Separation and Tram Safety
Detailed Report
October 2018
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This report highlights the operational perspective on tram road safety in Melbourne. It highlights the challenges, but also recent successes, in improving tram safety for the 200 million passengers carried every year.

Our passengers and staff have experienced close to:

- one thousand vehicle to tram collisions every year for the past four years – an average of three collisions every day
- 30 serious passenger falls, and
- nearly 300 minor passenger falls, many due to emergency braking for other vehicles.

Yarra Trams reviewed four years of vehicle-to-tram collisions, passenger falls on trams, and near hit incident reports. We filtered out incidents that were clearly not related to other road users. We then mapped the remaining 4,350 incidents, and the associated serious injuries, and assessed the type of separation in place on that section of the network.

**Key safety findings**

- Across Melbourne, nearly 40 per cent of collisions, falls and near hits happen on the 15 per cent of the tram network with full time separation by plastic strips and painted lines.
- Substantial improvements in tram safety are possible by upgrading existing ‘moderate’ and ‘weak’ separation to stronger, safer designs.
- More effective separation is appropriate on the busiest parts of the tram network.
- Yarra Trams has measures in place to reduce the number of incidents. Despite this, the number of incidents has stayed at around 1,000, suggesting new initiatives are needed.

Road safety incidents are a source of delay and disruption to passengers.

**Key disruption findings**

- ‘More disruptive’ and ‘most disruptive’ incidents cluster at key intersections on the approach to the CBD.
- Typically 10 trams are unavailable for peak services due to collision repairs.
- Tram repairs after a vehicle collision took 13 days on average in 2017.
- 40 per cent of collisions take more than a week to repair.

**Next Steps**

Road authorities may be able to influence road safety involving trams by:

- Undertaking Road Safety Audits and sharing the findings with VicRoads, Transport for Victoria and Yarra Trams to find solutions.
- Incorporating tram safety into Road Management Plans through planning for regular maintenance of plastic strips and linemarking.
- Supporting the upgrade of less safe separation designs to safer separation using kerbs, moving along the ‘separation spectrum’.
- Planning for new ‘safe separation’ such as raised track and green tracks.
- Improving traffic signals to reduce conflicts between trams and other road users.
- Reviewing where cars need to make turns along tram routes, and removing uncontrolled turns where possible to reduce conflicts with tram movements.
As part of its commitment to Zero Harm, Yarra Trams has prepared this report to inform our stakeholders about the relationship between tram safety and the design of separation on roads.

Zero Harm is one of Yarra Trams’ fundamental values. Our passengers and staff have experienced close to one thousand vehicle to tram collisions every year for the past four years – an average of three collisions every day. There are also 30 serious passenger falls, and nearly 300 minor passenger falls every year, many due to emergency braking for other vehicles.

About the data used in this report

Yarra Trams has undertaken a comprehensive review of four years of tram safety data to prepare this report.

When an incident occurs on Melbourne’s tram network, Yarra Trams’ operations centre records the details as reported by the tram driver. Location is reported to the nearest known intersection. In the City, this is usually one of the main or “Little” streets; in the suburbs it is the side streets.

In line with our Zero Harm commitment, we capture many incidents that otherwise go unreported in road safety databases like CrashStats.

Yarra Trams reviewed four years of vehicle-to-tram collisions, passenger falls on trams, and near hit incident reports. We filtered out incidents that were clearly not related to other road users. We then mapped the remaining 4,350 incidents, and the associated serious injuries, and assessed the type of separation in place on that section of the network (e.g. Figure 1 and Figure 2).

This report is an update of the previous edition dated May 2018. The main changes are:

- further classification of past incidents resulting in injuries; and
- incorporation of 2017/18 financial year safety data.

Figure 1: A midblock vehicle to tram collision in Bridge Road. Note the raised dividing strips

Figure 2: A midblock vehicle to tram collision in St Kilda Road, occurring in full time tram lanes
Background
An important road safety issue: preventable vehicle to tram collisions

Yarra Trams has experienced close to one thousand vehicle to tram collisions every year for the past four years – an average of three collisions every day. Yarra Trams also experiences 30 serious passenger falls, and nearly 300 minor passenger falls every year.

This ongoing rate of incidents is a major strategic concern, given Yarra Trams’ value of ‘Zero Harm’ in provision of tram services for Melbourne.

