are familiar with the crossing and whether this would garner attention for those users.
• May startle people on the Level crossing.</td></tr>
<tr><td>Opportunities</td><td colspan="3">• Different colours of light are expected to improve vehicle conspicuity during daylight hours.
• Different wavelengths of light may reach out further in front of the train, providing an earlier warning to road users.
• Alternating lighting under day and night conditions would be beneficial to maximise conspicuity and linking this into train master clocks (rather than reliant on driver).</td></tr>
<tr><td colspan="4">Conclusions</td></tr>
<tr><td>Efficacy</td><td colspan="3">Using different wavelengths i.e. colours of light is unlikely to improve the vehicle conspicuity during night time operation, however improvements may occur during the day. Care should be taken to ensure that an optimum colour is defined and lies outside the above-mentioned emergency lighting schemes in Australia. Use of different light colours in rail industry requires campaigns to educate road users about the intent of other coloured light.</td></tr>
<tr><td>Financial Implications</td><td colspan="3">The solution itself is expected to be a low-cost alternative but education campaigns will require sufficient funding to ensure adequate understanding of the light’s intent.</td></tr>
<tr><td>Further Comments</td><td colspan="3">Nil</td></tr>
</table>

<table>
<tr><td>Title</td><td colspan="4">Recognisable device/ face</td><td>ID</td><td>21</td></tr>
<tr><td>Description</td><td colspan="6">Standardising locomotive cab design and/or paint regimes to allow for more immediate differentiation between road and rail vehicles</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="6">Using an optimum recognisable device or consistent front face schemes can help in train conspicuity without any need for significant changes to vehicle configuration.</td></tr>
<tr><th colspan="7">Implications & Considerations</th></tr>
<tr><td>Data, Stats & Standards</td><td colspan="6">In 1950s, UK mandated rail freight to at least have yellow pilot at the front face or entirely yellow front face in order to make them more visible.
Due to the advancement in headlight technology, in current GM/RT 2131 standard, the yellow front ends have become optional. Only for trains with headlights not complying to TSI, yellow front ends are still required.
AS 7531 has a requirement regarding painting the front face of loco with high visibility colours.</td></tr>
<tr><td>Technology</td><td colspan="6">Currently, the Australian rail freight have different face front ends. For instance, Pacific National has yellow face front, SCT has white and red, Aurizon has yellow and orange face front, etc. It may be useful to have a standardised face front colour schemes for consistency and educating public regarding the same.
Alternative to painting the front face of locomotive, vinyl wraps of consistent colours can be used. The vinyl wrap can be easily removed and discarded if it gets dirty, given it should be eco-friendly too.</td></tr>
<tr><td>Education</td><td colspan="6">Community awareness/education to support identification and recognition that this is a freight locomotive. Education campaign to also teach about the front of the train, what to look for and their approach at speed.</td></tr>
<tr><td rowspan="4">Human Factors</td><th>General</th><th colspan="2">Visibility</th><th colspan="3">Sensory Conspicuity</th></tr>
<tr><td>Facial recognition ability varies greatly between individuals. Significant East-West differences in face processing and this should be considered for informing design.
Issues for further investigation: What are the UK/Other Countries currently implementing? What is effective?</td><td colspan="2">Research shows that red should not be used as it looks black under dark/night conditions. Additionally, research shows yellow-green is best for daytime and blue-green is best for night.</td><td colspan="3">Nil</td></tr>
<tr><th colspan="2">Cognitive Conspicuity - <i>Search</i></th><th colspan="4">Cognitive Conspicuity - <i>Attentional</i></th></tr>
<tr><td colspan="2">Nil</td><td colspan="4">A standardised face may enhance recognition if the 'face' of the train is associated with 'train' and scheme of what that means (i.e. big, heavy, fast, dangerous etc.).
Creating a consistent colour scheme or pattern will help road users to differentiate freight vehicles from other vehicles; and bright yellow can be easily distinguished from the environment.</td></tr>
<tr><th colspan="7">Risks, Issues & Opportunities</th></tr>
<tr><td>Risks & Issues</td><td colspan="6">• High contrasting colours and livery is ineffective when the vehicle is dirty.
• Graffiti on wagons can cover safety features, including conspicuity controls.
• Optimal colours for the front of a loco may vary throughout a journey. For example, drought affected land, lush green vegetation and desert will all have varying contrasting colours.
• Difficulty in achieving widespread standardisation.</td></tr>
</table>

Opportunities	• Provision of a recognisable face may help improve freight vehicle identification and differentiation from other types of vehicle. • Creating a consistent colour scheme or pattern will help road user to differentiate freight vehicle from other vehicles; and bright yellow can be easily distinguished from the environment. • The face doesn't necessarily have to be painted; a disposable film similar to motorcycle helmet visor can be used. It can be removed after each journey to avoid washing the train. Sustainable disposable materials can be considered.
Conclusions	
Efficacy	The body of evidence supporting the efficacy of this solution is somewhat limited from the past experiences in UK. Efficacy will be dependent on the colours and patterns utilised, however it should be noted that certain patterns can distort a person's ability to judge speed successfully, which may further contribute to issues in judging train speed when looking down the rail corridor. Further investigation will be required to confirm optimum patterns and colour scheme.
Financial Implications	This is expected to be a low-cost solution but the cost of using disposable vinyl wraps requires further investigation.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="2">Targeted Awareness Campaigns</td><td>ID</td><td>23</td></tr>
<tr><td>Description</td><td colspan="4">Include targeted campaigns for road users, heavy vehicle drivers, and pedestrians to improve behaviour around, and interaction with level crossings.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="4">Behavioural changes of road users take a long time. This would also require constant reinforcements to their behaviour.</td></tr>
<tr><td colspan="5">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="4">Rhino on skateboards- Trams weigh around 50 tonnes and a Rhino weighs about 1.5 tonnes. So, a tram is comparable to 30 Rhinos. Good example to show the dangers around trams.</td></tr>
<tr><td>Technology</td><td colspan="4">No additional technology required.</td></tr>
<tr><td>Education</td><td colspan="4">Education interventions will be more effective for some contributing factors around level crossing behaviour and specific investigation into the contributing behaviours is key (i.e. looking but not seeing, deliberate risk taking). For example, it is likely to be most effective for targeting biases such as 'big object = slow object' effects or general awareness of any conspicuity changes made. Training will need to be informed by more detailed data capture from incident analysis. It is possible that in surveying people they are not familiar with how to use passive level crossings if they are not part of Driver Instruction training across all Australian States. Also, if passive crossings are encountered in certain regions/areas, locals may demonstrate different behaviours to non-locals (different risk factors or contributory issues) for example, locals know there is always a 10 am train so at 945 approach the Level crossing with that bias versus non-locals think it does not have a boom therefore it is no longer used or do not recognise it as a passive crossing and how to engage with it safely.
Community-level training should include more level crossing scenarios into new driving training/testing.
Frequency of rail traffic vs. LRV exposure means this is unlikely to work long-term.
Some drivers not wanting to wait and choose to chance driving across and some drives do not treat a stop sign at a LX the same as they would at a road intersection. These elements would require specific education work.</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td colspan="2">Visibility</td><td>Sensory Conspicuity</td></tr>
<tr><td>Yarra trams campaign achieved very high recall and is reported to have achieved a 26% reduction in passenger tram incidents.
Increasing the prevalence of trains, particularly in areas where they are not seen often can potentially increase the ability to detect them by effectually increasing prevalence to the driver through education delivery. This is also likely to decrease in efficacy over time if prevalence wanes.</td><td colspan="2">A person who is primed to look for A particular object or characteristics (high Prevalence in memory) is more likely to detect an object when performing A visual scan and detect sooner.</td><td>Nil</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td colspan="2">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="2">Melbourne Yarra Trams - Beware the Rhino campaign has showed a reduction in pedestrian impacts with trams. Increased community awareness.</td><td colspan="2">Nil</td></tr>
<tr><td colspan="5">Risks, Issues & Opportunities</td></tr>
</table>

Risks & Issues	• Lacking the understanding of key failure mechanisms/cause of incidents & near misses will present challenges in generating targeted campaigns. • Relies on organisational buy-in/safety culture and cost-driven factors may influence whether procedure is adhered to.
Opportunities	• People become more aware and are more cautious around level crossings. • People are less likely to take risks when approaching level crossings. • Community awareness campaign in line with Victorian implementation of 'Beware the Rhino' trams program. • Facilitates community engagement - could involve community members in the design process to achieve buy-in for education. • Data capture: opportunity to understand the perspectives of various road users and what the key issues are.
Conclusions	
Efficacy	The Rhino campaign resulted in a 26% reduction in tram-pedestrian accidents in the first 12 months following the campaigns launch. So similar campaigns are also expected to have good efficacy.
Financial Implications	Supporting an Ad campaign would require significant investments. Similarly changing the livery on the trains, adding posters and informing the public would require additional staff and volunteers.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="2">Increased Cleaning Schedules</td><td>ID</td><td>24</td></tr>
<tr><td>Description</td><td colspan="4">Increased frequency of locomotive cleaning, with consideration to smart monitoring devices to conduct reactive cleaning.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="4">Increased cleaning frequency for locomotives does not require the introduction of new technology. Only operational changes are required.</td></tr>
<tr><td colspan="5">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="4">Locomotives are regularly cleaned before each service, typically every 180 days. Reflective delineators are cleaned on a more regular basis. NSW locomotives get a lot of soot build up from operating in tunnels, particularly the trailing locomotives. Generally, the freshly serviced and cleaned locomotive would be placed on to the front of the train where it reportedly remains relatively clean. However, there are instances where poor vehicle condition may have significantly contributed to vehicle collisions, as reported in Section 3.3 of the report.
The increased frequency of cleaning is not anticipated to incur any changes to standards, however operators/maintainers would be required to absorb the cost associated with the additional cleaning activities.</td></tr>
<tr><td>Technology</td><td colspan="4">Increased cleaning frequency does not require any adaptation to existing technology. However, it should be noted that new technologies could be coupled with this solution to improve operational efficiency. These include:
• Laser based cleaning systems (such as those produced by PowerLase) to efficiently clean Graffiti and dirt whilst minimising damage to the structure of the trains.
• Sensor Technology, such as that deployed to monitor rail track and wheels, to more accurately determine when cleaning is required, allowing operators to react to poor conditions rather than routinely performing cleaning activities (i.e. potentially reducing operational expenditure).</td></tr>
<tr><td>Education</td><td colspan="4">There will be a need for maintenance training / awareness that identification of cleaning will require immediate action/priority.</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td colspan="2">Visibility</td><td>Sensory Conspicuity</td></tr>
<tr><td>Additional tasking may cause driver dissent.
Relies on organisational buy-in/safety culture and cost-driven factors may influence whether procedure is adhered to.</td><td colspan="2">Cleaning may retain the visibility of existing train livery.</td><td>Paint or coating solution relies on the effectiveness of the existing paint/colour in providing sensory conspicuity (i.e. contrast).</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td colspan="2">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="2">Nil</td><td colspan="2">Nil</td></tr>
<tr><td colspan="5">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="4">• May result in resistance from operators and higher operational cost.
• Relies on organisational buy-in/safety culture and cost-driven factors may influence whether procedure is adhered to.</td></tr>
<tr><td>Opportunities</td><td colspan="4">• Reduction in visibility/conspicuity controls being covered by foreign matter and rendered ineffective.
• Improvement to vehicle aesthetics.
• Depending on method of cleaning, wear may reduce for certain components due to reduced time in sub-optimal condition.
• Opportunity to utilise sensor technology and adopt reactive cleaning procedures that are based on vehicle condition.</td></tr>
<tr><td colspan="5">Conclusions</td></tr>
</table>

Efficacy	The adoption of this control will help to prevent issues arising from conspicuity controls being covered by dirt/soot etc. This is a known issue, with collisions having previously occurred with vehicles in an unclean state. However, the level at which vehicle cleanliness contributes to level crossing safety cannot currently be accurately quantified and it is recommended that the efficacy of this control is determined through trials/tests once implemented. It should be noted that the efficacy of this control can be improved by adopting smart technology, such as sensors, however this will increase the timeframe for implementation.
Financial Implications	Without introducing new technological systems to aid in the implementation of this control, costs are expected to be low as only procedural changes are required. However, should more advanced technologies be desired, this will give rise to both CAPEX and OPEX.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="4">Self-cleaning photocatalyst based agents / coatings</td><td>ID</td><td>56</td></tr>
<tr><td>Description</td><td colspan="6">Applying a clear agent or coating that is dirt repellent on train surface for more efficient cleaning.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="6">Photocatalytic based agent or coating can be applied directly on the existing paint without any changes to the vehicle and is expected to be a low-cost solution.</td></tr>
<tr><td colspan="7">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="6">Currently, photocatalyst coatings are popular in Japan and Asia in modern buildings because of its numerous advantages - air purifying, reduced maintenance cost, anti-viral, anti-bacterial, mould prevention, self-cleaning, deodorising, building wellness, anti-carbonation and graffiti resistant.
Self-cleaning coating (not necessarily photocatalytic coatings) is used in marine applications for thermal stability, long-term durability under UV radiation and resistance against wide range of pH solution.
Options for new paint or coating materials that provide dirt/oil etc. repellent properties should be specified within the relevant standards.
Any coatings will be required to comply with environmental requirements and legislation.</td></tr>
<tr><td>Technology</td><td colspan="6">Photocatalytic coating is a transparent layer of paint/varnish that can be applied on the surface of train. There are different types of self-cleaning coating.
The photocatalytic coating that can be used on locomotives to reduce the amount of adsorbed dirt and facilitate the removal of impurities should have following properties:
• Oleophobic-hydrophilic with a contact angle <10 deg for water; and an angle >150 deg for non-polar substances.
Some suppliers that cater to the need of Australian market are ecotio2, Ceramic Pro TAG, CHOOSE NanoTech, SmartCoat Australia, etc.
SNC-Lavalin reached out to one of the suppliers, ecotio2 mentioned above to understand more about photocatalytic paint/coating. It was suggested that general photocatalysts are not suitable for surfaces that build up a lot of dirt as they are normally used for the outside of buildings that are not subjected to contact/any abrasion.</td></tr>
<tr><td>Education</td><td colspan="6">There is a need for training for maintenance personnel to use the correct cleaning materials as well as covering how to address the incorrect cleaning product use. Training will also need to align with procedures for the MSDS of new materials.</td></tr>
<tr><td rowspan="4">Human Factors</td><td colspan="2">General</td><td colspan="2">Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td colspan="2">Paint surface roughness can affect reflectance.
Consideration for front vs. side of train implementation and impact (effectiveness).</td><td colspan="2">Cleaning may retain the visibility of existing train livery.</td><td colspan="2">Paint or coating solution relies on the effectiveness of the existing paint/colour in providing sensory conspicuity (i.e. contrast).
Considerations for luminance/reflectance of the coating when applied under both day/night conditions.</td></tr>
<tr><td colspan="3">Cognitive Conspicuity - <i>Search</i></td><td colspan="3">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="3">Nil</td><td colspan="3">Nil</td></tr>
<tr><td colspan="7">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="6">• Dirt/oil etc. repellent paint or coatings may have adverse environmental effects.
• Application of coatings or dirt repellent paint may increase procurement and maintenance costs.
• Cleaning solution would need to be incorporated into supply chain for maintainers/operators and procedures would have to be updated accordingly.</td></tr>
</table>

	• Effectiveness may be possibly reduced by using wrong solution for cleaning or train washes.
Opportunities	• Any materials such as paint or coatings that aid in repelling dirt, oil, coal etc. will present advantages in ensuring high contrast between the vehicle and its environment for a greater proportion of time in operation. This is a result of keeping the vehicle in a cleaner condition, allowing the high visibility paint to remain visible. Similarly, any improvements to graffiti repellent materials may also improve vehicle visibility. • Luminescence in the paint/coating can allow glowing at night feature.
Conclusions	
Efficacy	It's suggested to verify the effectiveness of the material in real conditions as laboratory conditions or application in other industry do not provide/consider the possibility of creating air samples that reflects the composition of real air in different places. Also, temperature has a significant impact on the efficiency of the coating. Photocatalytic paint or coating that are dirt repellent alone is unlikely to be an effective control to improve the vehicle conspicuity. Instead, this must be coupled with adequate cleaning procedures to ensure that the vehicle maintains its visibility throughout operation. However, dirt repellent paint/coatings will improve efficiencies regarding vehicle cleaning and may facilitate an increase in cleaning frequency due to shorter required periods.
Financial Implications	Photocatalytic coating is considered a low-cost option.
Further Comments	Photocatalytic paint or coating cannot be used in rail environment as general photocatalysts are not suitable for surfaces that get a lot of dirt build up as they are normally used for the outside of buildings that are not subjected to contact/any abrasion.

