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Effectiveness and Implementation of Raised Safety Platforms

Effectiveness and Implementation of Raised Safety Platforms

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Abstract

The purpose of this report is to provide clarity around the design and operation of raised safety platforms and deepen understanding of leading international practice across a range of applications and performance dimensions.

A review of literature and sample site investigations have found that a community of practice around raised safety platforms at arterial signalised intersections is emerging and that installations to date are reducing traffic speed and therefore should improve safety in line with overseas literature.

Minor design and construction inconsistencies should be addressed, and any reported issues should be investigated within the context of Safe System performance. A range of new and innovative raised safety platform applications in rural and urban contexts also look promising.

Keywords

Raised safety platform, speed management, intersection

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- Transport Canberra and City Services Directorate, Australian Capital Territory
- Department of Infrastructure, Transport, Regional Development and Communications
- Australian Local Government Association
- New Zealand Transport Agency.

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Summary

Raised Safety Platforms (RSPs) are a vertical deflection device increasingly used to reduce the maximum comfortable operating speed for vehicles to Safe System collision speeds, particularly at intersections. While the use of vertical deflection devices has typically been limited to lower speed environments, there is increasing interest in the use of RSPs in higher speed environments and for other locations where pedestrians and cyclists would typically be injured.

The purpose of this report is to provide clarity around the design and operation of RSPs and deepen understanding of leading international practice across a range of applications and performance dimensions. The research included a review of literature, sample investigations, and edits to relevant Austroads Guides.

The literature has shown that, outside of the Netherlands, where RSPs have been used extensively, a 'community of practice' is developing in Australia and New Zealand, with the majority of applications at signalised intersections above 50 km/h to date being in Victoria.

From sample investigations of five higher speed signalised intersection locations (two involving multiple intersections) and six locations of secondary interest in rural and urban settings, the following key lessons emerged:

- RSPs are effective in reducing traffic speeds to Safe System levels for vehicle collisions (50 km/h), and pedestrian survivability levels (30 km/h).
- To date a 40 km/h advisory speed at more recent 60 km/h speed limit installations is commonly being used by jurisdictions, reflecting a pragmatic trade-off between harm minimisation for side impact collisions and for pedestrians.
- There are a range of inconsistencies in 'as-built' ramp profiles, construction techniques, signage and marking relative to approach platforms but more recent applications are settling on agreed practices.
- Accelerometry shows variability in the severity of ramps. However, when a 1:20-1:25 approach ramp and 1:35 departure ramp is accurately built, they appear to be effective for 40-50 km/h approach speeds, with minimal adverse effects. Land and vehicle use considerations are important, however.
- There are some examples of late braking ahead of the platforms, but this appears to have diminished at more established locations and there is no tangible evidence of significant safety concerns. Further monitoring for newer projects is suggested.
- Impacts on intersection capacity appear to be mixed, with little evidence that the RSPs alone materially affect intersection capacity. Newer installations are placing stop lines further forward on the platform to avoid delays for right turning traffic.
- More work is needed to determine any specific impacts on emergency services, buses, and other road users, although trials and applications to date suggest there is no tangible evidence that RSPs are causing operational or safety problems for any road user group.

Although concerns have diminished over time, there is an ongoing need to communicate the purpose of RSPs, engage effectively with stakeholders, educate road users about how they should be approached, and warn motorists when they are new.

The role of RSPs within a wider Vision Zero conversation is needed, so that a strategic context for their use filters down to project level investment decisions. A program of scaling up including necessary capability development is also suggested.

Raised Safety Platforms in other innovative contexts are also showing their promise in a range of other rural and urban contexts. The next steps should clarify their effectiveness and roll out if merited.

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1. Introduction to the Research

1.1 Background

Raised Safety Platforms (RSPs) are a vertical deflection device increasingly used to reduce the maximum comfortable operating speed for vehicles to Safe System collision speeds, particularly at intersections. Safe System speeds ensure that in the event of a crash, death or serious injury is avoided (Welle et al 2018). It is generally accepted that for side impact vehicle collisions, the Safe System maximum speed is 50 km/h, while for vehicle crashes involving pedestrians and cyclists, the maximum speed is 30 km/h (ITF 2016).

In the past, the use of vertical deflection devices has typically been limited to lower speed environments (<50 km/h) such as local road intersections and mid-block zebra crossings (Turner, Jurewicz, and Makwasha 2017; Pratt, McGarrigle, and Turner 2015). Some devices, such as traditional road humps, tables, and cushions, are not considered appropriate for environments above 60 km/h (Austroads 2016c).

However, in response to the challenge of managing impact speeds, there is increasing interest in the use of RSPs in higher speed environments (e.g. 60-80 km/h urban arterial roads). The harm minimisation potential of vertical deflection is a key driver to the increasing interest and use of these treatments on busier roads such as collectors and arterials (Austroads 2018).

When used on approach to an intersection, RSPs are commonly referred to as ‘approach platforms’, or ‘elevated stop lines’ (ESLs) (also known in the Netherlands as raised stop bars; Corben 2014). When used to raise the entire intersection, applications are commonly referred as ‘raised intersections’. Raised Safety Platforms on higher order roads typically have a lower ramp profile than traditional speed humps or platforms, allowing higher speed traffic to continue through the intersection at a speed no higher than the Safe System speed, without any hard braking.

Safe intersection design principles, established to guide harm minimisation approaches, show that many current intersection designs cannot deliver Safe System outcomes (Austroads 2018). Designs that guarantee safe interaction speeds at intersections, by managing speeds on approach or within the intersection footprint (e.g. via vertical or horizontal deflection devices), such as roundabouts or raised intersections, are associated with good safety performance and need to become more widespread (Austroads 2018).

The use of RSPs on higher order roads is not without precedence, with some European countries having done this for many years (Fortuijn, Carton and Feddes 2005; Van der Dussen 2002). Recent higher speed applications in Australasia (Candappa and Colobong 2015; Corben and Candappa 2014; Mackie et al 2019) have progressed local understanding, however, there is a need to both consolidate and advance understanding of performance and benefits in these environments. Design guidance now exists for RSPs (VicRoads 2019), but further work is needed to consolidate design parameters and expected performance outcomes, so that applications can be scaled up with confidence in jurisdictions.

1.2 Purpose

The purpose of this report is to provide clarity around the design and operation of RSPs and to deepen understanding of leading international practice across a range of performance dimensions.