Yarra Trams’ data shows that:
- Around 65 per cent of the vehicle collisions are due to vehicles merging midblock or doing a U-turn in front of a tram. About 30 per cent are at intersections. Only 3 per cent of the incidents are estimated to be caused by trams.
- 40 per cent of serious falls are estimated to be due to emergency braking to avoid a collision.

The general location of these incidents over the past four financial years is shown in Figure 3 below. This map shows vehicle collisions (including derailments from collisions), passenger falls due to emergency braking, and near hits to vehicles, and the locations of incidents that resulted in serious injuries (37 incidents in total).

Figure 3: Locations of vehicle to tram collisions, near hits, passenger falls and resulting serious injuries (FY 2014/15 through 2017/18)
The Significance of Separation

Melbourne is home to the largest tram network in the world, where electric trams have operated in the city continuously since 1906. The network’s age and extensive coverage come with some strategic challenges such as the high proportion of track that shares road space with general traffic.

Modern tram networks typically use ‘surface’ and ‘edge’ design features to effectively prevent unmanaged vehicles on tram tracks. A ‘spectrum’ of design options is available of varying effectiveness in transport and urban design outcomes. The more effective tram separation design interventions are larger in scope, with greater potential to contribute to meeting non-transport placemaking and urban design objectives across the wider public realm.

Fully implemented ‘strong’ separation includes:

- Combined surface and edge treatments to provide separation along and across tram tracks,
- Minimisation of remaining crossing points over the tram tracks, and
- Signal controls to prioritise tram movements.

Figure 4: The ‘separation spectrum’ of separation design effectiveness and opportunity for placemaking
In Figure 5, the separation environments are characterised as:

**Strongly separated**
- Right of way: trams operate in an exclusive right of way that is separated from traffic and in some cases also pedestrians
- Boulevard (hard median): trams are separated from traffic (except when crossing through an intersection), but not from pedestrians

**Moderately separated**
- Mountable separation kerb: trams are separated from traffic by raised dividing strips that vehicles can cross

**Weakly separated**
- Full Time Tram Lane: trams are separated from traffic by painted lines and regulations
- Part Time Tram Lane: trams are separated from traffic by painted lines and regulations but only at some times of day

**Not separated**
- Shared Running: trams operate in the general traffic flow
- Shared Space: trams operate in a street with pedestrians but no motorised vehicles

With approximately 25% of the tram network ‘strongly separated’ from general traffic using design solutions to prevent unmanaged motor vehicles on tram track, there is a much greater chance of conflict between trams and other road users, as well as a higher rate of preventable safety incidents and delays, than there would otherwise be if stronger tram separation design strategies were increased across the network.

![Figure 5: Overview of separation environments, 2017 (Source: Yarra Trams analysis)](image-url)
Table 1 below shows a disproportionate number of safety incidents occurred where trams are moderately or weakly separated from general traffic. Full time separation designs within these two categories perform the poorest, with nearly 40% of safety incidents occurring on 14.6% of the network.

<table>
<thead>
<tr>
<th>Level</th>
<th>Type</th>
<th>% of Track</th>
<th>% of Incidents</th>
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<tr>
<td>Strong</td>
<td>Right of Way</td>
<td>15.3</td>
<td>4.53</td>
</tr>
<tr>
<td></td>
<td>Boulevard</td>
<td>10.5</td>
<td>14.30</td>
</tr>
<tr>
<td>Moderate</td>
<td>Raised Dividing Strips</td>
<td>8.3</td>
<td>24.16</td>
</tr>
<tr>
<td>Weak</td>
<td>Full Time Tram Lane</td>
<td>6.3</td>
<td>15.36</td>
</tr>
<tr>
<td></td>
<td>Part Time Tram Lane</td>
<td>2.4</td>
<td>0.57</td>
</tr>
<tr>
<td>None</td>
<td>Shared running</td>
<td>56.5</td>
<td>39.91</td>
</tr>
<tr>
<td></td>
<td>Shared space</td>
<td>0.7</td>
<td>1.17</td>
</tr>
</tbody>
</table>

Table 1: Overview of separation statistics (FY 14/15 to FY 17/18). Source: Yarra Trams analysis

In comparison:

- Around 20% of incidents occurred in the 25% of the network that is strongly separated
- 41% of incidents occurred in the 57% of the network where trams operated in shared environments

Across Melbourne, nearly 40 per cent of collisions, falls and near hits happen on the 15 per cent of the tram network with full time separation by plastic strips and painted lines.