<table>
<tr><td>Title</td><td colspan="3">**Driver Conducted Localised Cleaning**</td><td>ID</td><td>**57**</td></tr>
<tr><td>Description</td><td colspan="5">Localised cleaning of dirt/oil/etc. conducted by the train driver to remedy instances where conspicuity controls are covered or impaired.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="5">Control requires changes to operational approaches only, with no changes to vehicle configuration.</td></tr>
<tr><td colspan="6">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="5">Nil</td></tr>
<tr><td>Technology</td><td colspan="5">Cleaning products currently used by operators are expected to be suitable to allow for drivers to conduct local cleaning of the front and sides of the vehicle.</td></tr>
<tr><td>Education</td><td colspan="5">Driver training will be required to ensure they are competent in identifying safety impairing dirt accumulation and can perform cleaning in accordance with appropriate OH&S procedures.
Organisational awareness and training (i.e. rostering personnel, management) to ensure delays in performing the task are supported or time allocated. If organisation places pressure on Drivers to run on time, there may be a risk of this task not being performed.
Training to cover/counteract perceptions about what needs to be cleaned and when, and how to determine whether a situation is an issue.
Work with RSOs and drivers, cleaning lights and side reflectors is a critical task.</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td colspan="2">Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td>Additional manual handling and labour activities will be required by drivers, which will likely require adaptation to driver/operator training materials and manuals.
This will require articulation of a minimum standard (and procedure) for taking the consist out of service/keeping it in. Drivers already perform walkaround checks as part of pre-start, this could be incorporated but would require some way for Drivers to gauge whether the consist is fit for service.</td><td colspan="2">Cleaning may retain the visibility of existing train livery.</td><td colspan="2">Paint or coating solution relies on the effectiveness of the existing paint/colour in providing sensory conspicuity (i.e. contrast).</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - *Search*</td><td colspan="3">Cognitive Conspicuity - *Attentional*</td></tr>
<tr><td colspan="2">Nil</td><td colspan="3">Nil</td></tr>
<tr><td colspan="6">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="5">• Drivers’ union may resist change, leading to challenges in implementing solution.
• May result in longer timeframes at terminating locations and a roll-on impact to rosters, schedules and logistics.
• Organisational pressure may result in shortcuts.
• Infrastructure non-compliances may cause difficulties in driver's conducting cleaning tasks (i.e. lack of clearance on one side, lack of pathway around vehicle etc.).
• Exposure of drivers to bio-hazards and other potential safeworking issues/challenges.</td></tr>
<tr><td>Opportunities</td><td colspan="5">• Localised cleaning during operation will help prevent conspicuity/visibility controls from being covered by dirt/oil/graffiti for prolonged periods in service.
• Resistance is expected to change from organisation to organisation, meaning there may be opportunity for early testing of efficacy with willing operators.
• Potential to incorporate incentives/rewards for drivers based on the cleanliness of their loco.</td></tr>
<tr><td colspan="6">Conclusions</td></tr>
</table>

Efficacy	The efficacy of the control is reliant on cooperation of the train drivers to conduct localised cleaning and the training of these drivers to ensure that conspicuity impeding dirt/oil etc. can be accurately identified. Successful implementation may require increased auditing or oversight from operator/maintainer organisations.
Financial Implications	Financial implications are expected to be low as only operational changes are required.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="2">Solar Powered Lane Markers</td><td>ID</td><td>58</td></tr>
<tr><td>Description</td><td colspan="4">Fitment of solar powered lane markers, as used on roads, along the side of the wagons to illuminate the train and clearly show its length during night time operation.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="4">The implementation of this technology is already being trialled in Australia. Introduction of such technology would require minimal changes to the wider vehicle configuration, particularly noting that new cables would not be required to run down the side of the vehicle (dissimilar to other vehicle side lighting solutions).</td></tr>
<tr><td colspan="5">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="4">Solar powered lighting will need to meet the luminance level prescribed by relevant standards. The attachment method must also be suitable for the rail environment and will have to meet shock & vibration and crashworthiness standards.</td></tr>
<tr><td>Technology</td><td colspan="4">Solar powered lane markers currently exist in the road industry and have a design life between 3 and 5 years.
Current systems are rated at IP68 and are therefore deemed suitable for rail operation and the expected extreme weather conditions. However, consideration will need to be given to the equipment attachment/fitment strategy to ensure the components can with withstand the levels of shock and vibration experienced in the rail corridor.</td></tr>
<tr><td>Education</td><td colspan="4">May require training and procedural changes for walkaround and pre-start checks for Drivers to confirm lights are functional. There is a need to educate people on the importance of this task and why they are doing it.</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td>Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td>Luminance levels would need to be comparable or better than hard wired.
Consideration needs to be given to what information the solution is trying to convey to road users.</td><td>Nil</td><td colspan="2">Considerations for location of solar lights (if there are limitations to situating these at effective positions).</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td colspan="2">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="2">Nil</td><td colspan="2">Nil</td></tr>
<tr><td colspan="5">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="4">• Solar panels placed horizontally instead of vertically on the locomotive thus reducing the amount of sunlight it can capture.
• Concerns regarding operation during winter or after being stored in maintenance facilities with low light levels.
• HF risk of post-maintenance services needing to charge the solar sufficiently to ensure the lights function as intended. Risk of taking trains out where these lights are non-functional (i.e. after night, after maintenance in a depot) would need to understand battery charge/life and suitability.</td></tr>
<tr><td>Opportunities</td><td colspan="4">• Increased visibility of trains without the requirement of additional electrical connections.
• Easy to attach to the sides of the train, requires almost zero maintenance and easy to replace.</td></tr>
<tr><td colspan="5">Conclusions</td></tr>
<tr><td>Efficacy</td><td colspan="4">Proven to be highly useful on the roads at night. Would need to run trials to confirm the efficacy on trains.</td></tr>
<tr><td>Financial Implications</td><td colspan="4">Low Financial implications as they are cheap, easy to replace and attach onto the wagons. Cost effective @ $26 each. 8x per wagon so would cost $208 in total. Waterproof (IP68), automatic activation and simple installation.</td></tr>
<tr><td>Further Comments</td><td colspan="4">Nil</td></tr>
</table>

A.2. Medium-term Opportunities

<table>
<tr><td>Title</td><td colspan="3">Dirt repellent reflectors</td><td>ID</td><td>05</td></tr>
<tr><td>Description</td><td colspan="5">Dirt repellent reflective delineators that can be cleaned more easily and remain in a clean condition for longer.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="5">They can be applied directly to the train surface without any requirement for changes to vehicle configuration.</td></tr>
<tr><td colspan="6">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="5">Options for new reflective materials that provide dirt/oil etc. repellent properties should be specified within the relevant standards.
It will be required to comply with environmental requirements and legislation.</td></tr>
<tr><td>Technology</td><td colspan="5">At the time of writing, it does not appear that coatings similar to Aqueous Guard exist for application specifically to reflective delineators. As such, to implement this control would require advancements in technology and testing to ensure functionality is realised and application is suitable.
An alternative approach would be to use reflective materials that can more readily be replaced, allowing for an increase in frequency of reflective delineator replacement. Products such as Accuform's rail car delineator reflective tape (SKU: PTC202) may be suitable for this purpose, however it is likely that this approach would incur higher maintenance costs for the freight vehicles and wagons. The attempted adoption of such materials may also incur challenges throughout environmental approval processes should any alternative materials be adopted by the suppliers.</td></tr>
<tr><td>Education</td><td colspan="5">Nil</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td>Visibility</td><td colspan="3">Sensory Conspicuity</td></tr>
<tr><td>Placement of reflectors should consider the field of view for RVM while also considering the placement location to maximise material cleanliness as well as risk of debris /damage.</td><td>Dirt repellent reflectors, may retain the visibility of existing train livery.</td><td colspan="3">Retroreflective materials/markings are only effective at night and rely on external light sources. Height of reflectors will need to be considered for vehicle lighting positioning/angle (i.e. car vs heavy goods vehicle).
Some research shows the implementation of retro-reflective screens that reflect vehicle headlights could improve visibility of oncoming vehicles. If this is located on the train, the reflection may be of other vehicles causing confusion or delayed reaction times.
If containers are used for this solution, some containers or trains may have it implemented while others do not. This discrepancy could lead to some biases by road users on approach (i.e. if I don't see a reflector there is no train, however this may not be the case).</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td colspan="3">Cognitive Conspicuity – <i>Attentional</i></td></tr>
<tr><td colspan="2">Research indicating that positioning/layout affects speed-size illusion with central positions more at risk of maintaining the effect.</td><td colspan="3">Nil</td></tr>
</table>

Risks, Issues & Opportunities	
Risks & Issues	• Dirt/oil etc. repellent delineators or coatings may have adverse environmental effects. • Application of coatings or dirt repellent delineators may increase procurement and maintenance costs. • Reflective tapes adopted would have to comply with Australian environmental requirements. • Reflector effectiveness can be reduced by debris or soot on-route and may require cleaning in middle of the journey.
Opportunities	• Any reflector materials that aid in repelling dirt, oil, coal etc. will present advantages in ensuring their function is realised for a greater proportion of time in operation. This is a result of keeping the vehicle in a cleaner condition and potentially reducing the maintenance effort or increasing the life of the components. Similarly, any improvements to graffiti repellent materials may also improve vehicle visibility. • Carefully consider the location or placement of reflective strips.
Conclusions	
Efficacy	Dirt repellent reflectors alone is unlikely to be an effective control to improve the vehicle conspicuity. Instead, this must be coupled with adequate cleaning procedures to ensure that the reflectors maintain their reflective properties (i.e. are note obscured or covered by dirt) throughout operation. However, dirt repellent reflectors will improve efficiencies regarding vehicle cleaning and may facilitate an increase in cleaning frequency due to shorter required periods.
Financial Implications	This is expected to be a low-cost solution, however price will be driven by the coating/reflector type utilised.
Further Comments	Nil

Title	Road Driver Education Improvements	ID	06
Description	Incorporation of level crossing safety into road driver education, including appropriate scenarios for hazard perception training and testing.		
Categorisation Rationale	Updates have to be made to the current hazard perceptions tests to include different types of level crossing scenarios to help the drivers to be able to judge whether is it safe to pass along a level crossing. Would also need to update the current driver education manuals and this would require an approval process.		
Implications & Considerations			
Data, Stats & Standards	No anticipated changes to rolling stock standards.		
Technology	Improvements in training may include incorporation of virtual reality technology for hazard perception training, particularly for level crossing scenarios for identifying the presence of trains and determining their speeds. Virtual reality technology is currently in use in Australia and utilised for a variety of purposes. It is therefore anticipated that a feasible technological solution could be achieved, however it is likely that delivery of VR training would be limited to those with person VR devices. The adoption of new technology, however, may not be necessary to achieve reasonable improvements in driver education. A review of the Australian hazard perception and driver training has highlighted that level crossing scenarios are not widely utilised as part of driver training. As such, the key change to be implemented is for level crossing scenarios to be incorporated as part of the road driver training curriculum.		
Education	There are training efficacy considerations if training or awareness is the only mitigation strategy selected. It is important to note that training is not the most effective solution for some psychological aspects of information processing (e.g. inattentional blindness) and that there may be impacts of age on cognition (i.e. older drivers may be more at risk of inattentional or change blindness). Improvements in road driver training and education may help to alleviate current issues with driver habituation, complacence, non-compliance with road rules, misinterpreting distances across crossings and train speed when viewed along the rail corridor. Research in hazard perception shows this is not automatic nor can be explicitly trained, but overall research still needs to demonstrate that HP training actually makes drivers safer. Currently, only weak forms of evidence and inconclusive. 'Beware the Rhino' campaign, Yarra Trams in Melbourne is reported to have reduced passenger 'knockdowns' since implementation. Passive level crossing training could likely benefit road user’s awareness of how to approach, evaluate, and progress through the level-crossing. This would require a national program not state-by-state divergence. Specifically, it may be useful to build more level crossing scenarios into new driver training/testing. Beware of the rhino has high recall but not as much evidence about change in behaviour. Rhino campaign or similar is good to get the convo going and raise awareness. it must be followed for a long period with other awareness raising activities to change behaviour. There may be a need for refresher training or community awareness at intervals for existing drivers who are driving on a route regularly. (i.e. to combat habituation).		
Human Factors	General	Visibility	Sensory Conspicuity
	Driver education paired with additional design strategies could be useful for awareness. If car-based systems such as Google (or in-car) maps show locations of passive level crossings this may benefit drivers. Interface with GPS systems or car-based system to alert	Research shows that detection is decreased for low prevalence targets (not seen often). Education would need to be reinforced by exposing drivers regularly to trains in some way so that it remains high prevalence and thus maintains an increased ability for detection of the train stimulus.	Nil

	drivers to their presence along the route. Further data analysis needed for what people are looking for at a level crossing.	
	Cognitive Conspicuity - *Search*	Cognitive Conspicuity - *Attentional*
	Training (large objects moving faster vs. small objects moving slow) in the lab showed some effect in counteracting the speed-size illusion however, more research is needed.	UK road safety awareness campaign of inattentional blindness showed that after training participants' self-reported ability to detect change in the environment decreased (i.e. mitigating effect of overconfidence). This may indicate those who are given awareness training are more cautious. There is inconclusive evidence as to how long this training effect lasts and whether it helps prevent incidents. Training or campaigns could help people identify what to look for at passive level crossing so they are aware of the hazards and what their search should include (as well as some of the challenges).
Risks, Issues & Opportunities		
Risks & Issues	• Lack of understanding of the key failure mechanisms and causes of incidents & near misses makes it difficult to determine what elements to focus on and whether the proposed targeted campaigns will improve safety or not. • Many heavy vehicle drivers are reluctant to stop at crossings due to the operational difficulties when using crash gearboxes. It is not anticipated that driver education would significantly reduce the risky behaviour for these drivers. • New truck routes are currently approved without rail consultation, making it difficult to perform targeted training and awareness campaigns for logistics companies. • Relies heavily on ways in which road users are engaged and messaging occurs (i.e. via TV ads, signage, or as part of Learner Training across States). • Variability in effectiveness of campaigns -need for strong marketing and messaging (i.e. focus groups etc). • Relies on understanding the key human factors aspects of collisions/near miss incidents (i.e. is it distraction, fatigue, task focus, lack of knowledge of how to traverse as a passive crossing, non-locals being unaware of how to traverse). Correct messaging and targeting needs strong data for behavioural change and awareness.	
Opportunities	• Improvements in education may help alleviate issues associated with driver habituation and complacence. • Improved educations allow for clear communication of train horn sound and purpose. • Clear communication of varying conditions and geometrical conditions, and the issues they impose. • Change in media reporting may assist in highlighting that road driver error is a key cause for LX incidents, rather than placing blame on the rail system. • Clear communication that train frequencies and timetable can be highly variable. • Training associated with level crossings could be harmonized between state to state to ensure consistent interaction approaches for level crossing.	
Conclusions		
Efficacy	The efficacy of any improvements to driver training can be regarded as being driven by the data associated with vehicle collisions and near misses. This data is lacking key information to perform targeted training campaigns, such as demographics of drivers involved in collisions/near misses, years of experience etc.	

	The efficacy of this control is therefore considered variable based on the inputs that will drive the training approach, i.e. will this target new drivers only? Will it primarily target residents of regional areas? Will is target heavy vehicle drivers? etc.
Financial Implications	The cost of this solution is also considered variable and will be dependent on the amount of data capture to be conducted prior to the training initiative. It can be considered that the financial implications will be proportional to the efficacy for this control, as the efficacy will be directly driven by the data capture that precedes it and the processing of this to ensure that targeted training can be conducted.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="2">In-Situ Cleaning</td><td>ID</td><td>7</td></tr>
<tr><td>Description</td><td colspan="4">Cleaning of the locos while they are coupled to the wagons, utilising technology such as train washes, to ensure that the vehicles remain clean while operating in service and that dirt does not prevent the efficacy of the conspicuity controls.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="4">It is expected that existing passenger train washes will not be suitable for the cleaning of freight consists, due to the longer vehicle length and issues associated with fouling mainline track for example. This may, therefore, require of purpose-built facilities for in-situ washing of freight vehicles.</td></tr>
<tr><td colspan="5">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="4">No anticipated changes to rail design standards</td></tr>
<tr><td>Technology</td><td colspan="4">Train wash technology exists and is currently implemented in Australia; however train wash and associated yard design is derived from the rolling stock configuration, and it is understood that these systems are currently not widely adopted for freight vehicles.
Current passenger train wash systems in Australia may not be suitable for freight operation when the locomotive is coupled to the wagons (for example, accessing the train wash may cause fouling of turnouts, crossovers etc. and may not allow mainline movements). New technology, new systems or infrastructure upgrades may need to be considered to facilitate this option. Otherwise, decoupling of the locos may have to occur to allow for the vehicles to be cleaned.
Decoupling is not anticipated to result in significant procedural challenges; however it should be noted that the wider rail operations may suffer as potentially long wagon consists will have to be stabled, the locos driven to an appropriate train wash, then returned and re-coupled to the wagons. This could take a significant amount of time and will occupy large sidings throughout the duration.</td></tr>
<tr><td>Education</td><td colspan="4">There will be a need for maintenance training / awareness that identification of cleaning will require immediate action/priority.</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td colspan="2">Visibility</td><td>Sensory Conspicuity</td></tr>
<tr><td>Additional tasking may cause driver dissent.
Relies on organisational buy-in/safety culture and cost-driven factors may influence whether procedure is adhered to.</td><td colspan="2">Cleaning may retain the visibility of existing train livery.</td><td>Paint or coating solution relies on the effectiveness of the existing paint/colour in providing sensory conspicuity (i.e. contrast).</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td colspan="2">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="2">Nil</td><td colspan="2">Nil</td></tr>
<tr><td colspan="5">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="4">• Suitable drive through train washes currently installed may require significant infrastructure upgrades, or otherwise result in fouling of track (including mainline).
• Utilisation of current train washes may require locos to be de-coupled, resulting in large periods being required for cleaning activities (see technological impacts for further details).
• Introduction of in-situ cleaning will increase operational costs.
• Quality of in-situ cleaning is variable, potentially failing to clean dirt off conspicuity/visibility controls.
• Drive-through train washes are particularly expensive. Therefore, if existing train washes are not suitable, this option would require considerable investment into infrastructure upgrades.</td></tr>
</table>

Opportunities	• Better cleaning approaches will allow for high contrast colours to be visible more often and alleviate issues associated with the vehicles becoming dirty. • In-situ train washes are expected to allow for more frequent cleaning activities capable of removing graffiti, which can often hide conspicuity controls, such as paint, reflectors, and lights. • Roof level lighting is currently difficult to clean using current methods. The adoption of appropriate train wash technology should improve the operator's ability to clean roof level lights.
Conclusions	
Efficacy	The efficacy of this control will be directly linked to the frequency at which trains are cleaned and will hence depend on operational and maintenance approaches. However, it is expected that in-situ cleaning, utilising technology such as a train wash will result in operators cleaning the vehicles more frequently, allowing for the high visibility elements to remain effective throughout a longer proportion of operation.
Financial Implications	Financial implications for this option could either be very low or extreme. This will depend on the adequacy of existing train wash infrastructure to accommodate the locos in-situ with the wagons. It is unlikely that current train washes utilised for passenger rolling stock could be used (i.e. due to significantly shorter train lengths and the risks associated with fouling mainline track). It is therefore expected that adoption of this control would require new facilities to be constructed, which will incur considerable CAPEX and OPEX costs.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="4">Lighting Arrays</td><td>ID</td><td>12</td></tr>
<tr><td>Description</td><td colspan="6">Patterns in which arrays of single or multi-coloured lighting can be used to improve train visibility.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="6">No lighting array suitable for rail operation has been identified during this research and thus, production of suitable lighting array needs to be validated for rail environment. The solution requires additional electrical wiring modifications on the train and upgrade in power supply if insufficient.</td></tr>
<tr><td colspan="7">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="6">Standards do not currently include requirements that govern, prescribe or prevent the implementation of lighting arrays. It is expected that light intensities would be similar to ditch lights/marker lights. However, standards would have to be updated to provide guidance and requirements for the application of lighting arrays.</td></tr>
<tr><td>Technology</td><td colspan="6">At the time of writing, lighting arrays suitable for rail operation, or currently adopted for freight rolling stock have not been identified. However, lighting arrays are utilised in other industries, including on manufacturing lines.
Companies such as Banner Engineering, who have distributors in Australia, provide linear array lights in various colours and rated up to IP68. Colours include white and blue arrays, which could be combined to create a pattern of lighting arrays to make the vehicle more visible during daylight and night time hours. Colours also include green and red, however these are not suitable for the rail corridor.
For implementation into the rail corridor, solutions currently in production would have to be validated against rail specific requirements, such as shock and vibration, or the components would have to be adapted to ensure their suitability for implementation into rolling stock systems. This would include assessing equipment attachment options.
Using lighting arrays would likely require a significant amount of cabling, warranting additional conduits through the vehicle cab to the power source. Upgrading of the power supply may also be required, depending on the spare capacity of the supply and the power required for the lighting arrays.</td></tr>
<tr><td>Education</td><td colspan="6">Community awareness would be needed as part of informing people that the array indicates a train for enhanced recognition properties.
This solution will require community awareness and education to road vehicles (avoid startle/surprise effect). This may work against the cognitive conspicuity of vehicle identification if training/education is not provided. There may be a period of initial implementation and rollout where the public need to adjust and become familiar. Precautionary approaches to train handling may be appropriate during this rollout phase.</td></tr>
<tr><td rowspan="3">Human Factors</td><td colspan="2">General</td><td colspan="2">Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td colspan="2">In general, HF analysis will need to be conducted on the 'pattern' of lighting selected.
Consider extending the alternating flash timing to >15 seconds on approach to crossings.</td><td colspan="2">Light patterns may affect crew/driver visibility and/or contributes to distraction.
There can be difficulty achieving depth perception or seeing track-based information with patterns.</td><td colspan="2">Lighting needs to consider sunlight (rise and sunset) for potential obscurity and/or glare effects. Considerations for the brightness and colour contrast of the light and how this contrasts with the train and ambient conditions.
There is evidence that light arrays/movement that reflects biological motion (such as a person moving) is inherently more conspicuous and attention grabbing than other types of light displays.</td></tr>
<tr><td colspan="3">Cognitive Conspicuity - <i>Search</i></td><td colspan="3">Cognitive Conspicuity - <i>Attentional</i></td></tr>
</table>