1.3 Scope

The project gave primary interest to RSPs at signalised urban intersections but also examined traditional and more innovative RSP applications across a range of different speed environments, locations, road types, and with varying mixtures of road users.

The need for further design guidance for different application types, road environments, and intersection entry speeds (Austroads 2015; Turner, Jurewicz, and Makwasha 2017; VicRoads 2018) has also been noted. This report therefore also provides design and performance evidence for other applications that are not yet considered mainstream in road safety practice or guidance.

1.4 Methodology

There were three main stages to this research and they are outlined below.

Stage One - International literature review

An international literature review of RSP practice and application was conducted. The review encompassed published and unpublished literature and other relevant technical and operational documents, obtained both through online and database searches, and from the Austroads project manager and research Project Reference Group. Further detail on the literature review method is provided in Section 2.2.

Stage Two - RSP sample site investigations

In the second stage of the project, a detailed mixed method investigation of a sample of existing RSP applications at multiple sites across two jurisdictions (Victoria, Australia; and Hamilton/Auckland, New Zealand) was carried out. Sites with RSP applications of primary interest (signalised intersections on urban arterials higher than 50 km/h) were prioritised, along with rural and urban sites with applications of secondary interest (any application not at a higher speed signalised intersection).

For sites of primary interest, a gap analysis was conducted across various design and performance dimensions to compare the literature review findings with site investigation lessons, and also to suggest principles for changes to guidance. Further information on the site investigation method is provided in Section 4.

Stage Three - Edits to Austroads Guide to Traffic Management, and Guide to Road Design

In this third stage, the findings of the literature review, site investigations and gap analysis were synthesised and recommended edits to the Austroads Guide to Traffic Management (Appendix A) and Guide to Road Design were identified. The Guide to Road Design recommended edits were provided to the Road Safety & Design Program for future incorporation in the Guide to Road Design.

2. Introduction to the Literature Review

2.1 Purpose and Scope

The purpose of the RSP literature review is to provide an up-to-date review of international RSP practice, applications and performance. The literature review included published literature as well as unpublished ('grey') literature such as technical reports and operational documents.

The research question addressed by the review is:

> *What is international leading practice for RSPs on key design and performance dimensions and in different speed environments and applications?*

The literature review is focused on RSP applications that are new or innovative, and in general, business as usual applications are excluded. Applications of primary interest are RSPs in >50 km/h speed environments at signalised intersections on urban arterial roads. Applications of secondary interest include any other innovative and non-standard application of RSPs including mid-block pedestrian crossings (signalised in particular), RSPs at roundabouts, left-turn slip lanes at traffic signals, and rural land use environments such as rural priority-controlled intersections. Speed humps, tables and cushions used in traditional ways, were only included where these provided necessary context and background to the use of RSPs, or where they showed innovative practice around their use.

2.2 Literature Review Methods

This report summarises literature identified to date primarily through internet and database searches, and material provided by the wider project team to date. The method section below describes the internet and database search strategy employed so far in the research.

2.2.1 Internet and Database Search

Internet and database searches were undertaken to identify published and unpublished materials on the design, installation, use, and effectiveness of vertical deflection devices. The following databases were searched:

- Google Scholar
- Web of Science Core Collection
- Engineering Village (Compendex)
- Australasian College of Road Safety (ACRS)
- Australasian Transport Index (ATRE)
- Transport Research International Documentation (TRID).

The following search terms were used in the internet and database search:

- Traffic calming
- Vertical deflection devices
- Raised safety platforms
- Raised platforms

- Raised table
- Raised stop bars
- Raised intersections
- Wombat crossings.

Additional materials included in this draft report were also sourced from the Austroads project manager and research Project Reference Group.

2.2.2 Review Framework/Synthesis

A review framework, comprising the core areas of focus in the research, was used to summarise relevant information from the located source documents. The recorded content was in turn further summarised and synthesised during the writing of this draft report.

3. Literature Review Findings

3.1 Purpose of RSPs

Raised Safety Platforms (RSPs) are used to lower the speed of vehicles at potential conflict points so that in the event of collision, impact forces are within human tolerances. Following Safe System principles (Tingvall and Haworth 1999; Candappa, Logan et al 2015), design speeds ≤ 50 km/h are encouraged to reduce side-impact severity for a vehicle, while design speeds ≤ 30 km/h are encouraged to reduce the severity of any pedestrian or cyclist related crashes (ITF 2016; Tingvall and Haworth 1999; VicRoads 2019). As a Safe System intersection treatment, raised safety platforms have been classified as a 'primary' or 'transformational' treatment, acting to reduce both the likelihood and severity of crashes (Austroads 2016a).

Recent research by Austroads (2017) concluded there was a need to shift Safe System intersection design focus towards:

- control of impact speeds through regulatory and geometric means, e.g. speed limits, approach traffic calming, geometry of the intersection
- control of impact angles through geometric design
- greater control of critical movements (e.g. turn bans, simplification of decision making).

Roundabout design and safety performance have received a significant focus in the recent literature. The traditional approach to roundabout design has not served pedestrians and cyclists well, and more contemporary successful outcomes are linked to geometric elements that reduce vehicle approach speeds and speeds within the roundabout to 40 km/h or below where vulnerable road users are present. Current Austroads design guidance reflects this, recognising the importance of speed reduction at the approach to the intersection (Austroads 2017).

A project to develop an assessment framework to help road agencies methodically consider Safe System objectives in road infrastructure projects noted the potential for raised safety platforms at intersections and pedestrian crossings as a primary Safe System treatment (Austroads 2016a).

Raised Safety Platforms are a form of vertical deflection device used to reduce the speed of vehicles on approach to a potential collision zone (Austroads 2008). Vertical deflection treatments include speed bumps, speed humps, road cushions, speed tables/platforms, raised pedestrian crossings (commonly referred to as Wombat crossings in Australia), elevated stop-lines, and raised intersections (Austroads 2015; see Table 3.1).

Raised Safety Platforms (RSPs) are essentially speed tables, however, they are distinguished from other vertical deflection devices when being designed for use in higher speed environments, with the aim to achieve Safe System speeds while not unduly impacting comfort and speed of motorists. Identified benefits of RSPs include relative ease of installation and replication compared to other more transformative treatments, such as raising a whole intersection (if approach platforms are chosen), with similar benefits to different road users, and lower cost (Pratt and Aumann 2014).