- A smaller proportion of incidents occurred in ‘boulevard’ environments, even though they are a larger proportion of the network than raised dividing strips and full time tram lanes.

The incident rate by design type, shown in Table 2, normalises for the amount of tram service operating. Strong separation is typically around four times more effective, and can be up to ten times more effective, than moderate and weak separation designs.

<table>
<thead>
<tr>
<th>Type</th>
<th>Estimated incident rate per 10,000 kms of tram service</th>
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<tbody>
<tr>
<td>Boulevard</td>
<td>0.2-0.5</td>
</tr>
<tr>
<td>Full Time Tram Lanes</td>
<td>0.6-1.4</td>
</tr>
<tr>
<td>Raised Dividing Strips</td>
<td>0.9-2.0</td>
</tr>
</tbody>
</table>

Table 2: Range of incident rates by service kilometre, sample of three corridors of each type. Source: Yarra Trams analysis
Moderate and weakly separated environments represent one of the best opportunities to improve the overall safety of Melbourne’s tram network, particularly since the roadways are generally already designed for some form of separation that can be upgraded to a stronger separation design.

Separation is better for road safety overall, not just tram road safety. In 2017, researchers investigated whether general road safety (including collisions not involving trams) was improved by tram priority. The research investigated CrashStats data, which reports fewer vehicle to tram collisions than Yarra Trams data, as collisions must have resulted in an injury to be included in CrashStats. It did not distinguish between the different kinds of separation treatment. The findings were published in an article in the journal Traffic Injury Prevention. They include:

- Separation is safer for all road users. Separation is statistically associated with a 19.4 per cent reduction in vehicle- and pedestrian-involved collisions; and
- Intersections with hook turns have a lower general crash rate than intersections without hook turns, which is important context for considering the high number of vehicle to tram collisions in the CBD.

Safety and Separation in Tram Lanes

The busiest sections of Melbourne’s tram network are in the CBD and inner suburbs. In many streets in these areas, trams are separated from traffic only by tram lanes, one of the weaker choices on the ‘separation spectrum’. These designs permit various traffic movements on the tram tracks, as shown in Figure 6.

In the CBD, tram streets usually provide parallel kerbside parking and a single lane of traffic in each direction. Where double-parking occurs around parking bays, loading zones and taxi ranks, current separation designs allow vehicles to encroach on the tram track, putting tram passengers at risk.

These design choices mean the safe and efficient movement of trams and tram passengers in the busiest part of the tram network is largely reliant on compliance by motorists.

Ironically, this design passively enables double-parking behaviour. Safer separation would deter double parking because its impacts on other motorists would be greater, helping to keep the whole city moving and safe.

Figure 6: Vehicle use of tram lanes (Bourke Street (top) and Collins Street (bottom))
A Passenger Perspective on Separation

Tram separation contributes to a number of ‘moments that matter’ that are also ‘pain points’ and of high importance to passengers, as shown in Figure 7:

- Being on time and keeping to timetable. More effective separation contributes to reducing delays.
- Feeling safe on trams. Separation can contribute to reducing the actual and perceived risk of a crash or fall.

Monash University data indicates an average of three hospital admissions per month are related to injuries experienced from a fall on a tram that could have been prevented through more effective separation.

Figure 7: Tram Customer Journey Map (Source: PTV)
Disruption impacts of tram road safety issues

Road safety incidents are a source of delay and disruption to passengers. The effects of a collision can vary widely, depending on its severity and its location. Although not every collision currently has delay data associated with it, Figure 8 below presents an analysis, based on standard deviations from the mean delay, for the last three financial years for which data was available.

It shows the widespread nature of ‘disruptive’ and ‘more disruptive’ incidents, clusters of ‘more disruptive’ and ‘most disruptive’ incidents at key intersections on the approach to the CBD and along corridors where diversion routes are not readily available. It also shows a seriously disruptive incident can occur anywhere on the network.

Figure 8: Estimated disruption associated with safety incidents
The high rate of vehicle to tram collisions has major impacts on ‘behind the scenes’ tram availability for passenger services.

Error! Reference source not found. shows the number of trams unavailable in each peak period due to road safety related collision repairs. In recent times typically around 10 trams have been unavailable. These trams could potentially be providing customer services and Yarra Trams has improved workflows to reduce the repair time as far as possible.