	Pattern integration with the following may assist with determining vehicle speed: • Triangle of conspicuity may assist with detection distance/speed. • Spinner illusion may be effective to leverage such that light arrays and movement of light gives the vehicle driver the illusion of faster movement.	Unless indicative of 'train' a pattern solution may not provide the information that this object is a train.
Risks, Issues & Opportunities		
Risks & Issues	• Roof level lightings are hard to clean. • Implementation of new powered treatments will require significant adaptation to maintenance procedures. • Patterns or flashing lights may distract other train drivers. • Considerations for the crew/driver and whether this option impedes or affects driver visibility and/or contributes to distraction, difficulty achieving depth perception or seeing track-based information. • The right lighting solution is difficult to achieve for all environmental considerations.	
Opportunities	• Arrays of lights could utilise different colours, improving conspicuity during daylight hours. • Provides opportunity to reconfigure current lighting solutions such as visibility lights and ditch lights on loco. • Consider extending the alternating flash timing to be greater than 15s as the loco is approaching the crossing.	
Conclusions		
Efficacy	Trial needs to be conducted to understand the efficiency of using lighting arrays.	
Financial Implications	It is assumed to be a low-cost solution, but the cost also depends on the type of light used and market availability of such product.	
Further Comments	Nil	

<table>
<tr><td>Title</td><td colspan="2">Vehicle Side Lighting</td><td>ID</td><td>14</td></tr>
<tr><td>Description</td><td colspan="4">Dynamo lighting along the side of the train to increase the visibility of the wagons while crossing through a level crossing, particularly at night</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="4">Additional Dynamo lighting would require wiring along the side of the train and additional power. This would also require frequent cleaning and maintenance of dynamos for them to be fully functional and provide the required level of illumination.</td></tr>
<tr><td colspan="5">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="4">Daytime running lamps (DRLs) - Depending on the regulations of the country, some countries permit or require vehicles to be equipped with daytime running lamps (DRL). Passenger cars and small delivery vans were first type approved to UN Regulation 48 in 2011; and large vehicles (trucks and buses) in 2012.
UN Regulation 87 stipulates that DRLs must emit white light with an intensity of at least 400 candelas on axis and no more than 1200 candela in any direction. In the US, daytime running lamps may emit either amber or white light and may produce up to 7,000 candela.
DRLs significantly reduced daytime car crashes by 5.7% in US.</td></tr>
<tr><td>Technology</td><td colspan="4">Different lighting technologies used on other vehicles can be adopted for use in rail industry.
Daytime running lamp (DRLs), either amber or white can be adopted from road vehicles to light the side of train. While the use of DRL is permitted on Australian vehicles, they are not legally required. Use of red and blue DRLs is illegal as they are meant for emergency services only. They are readily available in any auto shop in Australia. DRLs have also provoked a large number of complaints about glare.
Dynamo lights are used on cycles, which switch on when the cycle is moving and go out when the cycle stops. Some modern dynamo systems have stand light technology which means the light stays on for a while after you have stopped. Modern dynamo systems use LEDs and have higher outputs, increased efficiency and reduced drag time. Dynamo lighting system can also be used as lighting along the side of train. The working of the dynamo can be arranged in such a way that they are turned off when traction power supply is cut. It requires use of control logic and a longer time period to trial.
Both lighting technologies will require modifying the wiring configuration for power supply.
To overcome glaring issue, the lights can be placed at a certain angle or can be covered by a transparent casing to distribute light rays.
The lights should be placed in such as that they don't obstruct any other things on the side of train.</td></tr>
<tr><td>Education</td><td colspan="4">Nil</td></tr>
<tr><td rowspan="2">Human Factors</td><td>General</td><td>Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td>Depending on design, speed of train and environment interaction, side lights could induce a strobe-like effect. Could lead to distraction or health effects as noted previously for strobe solutions.
Side of train solutions in general could be useful including livery etc as per the front of the train given the various angles of LX intersections.
Research indicates showing less structural variability, including outline information, will aid recognition (e.g. all elephants look similar).</td><td>This solution will require consideration of the increased illumination that is provided as a target from the RMV at the Level crossing.</td><td colspan="2">Lighting needs to consider sunlight (rise and sunset) for potential obscurity and/or glare effects. Considerations for the brightness contrast and COLOUR contrast of the light and how it contrasts with the train and ambient conditions.
Lighting along the side of the train could improve contrast of the train to surrounds when passive crossings are at an angle (as opposed to only the front of the train having lighting - akin to passenger rail cars with windows and lights).</td></tr>
</table>

	Cognitive Conspicuity - *Search*	Cognitive Conspicuity - *Attentional*
	Movement of light could induce the spinner illusion or similar effect whereby drivers detect train and speed earlier.	Depending on scope, if the solution includes whole train adaptation (as opposed to only front unit) and the approach to fixed rail car container style or flat beds with loads on them--research indicates showing less structural variability and including outline information, will aid recognition (e.g. all elephants look similar).
Risks, Issues & Opportunities		
Risks & Issues	• Side lighting showing train length anticipated to encourage racing to beat the train for long consists. • Difficulties in implementing failsafe nature - i.e. side light failure may lead to driver expecting that carriages are not present. • Train side lighting can be mis-interpreted as belonging to a road train, particularly when running parallel. • Challenges in modifying configurations for bringing power (cables/wires) down the train for side lighting, such as changing vehicle conduits, power supply, coupling etc. • Implementation of new powered treatments will require significant adaptation to maintenance procedures. • Depending on design, speed of train and environment interaction, side lights could induce a strobe-like effect. Could lead to distraction or health effects as noted previously for strobe solutions. • Introduction of additional electrical hazards in the work environment.	
Opportunities	• Lighting along the side of the train may help to reduce collisions where the road vehicle hits the side of the train, especially in night time scenarios and where the road geometry is skewed with the track geometry (i.e. where the rolling stock the reflectors are ineffective).	
Conclusions		
Efficacy	Proven to be highly useful with motorcycles in reducing accident on the roads.	
Financial Implications	Cost of one 5 LED DRL from Supercheap Auto = $88	
Further Comments	Take into consideration how the additional electrical systems would behave during a collision or derailment.	

<table>
<tr><td>Title</td><td colspan="4">Vertical Scrolling Lights</td><td>ID</td><td>15</td></tr>
<tr><td>Description</td><td colspan="6">Vertical LED lights that are programmable to be attached on the front of the locomotive and display certain moving or stationary patterns and/or messages.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="6">Vertical scrolling lights on the front of the locomotive may require minor electrical overhaul, wiring changes, additional conduits and power supply upgrade.</td></tr>
<tr><td colspan="7">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="6">Standards do not currently include requirements that govern, prescribe or prevent the implementation of light used in patterns. It is expected that light intensities would be similar to ditch lights/marker lights. However, standards would have to be updated to provide guidance and requirements for the application of lighting arrays.</td></tr>
<tr><td>Technology</td><td colspan="6">Scrolling lights are programmable LED displays with multi-action display effects. The message is programmable and can be fixed or moving. The message is bright and attractive for advertising but has a short viewing distance of 1-10m.
Due to the short viewing range of scrolling lights, they alone are not a viable option to be used on the front of loco to improve visibility.</td></tr>
<tr><td>Education</td><td colspan="6">Nil</td></tr>
<tr><td rowspan="4">Human Factors</td><td colspan="2">General</td><td colspan="2">Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td colspan="2">Determination of light vs. speed of train and whether this can be used effectively will require further investigation.</td><td colspan="2">Nil</td><td colspan="2">This solution would need to consider colour, arrays, frequency of movement for use in day and night conditions.</td></tr>
<tr><td colspan="3">Cognitive Conspicuity - Search</td><td colspan="3">Cognitive Conspicuity - Attentional</td></tr>
<tr><td colspan="3">It may be hard to judge speed of train if there are vertical scrolling lights presented as this conflict with the train moving forward. Perceptual effect/features would need assessment of the solution.
Alternative may be to incorporate spirals within the scrolling - refer to spinner illusion and how speed detection could be enhanced by including moving circle forms.</td><td colspan="3">Nil</td></tr>
<tr><td colspan="7">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="6">• If only white lights are implemented, these are not as visible during daylight hours.
• Roof level lighting is very hard to clean, meaning some of the luminaires may not be fully visible in operation.
• Strobe lighting effect may adversely impact the drivers/ track workers/ community/ environment.
• Implementation of new powered treatments will require significant adaptation to maintenance procedures.
• Potential for Driver distraction of vehicle and of crew (if lights and patterns show on other infrastructure).
• Hard to judge speed of train if vertical scrolling effect presented but train is moving forward. Perceptual effect/features would need assessment.</td></tr>
<tr><td>Opportunities</td><td colspan="6">• Vertical scrolling lights may be successful in grabbing the attention of road users while approaching a level crossing.</td></tr>
<tr><td colspan="7">Conclusions</td></tr>
<tr><td>Efficacy</td><td colspan="6">Trial needs to be conducted to understand the efficiency of using vertical scrolling lights on the front of the locomotive.</td></tr>
</table>

Financial Implications	It is assumed to be a low-cost solution, but the cost will depend on the type of light used and market availability of such product.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="3">Low Frequency Sound</td><td colspan="2">ID 17</td></tr>
<tr><td>Description</td><td colspan="5">Incorporation of horns with lower frequency sound to enable better penetration of materials and aid in road user’s ability to hear an oncoming train.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="5">Given that previous research indicates that horns are currently at their sound pressure level limit, due to the adverse environmental impacts and community disturbance that would occur with greater levels, replacement of the current horn system with that which produces a lower frequency sound is not possible. Instead, consideration of lower frequency sound should only be given to new, emergency horn devices that are sounded as a last line of defence when unsafe behaviour is witnessed by the driver.
It should be noted that ACRI is conducting a separate research project specifically assessing vehicle horns, and this should be referred to for further discussion.</td></tr>
<tr><td colspan="6">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="5">Governing standards include
• T-HR-RS-00A600-ST-v2.0
• EN 15153-2: 2020
• GM/RT 2131 - 2016</td></tr>
<tr><td>Technology</td><td colspan="5">Lower frequency sounds can penetrate through objects easier than high frequencies. They lose less energy as they pass through solid objects. This due to their longer wavelength and their ability to create resonance/vibrations in walls and this helps propagate the sounds.
Lower frequency can be achieved for vehicle horns, however it should be noted that previous research highlights that the sound pressure level of horns is already at its limit due to potential adverse impacts to surrounding communities and environment. It is expected that lower frequencies will be prohibited for normal horn operation as these would incur the same effects. However, there may be potential to adopt a lower horn as an emergency horn to provide the driver with a more effective last line of defence when inappropriate/non-compliant road user behaviour is witnessed by the train driver.
It should be noted that ACRI is undertaking a separate project specifically devoted to assessing vehicle horns. Any further discussion on this topic should refer to the horn specific ongoing works.</td></tr>
<tr><td>Education</td><td colspan="5">There may be a need for Driver training for when to use the horn (based on route knowledge) for timing effectiveness and sound travel. This is likely to differ based on location so will need to be packaged in with route knowledge, refresher training, competence assurance.
Community awareness to recognise what the horn tone is and what it means. There may be a period of initial implementation and rollout where the public need to adjust and become familiar. Precautionary approaches to train handling may be appropriate during this rollout phase.</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td colspan="2">Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td>Nil</td><td colspan="2">Nil</td><td colspan="2">Contrast of low frequency tone to other ambient noise. Need to understand the level / frequency necessary to be detected against this backdrop and whether this tone is masked or not. This solution may not be viable if the frequency required is too great (i.e. community impacts).</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td colspan="3">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="2">Nil</td><td colspan="3">Nil</td></tr>
<tr><td colspan="6">Risks, Issues & Opportunities</td></tr>
</table>

Risks & Issues	• There is currently an apparent lack of community/road user awareness of train horn sound and purpose, especially when different tones are used to indicate operational movements. • Error potential if not automated as Drivers may forget to activate if other tasks involved. • Sound pressure level of horns is currently at its limit and any increase to horn sound/ability for horn noise to travel further would incur adverse impacts to environment/surrounding communities. • Adverse impacts to surrounding wildlife. • Wind can impair efficacy of horns. Despite lower frequency sounds performing better than higher frequency, this may still be a significant contributing factor to the success of a low frequency horn in alerting a road user.
Opportunities	• Improvements in sound penetration may help to alleviate issues associated with driver habituation, distraction/inattentiveness, complacence etc. • May help to alleviate issues associated with the variable nature of rail movements and somewhat fluid timetable, which can catch road users that frequently use a crossing off-guard. • Opportunity to adopt a low frequency horn as an emergency horn, rather than replacing existing horns.
Conclusions	
Efficacy	Refer to ACRI horn research project.
Financial Implications	Refer to ACRI horn research project.
Further Comments	Refer to ACRI horn research project.

<table>
<tr><td>Title</td><td colspan="2">Exterior Edge Lighting</td><td>ID</td><td>20</td></tr>
<tr><td>Description</td><td colspan="4">Additional exterior ‘edge’ lighting to be added to increase the visibility of the train by illuminating its outline.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="4">This would require additional led strips or some similar technology to be run along the side of the locomotive. This means additional power, maintenance, and implementation costs. Testing would also be required to be done prior to implementation.</td></tr>
<tr><td colspan="5">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="4">The standard needs to be updated to specify the intensity of such exterior edge lighting, IP rating, location where it can be placed without obstructing other things on train, etc.</td></tr>
<tr><td>Technology</td><td colspan="4">LED colour changing lights can be used to outline the loco. The intensity of such exterior edge lighting needs to be specified in appropriate standards.
The strip of lighting should be weather-resistant and easy to clean.
There's a possibility that the visibility of the light is dimmed by other lights on the train.
It should be kept in mind that to change colour the command will be provided from inside the train or a wireless mobile application can be used (requires Bluetooth or Wi-Fi). Therefore, requiring system integration and teaching train drivers to operate the switches.
The placement of the light should be done in such a way that it is not obstructing other things on loco.</td></tr>
<tr><td>Education</td><td colspan="4">Community awareness/education to support identification and recognition that this is a freight locomotive.</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td colspan="2">Visibility</td><td>Sensory Conspicuity</td></tr>
<tr><td>Benefits for whole vehicle where possible - front face and side/exterior. Considerations as per other options of colour/flashing lighting.</td><td colspan="2">Nil</td><td>Lighting needs to consider sunlight (rise and sunset) for potential obscurity and/or glare effects. Considerations for the brightness contrast and colour contrast of the light and how it contrasts with the train and ambient conditions.</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td colspan="2">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="2">Improvement to overall size salience, however, may further induce 'speed-size' illusion effects.</td><td colspan="2">Recognisable shape demonstrating this is something different.
Improvement to length and width identification, effectiveness reported by Dutch Transport Safety Board.
Research indicates to recognise objects the edges, line orientations, shapes and features are extracted first.
Distinction of these artefacts may enhance daytime recognition.</td></tr>
<tr><td colspan="5">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="4">• Side lighting showing train length anticipated to encourage racing to beat the train for long consists.
• Difficulties in implementing failsafe nature - i.e. side light failure may lead to driver expecting that carriages are not present.
• Implementation of new powered treatments will require significant adaptation to maintenance procedures.</td></tr>
</table>

Opportunities	• Coloured edge lighting is expected to improve conspicuity during daylight hours. • Edge lighting may improve road user's ability to identify that the vehicle is a train. • Edge lighting expected to improve road user's ability to see side of train and determine overall length.
Conclusions	
Efficacy	Efficacy needs to be calculated. Would reduce the number of side impacts.
Financial Implications	Cost of light per loco = ~ $2300
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="4">UHF/CB Automated Radio Broadcast</td><td>ID</td><td>25</td></tr>
<tr><td>Description</td><td colspan="6">Ultra-High Frequency Citizen Band radio broadcast to automatically communicate to road vehicles upon approaching level crossings.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="6">UHF CB radio broadcast requires both the train and road vehicle to have radio and uses range of frequency bands to communicate. This technology requires to be adopted widely though training and information to use frequency band allocated for public access.</td></tr>
<tr><td colspan="7">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="6">UHF CB radios are primarily used in Australia in 4WD vehicles, trucks, and campervans.
While a license is not required in order to operate UHF radio, there is still a requirement to abide by the specific regulations in place.
Please refer to following websites for more information on use of UHF radios:
• Australia: https://www.acma.gov.au/
• New Zealand: https://www.rsm.govt.nz/
Current trial is underway in Victoria (Vic track) considering Telematics on OD Vehicles and trains.
There are no anticipated changes to rail design standards.</td></tr>
<tr><td>Technology</td><td colspan="6">UHF CB or citizen band radio is a two-way radio system that uses the 476.4250–477.4125MHz, radio spectrum for short-distance communications. It is divided into 80 channels for various uses. The service is for public access and available to everyone but not all channels can be used by anyone for just any reason – there are significant penalties for misuse of channels.
UHF's distinct advantage over mobile phones is that it can work anywhere and requires little to no infrastructure to be in place. At the user end, a basic radio set is required in both the vehicles.
The key disadvantage is that it operates on a line-of-sight basis, and therefore has very short reach. Under normal conditions, anyone can expect a good signal over a distance of 5km to 8km. The upside is that the road users are always communicating with those around them in their immediate vicinity.</td></tr>
<tr><td>Education</td><td colspan="6">Additional training may be required for truck drivers for alphanumeric protocols or railway radio protocols to align with train driver expectations.</td></tr>
<tr><td rowspan="4">Human Factors</td><td colspan="2">General</td><td colspan="2">Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td colspan="2">Nil</td><td colspan="2">Nil</td><td colspan="2">An alert of radio broadcast can assist in the detection of the train through essentially an audible means and can prime a driver to detect the train visually if they have not.</td></tr>
<tr><td colspan="3">Cognitive Conspicuity - <i>Search</i></td><td colspan="3">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="6">There is a possibility that making the approaching train more human by having drivers interact will increase the heavy road vehicles risk aversion or otherwise impact how illusions and speed are perceived and acted on. This is an area for further investigation.</td></tr>
<tr><td colspan="7">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="6">• Limited to trucks and 4WD. UHF/CB radios can be configured for different frequency bands and may not receive signal.
• The use of UHF/CB radio broadcast does not guarantee a fail-safe nature as reliance may be placed upon this system and collisions may occur as a result of system failure</td></tr>
<tr><td>Opportunities</td><td colspan="6">• Increased communication between the heavy road vehicles at level crossing and trains leading to higher security on the level crossing.
• Reduces the risk of heavy road vehicles being unable to travel across the level crossings by the time the train arrives at the crossing.</td></tr>
</table>