Table 3.1: Commonly used vertical deflection devices

Vertical deflection device	Description
Speed bump	Between 76-102 mm high, with a traverse distance of approximately 0.30 m.
Road hump	Raised curved profile extending across the roadway, typically 70 to 120 mm high with a total length of 3 to 4 m; generally recommended for use on local roads.
Road cushion	Short, raised, rounded device, normally in the centre of a lane; slightly wider than a car, while able to be 'straddled' by vehicles with larger wheelbases (e.g. emergency services, buses).
Flat-top road hump/raised table	Raised surface approximately 75–100 mm high, typically with a 2 to 6 m long platform ramped up from the normal level of the street. The raised section (or platform) is flat instead of being curved.
Raised pedestrian crossings	Similar profile as a flat top speed hump, but which give priority to pedestrians.
Elevated stop-lines	Mild elevations in the section of the road close to the stop-line to induce a reduction in speed through the intersection.
Raised intersections	Raising of the entire intersection to induce a reduction in speed through the intersection. Raised Safety Platforms are an evolution of this concept, where the same outcomes can potentially be achieved with a lower level of intervention, particularly in retrofit situations.

Source: Austroads, 2008

3.2 RSP Applications

Raised Safety Platforms have demonstrated performance across different applications (Cairney et al. 2019b; Candappa and Colobong 2015; Mackie et al 2019). The primary focus of this report is on their application at urban signalised intersections with speed limits above 50 km/h and the performance and design considerations for them, with the aim of identifying leading practice for future use. A comprehensive approach to understanding the literature that relates to these specific applications has therefore been taken.

A secondary focus for this report is on other applications of raised safety platforms where they are not conventionally used or are being used in innovative ways. Raised table zebra crossings are not included here as they are now considered a standard safety intervention treatment, except when they are used on arterial roads - a non-traditional application of RSPs. For these secondary applications, they are summarised with the goal of raising key points related to implementation examples, design, and performance, and references for more detailed information.

A summary of the RSP applications covered in this review of literature is shown below in Table 3.2.

Table 3.2: RSP applications covered in literature review

RSP Application	Context	Variations
Primary Application of Interest		
Signalised Intersections	>50 km/h, urban/peri-urban	Raised approach table Raised intersection
Other Innovative Applications		
Roundabouts	Urban	High Capacity Compact
Roundabouts	Rural	Compact
Midblock crossings	Urban arterial	Signalised crossings Zebra crossings
Intersections with cycle-lanes and shared paths	Urban	Local roads Arterial roads

3.3 Design Considerations for Applications at Higher Speed Signalised Urban Intersections

This section focusses on the design considerations of RSPs used at higher speed signalised urban intersections.

3.3.1 Location Suitability

The target locations for the use of RSPs at intersection or mid-block locations is where there is the potential for collisions at non-Safe System speeds (i.e. > 50 km/h for vehicle to vehicle side impacts or > 30 km/h for collisions with pedestrians or cyclists). Other factors include a history of fatal and serious injury crashes (FSIs), particularly cross-traffic, right turn against, and those involving pedestrians, and in locations where pedestrian priority is warranted (VicRoads 2019). For urban arterials that need to cater for high volumes of traffic, RSPs or raised intersections can be used to reduce conflicts to Safe System speeds, including for pedestrians and cyclists, and access to public transport (Austroads 2017). Signalised intersections on arterial roads have poor alignment with the Safe System (Austroads 2017), and RSPs are a tool to help align existing signalised intersections with the Safe System.

Roundabouts in both urban and rural contexts are considered a closer fit with the Safe System (Austroads 2017) as long as they are made safe and user-friendly for pedestrians and cyclists, but the reality is that in many urban environments, signalised intersections on arterial roads are commonplace and have often been selected for their traffic flow efficiency. This means that RSPs are likely to be best placed as a retrofit to existing intersections to improve safety performance.

In greenfield situations, Safe System solutions might favour well designed roundabouts. RSPs have the potential to improve the safety of roundabouts also (Campbell et al 2012), and examples will be considered later.

At any site, consideration must be given to ensuring RSPs will address the factors causing crashes. For example, RSPs may provide minimal benefit in a site where crashes are primarily occurring during congested, low speed conditions (VicRoads 2019).

Other key elements for consideration include vehicle types, turning movements (i.e. ensure devices do not impact on vehicle turning movements), vehicle stability, minimum ground clearances for different vehicle types, and pedestrian crossing locations and desire lines (VicRoads 2019). Designs should also minimise speed differentials between different vehicle types (Pratt and Aumann 2014).

Existing guidance states that when determining the location of RSPs, specific site characteristics should also be avoided (VicRoads 2019). These include tram routes, routes with high volumes of heavy vehicles (particularly with significant turning movements that could increase the risk of rollover), sites with horizontal or vertical curves that may impede sight lines and visibility of warning signage, and sites with restricted vertical clearance (e.g. due to bridges, traffic signal mast arms, overhead power lines and other utilities). Stakeholders reflecting on lessons learnt from the RSP sites recently completed across Victoria also suggested that red light camera sites should be avoided when determining site selection (VicRoads 2018).[1] Subsequently it was clarified that the reason for this is due to potential delays it would cause to implementation, presumably from the RSP implementation also depending on red light camera implementation. This is interesting as earlier Dutch applications have combined RSPs with red light cameras (Fortuijn, Carton, and Feddes 2005) to provide a more comprehensive solution for intersections.

There is a need to review guidance following the findings of recent demonstration projects. For example, in New Zealand both modelling and physical application (Jamieson 2018) found that the performance impacts on heavy vehicles from arterial road RSPs (described later) are negligible with careful design and implementation. This suggests that, with appropriate ramp design, RSPs can still be useful on routes with heavy vehicles, including buses and trucks.

1 workshop minutes from DOT workshop explained more in Section 5.1.7

Corben (2018) addressed a number of site related safety concerns raised in a Safety audit report on the proposed RSPs at the Thomas and Gordonton Roads intersection in Hamilton, New Zealand. It was noted that no treatment can ever be guaranteed as totally effective and that safety assessments must consider overall performance and alignment with Safe System principles. The Hamilton (Thomas/Gordonton) treatment was noted as incorporating multiple measures to support drivers to approach the RSPs at the desired speed, for example, a rural to urban threshold treatment prior to the intersection, kerb and channel to indicate an urbanised environment, and signage. Corben noted that such drivers could lose control of their vehicles if they attempted to traverse the RSPs at high speeds, but that in the absence of RSPs, these same speeding drivers could run a red light and collide with side-road traffic, or contribute to a high-speed turn against collision. These crash types need to be addressed specifically to satisfy Safe System performance standards.