The upwards trend beginning in mid-2015 is largely due to the introduction of new tram classes to the fleet. More modern tram classes have different body types, as well as more advanced technology.

Collision repair times are affected by material, facility, manpower resources and the creation and approval of repair processes that meet original equipment manufacturer requirements.

As the fleet evolves towards newer trams, the case to prevent collisions wherever possible becomes stronger for safety and asset management outcomes.

Figure 9: Number of trams out of service in the peak due to collision repairs. Source: Yarra Trams
Figure 10 shows that even the most minor collision can result in a loss of services. Minor repairs affecting one or two peak periods make up about 29 per cent of all tram unavailability due to collision repairs. However, 31 per cent of minor collisions result in anywhere from three to ten peak periods of service availability loss, meaning that the tram might be unavailable for a whole week of service. 40 per cent require more than a whole week to repair. This displays the major effects that minor collisions have on the tram fleet.

Tram repairs after a vehicle collision took 13 days on average in 2017, down from 16 days in 2015.

Impact of Minor Collision Repairs

- 29%: 1 to 2 (one day's service)
- 40%: 3 to 10 (up to one week's service)
- 31%: More than 10 (more than one week of service)

Figure 10: Duration of collision repairs measured in number of peak periods missed. Source: Yarra Trams
Yarra Trams’ road safety controls
How we’re managing this problem today

Consistent with the scale of the vehicle-to-tram collision problem and its impacts, Yarra Trams has a number of safety controls in place to reduce the risk of separation-related incidents so far as is reasonably practicable.

The main controls are:

- Tram braking system: trams are fitted with regular and emergency brakes in recognition of the complex operational environment, and these are regularly maintained and tested
- Driver general operational rules and procedures training: Drivers are instructed in rules on safe distances between trams and other vehicles
- Yarra Trams rule book: Yarra Trams has a rule book in place which provides instruction on safe operations, and this book is regularly updated and reviewed to ensure it reflects operational requirements
- Defensive driving technique training: Drivers are trained to drive trams defensively and to anticipate potential hazards.
- Network monitoring of driver performance: Drivers’ skills and adherence to the rules is regularly monitored and corrective actions taken as appropriate
- Line markings e.g. clearance lines: consistent with the Road Management Act, Yarra Trams implements line marking to show other motorists the swept path of the tram to try to avoid vehicle encroachment.
- Signage: Yarra Trams highlights locations on the network as hotspots using signage and regularly liaises with road authorities to rectify signage issues for tram / vehicle interfaces
- Jerk reduction software: Yarra Trams has worked with the tram provider to equip new software to vehicles to reduce controllable causes of passenger falls in particular with promising initial results
- Identified hot spot locations and driver training on the specific risk at these locations: Yarra Trams analyses the safety data to identify hot spots and provide guidance to drivers to better operate trams through those locations
- Provide Victoria Police with data on vehicle to tram incidents so they can increase patrols/enforcement: Yarra Trams engages with the stakeholders that are accountable for enforcement of road rules to try to encourage better compliance
- Gong: all trams are fitted with an audible warning device and drivers are trained in its use in warning motorists
- Lighting/indicators on tram: all trams have a range of lights and indicators to improve motorist awareness of the tram on the road.

The 1000 road safety incidents a year (of which 97 per cent are not attributed to trams) indicates the magnitude of the residual risk to safe tram operations from motorists.

Yarra Trams has a standing working group reviewing these controls and identifying new actions and controls to implement to improve road safety.

This report is also part of Yarra Trams’ Safety Strategy and is an important step to assisting stakeholders to understand the role of safe system road designs for the tram network.
Plan Melbourne, the overarching strategic transport and land use plan for metropolitan Melbourne, was recently refreshed with the government committing to improving the quality and efficiency of the tram network.

The plan’s strategic direction for the tram network is to “improve tram travel times, reliability and capacity to support major movements of people by gradually transforming to a light-rail system with increased right-of-way, more accessible, low-floor, high-capacity vehicles, and level-access stops.”

One of the identified initiatives is to “improve inner Melbourne tram reliability with a range of measures that give trams greater priority on the road network (such as greater physical separation from other road users and improved technology to manage traffic flows).”

The State Government’s SmartRoads framework (and its evolution into a Movement and Place framework) identifies all tram routes as Tram Priority Routes and, in the CBD and inner suburbs, often as Pedestrian Priority Areas.