	• Vehicle can be installed with GPS-based announcement for 'approaching level crossing'.
Conclusions	
Efficacy	UHF CB radio is a bidirectional communication pathway and requires to be installed in both, the road vehicle as well as the rolling stock. Since, it works on line-of-sight principal to initiate the conversation with the nearby driver, the solution is not fail-safe and has a high risk of human error in detecting/spotting the other vehicle. It may require additional educational programs or campaigns to encourage road vehicle user to use UHF radio and/or to teach them how and where to use radio.
Financial Implications	The cost of UHF CB radio depends on the type of radio and its frequency range.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="4">Operation Life Saver Equivalent</td><td>ID</td><td>32</td></tr>
<tr><td>Description</td><td colspan="6">Operation life saver (OLI) is a leader in rail safety education and is adopted in North America. OLI has been running public education programs across the U.S. preventing collisions, injuries, and fatalities on and around railroad tracks and highway-rail grade crossings.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="6">It would require investment and time for something similar to be implemented in Australia and to get the reach that such a program would need to be successful.</td></tr>
<tr><td colspan="7">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="6">• 84% reduction in the number of collisions from 1972 to 2020.
• 2.5 million people made aware about safety regarding railway crossings in 2019. Up from 1.6M in 2018
• 19,542 Safety Presentations to 575,225 students, school bus drivers, professional drivers, law enforcement officers, firefighters, and snowmobile operators in 2019.
• Need FRA data</td></tr>
<tr><td>Technology</td><td colspan="6">No additional technology required.</td></tr>
<tr><td>Education</td><td colspan="6">More detail required on the effectiveness of the campaign.
National awareness and training could be useful for all road users. Option to target specific road user groups (i.e. truck and haulage companies, learners, older Drivers - given cognitive changes with age).
Notable differences in Australia are the road rules between states (a nice example is Melbourne trams vs. other states with no trams and how to perform a hook turn!) and not being taught what isn't part of that state infrastructure. Urban vs. regional learner experiences (some may experience passive crossings more frequently and understand how to engage safely compared to those from other areas)</td></tr>
<tr><td rowspan="4">Human Factors</td><td colspan="2">General</td><td colspan="2">Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td colspan="2">One component of Operation Life Saver was increasing the prevalence of the danger and what to pay attention to even through exposure to trains at crossings did not change. Increasing the prevalence of the danger and trains in general can potentially have impacts on better detection.</td><td colspan="2">Greater awareness and priming of dangers and trains in general may increase the ability to detect the stimulus</td><td colspan="2">Nil</td></tr>
<tr><td colspan="3">Cognitive Conspicuity - *Search*</td><td colspan="3">Cognitive Conspicuity - *Attentional*</td></tr>
<tr><td colspan="3">Nil</td><td colspan="3">Nil</td></tr>
<tr><td colspan="7">Risks, Issues & Opportunities</td></tr>
<tr><td>Risks & Issues</td><td colspan="6">• Lacking the understanding of key failure mechanisms/ cause of incidents & near misses makes it difficult to determine the precise road user activities and habits to target as part of an educational campaign.
• Reach may not equal behaviour change.</td></tr>
<tr><td>Opportunities</td><td colspan="6">• Opportunity to reduce issues arising from road driver behaviour, such as:
• Complacence (thinking 'it won't happen to me').
• Non-compliance with road rules i.e. Give Way/Stop, speed restrictions etc.
• Distraction/inattentiveness (not looking).
• Road driver habituation, tendencies and complacence.
• Mis-interpreting short distance across the crossing as means of quick path to race across (rushing & ignoring level of danger).
• Difficulty in recognizing trains in azimuth and judging train speeds.</td></tr>
</table>

	• Opportunity to better educate heavy vehicle drivers, who are often reluctant to stop at crossings due to operational difficulties, especially when crash gearboxes are installed. • Better awareness may change media reporting, which currently does not often highlight that collision cause is generally a result of inappropriate road driver behaviour - "Train SMASHES into truck!" • Potential to encourage rail consultation when developing new truck routes that utilise level crossings. • May raise awareness of variability in train timetable, which can often catch road users off guard. • Opportunity to provide data to RISSB/ONRSR.
Conclusions	
Efficacy	Operation life saver has been highly successful in reducing the number of collisions and fatalities on level crossings. So, something similar can be expected if it gets implemented in Australia.
Financial Implications	Would require some investment to get operation life saver started in Australia.
Further Comments	Nil

<table>
<tr><td>Title</td><td colspan="2">Alterations to Existing Paint Schemes</td><td>ID</td><td>66</td></tr>
<tr><td>Description</td><td colspan="4">Alter existing train colour/livery to colour schemes to allow for better contrast between the locomotive and its background, including the adoption of fluorescent and photo reflective paint</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="4">New colour schemes adoption requires community awareness to recognise and interpret an approaching object as freight locomotive.</td></tr>
<tr><td colspan="5">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="4">According to a research in UK, fluorescent materials enhance the conspicuity of an object during the daytime but provides no additional benefit at night
Current Australian standard dictates that the livery can be yellow, orange, orange-red, red and white in colour.
Appropriate paint and livery materials will have to be identified and will need to comply with other applicable AS standards. Subsequently, AS 7531 has a requirement regarding painting the front face of loco with high visibility colours.</td></tr>
<tr><td>Technology</td><td colspan="4">Fluorescent or photo reflective paints "glow" vividly under ultraviolet lights. They can be used to create special effects using ultraviolet black light or combined with other paints to make the colours more vibrant. Fluorescents use the same high quality, water-base, vinyl acrylic binder found in Off Broadway Paints. It is suitable for use on most surfaces after the surface has been properly prepped.
According to a research in UK, fluorescent materials enhance the conspicuity of an object during the daytime but provides no additional benefit at night.
One of the Australian suppliers is Rosco fluorescent paints.</td></tr>
<tr><td>Education</td><td colspan="4">Community awareness of the new design so they recognise and interpret it as a freight locomotive.</td></tr>
<tr><td rowspan="4">Human Factors</td><td>General</td><td colspan="2">Visibility</td><td>Sensory Conspicuity</td></tr>
<tr><td>Current standard states colours that can be used: yellow, orange, orange-red, red, white.</td><td colspan="2">Ambulance vehicle research shows:
Light vehicle colours (e.g. white, yellow lime, yellow) are more visible during daytime under clear weather
Influence of vehicle colour on visibility is significantly reduced in adverse light conditions
Retroreflective markings are only effective at night and rely on an external light source
Colour contrast enhances visibility by making it easier to discern the relevant outlines of the object against the background. However, it is dependent on the background, for example yellow may be effective against a rainforest type landscape but less effective against wheat fields.</td><td>Assessment of the Australian context - backgrounds, colours of typical backdrops for trains to understand what high contrast in this context is.
Luminance contrast is considered to be the best measure of contrast and is more likely to allow an object to be seen quickly, particularly in the peripheral vision where colour vision is less acute. A margin of 30% luminance contrast is used as the measure in industry to assist people with low vision.
Ambulance vehicle research shows:
The use of fluorescent materials combined in retroreflective sheeting is reported to enhance daytime sensory conspicuity.</td></tr>
<tr><td colspan="2">Cognitive Conspicuity - <i>Search</i></td><td colspan="2">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="2">Nil</td><td colspan="2">Objects which have greater sensory conspicuity can also increase cognitive conspicuity as the image is more likely to be held in the working memory and may prompt a person to look again, particularly</td></tr>
</table>

		if the colour scheme is highly associated with a particular mental model.
Risks, Issues & Opportunities		
Risks & Issues	• Fluorescent colours may have significant adverse impacts to the environment when compared to traditional paint. • Certain colours are not prohibited in the rail corridor (such as red). • Fluorescent paint may not be as durable, requiring greater maintenance costs. • Cost for paint with photo reflective/fluorescent properties is expected to be greater than current paint products, leading to an increase in both CAPEX and OPEX. • New paint materials may require additional PPE for maintenance staff to prevent inhaling toxic fumes, for example.	
Opportunities	• Photo reflective or fluorescent paint may improve vehicle conspicuity during daylight hours. • Vinyl wrap can be used. They can be replaced after every journey, given they are eco-friendly.	
Conclusions		
Efficacy	Fluorescent or retro reflective paint alone is unlikely to be an effective control to improve the vehicle conspicuity. Instead, this must be coupled with adequate cleaning procedures to ensure that the vehicle maintains its visibility throughout operation. It also requires increasing public awareness about the colour schemes to distinguish freight locomotive on the level crossing.	
Financial Implications	This is expected to be a low-cost solution but the cost of using disposable vinyl wraps requires further investigation.	
Further Comments	Nil	

A.3. Long-term Opportunities

Title	**Light Projections**	ID	11
Description	Light projections from the train to the level crossing to provide early warning to road users, particularly in scenarios where sightlines of the rail corridor are poor (e.g. where thick vegetation exists).		
Categorisation Rationale	Although projection technology exists, it is a novel solution for the rail corridor. At the time of writing, the application of such systems in a dynamic environment does not appear to have been conducted and it is anticipated that significant work would be required to implement this control in an effective manner. The implementation of this control would require mechanisms to correctly position the projection at the level crossing under variable track and road geometry conditions.		
Implications & Considerations			
Data, Stats & Standards	Standards will have to be updated to include guidance on the adopted technology and to protect it from cybersecurity risks.		
Technology	Holographic imaging, cameras and artificial intelligence are gaining popularity to provide Passenger Information Holograms to improve customer assistance. This technology is used in several potential applications such as military mapping, information storage and advanced medical imaging technology. Like with other digital technologies, the hacking of hologram software is a risk that should be considered prior to implementation It is expected that this solution will present significant technical challenges to overcome the road and rail geometries in pursuit of a useful safety mitigation approach. The Rail alignment, including horizontal and vertical curves will either require a wide spreading projection, which would spill onto the surrounding communities and environment, or require the projection system to re-position/aim itself during operation to point at each upcoming level crossing. Gobo projection systems exist and are utilised in multiple applications, however at the time of writing, examples of gobo projector application in dynamic scenarios (i.e. where the gobo system is moving and must maintain a constant projection location) do not appear to exist. As such, it is expected that implementation into the rolling stock industry would require additional technological development to provide smart mounting devices, and associated control mechanisms, capable of aiming the projection system. Subsequently, the road geometry generally includes a raised section across the LX, which may result in the laser projection system being ineffective (due to sighting angles) unless additional infrastructure elements were included. Additional infrastructure elements may include vertical panels for the rolling stock system to project onto.		
Education	It is expected that community awareness campaigns would be required to facilitate this solution to ensure that the meaning of the projection and its position is fully understood. There may be a period of initial implementation and rollout where the public need to adjust and become familiar. Precautionary approaches to train handling may be appropriate during this rollout phase. This may also warrant an update to current driver training, including hazard perception training/testing if it were implemented. Training and assessment of new drivers could include more level crossing scenarios - this would need to be included across national training.		
Human Factors	General	Visibility	Sensory Conspicuity
	Static lighting might not grab attention. Hologram/projections for daytime may encounter lighting issues.	Visibility of train may improve - depends on intensity of light, duration, where projections land and whether this is visible from a range of locations (i.e. eye-level of drivers at different vehicle heights). Considerations for the crew/driver and whether this	Light projections that have sufficient luminance contrast to surrounds and colour contrast of projections could improve conspicuity. There is evidence that light arrays/movement that reflects biological motion

	option impedes or affects driver visibility and/or contributes to distraction, difficulty achieving depth perception or seeing track-based information.	(such as a person moving) is inherently more conspicuous and attention grabbing than other types of light displays.
	Cognitive Conspicuity - *Search*	Cognitive Conspicuity - *Attentional*
	Improvements may be made for the retinal image being ahead of the train itself enabling the Driver (of the car) to detect the object distance/speed earlier. Car driver behaviour research suggests effectiveness of flashing warning lights on other vehicles aid identification of vehicle direction when lights flash in a sequential pattern. Issues for further investigation: What reaction might road users have to seeing a flashing light? Can they perceive speed effectively?	Considerations for what the projection/hologram consists of as to effectiveness.
Risks, Issues & Opportunities		
Risks & Issues	• If mounted at roof level, it is expected that this component would be very hard to clean using current methods (i.e. as per lighting). • Implementation of new powered treatments will require significant adaptation to maintenance procedures. • Dirt accumulation on the system lens may prevent improvements to safety. • The nature of this device may not be failsafe, i.e. road users/pedestrians may interpret the lack of projection as meaning that a train is not on approach and fail to identify the train in a failure scenario. • The projection may cause a distraction for road users, raising the risk of vehicle-to-vehicle collision on the road. • Control is expected to be less effective during daylight hours, where the majority of collisions occur. • Vegetation growth or surrounding infrastructure may block the projection from reaching the level crossing.	
Opportunities	• Help to further delineate position of safety for road users. • Provides an early warning to road users that the train is on approach. • Projection systems currently have capability to project moving images, which may aid in grabbing road driver/pedestrian attention. • Technology could be utilised quicker as an infrastructure control. • Projections can be changed periodically to ensure attention capture and mitigate against road driver complacency.	
Conclusions		
Efficacy	The application of projection technology has not yet been adopted in the rail industry. Subsequently, it does not appear that such technology has been applied where dynamic movement of the projector mounting point and daytime operation are key considerations. There is currently a lack of information on the luminance level and contrast that could be achieved during daylight hours, when operating in a variable environment, such as the rail corridor. Further research would be required to determine the efficacy of such a control in improving conspicuity. This research would also need to consider the failsafe nature of the device and the resulting driver actions when no projection is present.	
Financial Implications	Financial implications are expected to be moderate to significant for this option. Although projection systems exist, development of smart mounting devices, capable of aiming the projection system, would be required. Significant data capture and maintenance may also be needed to ensure the system is adequately informed on infrastructure upgrades, track geometry etc.	
Further Comments	Nil	

<table>
<tr><td>Title</td><td colspan="4">Intelligent Transport Systems</td><td>ID</td><td>22</td></tr>
<tr><td>Description</td><td colspan="6">Integrating GPS tracking and warning systems in the form of intelligent transport system between road traffic and rolling stock to provide a channel of communication between the vehicles.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="6">Although Intelligent Transport System testing is underway in Australia, mass acceptance and use of this system will require the vehicle technology to improve over the years. Significant work and funding would be required to implement this control in an effective manner.</td></tr>
<tr><td colspan="7">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="6">Intelligent Transport Systems can be classified into following categories:
• Vehicle-to-vehicle (V2V) communication
• Vehicle-to-everything (V2X) communication
• Vehicle-to-Infrastructure (V2I) communication
In the US, more than 70 active deployments of V2X communications have been successful by using all the 7 channels of the 5.9 GHz spectrum. It is to be noted that the data is not specific to any particular transport industry.
Some of Intelligent Transport System ongoing and proposed trails are as below:
• Current proposed trials in Victoria is underway for V2V telematics (AIMES test bed).
• ACRI OTH20 Passive LX CAV tech iMOVE project starting soon.
• TfNSW various trials starting soon.
Standards will have to be updated to include guidance on the adopted technology and also to protect it from cybersecurity risks.</td></tr>
<tr><td>Technology</td><td colspan="6">V2V communication technology enables vehicles to wirelessly exchange information about speed, location, direction, etc. It allows vehicles to broadcast and receive omni-directional messages by creating a "360 degree awareness" of other vehicle in proximity.
For V2V communication, both vehicle and rolling stock needs to be equipped with appropriate software. The communication requires a dedicated spectrum band for transportation communication.
This could be similar to electronic conspicuity, as adopted in the aviation industry.</td></tr>
<tr><td>Education</td><td colspan="6">Crew training would be required in the use of the in-cab system.
Training for crew (and for road users if implemented in cars) to cover failure modes and how to operate accordingly. It is possible that upon implementation crew rely on the automation/system and if that is misreading or degraded, an event may still occur or be worsened as crew do not approach the level crossing with the same degree of caution/awareness as they do now without such systems in place.
There will be a need for training for drivers of both vehicles for alerts/alarms, their prioritisation and meaning, and appropriate actions.</td></tr>
<tr><td rowspan="4">Human Factors</td><td colspan="2">General</td><td colspan="2">Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td colspan="2">Need for degraded and failure modes of such system to be understood and how to proceed.
Design – alerts/alarms would need HF input for alarm prioritisation, messaging, audible/visual alerting.</td><td colspan="2">Nil</td><td colspan="2">Nil</td></tr>
<tr><td colspan="3">Cognitive Conspicuity - <i>Search</i></td><td colspan="3">Cognitive Conspicuity - <i>Attentional</i></td></tr>
<tr><td colspan="3">Nil</td><td colspan="3">Nil</td></tr>
<tr><td colspan="7">Risks, Issues & Opportunities</td></tr>
</table>

Risks & Issues	• Implementation of new powered treatments will require significant adaptation to maintenance procedures. • Need for degraded and failure modes of such system to be understood and how to proceed. • Potential EMC concerns for adoption in Australia. • Needs fail-safe system for reliance. If system is off, will this be interpreted as no loco presence? • Reliance on GPS boundaries will not allow for an accurate determination of position. A pin-point accurate system is required.
Opportunities	• Integration of level crossing locations into GPS services such as google maps. • Many heavy vehicle drivers are reluctant to stop at crossings due to operational difficulties when crash gearboxes are installed. This solution may alleviate the associated issue as it allows for better communication to the heavy road vehicle user. • Trains to broadcast a 'Driver Advisory System' to road users to tell them to speed up or down. • ITS could inform road users of variations in "usual" train operations.
Conclusions	
Efficacy	In other countries, the use of V2V communication has had positive impacts. The trials for use of Intelligent Transport System proposed in Australia will provide efficacy rate of such system for use in rail industry. This research would also need to consider the failsafe nature of the system and the resulting driver actions when systems are inactive.
Financial Implications	At the current instance, financial implications are expected to be significant for this option. Although the system is being used in other parts of the globe, development of such system according to Australian standards and environment would be required. Significant maintenance may also be needed to ensure the system is active at all the time.
Further Comments	Nil