Corben concluded that the proposed speed reduction measures on approach would have a comparatively stronger effect on driver speed choice than measures typically undertaken to lower speeds at signalised intersections in semi-rural settings. Given this, along with evidence of the overall likely impact of the RSPs on reducing injury-producing crashes, and considering a context whether other potential Safe System solutions were not feasible, he concluded there was a compelling and justified case for the use of RSPs at the intersection.

Figure 3.1: Existing RSP applications in the Netherlands (left) and Victoria, Australia (right)

Source: Corben and Candappa (2014), VicRoads (in Marsh 2017)

3.3.2 Choosing Approach Platforms or Raising Whole Intersection

Larger intersections and those with divided carriageways are suggested as being more suitable for approach RSPs due to the complexity and cost of raising such a large intersection, as opposed to lower-order roads where raising a whole intersection may be more feasible (VicRoads 2019). In the Netherlands this approach has been adopted for some time, although raised tables and speed humps are also used commonly on lower-order roads within a recognisable road hierarchy (Personal communication, John Boender).

3.3.3 Ramp/Platform Design

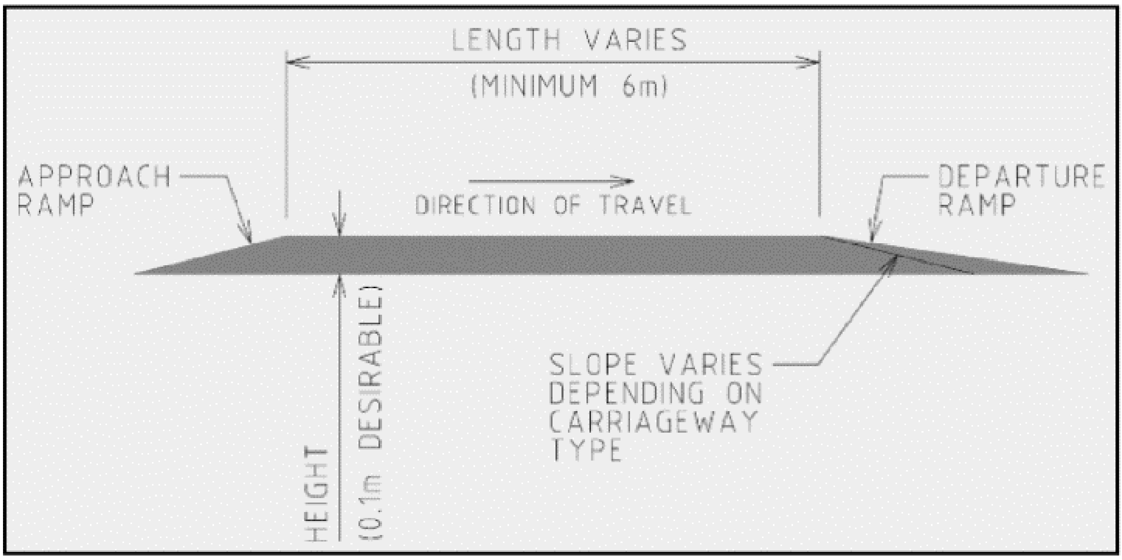
When designing RSPs, approach ramps must be orientated perpendicular to the direction of traffic flow (Pratt, McGarrigle, and Turner 2015; VicRoads 2019). This ensures the front wheels of a vehicle will rise and fall concurrently when entering and exiting the ramp. Traversing ramps with wheels at different levels may cause instability and could affect the driver's ability to operate their vehicle safely. Ramps should also be placed clear of the through lanes of the intersecting road, and if installed on turning lanes, located so the turn can be commenced or completed before crossing the ramp (VicRoads 2019).

The design of RSPs on arterial roads differ from the traditional 'speed hump' or raised table zebra crossing in that the ramp profile is generally softer and designed to match the Safe System speed threshold (Marsh 2018). Raised Safety Platforms must have a flat top profile and a consistent grade between the top and bottom of the ramp. When located on an undivided carriageway (typical for raised intersections), the approach and departure ramps must be of uniform grade, ideally one that meet the needs of both approaching and departing motorists (VicRoads 2019). Watts, Sinusoidal or other ramp shapes must not be used for arterial RSPs (VicRoads 2019).

A VicRoads internal report (Pratt and Aumann 2014) recommended that flat top arterial raised stop lines at signalised intersections should have a maximum height of 100 mm, a grade no steeper than 1:30, a platform length of 6.0 m, and an overall length of 15.0 m. Similarly, raised intersections were recommended to a maximum height of 100 mm (or flush with the footpath) and grade no steeper than 1:30. As is seen later, guidance has evolved to suggest steeper approach ramps and less steep departure ramps.

Figure 3.2 shows the typical design and shape of a RSP for intersections with posted speeds ≤ 70 km/h (VicRoads 2019).

Figure 3.2: RSP design and shape (posted speeds ≤ 70 km/h)



Source: VicRoads 2019

VicRoads (2019) current design specifications (intersections with posted speeds ≤ 70 km/h) for platform height, platform length, and ramp grades are summarised below.

Platform height

- The desirable height of platforms = 100 mm, although 75 mm may be considered when appropriate (e.g. site constraints, traffic composition including high truck volume routes2).
- Heights < 75 mm will not be effective at reducing speeds.
- 150 mm height platforms may be used for low speed (< 50 km/h) and low traffic volume environments.
- There is a risk of platforms > 100 mm damaging low-floor vehicles; platforms of this height should not be used on arterial roads.
- Platform height is generally to the top of kerb.

2 When fully loaded, low loader trailers often operate close to the minimum ground clearance of 100mm.

Platform length

- The length of the flat section (i.e. plateau) needs to accommodate a standard passenger vehicle, including when used as a pedestrian crossing (i.e. 6 m minimum). If the stop-line is positioned on the platform, a minimum length of 7 m is required for storage of a standard passenger vehicle.
- If there is a high percentage of heavy vehicles using the road, platform lengths may also be extended to accommodate these vehicles (so that the rear wheels are on the table before the front wheels reach the departure ramp).
- Platform lengths will also be greater when raising an entire intersection.