The Movement and Place framework provides support for the idea that tram movement should be prioritised in a way that is compatible with safe and efficient pedestrian movements in the CBD and inner city.

Local government transport strategies in Moreland, Glen Eira, and Melbourne are currently being revised, but recent key plans and policy directions relevant to tram road safety include:

**Plan Melbourne**
- Improve tram travel times, capacity, and reliability by increasing right-of-way in an effort to gradually transform the tram network to a light-rail system with more accessible rolling stock and stops.
- Investigate inner-Melbourne tram reliability improvements including a range of measures that give trams greater priority on the road network (such as greater physical separation from other road users and improved technology to manage traffic flows).

**Towards Zero Road Safety Vision and Victorian Road Safety Strategy**
- Incorporate safe system principles into the design of roads and roadsides…and develop innovative infrastructure solutions.

**City of Melbourne Transport Strategy Refresh**
- The City of Melbourne Public Transport Network Discussion Paper suggests that the tram network should be ‘supercharged’ through dedicated road space and enforcement of road rules.

**City of Port Phillip Integrated Transport Strategy**
- Partner with the Victorian Government and public transport providers to increase the reliability of tram services.
- Partner with PTV and Yarra Trams to deliver a pipeline of integrated movement and place tram projects.
- Target of 3.5 kilometres (by 2021/22) and 5.5 kilometres (by 2027/28) of dedicated tram (or bus) lanes on Council streets.
City of Glen Eira Integrated Transport Strategy
2018-2031
• Identification of Balaclava Road, Hawthorn Road and Dandenong Road as “express public transport routes” with trams
• Support for potential improvements including separating the service
• Identification of a pilot project in 2021 to design and implement a public transport corridor improvement project

Draft Moreland City Council Integrated Transport Strategy
• Strongly advocate and support on-road priority for buses and trams on existing and proposed routes. Removal of car parking will be supported if this increases public transport priority.
• Advocate for measures which improve tram travel time reliability (such as priority and signalling improvements), frequency and capacity.

Moonee Valley Integrated Transport Plan
• Work with State Government, VicRoads and Yarra Trams to accelerate works at key locations and ensure a holistic approach is applied.

City of Yarra Strategic Transport Statement
• Work with relevant authorities to improve tram travel time, quality, safety and reliability.
Complementing the above transport and land use outcomes, the ‘separation spectrum’ shows that separation design could allow tram infrastructure to contribute towards achieving non-transport place objectives.

For example, City of Melbourne strategies note that the city has low levels of water permeability. Hard surfaces on roads drain rapidly, meaning that rain has little opportunity to infiltrate the soil. Streets where trams operate also contribute to the urban heat island effect, as shown in Figure 11. Research in Sydney has confirmed that streetscapes are the more heat-sensitive urban feature at a precinct scale.\(^2\)

In the context of climate change, these factors lead to potential more serious storm and flood events. In turn, these increase the severity and frequency of disruption to tram services.

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Figure 11: Thermal Image Showing Streets as the Major Heat Stores in the City. Source: City of Melbourne urban forest strategy
Options
Reducing the vehicle to tram interface

There are a range of options available to road authorities to try to reduce the road safety issues associated with vehicles interacting with trams.

No Change
This option would result in a continuing trend of collisions, near hits and passenger falls. It would forego the associated benefits from preventing collisions, near hits and passenger falls. It would also mean that opportunities to implement State and local strategic plans for transport would not be progressed.

Education Campaign
VicRoads, Victoria Police and Yarra Trams regularly run education campaigns on tram lanes – for example the ‘Obey the Yellow’ campaign in 2008 (see Figure 12) and the award winning ‘Beware the Rhino’ campaign.

A 2015 campaign called ‘Travel Happy’ continued this theme. One of the specific messages of ‘Travel Happy’ was “on average there are three accidents between cars and trams every day. So, when driving near trams, never cross their path and always check before turning. To keep a safe distance, stay outside the yellow line or raised dividing strip near the tram tracks.”

Figure 12: “Obey the Yellow” Website Content (2008)

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Education campaigns about driving with trams are repeated regularly, but the safety and performance issues continue to occur. An evaluation of ‘Obey the Yellow’ found the program had ‘only modest impact because these road rules are hard to understand and remain a weak means of controlling driver behaviour around trams.’