A.4. Other Opportunities

<table>
<tr><td>Title</td><td colspan="2">Other Industry Solutions</td><td>ID</td><td>9</td></tr>
<tr><td>Description</td><td colspan="4">Adoption of conspicuity solutions adopted in other industries.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="4">The below presents details of conspicuity solutions adopted in other industries. For those items that are not yet adopted within the Australian rail industry, these have formed separate items that have been captured in A.1 to A.3 above. The below provides traceability to the original industry where the controls are currently implemented.</td></tr>
<tr><td colspan="5">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="4">See technology information - the majority of solutions adopted in other industries are consistent with controls already implemented within the rail industry, therefore warranting no change to standards.
For impacts associated with LED lighting, electronic conspicuity, Solar Powered Lane Markers and Self-cleaning Coatings, see the items captured in A.1 to A.3 above.</td></tr>
<tr><td>Technology</td><td colspan="4">Technology utilised in other industries is as follows:
• Heavy Road Vehicles: Colouring of extremities (outline), alternating coloured stripes, reflective delineators (provided by 3m for example), decals (provided by Orafol for example), high contrast colours.
• Emergency vehicles: Red and yellow reflective chevrons (e.g. on fire trucks), flashing/strobe lights, sirens, high contrast colours.
• Tractors: coloured mud flaps, reflective tape.
• Aviation: Electronic conspicuity, whereby aircraft are equipped with an EC device that emits a signal, allowing other aircraft to identify its precise position.
• Tug boats: Masthead light (white, forward facing), sidelights (red on starboard side, green on port side), stern light (white).
• Mining: Red & white conspicuity tape (reflective tape), LED lights, high visibility colours (such as yellow).
• Road Infrastructure: Solar powered lane markers.
• High-rise buildings: Self-cleaning coatings, such as TiO2.
For the majority of the above controls, the conspicuity approaches adopted in other industries are relatively similar in concept to that in the rail industry. Those controls not adopted, or only adopted in part, within the rail industry are discussed in isolation in separate items. These include vehicle to vehicle communication (aviation), LED lighting (mining), Solar powered lane markers and self-cleaning coatings.</td></tr>
<tr><td>Education</td><td colspan="4">Depending on the solution(s) from other industries, there may be a need for education (community) and training (crew).</td></tr>
<tr><td rowspan="2">Human Factors</td><td>General</td><td>Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td>Conspicuity solutions from other industries will require HF assessment for optimisation of specific considerations.</td><td>Nil</td><td colspan="2">Lighting needs to consider sunlight (rise and sunset) for potential obscurity and/or glare effects. Considerations for the brightness contrast and colour contrast of the light with the train and ambient conditions.
Research shows effectiveness of light arrays - triangle of conspicuity - to help process distance, speed, direction.
Given the varied nature of freight locomotive faces,</td></tr>
</table>

			there are placement considerations for consistency and achieving this on the train front, as well as any side based solutions for detection angles.

	Cognitive Conspicuity - *Search*	Cognitive Conspicuity - *Attentional*
	Triangle of conspicuity is shown to assist with detection distance and speed. Spinner illusion may be effective to leverage in lighting, such that light arrays and movement of light gives the vehicle the illusion of faster movement.	Drivers fixate in bright areas of their field of vision, this tendency may reduce situation awareness at night if lighting is centred in this field of view.

Risks, Issues & Opportunities	
Risks & Issues	• Any lighting solutions applied near the roof is expected to be is very hard to clean, noting current issues cleaning components in this area. • Implementation of new powered treatments will require significant adaptation to maintenance procedures. • Drivers fixate in bright areas of field of vision; consideration for reduction in situation awareness at night.
Opportunities	• Known successful procurement channels for other industries could be utilised for supply of rail components.

Conclusions	
Efficacy	See V2V, LED, Solar Powered Lane Markers and Self-Cleaning Photocatalyst items for further details.
Financial Implications	See V2V, LED, Solar Powered Lane Markers and Self-Cleaning photocatalyst items for further details.
Further Comments	See V2V, LED, Solar Powered Lane Markers and Self-Cleaning photocatalyst items for further details.

<table>
<tr><td>Title</td><td colspan="4">Count Down Timer</td><td>ID</td><td>31</td></tr>
<tr><td>Description</td><td colspan="6">Implementation of a countdown timer mounted to the front of the vehicle to signal to road users the time in which it will take the train to reach the level crossing.</td></tr>
<tr><td>Categorisation Rationale</td><td colspan="6">Implementation of this control would require the adoption of novel rolling stock systems and significant configuration changes to the vehicle.</td></tr>
<tr><td colspan="7">Implications & Considerations</td></tr>
<tr><td>Data, Stats & Standards</td><td colspan="6">Count down timers would have to be adequately controlled by standards, potentially mandating and update to AS 7531</td></tr>
<tr><td>Technology</td><td colspan="6">The implementation of a countdown timer linked to the track signal detectors would be reliant on the track signalling infrastructure installed on the network or would require additional works to facilitate the implementation of the control.
Assuming no infrastructure works were conducted, the adoption of this control would be limited to level crossings with active protection, where the trains presence in the level crossing approach is identified by suitable signalling systems.
Currently, there are no train mounted systems that receive signals within the level crossing approach, and fitment of a countdown timer on the train would require the installation of suitable train mounted signalling systems to communicate with the track infrastructure and start the timer.
Subsequently, the system would be required to calculate the time taken to arrive at each level crossing, utilising the current train speed, braking/acceleration rates (particularly important for LXs close to stations) and distances between the signalling infrastructure and each level crossing. The last item would likely require significant effort to capture and consolidate network information, and an ongoing effort to maintain this information in a centralised location.
A simpler solution would be to include an infrastructure system that provides such a countdown.</td></tr>
<tr><td>Education</td><td colspan="6">It may not be immediately clear to road users/pedestrians what number would represent a safe number to cross. This may lead to risky behaviour due to incorrect interpretation of "safe" remaining time. Community awareness campaigns would be required to communicate how to use the information appropriately.</td></tr>
<tr><td rowspan="3">Human Factors</td><td colspan="2">General</td><td colspan="2">Visibility</td><td colspan="2">Sensory Conspicuity</td></tr>
<tr><td colspan="2">Benefits for slow movers, for fast movers may encourage beat the crossing mentalities.</td><td colspan="2">For text to be visible to the vehicle Driver, work would need to be performed on arc minutes, font height and considerations for viewing distance. The size of the countdown timer will initially be small when the vehicle is far from the crossing, and may not be readable at critical distances
Skewing of the timer relative to the road (i.e. due to geometry) will also present readability challenges and the system may only be effective when looking down the track from the level crossing stop mark.</td><td colspan="2">For a train mounted system, a countdown timer will not always appear in a consistent position. The position of the timer will vary upon track and road geometry and rolling stock design.
The changing visual stimuli (number changing) can enhance sensory conspicuity due to additional changing/moving stimuli.</td></tr>
<tr><td colspan="3">Cognitive Conspicuity - <i>Search</i></td><td colspan="3">Cognitive Conspicuity - <i>Attentional</i></td></tr>
</table>

	Does not address the issue of not seeing the train in the first place.	Nil
	Risks, Issues & Opportunities	
Risks & Issues	• Implementation of new powered treatments will require significant adaptation to maintenance procedures. • Potential for countdown timer to encourage risky behaviour (i.e. road users taking additional risks to "beat the train/crossing"). • May lead to unwanted behaviour (i.e. riskier behaviour) with Drivers perceiving 'safe' at 10 when this may not be safe in context.	
Opportunities	• Many heavy vehicle drivers are reluctant to stop at crossings due to operational difficulties when crash gearboxes are installed. Subsequently, road drivers can have a tendency to try to "beat the train", especially when long freight consists are visible. The implementation of a countdown timer may alleviate these issues. • An alternative option to install a countdown timer as part of the road infrastructure may allow for some of the issues associated with this option (such as consistency in position, readability etc.) to be overcome. Installation as part of the infrastructure could also allow for positioning the countdown timer farther from the crossing to provide early warning, however careful consideration will have to be given to negative impacts to road driver behaviour in this circumstance.	
	Conclusions	
Efficacy	This control is not expected to be effective as a vehicle mounted system due to the difficulties in reading the countdown timer when the train is not in close proximity to the road user.	
Financial Implications	Financial implications associated with implementing this control are expected to be moderate to high. The countdown timer display is expected to be relatively cost effective to implement, however the control mechanism to display the correct time may incur significant costs and wider network upgrades.	
Further Comments	An infrastructure system would be recommended in place of a rolling stock mounted timer as it could achieve continuity in timer positioning, creating better usability and overall effectiveness of the control. It is also expected to interface with existing infrastructure (LX approach signalling systems) more seamlessly	

Appendix B. Data Analysis

The following should be noted regarding the data analysis conducted:

- A data extract was provided by ONRSR on 25th October 2021, which forms the basis of the data analysis
- SNC-Lavalin has limited their assessment to occurrences (collision and near-miss) of freight trains with road vehicles. Other train types and colissions with pedestrians are beyond the scope of this study, as justified in Section 5.2
- Data has been separated according to level crossing protection type (active or passive) and by time of day (day and night)
- As data prior to 2015 is incomplete, the weighted average method has been used to compare incident data from 2007 to 2015 to post-2015 data

All relevant data extracts are provided below.

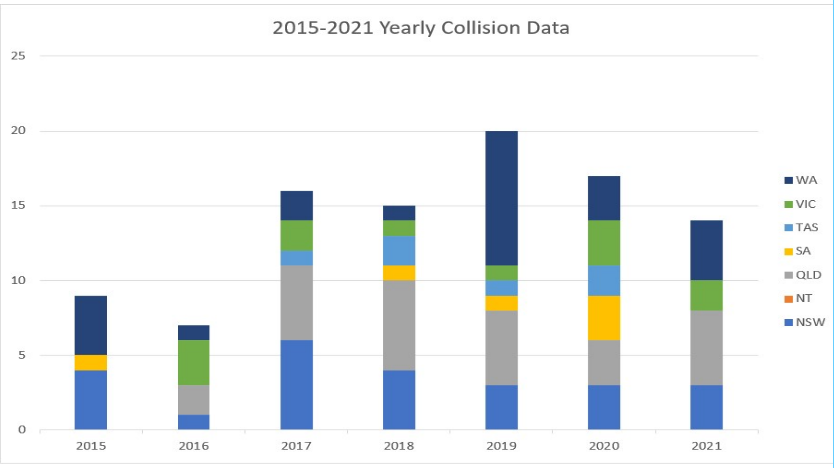
Yearly overall collision

2015-2021

Table B-1 - 2015-2021: Yearly overall collisions

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	4	0	0	1	0	0	4
2016	1	0	2	0	0	3	1
2017	6	0	5	0	1	2	2
2018	4	0	6	1	2	1	1
2019	3	0	5	1	1	1	9
2020	3	0	3	3	2	3	3
2021	3	0	5	0	0	2	4
TOTAL	**24**	**0**	**26**	**6**	**6**	**12**	**24**

Figure B-1 - 2015-2021: Yearly overall collisions

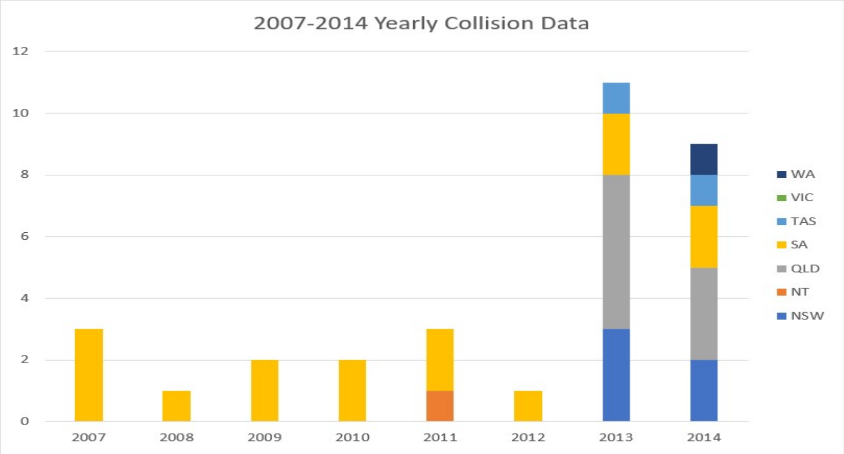


2007-2014

Table B-2 - 2007-2014: Yearly overall collisions

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				3			
2008				1			
2009				2			
2010				2			
2011		1		2			
2012		0		1			
2013	3	0	5	2	1		
2014	2	0	3	2	1	0	1
TOTAL	**5**	**1**	**8**	**15**	**2**	**0**	**1**

Figure B-2 - 2007-2014: Yearly overall collisions



Yearly overall near-miss

Table B-3 – 2015-2021: Yearly overall near misses

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	60	3	125	18	24	12	51

Table B-4 - 2007-2014: Yearly overall near misses

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				0			

2016	41	2	110	17	8	30	34
2017	25	1	121	15	19	18	41
2018	40	1	104	11	22	24	27
2019	43	1	68	14	12	16	21
2020	40	0	60	7	17	17	37
2021	32	0	49	11	14	9	27
TOTAL	**281**	**8**	**637**	**93**	**116**	**126**	**238**

2008				1			
2009				12			
2010				111			
2011		2		67			
2012		4		35			
2013	89	3	138	33	11		
2014	76	6	110	29	21	14	34
TOTAL	**165**	**15**	**248**	**288**	**32**	**14**	**34**

Figure B-3 - 2015-2021: Yearly overall near misses

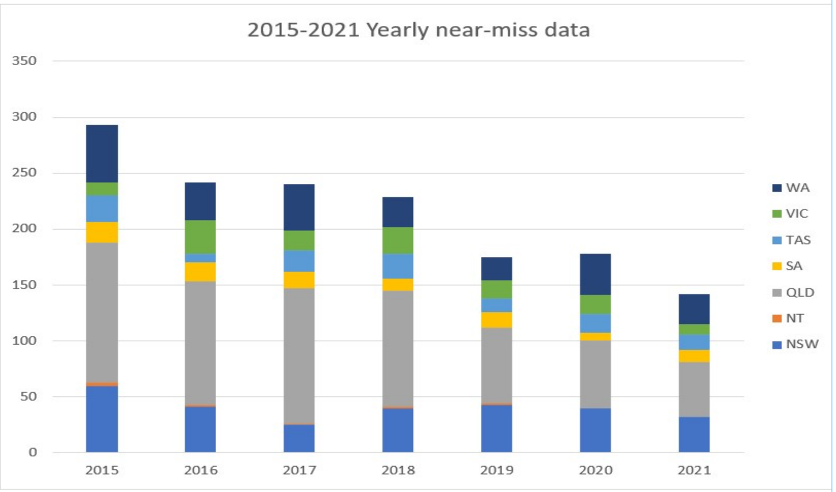
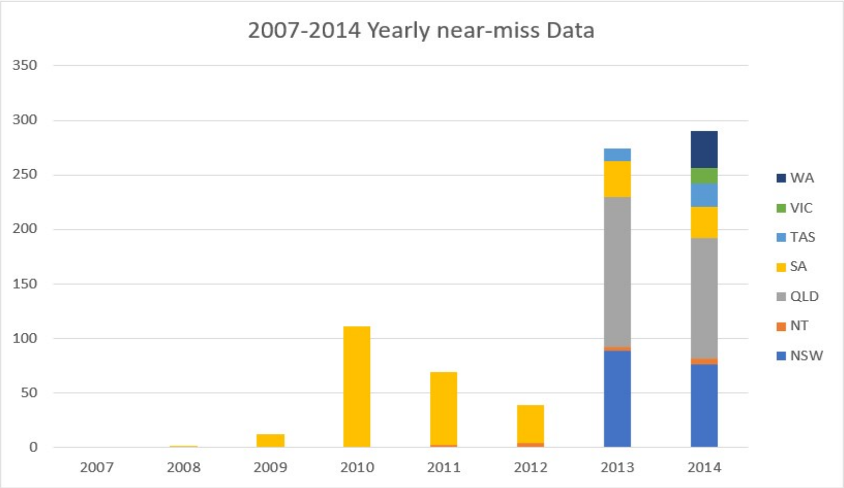


Figure B-4 - 2007-2014: Yearly overall near misses



Yearly collision at Active level crossing

Table B-5 - 2015-2021: Yearly collisions at Active level crossing

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	1	0	0	0	0	0	3
2016	0	0	2	0	0	2	1

Table B-6 - 2007-2014: Yearly collisions at Active level crossing

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				1			
2008				0			

2017	2	0	1	0	0	0	1
2018	2	0	2	0	0	1	0
2019	0	0	2	1	1	0	7
2020	1	0	0	1	0	1	0
2021	1	0	4	0	0	0	2
TOTAL	**7**	**0**	**11**	**2**	**1**	**4**	**14**

2009				0			
2010				0			
2011		0		1			
2012		0		0			
2013	2	0	3	2	1		
2014	0	0	2	1	0	0	1
TOTAL	**2**	**0**	**5**	**5**	**1**	**0**	**1**