Ramp grades

- Ramp grades currently recommended by VicRoads (2019) to achieve Safe System speeds are detailed in Table 3.3. The grades are designed to achieve desired reductions in speed while minimising occupant discomfort, the risk of heavy braking, vehicle damage, or heavy vehicle rollover.
- Reduced grades may be considered to accommodate certain road users (e.g. heavy vehicles, emergency vehicles, buses, bicycles, low floor vehicles), however the extent this may reduce effectiveness for the majority needs to be considered.
- The grade of the departure ramp should provide for smooth exit from a RSP; a 1:35 grade is considered appropriate. While flatter slopes can be considered, this will mean a greater distance between the approach ramp and the intersection conflict points for approach platforms.

Table 3.3: Recommended ramp grades for different speeds

Operating Speed (km/h)	Divided Carriageway		Undivided Carriageway	
	Approach Ramp Grade	Comfortable Max. Speed (km/h)	Approach/Departure Ramp Grade	Comfortable Max. Speed (km/h)
50	1:15 (6.7%)	30*	1:20 (5%)	40
60	1:20 (5%)	40	1:25 (4%)	50
70	1:25 (4%)	50	1:25 (4%)	50

**Desired max. speed for a pedestrian or cyclist related crash. May result in increased motorist discomfort. RSP should achieve an equivalent change in grade if longitudinal grade of site is not flat.*

Source: VicRoads 2019

Table 3.4 shows the dimensions of the RSP at the intersection of Surf Coast Hwy and Kidman Avenue, Belmont in Victoria, Australia (Candappa and Colobong 2015). The treatment was combined with clearly marked warning signs with recommended travel speeds on approach and at the RSP. While the design of the RSP was based on Dutch design standards (CROW 2019), the final design was also considered best fit to Victorian conditions (Candappa and Colobong 2015; Corben and Candappa 2014). Notably, ramp gradients are lower than those recommended by VicRoads (2019) but reflected best practice at the time of construction.

Table 3.4: Design dimensions of Belmont, Victoria, RSP

Design element	Dimensions
Approach ramp gradient	1:30
Approach ramp length	3 m
Departure ramp gradient	1:35
Departure ramp length	3.5 m
Platform (plateau) length	7m
Height of platform	100mm (above pavement)
Overall length	13.5 m

Source: Candappa and Colobong 2015

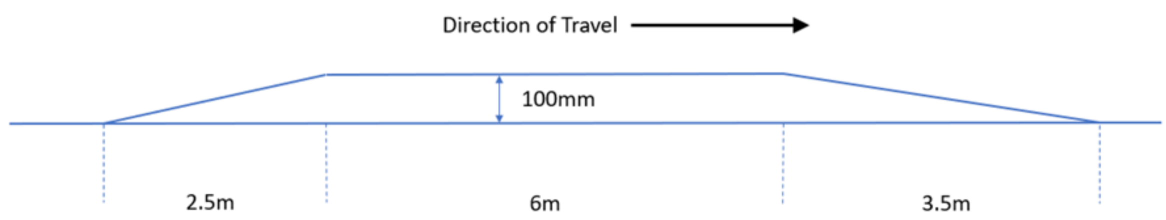
Table 3.5 and Figure 3.3 show the design of the recently installed RSP in Hamilton, New Zealand. The dimensions are generally aligned with the VicRoads (2019) guidance and the approach ramp gradient is slightly steeper than the 1:30 reported for the Belmont, Australia application.

Table 3.5 Design dimensions of Hamilton (NZ) RSP

Design element	Dimensions
Approach ramp gradient	1:25
Approach ramp length	2.5m
Departure ramp gradient	1:35
Departure ramp length	3.5m
Platform (plateau) length	6m
Height of platform	100 mm (above pavement)
Overall length	12m

Source: Mackie et al 2019

Figure 3.3 Design dimensions of Hamilton RSP



Source: Mackie et al 2019

The extent of the speed reduction can be regulated by the specific platform design features, i.e. height and length of the raised section and gradient of the ramp sections. The typical platform height is between 75 and 100 mm according to the traffic calming guide, with lengths up to 6 m (Austroads 2016c), although longer platforms are also used. VicRoads design trials produced satisfactory vertical acceleration results with ramps of 1:30 on platform approach and 1:35 on departure. These were tested for intersection approach speeds up to 80 km/h with platform exit speeds of 60 km/h (Pratt, McGarrigle and Turner 2015). The 1:25 approach ramp also produced a very satisfactory balance between speed reduction, comfort, and vehicle safety.

Ramp gradients need to be carefully selected to balance entry speed reduction potential (improved safety) with risk of adverse operational effects such as 'bottoming out' by vehicles with lower suspension, or discomfort or risk of falls for bus passengers. Consideration needs to be applied to turning heavy vehicles, as the combined horizontal and vertical forces on the axles may lead to increased risk of overturning. Water flow paths and drainage need to be considered as well to ensure water does not pond around traffic islands. Furthermore, the platforms should not be sloped down towards the kerb as this may create a hazard for cyclists (Austroads 2017).

3.3.4 Stop-line, Line Marking, Platform Conspicuity and Other Delineation

To avoid confusion about where to stop, the design of RSPs must ensure that the conspicuity of the stop line is maintained. Options for placement of the stop-line include prior to the approach ramp[3] or on the platform itself (more recent practice). If located on the platform, the stop-line should be positioned just prior to the beginning of the departing ramp for platforms and prior to the beginning of the pedestrian crossing for raised intersections (VicRoads 2019).

VicRoads (2019) provides Victoria State line-marking specifications for RSPs located at intersections and divided carriageways, when pedestrian crossings are incorporated, and when placed at mid-block.

When incorporating pedestrian crossings into RSPs, pedestrian facilities must be clearly delineated from RSP ramp line markings (Pratt, McGarrigle, and Turner 2015; VicRoads 2019). Similarly, if RSPs are installed near pedestrian facilities, the ramp and pedestrian space must have a minimum of 1 m separation to avoid any confusion (VicRoads 2019).

Other treatments suggested to ensure clear delineation between the road space and pedestrian space include edge-line marking (including tactile line marking), coloured treatments of the pedestrian space, and bollards and or street furniture at the roads edge (VicRoads 2019).

In New Zealand, for the recent Hamilton RSP (Mackie et al 2019), after initial installation the colour of the approach ramps were modified to improve the conspicuity of the RSP, which was somewhat difficult to distinguish initially.