**Enforcement**

Enforcement of tram lanes is made more difficult by the Road Rules which permit a motorist to drive in a tram lane for up to 50 metres if making a turn. Labour-intensive observation of tram lanes is needed to prove infringements of the Road Rules, making it difficult to cost-effectively resource enforcement.

Implementation of raised dividing strips would assist by simplifying enforcement, as driving over a raised dividing strip is an offence unless done to avoid an obstacle.

Good design can effectively ‘design out’ non-compliance, making it less important to enforce regulations.

**Change in Regulation**

Changes to the Road Rules to make it an offence to drive in a tram lane could make enforcement easier. However, physical controls would serve to prevent safety incidents, whereas regulatory change only deters inappropriate behaviour.

Enforcement of changed regulations would need to be considered by VicRoads and PTV in conjunction with Victoria Police, and the alternative of effective design would still be available.

**Raised Dividing Strips (‘Moderate’ Separation)**

The Melbourne tram network has numerous areas where a mountable separation kerb, also known as ‘raised dividing strips’, are used to provide greater physical separation between trams and other vehicles.

Raised dividing strips are quick and easy to install and reduce the rate of tram-to-vehicle collisions, passenger falls and near hits compared to full time tram lanes.

However, they are not particularly effective, and do not have a long design life. They are not self-enforcing and do not ensure the transport objectives for separation are fully achieved. They are easily displaced by cars and trucks turning across the tracks, and degrade under ultraviolet light exposure. In Yarra Trams’ experience the material lasts no more than 10 years under Melbourne conditions.

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Currie, G. “Improving Driver Compliance with Streetcar Transit Lanes Using a Public Education Campaign”, Transportation Research Record, v. 2112 pp. 62-69
Strong separation

Strong separation uses the most effective elements of the ‘separation spectrum’.

There are ‘quick win’ opportunities to implement strong separation where stakeholders agree on the vision for, and operation of, the street. Separation designs can then be improved with minimal issues.

In other circumstances, there may be impacts on the transport role of the street. For example:

- Taxi ranks may be needed on both sides of a street, and safe pedestrian crossing points planned.
- Emergency services and tram recovery vehicles may need to drive on the track, constraining the design options available.
- More data and stakeholder consultation may be required to close median gaps and crossing points, which can delay implementation.
- Occasional activities like roadside construction may need to be planned for through management plans

Addressing these needs may require budget and planning support.

The VicRoads Traffic Engineering Manual provides some innovative designs. For example, to enable emergency services to use tracks and exit mid-block where required, a kerb can provide a barrier on the traffic side, but be mountable on the tram side, as shown in Figure 13.

A common material choice for strong separation in Melbourne is a 100mm wide bluestone block. This kerb:

- has a small footprint that can be accommodated where painted lines are in place
- is effective in supporting the desired policy and transport outcomes
- has a very long material lifespan with low maintenance requirements, and
- can be recovered during track renewal and reused if the overall separation design is changed to provide a more integrated urban design outcome.

There can be urban design benefits from introducing strong separation as part of an integrated change to tram tracks, noting that:

- Cost-effective implementation at this level of design integration may be best achieved as part of routine track renewal
- The more effective surface design solutions on the ‘separation spectrum’ may affect the track.
- Addressing urban design desired outcomes whilst still meeting transport requirements may need further design development.
Case studies

Collins Street Separation Improvements

In 2014, Yarra Trams delivered a project in Collins Street to provide greater physical separation for trams by upgrading painted full time tram lanes to 50mm raised dividing strips.

This project reduced tram to vehicle crashes, passenger falls, and near hits by around 20 per cent, as shown in Table 3. The street has also become less variable from a safety point of view, with the standard deviation nearly halving. This suggests that many of the easily preventable incidents are now being avoided, with the remaining issues reflective of what can be achieved in a busy street with raised dividing strips.

In Collins Street in Docklands, trams have strong separation using a bluestone kerb (Figure 14). The kerb in Docklands is significantly more effective again than the plastic strips used in the Hoddle Grid, suggesting a further improvement in tram safety is feasible through improved designs.