Figure B-5 - 2015-2021: Yearly collisions at Active level crossing

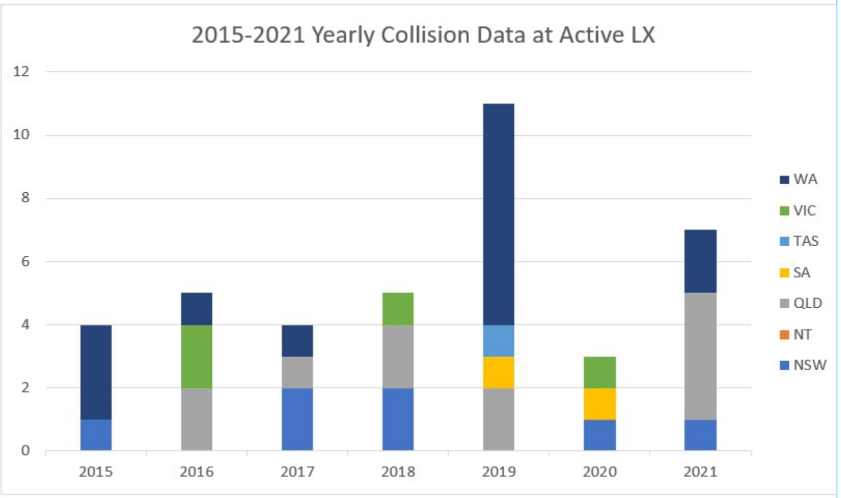
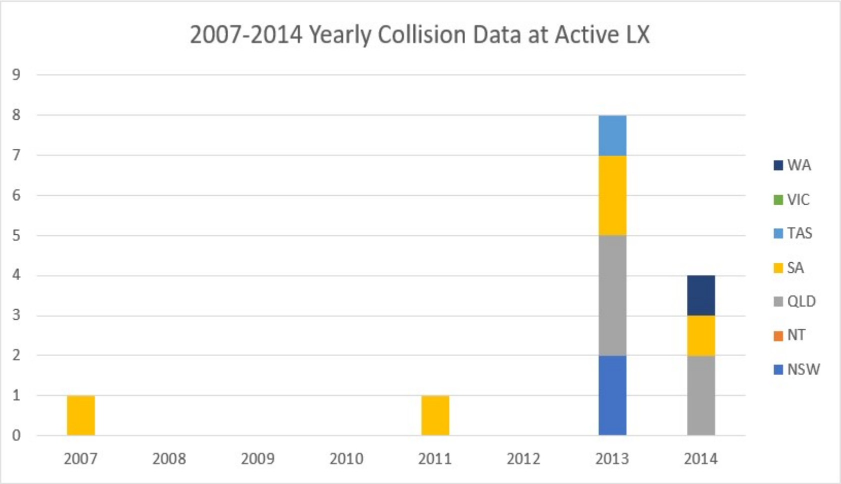


Figure B-6 - 2007-2014: Yearly collisions at Active level crossing



Yearly near-miss at Active level crossing

Table B-7 - 2015-2021: Yearly near misses at Active level crossing

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	35	2	90	8	14	5	35
2016	23	1	80	15	5	22	22
2017	9	0	83	9	16	9	29
2018	22	0	69	8	16	13	13

Table B-8 - 2007-2014: Yearly near misses at Active level crossing

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				0			
2008				1			
2009				6			
2010				43			

2019	22	0	40	5	10	10	13
2020	18	0	38	4	9	7	24
2021	9	0	30	4	9	3	16
TOTAL	**138**	**3**	**430**	**53**	**79**	**69**	**152**

2011		2		28			
2012		3		19			
2013	62		97	18	9		
2014	45	1	78	16	16	8	23
TOTAL	**107**	**6**	**175**	**131**	**25**	**8**	**23**

Figure B-7 - 2015-2021: Yearly near misses at Active level crossing

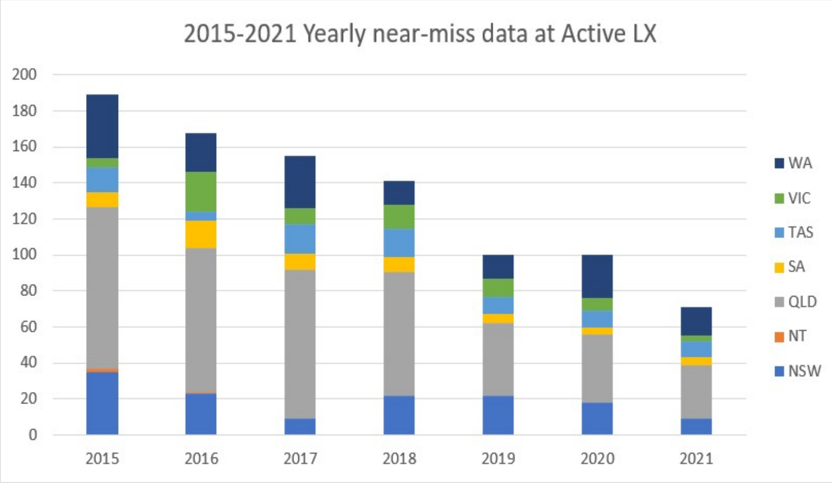
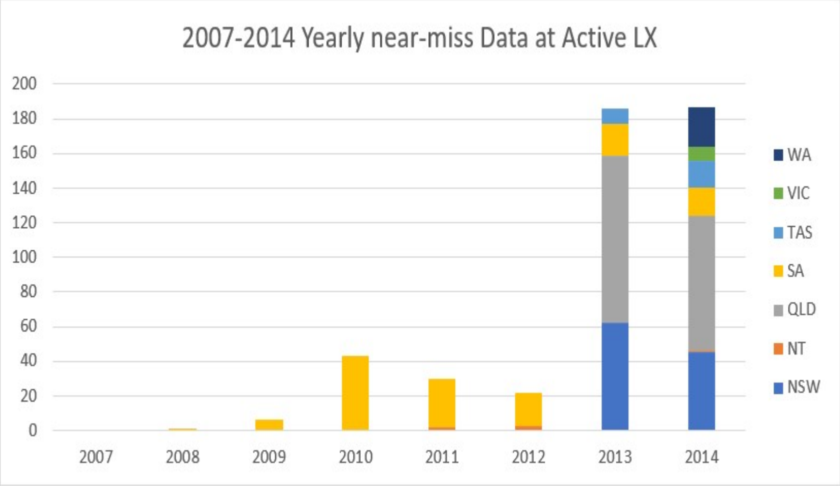


Figure B-8 - 2007-2014: Yearly near misses at Active level crossing



Yearly collision at Passive level crossing

Table B-9 - 2015-2021: Yearly collisions at Passive level crossing

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	3	0	0	1	0	0	1
2016	1	0	0	0	0	1	0
2017	4	0	4	0	1	1	0
2018	2	0	4	1	2	0	1
2019	3	0	3	0	0	1	2
2020	2	0	3	2	1	2	3

Table B-10 - 2007-2014: Yearly collisions at Passive level crossing

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				2			
2008				1			
2009				2			
2010				2			
2011		1		1			
2012		0		1			

2021	2	0	0	0	0	2	2
TOTAL	**17**	**0**	**14**	**4**	**4**	**7**	**9**

2013	1	0	2	0	0		
2014	2	0	1	1	1	0	0
TOTAL	**3**	**1**	**3**	**10**	**1**	**0**	**0**

Figure B-9 - 2015-2021: Yearly collisions at Passive level crossing

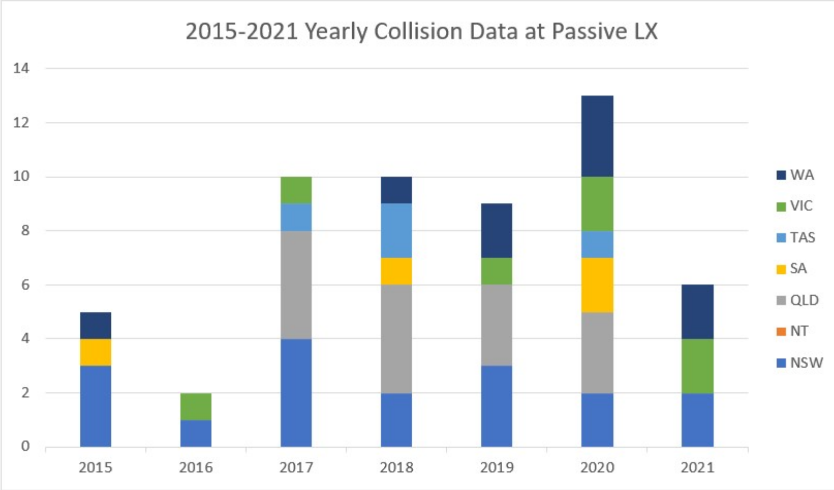
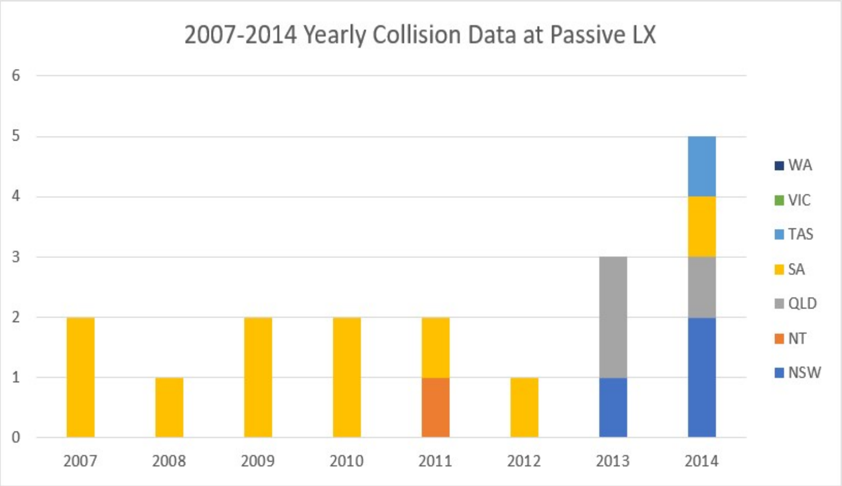


Figure B-10 - 2007-2014: Yearly collisions at Passive level crossing



Yearly near-miss at Passive level crossing

Table B-11 - 2015-2021: Yearly near misses at Passive level crossing

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	23	1	34	10	8	7	14
2016	17	1	30	2	3	7	11
2017	15	0	35	6	3	9	12
2018	18	1	33	3	5	11	12
2019	18	1	28	9	2	6	7
2020	19	0	21	3	8	9	13
2021	20	0	18	7	4	6	9
TOTAL	**130**	**4**	**199**	**40**	**33**	**55**	**78**

Table B-12 - 2007-2014: Yearly near misses at Passive level crossing

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				0			
2008				0			
2009				5			
2010				40			
2011		0		23			
2012		1		13			
2013	24	3	40	15	2		
2014	29	5	30	12	4	5	9

TOTAL	**53**	**9**	**70**	**108**	**6**	**5**	**9**

Figure B-11 - 2015-2021: Yearly near misses at Passive level crossing

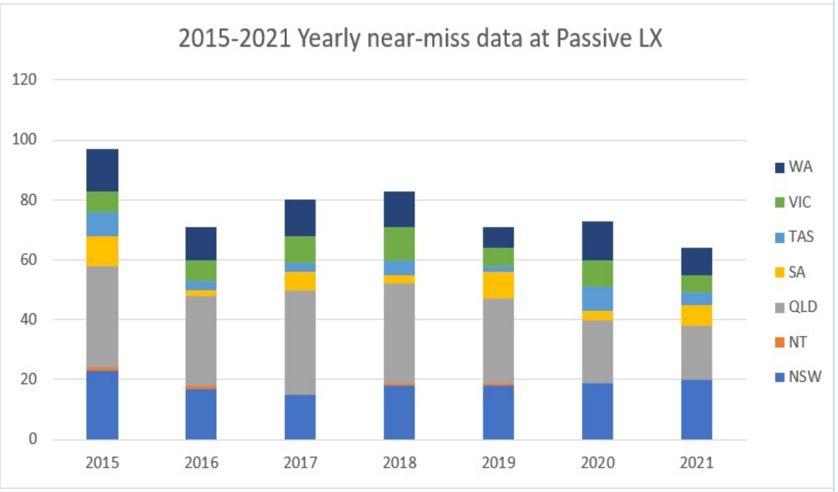
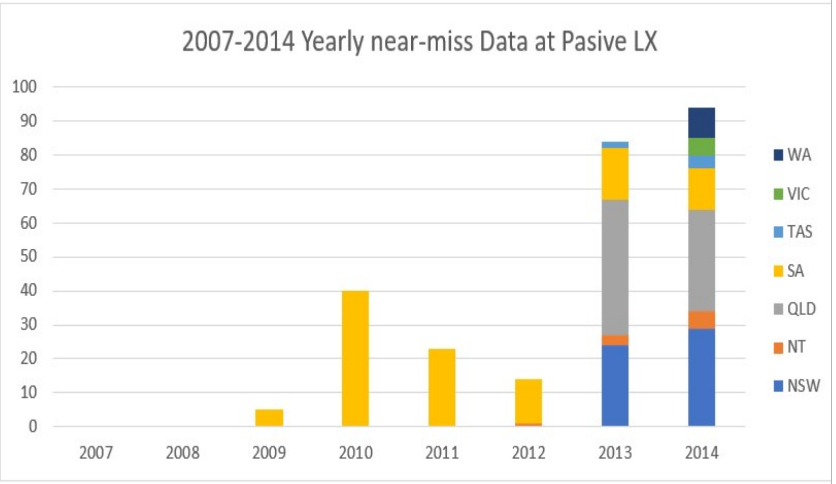


Figure B-12 - 2007-2014: Yearly near misses at Passive level crossing



Yearly collision during the day

Table B-13 - 2015-2021: Yearly collisions during the day

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	3	0	0	1	0	0	1
2016	1	0	2	0	0	1	1
2017	5	0	3	0	1	1	1
2018	2	0	4	1	1	0	0
2019	0	0	4	1	1	1	4
2020	2	0	2	3	0	3	3
2021	3	0	5	0	0	2	3
TOTAL	**16**	**0**	**20**	**6**	**3**	**8**	**13**

Table B-14 - 2007-2014: Yearly collisions during the day

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				2			
2008				1			
2009				2			
2010				2			
2011		0		2			
2012		0		1			
2013	2	0	3	2	0		
2014	1	0	2	1	1	0	0
TOTAL	**3**	**0**	**5**	**13**	**1**	**0**	**0**

Figure B-13 - 2015-2021: Yearly collisions during the day

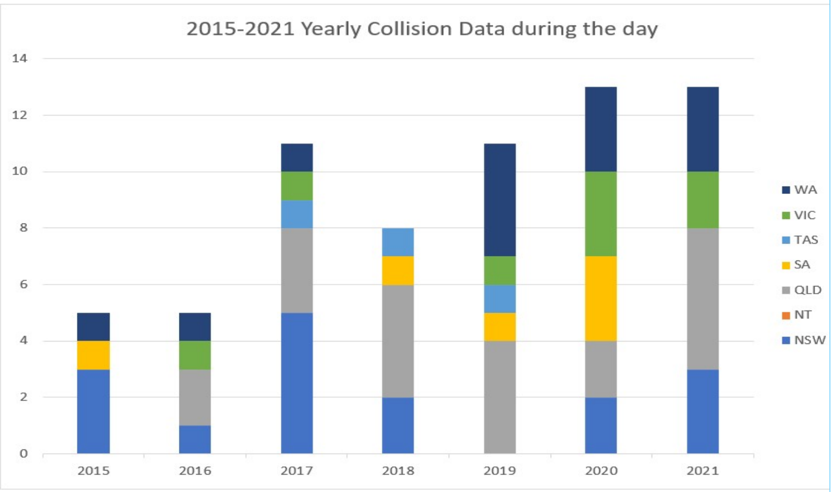
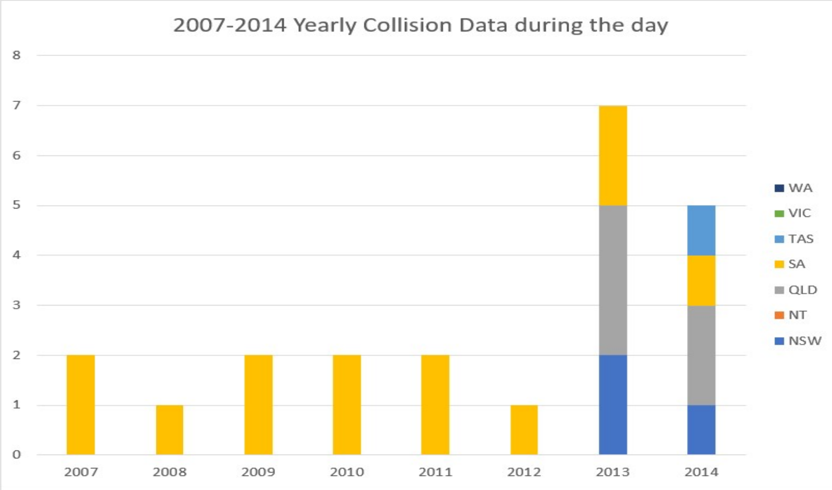


Figure B-14 - 2007-2014: Yearly collisions during the day



Yearly near-miss during the day

Table B-15 - 2015-2021: Yearly near misses during the day

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	47	2	105	16	22	7	43
2016	32	2	89	14	7	23	30
2017	17	1	101	15	15	13	34
2018	28	1	89	11	16	17	24
2019	36	1	59	11	9	13	15
2020	37	0	50	5	16	14	26
2021	25	0	39	8	10	7	24
TOTAL	**222**	**7**	**532**	**80**	**95**	**94**	**196**

Table B-16 - 2007-2014: Yearly near misses during the day

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				0			
2008				1			
2009				10			
2010				101			
2011		2		59			
2012		4		24			
2013	77	2	105	25	11		
2014	63	5	83	24	18	11	27
TOTAL	**140**	**13**	**188**	**244**	**29**	**11**	**27**

Figure B-15 - 2015-2021: Yearly near misses during the day

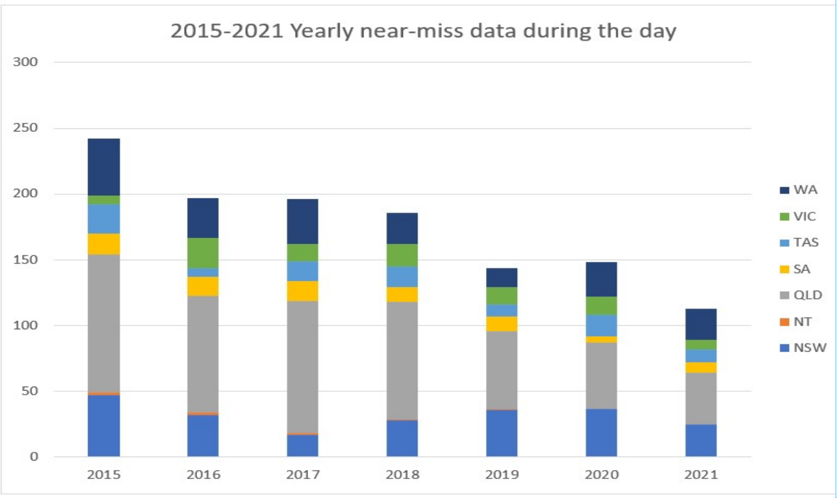
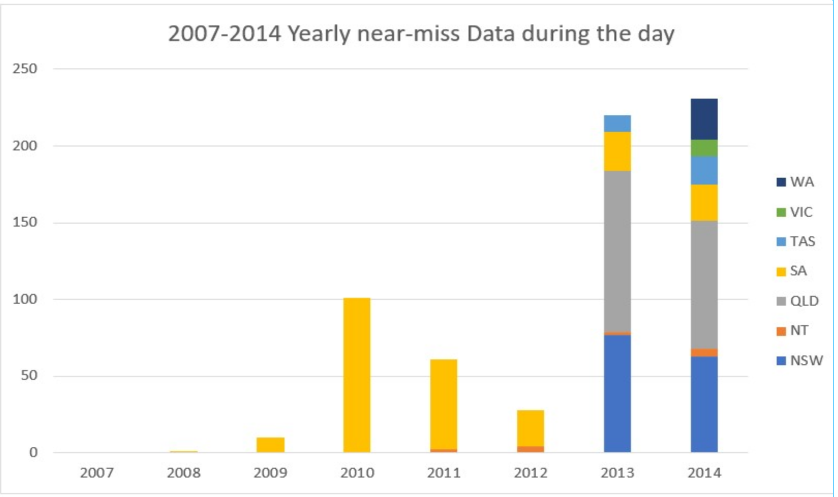