The Victorian and New Zealand approaches to delineating RSPs differ fundamentally. Piano keys are specified in the Victorian Guidance (VicRoads 2019) following Dutch convention, and 'shark's teeth' have been used for the Hamilton trial in New Zealand, utilising recognisable markings from other New Zealand speed table applications. Focus group testing (Mackie and Hirsch 2018) prior to the design in New Zealand showed that road users strongly supported the shark's teeth configuration. Presumably this perception was strongly influenced by the existing use of shark's teeth for similar applications such as raised table pedestrian crossings.

3.3.5 Construction

For ease of construction, flat sites should ideally be chosen for the installation of RSPs (VicRoads 2019; VicRoads 2018) although guidance on how to design and construct RSPs on non-flat sites is also provided. The potential of sites to enable area-wide treatments should also be considered (VicRoads 2019).

The smaller footprint and single direction of travel of 'Approach Platforms' mean they are easier and less expensive to construct compared to 'Raised Intersections' (VicRoads 2019).

3 VicRoads preferred option in guidance.

In New Zealand there has been some debate about the construction materials used for Raised Safety Platforms. In Hamilton, the Thomas/Gordonton and Angelsea Street RSPs were formed from asphalt (Figure 3.4) and this was considered a whole of life saving, due to inadequate previous concrete ramp applications interfacing with the more flexible pavement. Compared with the concrete raised platforms specified for use in Auckland, the cost of the Hamilton design was reportedly much less expensive (Personal communication, Simon Crowther, Hamilton City Council). In addition to the Hamilton asphalt RSPs, a strip of thicker reinforcing asphalt was installed immediately ahead of the ramps to reinforce this section of road that experiences relatively high forces due to the ramps.

Figure 3.4. Construction of asphalt raised safety platform at Thomas/Gordonton Intersection, and resulting intersection layout, Hamilton, New Zealand

Note: Wooden profile template used to shape the ramps.

Source: Simon Crowther

RSPs must be accompanied by warning signs prior to the approach ramp, and the recommended advisory speed located in-line with the approach ramp (VicRoads 2019).

VicRoads (2019) provides Victoria state warning sign designs and installation detail for approach platforms, raised intersections, RSPs incorporating pedestrian crossings, high risk sites, and heavy vehicles.

A distinction between Dutch and Australian/New Zealand applications is how speed is advised or mandated. Raised stop lines in the Netherlands include a speed limit change at the intersection (left below) while New Zealand/Australian examples utilise advisory speeds only (right below; Figure 3.5).

For higher speed environments (80 km/h and above), VicRoads guidance suggests that supporting measures should be used such as:

- speed reduction in stages (e.g. multiple platforms with appropriate ramp profiles)
- permanent speed limit reduction (supported by speed cameras to support operation where required)
- additional warning signs (e.g. flashing warning signs)
- speed calming line marking
- rumble strips
- gateway treatments.

It appears that best practice for signage, delineation, and supporting measures for different contexts, is not yet clearly defined for RSPs given the relatively few number of applications to date. Current guidance (VicRoads 2019) for signing and line marking builds upon Australian Standards, including VicRoads Traffic Engineering Manual Volume 2 (which are Victorian supplements to Australian Standards).

Although not a site of primary interest, staff involved in the construction of a compact rural roundabout with raised platforms at Lance Creek reported feedback from motorists about the amount of speed signage on approach to the intersection and that signage was confusing (VicRoads 2018). Staff also reported the process in which the site was open to traffic indicated that line-marking had been more effective than signage in informing motorists of the conditions and what was expected from motorists when traversing the intersection. Staff indicated the issue of sign clutter and oversaturation of cues would be investigated further with the aim of developing standard signage protocols further.

Figure 3.5: Approaches to speed signage

Source: Corben and Candappa 2014, VicRoads (in Marsh 2018)

3.3.6 Visibility and Lighting

Visibility and adequate lighting must be considered in the design of all RSPs (Austroads 2015). VicRoads (2019) provides Victoria state specifications for lighting roads and public spaces. There was no other literature regarding visibility and lighting available.

3.3.7 Heavy Vehicles

Site-specific risk assessment and additional design considerations are required for heavy vehicles, low floor vehicles, emergency services, buses, motorcyclists, cyclists, and the vision impaired. Issues to be considered include the potential to delay emergency services and bus services, and potential noise impacts from heavy vehicles (VicRoads 2019).

For sites with high volumes of heavy vehicles, computer simulation assessment should be undertaken to assess the impact of the RSP on heavy vehicle stability (VicRoads 2019). Designers must ensure that treatments do not present an undue dynamic stability (or roll-over) risk for the ‘critical unstable’ or ‘low performing’ vehicle (VicRoads 2019).

Competing objectives must be balanced when considering the installation of RSPs, however current guidance recommends that RSPs should not be installed if the treatment presents an unacceptable risk for other road users (VicRoads 2019)

Considerations for heavy vehicles include:

- location, orientation, and height of ramps to avoid critical vehicle instability
- that minor errors will not cause critical instability or truck roll
- maximum RSP height of 75 mm if there is a particularly high heavy vehicle movement high (e.g. >15%)
- reconsideration or modification of the RSP (e.g. flatter gradient) if there is a particularly high heavy vehicle movement (e.g. >25%)

- ensuring drivers are appropriately alerted to the unique environment
- potential for unacceptable operational deficiency or delays due to acceleration and deceleration impacts
- potential impacts elsewhere (e.g. local streets) should drivers seek alternate routes.

For low floor vehicles, considerations include:

- platform length that spans the length of the vehicle
- raising the entire intersection instead of using raised stop bars.

Earlier simulation work for the Hamilton NZ RSP installation was also carried out to investigate whether the proposed inclusion of an RSP on the right-hand turn (into Thomas Rd) would have a significant effect on the stability of turning trucks (Jamieson 2018). The RSP was modelled to have negligible effects on changing the critical roll-over speed, compared with the same turn without the RSP, for both constant speed and constant acceleration.