<table>
<thead>
<tr>
<th>Collins Street section</th>
<th>Estimated incident rate per 10,000 kilometres of tram service</th>
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<tbody>
<tr>
<td>CBD before plastic strips (2012-2014)</td>
<td>1.56</td>
</tr>
<tr>
<td>CBD after plastic strips (to 2015)</td>
<td>1.27</td>
</tr>
<tr>
<td>Docklands (2014-2017)</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Table 3: Incident rates in Collins Street

Figure 14: C Class tram on boulevard separation in Collins Street
Plastic Dividing Strips Lifecycle Case Study

VicRoads has identified the intersection of Nicholson Street with Palmerston and Henry Streets as an illegal manoeuvre hotspot. Four types of illegal turn routinely occur here:

- Turning right out of Henry Street
- Turning right from Nicholson Street into Palmer Street
- Doing a U-turn across Nicholson Street
- Exiting Palmerston Street onto Nicholson Street

The series of photos in Figure 15, from Google Street View, capture a motorist in the act of turning illegally across the raised dividing strips at this location. The raised dividing strips do not deter a small hatchback. Note also that many of the strips are missing, having been knocked out of place by the movements they are intended to prevent.

The second, third and fourth photos show a time series at the same location from Google Street View, highlighting the effect these movements have on the raised dividing strips.

- The second photo, from April 2013, shows a piece of the stripping has been knocked sideways, and some are missing entirely, due to illegal turning movements.
- The next photo, from July 2014, shows the sideways strip removed entirely.
- The last photo shows that as of October 2016, all strips had been replaced.

This demonstrates the ongoing maintenance attention and costs required to maintain this separation. These costs could be avoided if a more effective separation design type was put in place.

Figure 15: Google Street View time series at Nicholson, Palmerston and Henry Streets
The benefits of improved separation extend well beyond the compelling safety benefits.

Even if only the existing painted lines and plastic strip separation was upgraded to safer designs, Yarra Trams estimates this could reduce vehicle to tram collisions by around 250 a year.

Better separation is estimated to reduce the risk of injury to over 100,000 individual Melburnians every year – including the nearly 1000 motorists every year who collide with trams. With 200 million passengers a year on trams, and well over half of those catching trams in the areas with only moderate or poor separation, addressing this issue is one of the most effective improvements to tram safety.

Better separation is safer for all road users, with research showing a nearly 20 per cent reduction in vehicle- and pedestrian-involved collisions that don’t involve trams.

Addressing this problem will reduce the burden on emergency services and hospitals. Monash University data indicates an average of three hospital admissions per month are related to injuries experienced from a fall on a tram that could have been prevented through more effective separation.

Better separation on the 15 per cent of the network could provide the equivalent of up to 3 extra trams in service in the peak. These trams are otherwise wasted by being in Yarra Trams’ workshop being repaired after collisions. With up to ten trams out of service for collision repairs in recent years, collisions lead to ongoing disruptions to passengers due to shortages of trams. Funding spent on repairing trams could be better used to provide additional services.

Great separation can also provide significant benefits to the city. Tram tracks occupy one third to half of our key city streets, and could significantly contribute to the greening of streets. Planted tram tracks, which can be enabled by better separation, can potentially help cut the extent and impact of the problem of urban heat islands, and contribute to better management of water, noise and dust in the city.
This report has highlighted the operational perspective on tram road safety in Melbourne. It highlights the challenges, but also recent successes, in improving tram safety for the 200 million passengers carried every year.

More effective forms of separation and active management of conflicting movements are appropriate on the busiest parts of the tram network. Case studies show that substantial improvements in tram safety are possible by upgrading existing ‘moderate’ and ‘weak’ separation to stronger, safer designs.

There are established designs that have been approved by VicRoads and included in the appropriate design manuals that could be the basis for projects to improve the effectiveness of separation.

Design and traffic studies, and stakeholder and community engagement, are important to develop agreed solutions to minimise tram / vehicle interactions by further upgrading physical separation. These studies could consider the full role of the street. Urban design improvements can also add substantial value but can take longer to implement.

Some of the things road authorities may be able to influence to improve road safety involving trams include:

- Undertaking Road Safety Audits and sharing the findings with VicRoads, Transport for Victoria and Yarra Trams to find solutions
- Incorporating tram safety into Road Management Plans through planning for regular maintenance of plastic strips and linemarking
- Supporting the upgrade of less safe separation designs to safer separation using kerbs, moving along the ‘separation spectrum’
- Incorporating tram safety improvements into Road Safety Plans
- Identifying opportunities and planning for new ‘safe separation’ such as raised track and green tracks
- Improving traffic signals to reduce conflicts between trams and other road users
- Reviewing where cars need to make turns along tram routes, and removing uncontrolled turns where possible to reduce conflicts with tram movements
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