Figure B-16 - 2007-2014: Yearly near misses during the day



Yearly collision at night

Table B-17 - 2015-2021: Yearly collisions at night

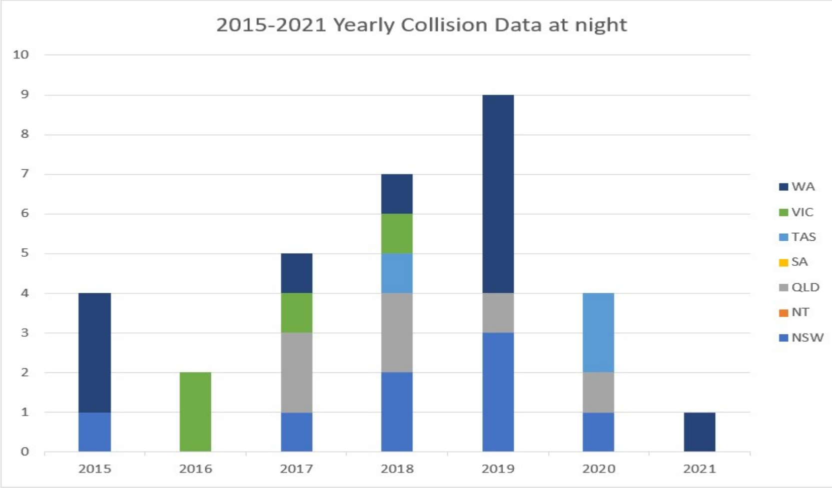
Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	1	0	0	0	0	0	3
2016	0	0	0	0	0	2	0
2017	1	0	2	0	0	1	1
2018	2	0	2	0	1	1	1
2019	3	0	1	0	0	0	5
2020	1	0	1	0	2	0	0
2021	0	0	0	0	0	0	1
TOTAL	**8**	**0**	**6**	**0**	**3**	**4**	**11**

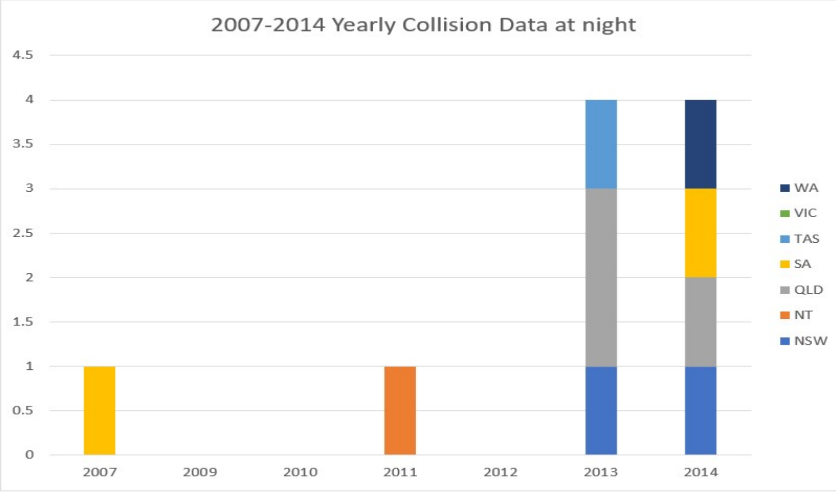
Figure B-17 - 2015-2021: Yearly collisions at night

Table B-18 - 2007-2014: Yearly collisions at night

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				1			
2008				0			
2009				0			
2010				0			
2011		1		0			
2012		0		0			
2013	1	0	2	0	1		
2014	1	0	1	1	0	0	1
TOTAL	**2**	**1**	**3**	**2**	**1**	**0**	**1**

Figure B-18 - 2007-2014: Yearly collisions at night





Yearly near-miss at night

Table B-19 - 2015-2021: Yearly near misses at night

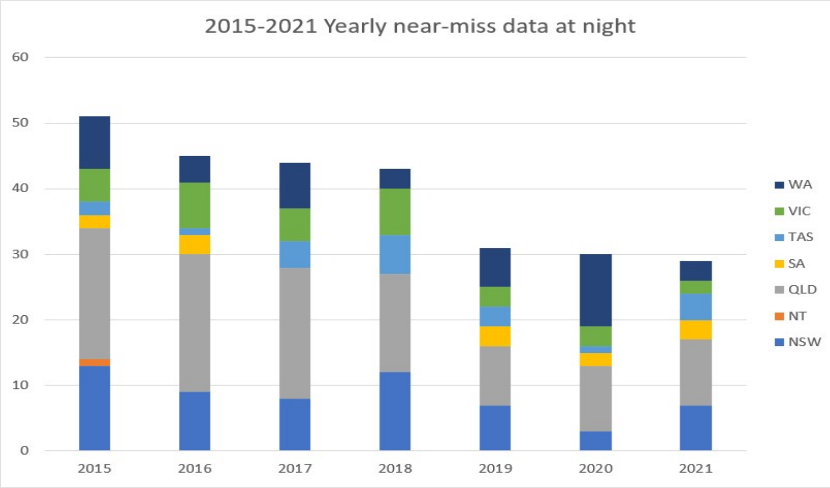
Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	13	1	20	2	2	5	8
2016	9	0	21	3	1	7	4
2017	8	0	20	0	4	5	7
2018	12	0	15	0	6	7	3
2019	7	0	9	3	3	3	6
2020	3	0	10	2	1	3	11
2021	7	0	10	3	4	2	3
TOTAL	**59**	**1**	**105**	**13**	**21**	**32**	**42**

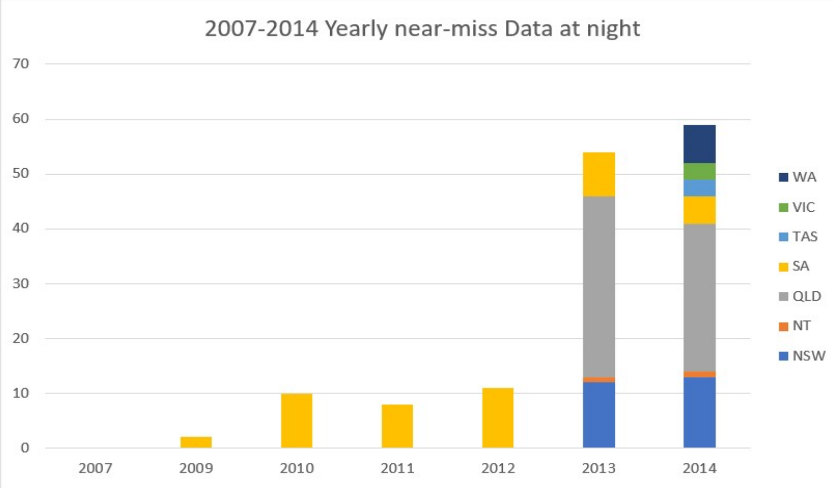
Figure B-19 - 2015-2021: Yearly near misses at night

Table B-20 - 2007-2014: Yearly near misses at night

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				0			
2008				0			
2009				2			
2010				10			
2011		0		8			
2012		0		11			
2013	12	1	33	8	0		
2014	13	1	27	5	3	3	7
TOTAL	**25**	**2**	**60**	**44**	**3**	**3**	**7**

Figure B-20 - 2007-2014: Yearly near misses at night





Yearly collision at Active level crossing during the day

Table B-21 - 2015-2021: Yearly collisions at Active level crossing during the day

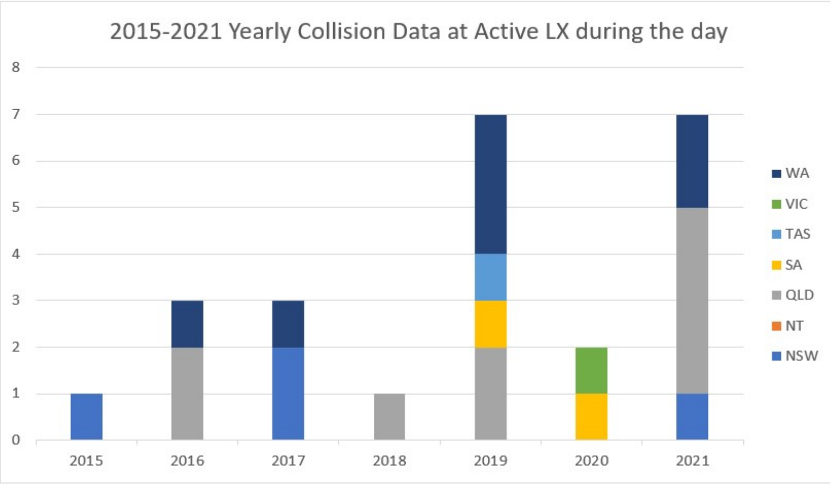
Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	1	0	0	0	0	0	0
2016	0	0	2	0	0	0	1
2017	2	0	0	0	0	0	1
2018	0	0	1	0	0	0	0
2019	0	0	2	1	1	0	3
2020	0	0	0	1	0	1	0
2021	1	0	4	0	0	0	2
TOTAL	**4**	**0**	**9**	**2**	**1**	**1**	**7**

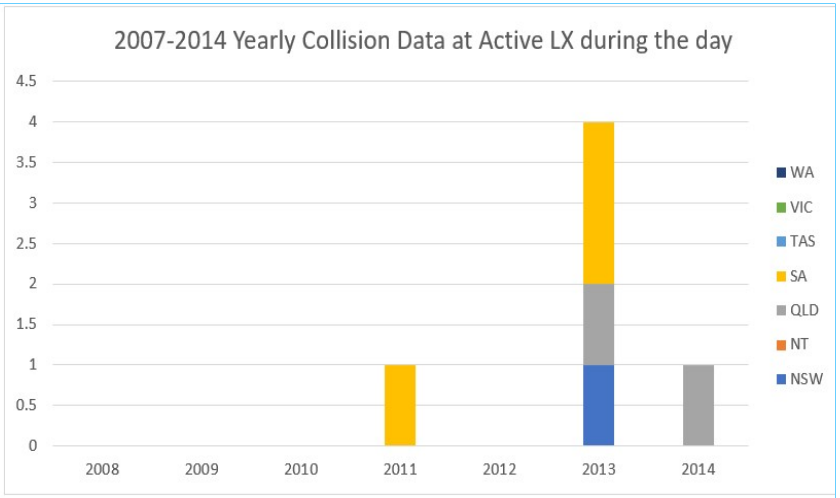
Figure B-21 - 2015-2021: Yearly collisions at Active level crossing during the day

Table B-22 - 2007-2014: Yearly collisions at Active level crossing during the day

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007							
2008				0			
2009				0			
2010				0			
2011		0		1			
2012		0		0			
2013	1	0	1	2	0		
2014	0	0	1	0	0	0	0
TOTAL	**1**	**0**	**2**	**3**	**0**	**0**	**0**

Figure B-22 - 2007-2014: Yearly collisions at Active level crossing during the day





Yearly near-miss at Active level crossing during the day

Table B-23 - 2015-2021: Yearly near misses at Active level crossing during the day

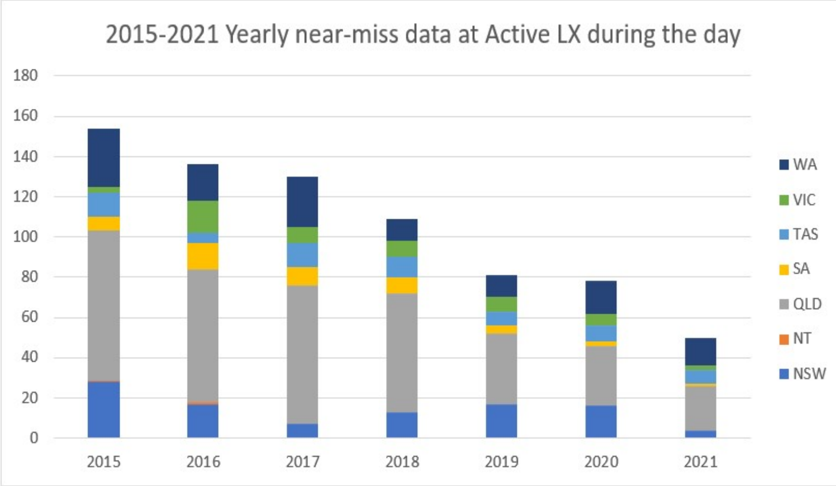
Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	28	1	74	7	12	3	29
2016	17	1	66	13	5	16	18
2017	7	0	69	9	12	8	25
2018	13	0	59	8	10	8	11
2019	17	0	35	4	7	7	11
2020	16	0	30	2	8	6	16
2021	4	0	22	1	7	2	14
TOTAL	**102**	**2**	**355**	**44**	**61**	**50**	**124**

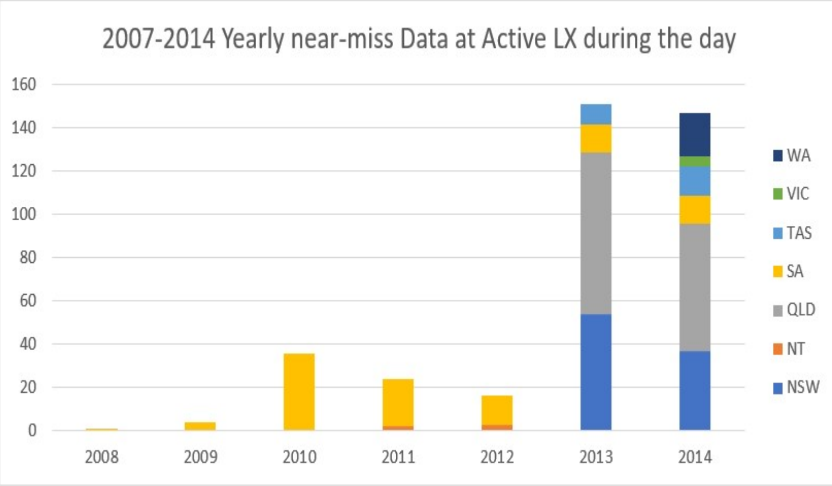
Figure B-23 - 2015-2021: Yearly near misses at Active level crossing during the day

Table B-24 - 2007-2014: Yearly near misses at Active level crossing during the day

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				0			
2008				1			
2009				4			
2010				36			
2011		2		22			
2012		3		13			
2013	54	0	75	13	9		
2014	37	0	59	13	13	5	20
TOTAL	**91**	**5**	**134**	**102**	**22**	**5**	**20**

Figure B-24 - 2007-2014: Yearly near misses at Active level crossing during the day


2015-2021 Yearly near-miss data at Active LX during the day


2007-2014 Yearly near-miss Data at Active LX during the day

Yearly collision at Active level crossing at night

Table B-25 - 2015-2021: Yearly collisions at Active level crossing at night

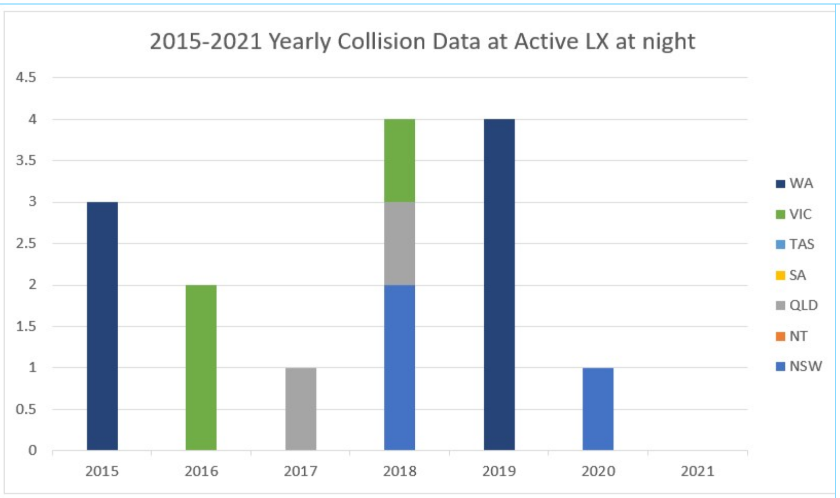
Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	0	0	0	0	0	0	3
2016	0	0	0	0		2	0
2017	0	0	1	0	0	0	0
2018	2	0	1	0	0	1	0
2019	0	0	0	0	0	0	4
2020	1	0	0	0	0	0	0
2021	0	0	0	0	0	0	0
TOTAL	**3**	**0**	**2**	**0**	**0**	**3**	**7**

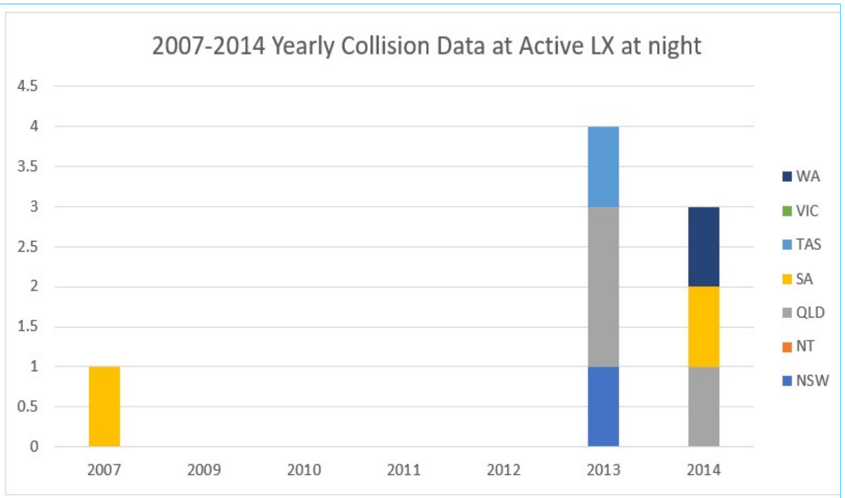
Figure B-25 - 2015-2021: Yearly collisions at Active level crossing at night

Table B-26 - 2007-2014: Yearly collisions at Active level crossing at night

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				1			
2008				0			
2009				0			
2010				0			
2011				0			
2012				0			
2013	1		2	0	1		
2014	0	0	1	1	0	0	1
TOTAL	**1**	**0**	**3**	**2**	**1**	**0**	**1**