In a recent interim evaluation of a corridor of RSP applications in Metro Melbourne, a heavy vehicle stability analysis was carried out (Cairney et al 2019a). Initial modelling suggests that under some conditions there is a risk of roll-over, but it is not yet clear whether the RSPs specifically contribute to the risk. Conversely, it has been suggested that vertical deflection devices may reduce the risk of roll-over given that they are likely to reduce turning speed before a truck's turn is carried out (Campbell et al 2012). It is suggested that further consideration is given to the real risk posed to heavy vehicle rollover, by RSPs, with revised guidance being developed as more evidence emerges. VicRoads (2019, p.6) recommends that:

> *…assessments be undertaken on designs both with and without RSPs to gain a clear understanding of how these treatments impact vehicle stability, as opposed to an intersection's horizontal geometry*

Staff involved in the construction of a compact rural roundabout with raised platforms at Lance Creek, reported feedback from truck owners that the profiles were too steep and short for truck and trailer (i.e. the truck was descending the profile as the trailer was ascending) (VicRoads 2018). Milk tanker drivers had also reported that trailers could separate from the turn table due to the ramp being too short. However, as can be seen in the following section, the table profiles seem very moderate and there have not been ongoing complaints.

3.3.8 Walking and Cycling

While the design and location of pedestrian crossing facilities are considered in current guidance (VicRoads 2018), raised safety platforms at higher speed signalised urban intersections in practice don't provide a Safe System for pedestrians and cyclists, as the target design speed is usually 40-50 km/h as opposed to the 30 km/h which is commonly used as the Safe System speed for pedestrian and cycle crashes. In an assessment of safe system intersection performance (Austroads 2017), RSPs at signalised intersections rated poor to moderate for pedestrians and cyclists using the Safe System Assessment Framework. It was noted that the safety platforms were effective in reducing the impact speeds, but not below the FSI threshold level for vulnerable users.

However, RSPs are still likely to have some benefit for pedestrian and cyclists (VicRoads 2016a; 2016b; 2016c), and particularly on slip roads where the design speed of the platforms can be targeted more to vulnerable road users. Furthermore, lower speed applications where pedestrians and cyclists are common, may be designed for 30 km/h, which would then rate more highly for pedestrians and cyclists, and examples are given in the next chapter.

The perceptions and acceptance of raised intersections by pedestrians and cyclists is also important, as this can determine both use of infrastructure and support for projects. Stokes et al (2019) found that plateau (or raised platform) intersections were perceived as less safe than a similarly controlled intersection without a plateau. Although no possible explanation was given for this, it may be a result of less physical grade separation between vehicles and pedestrians due to the raised plateau. This is counter to professional understanding and could suggest a lack of public understanding of the design, and also hint to a need for more engagement and education around RSP programs.

Because the literature related to raised safety platforms and pedestrian perceptions, behaviour, and safety is somewhat scarce, it suggested that more research is needed. This would then feed into guidance regarding pedestrians at higher speed signalised intersections. Pedestrian safety is, however, discussed further later in this report.

3.3.9 Drainage/Other Supporting Works

When determining site locations for RSPs, consideration must be given to impact on neighbouring streets and service roads, any potential for damage to vehicles and pavement, and storm water drainage requirements (VicRoads 2019).

Potential impacts on drainage include that RSPs introduce new high and low surface points on site and can act as barriers to existing drainage lines.

'Raised Intersections' have greater potential impact on services and drainage compared to 'Approach Platforms' (VicRoads 2019).

VicRoads (2019) provides detailed options for drainage design solutions.

3.3.10 Wider Network Considerations

Case study research was recently undertaken in Australia and New Zealand to further understand how the Safe System approach could be applied to mixed use urban arterials (Austroads 2017; Turner et al 2019). Indicative Safe System treatments developed in the study included raised intersections, Humps/Platforms, and Wombat Crossings. Process issues reported from the study (Turner et al 2019), relevant to this review, are summarised below.

- In all case study sites, a package of treatments was deemed necessary to achieve Safe System alignment and outcomes (e.g. reduced speed environment, gateway, colour or texture surface, cycle path, access management).
- The importance of initially assigning road function and intended use of routes within the broader urban context when planning for safety on urban arterials. Until function is agreed, it is difficult to establish speed and infrastructure requirements.
- The importance of systemic risk assessment at a route, rather than just location level, and delivery of Safe System outcomes on a route basis. In the mixed-use urban environments included in the study, crash risk was elevated for much of the routes, especially for vulnerable road users.
- As is often the intent, Safe System treatments can have a significant impact on traffic operations, and a change in road function and road user priority based on broader network objectives may be needed. It is therefore important to understand the vehicle mix/classification on routes and the surrounding network, and to ensure traffic is diverted to collector or local roads, if needed.

Multiple RSP applications have recently been installed at Thomastown, Melbourne as part of the Victoria Department of Transport's Safe System Road Infrastructure Program (SSRIP) program (Cairney et al 2019a). This is an important project for learning about taking a wider corridor or network approach to implementing RSPs and is discussed further later.

3.3.11 Public Engagement and Communication

Understanding public attitudes and communicating with the public is important as there is the potential for innovative treatments to be rejected by the community (Austroads 2017; Candappa and Colobong 2015). Public opposition to the installation of vertical deflection devices can result in the modification of plans as well as the removal of treatments after installation (Webster 1998).

Implementation challenges with raised intersections and elevated stop lines can include public acceptance of the measures (Candapppa et al 2015). It is also important that public transport providers are engaged throughout (VicRoads 2019).

Public engagement and communication is considered further later in the site visits of existing applications.

3.3.12 Sustainability

Vertical deflection devices will potentially result in greater operational maintenance costs compared to other treatments (Austroads 2015). Maintenance requirements stemming from the rutting of raised safety platforms has been previously raised as a potential issue (Austroads 2017).

Other issues to consider include drainage and debris, the re-application of line markings, and low parts of humps or platforms being subject to vehicle gouging. Vertical deflection devices may also lead to slightly higher emissions due to the additional deceleration and acceleration introduced by the treatments (Austroads 2015).