Figure B-26 - 2007-2014: Yearly collisions at Active level crossing at night





Yearly near-miss at Active level crossing at night

Table B-27 - 2015-2021: Yearly near misses at Active level crossing at night

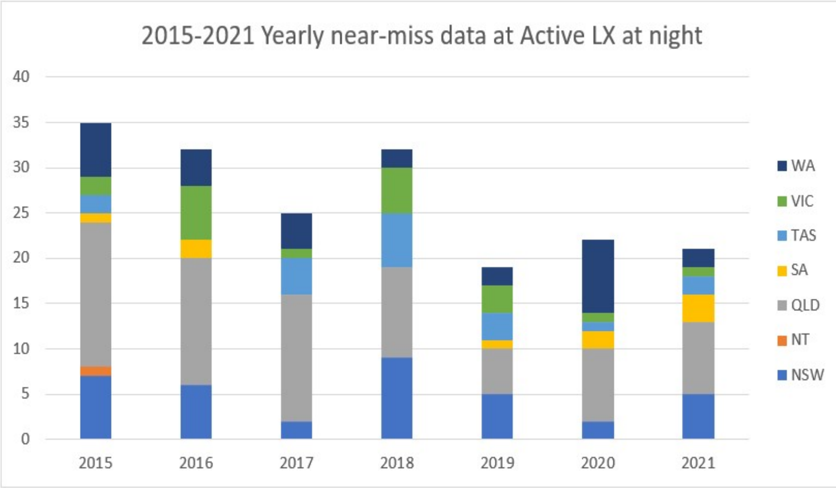
Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	7	1	16	1	2	2	6
2016	6		14	2		6	4
2017	2		14	0	4	1	4
2018	9		10	0	6	5	2
2019	5		5	1	3	3	2
2020	2		8	2	1	1	8
2021	5		8	3	2	1	2
TOTAL	**36**	**1**	**75**	**9**	**18**	**19**	**28**

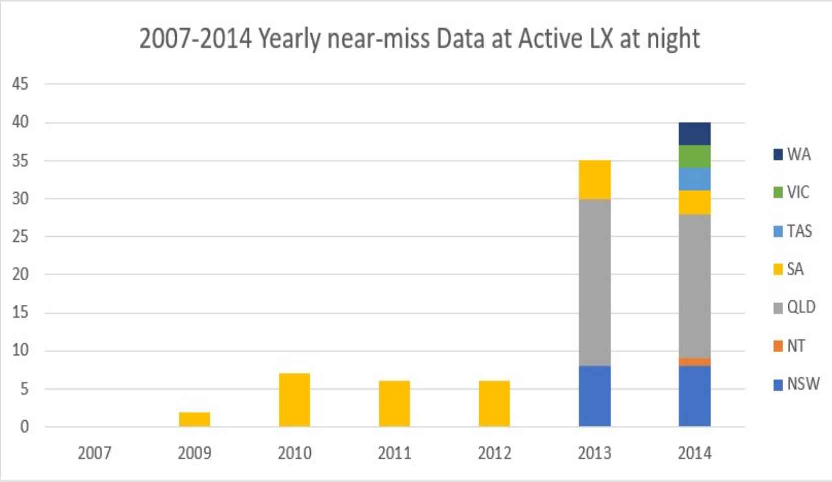
Figure B-27 - 2015-2021: Yearly near misses at Active level crossing at night

Table B-28 - 2007-2014: Yearly near misses at Active level crossing at night

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				0			
2008				0			
2009				2			
2010				7			
2011				6			
2012				6			
2013	8		22	5	0		
2014	8	1	19	3	3	3	3
TOTAL	**16**	**1**	**41**	**29**	**3**	**3**	**3**

Figure B-28 - 2007-2014: Yearly near misses at Active level crossing at night





Yearly collision at Passive level crossing during the day

Table B-29 - 2015-2021: Yearly collisions at Passive level crossing during the day

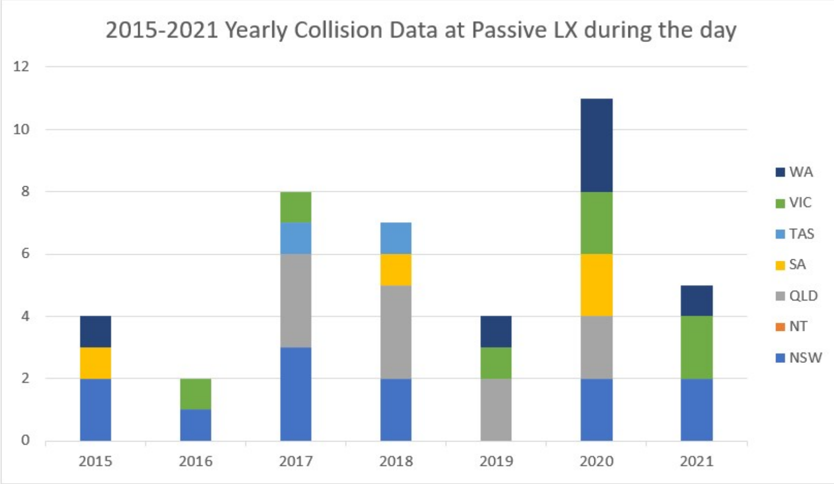
Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	2	0	0	1	0	0	1
2016	1	0	0	0	0	1	0
2017	3		3	0	1	1	0
2018	2	0	3	1	1	0	0
2019	0	0	2	0	0	1	1
2020	2		2	2	0	2	3
2021	2		0	0	0	2	1
TOTAL	**12**	**0**	**10**	**4**	**2**	**7**	**6**

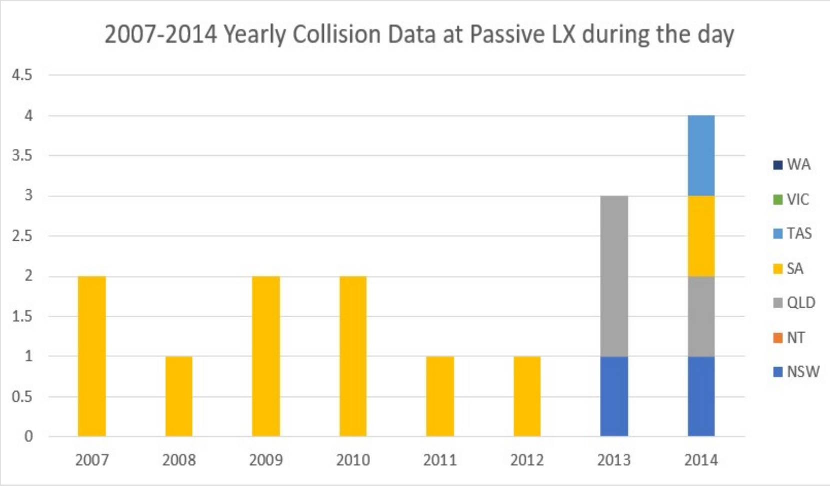
Figure B-29 - 2015-2021: Yearly collisions at Passive level crossing during the day

Table B-30 - 2007-2014: Yearly collisions at Passive level crossing during the day

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				2			
2008				1			
2009				2			
2010				2			
2011				1			
2012		0		1			
2013	1	0	2	0	0		
2014	1	0	1	1	1	0	0
TOTAL	**2**	**0**	**3**	**10**	**1**	**0**	**0**

Figure B-30 - 2007-2014: Yearly collisions at Passive level crossing during the day





Yearly near-miss at Passive level crossing during the day

Table B-31 - 2015-2021: Yearly near misses at Passive level crossing during the day

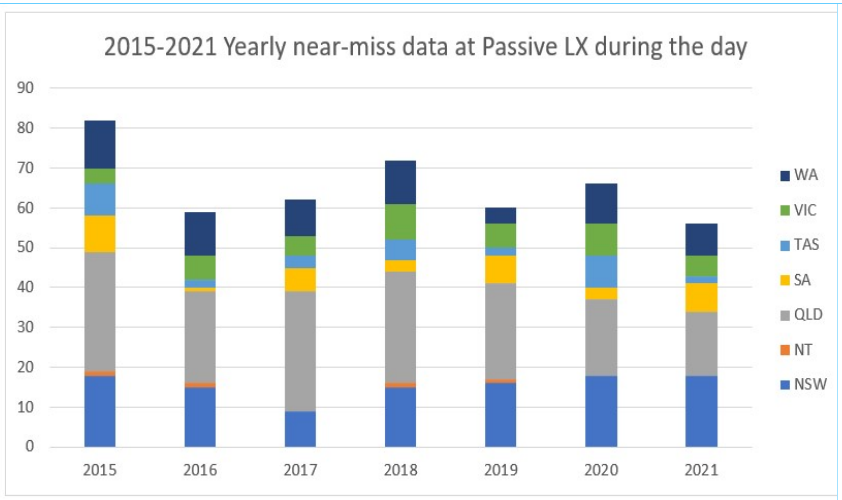
Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	18	1	30	9	8	4	12
2016	15	1	23	1	2	6	11
2017	9		30	6	3	5	9
2018	15	1	28	3	5	9	11
2019	16	1	24	7	2	6	4
2020	18		19	3	8	8	10
2021	18		16	7	2	5	8
TOTAL	**109**	**4**	**170**	**36**	**30**	**43**	**65**

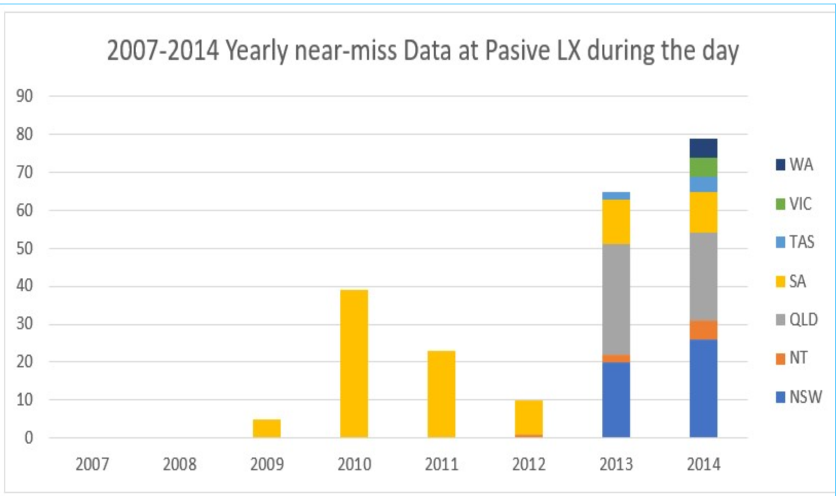
Table B-32 - 2007-2014: Yearly near misses at Passive level crossing during the day

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007				0			
2008				0			
2009				5			
2010				39			
2011				23			
2012		1		9			
2013	20	2	29	12	2		
2014	26	5	23	11	4	5	5
TOTAL	**46**	**8**	**52**	**99**	**6**	**5**	**5**

Figure B-31 - 2015-2021: Yearly near misses at Passive level crossing during the day

Figure B-32 - 2007-2014: Yearly near misses at Passive level crossing during the day





Yearly collision at Passive level crossing at night

Table B-33 - 2015-2021: Yearly collisions at Passive level crossing at night

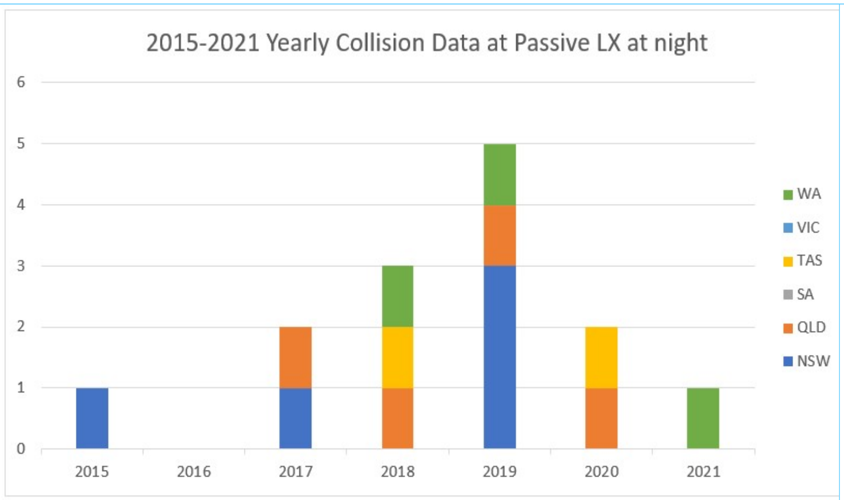
Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	1	0	0	0		0	0
2016	0	0	0	0	0	0	
2017	1	0	1			0	0
2018	0	0	1	0	1	0	1
2019	3	0	1	0			1
2020	0	0	1	0	1	0	0
2021	0	0	0		0	0	1
TOTAL	**5**	**0**	**4**	**0**	**2**	**0**	**3**

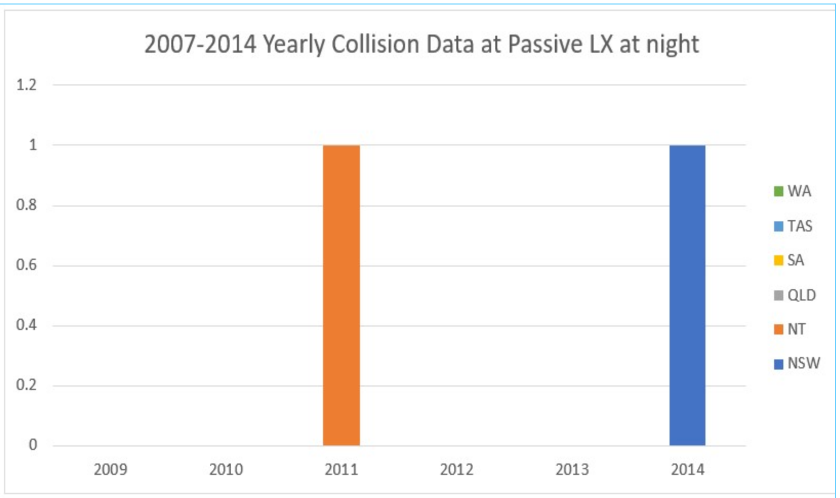
Table B-34 - 2007-2014: Yearly collisions at Passive level crossing at night

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007							
2008							
2009				0			
2010				0			
2011		1					
2012				0			
2013	0	0	0	0			
2014	1		0	0	0		0
TOTAL	**1**	**1**	**0**	**0**	**0**		**0**

Figure B-33 - 2015-2021: Yearly collisions at Passive level crossing at night

Figure B-34 - 2007-2014: Yearly collisions at Passive level crossing at night





Yearly near-miss at Passive level crossing at night

Table B-35 - 2015-2021: Yearly near misses at Passive level crossing at night

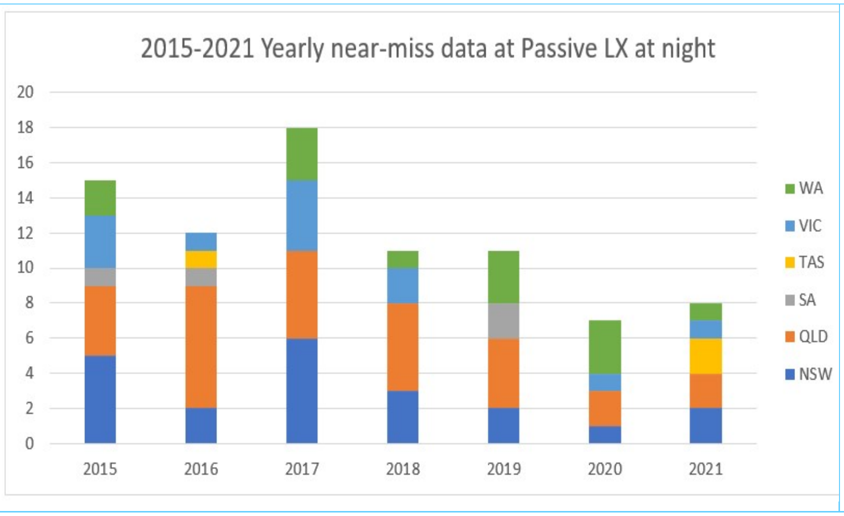
Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2015	5	0	4	1		3	2
2016	2	0	7	1	1	1	
2017	6	0	5			4	3
2018	3	0	5	0	0	2	1
2019	2	0	4	2			3
2020	1	0	2	0	0	1	3
2021	2	0	2		2	1	1
TOTAL	**21**	**0**	**29**	**4**	**3**	**12**	**13**

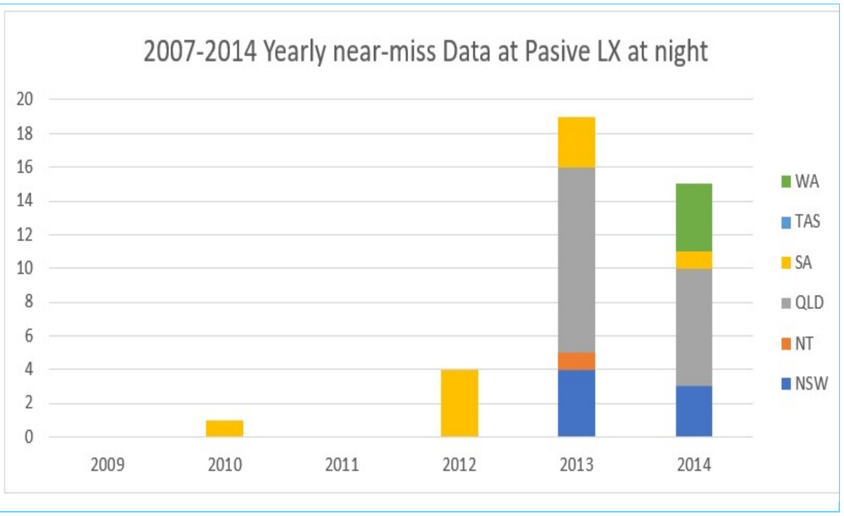
Figure B-35 - 2015-2021: Yearly near misses at Passive level crossing at night

Table B-36 - 2007-2014: Yearly near misses at Passive level crossing at night

Year/State	NSW	NT	QLD	SA	TAS	VIC	WA
2007							
2008							
2009				0			
2010				1			
2011		0					
2012				4			
2013	4	1	11	3			
2014	3		7	1	0		4
TOTAL	**7**	**1**	**18**	**9**	**0**		**4**

Figure B-36 - 2007-2014: Yearly near misses at Passive level crossing at night


2015-2021 Yearly near-miss data at Passive LX at night
20
18
16
14
12
10
8
6
4
2
0
2015
2016
2017
2018
2019
2020
2021
WA
VIC
TAS
SA
QLD
NSW


2007-2014 Yearly near-miss Data at Pasive LX at night
20
18
16
14
12
10
8
6
4
2
0
2009
2010
2011
2012
2013
2014
WA
TAS
SA
QLD
NT
NSW

CONTACT US

E acri@acri.net.au
W www.acri.net.au
A Ground Floor, 111 Alinga Street, Canberra, ACT 2601
P PO Box 238, Civic Square, ACT 2608, Australia