3.4 Performance Considerations for Applications at Higher Speed Signalised Urban Intersections

3.4.1 Vertical Acceleration

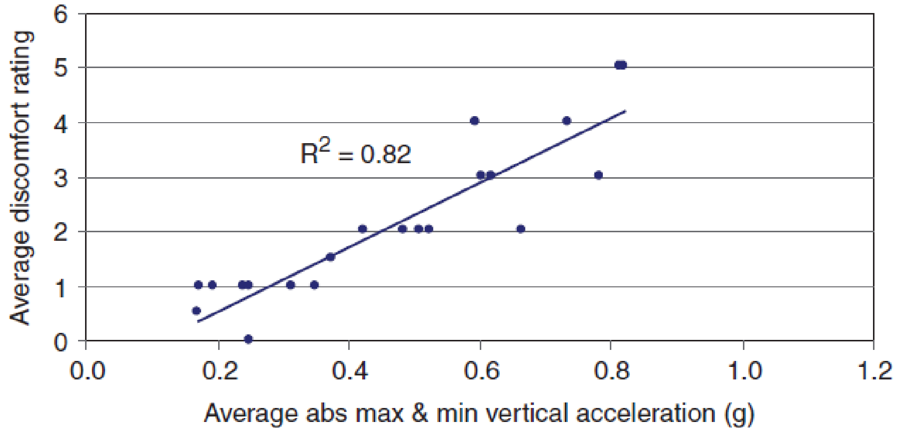
The vertical acceleration caused by RSPs is key to their performance. Vertical deflection devices operate on the principle that as vertical acceleration increases, so does discomfort for drivers and passengers (Kjemtrup 1988). In addition to hump design and vehicle speed, other factors determining vertical acceleration include vehicle suspension system, tire pressure and seat softness. Pitch[4], roll, and steering wheel feedback, are also influential (Callaway, Roper, and Germanchev 2010).

There is some consensus in the literature that 1.0 g is the maximum vertical acceleration able to be withstood and that levels around 0.5 g should be effective in reducing speed (Callaway, Roper, and Germanchev 2010; Kennedy et al 2004; Kjemtrup 1988, Mackie et al 2019, Pratt, Roper, and Wright 2014, Pratt et al 2014). Logically, a vertical acceleration of 0.5 g is also considered a comfort threshold (Pratt, Roper, and Wright 2014). Vertical accelerations exceeding 0.7 g is considered dangerous and may also damage vehicles (Pratt, McGarrigle, and Turner 2015).

Figure 3.6 shows the correlation between driver discomfort rating and vertical acceleration reported by Kennedy et al (2004). Vertical acceleration of approximately 0.4g correlated with average driver discomfort ratings of 2, where a rating of 2-3 equalled Slightly uncomfortable (with 0-1 = Comfortable, 4-5 = Uncomfortable, and 6 = Very uncomfortable). From the case studies described later, and this previous literature, a range of 0.4-0.7g appears to correspond to levels of acceleration that are acceptable for reducing speed, depending on other factors present, although 0.7g is likely to represent the very upper range of what is acceptable and may be unacceptable in some circumstances.

4 The rate of change in the angle of a vehicle while traversing a RSP.

Figure 3.6: Correlation between driver discomfort rating and vertical acceleration



Source: Kennedy et al 2004

An off-road trial in 2014 undertook on-site testing and simulation modelling of two RSP designs to determine the maximum acceptable speed to traverse each treatment and the vertical acceleration and pitch[5] experienced by different vehicle types[6] at different speeds (Pratt, Roper and Wright 2014). Acceleration and experience were also compared to a passenger vehicle travelling over other vertical deflection devices.

Table 3.6 shows the dimensions of the two RSPs tested. Previous work (Callaway, Roper, and Germanchev 2010) had determined the height and grade of both profiles was unlikely to have adverse effects on vehicle stability in braking or wet weather conditions.

Table 3.6: Dimensions of RSPs

Trial/ treatment	Direction	On-ramp length	On-ramp gradient	Platform length	Platform height	Off-ramp length	Off-ramp gradient
1	West	3.00 m	1:30	7.00 m	0.10 m	3.50 m	1:35
2	West	4.67 m	1:30	6.00 m	0.14 m	4.67 m	1:30

Source: Pratt, Roper and Wright 2014

The trial demonstrated that vertical acceleration was the primary determinant of comfort as pitch angles measured were no more than 10 degrees per second, and therefore unlikely to be experienced as a pitching movement (Pratt, Roper and Wright 2014). Overall, it was concluded that Treatment 1 was most effective, recording the smallest speed differential between vehicle types and generating the following expected speed results (if deployed on public roads):

- passenger vehicle speeds reduced to 60 km/h
- rigid truck and semi-trailer speeds reduced to 50 km/h
- airbag and spring suspension bus speeds reduced to 40 km/h.

The authors undertook further simulated trials to determine comfort levels when the RSPs were installed under varying vertical displacement conditions (Pratt, Roper and Wright 2014). These were Profile 1 installed on a downhill slope with an off-ramp gradient change of 4.17%, and the platform tilted slightly to achieve an off-ramp gradient change of 2.86%. This testing showed that with a downhill road gradient, the 4.17% off-ramp gradient change was most effective in maintaining the speed of larger vehicles, without experiencing severe discomfort, while still encouraging lower speeds in smaller vehicles.

5 The rate of change in the angle of a vehicle while traversing a RSP.
6 Bicycle, motorcycle (with pillion and without), passenger car, heavy rigid truck, semi-trailer, airbag suspension bus, spring suspension bus.

3.4.2 Operating Speed Reduction

Evaluation of the Belmont RSP following installation reported significantly reduced travel speed through the Surf Coast Hwy and Kidman Avenue intersection compared to control intersections (Candappa and Colobong 2015). Mean and 85th percentile speeds through the intersection were estimated to be 12.3 km/h and 12.6 km/h less compared to one control and 20.5 km/h and 15.2 km/h less compared to another control location.

Evaluation of the Hamilton, New Zealand, RSP following installation showed that 85th percentile speeds through the intersection were well below the Safe System standard of 50 km/h (Mackie et al 2019). When vehicles with <3 second headway were removed from the analysis, the 85th percentile speeds were 41 km/h and 44 km/h for northbound and southbound vehicles respectively. Prior to the RSPs (and associated signalised intersection), speeds through the intersection were estimated in the vicinity of 80 km/h. Effectiveness in suppressing speed was further demonstrated with radar showing that on approach, vehicles were generally at or just below the posted 60 km/h speed limit (Mackie et al 2019). However, for this study, due to other concurrent intersection improvements, the speed reducing value of the RSPs alone is still unknown.

A comprehensive evaluation of the speed reducing effects of RSPs at signalised intersections is currently underway on a series of RSPs implemented in Thomastown, Melbourne (Cairney et al 2019a; Cairney et al 2019b). A before/after analysis immediately following construction found significant overall reductions in travel speed on approach and departure across the seven treated intersections – a 13 km/h (28%) reduction in mean speed immediately prior to entering the intersection and an 8 km/h (17%) reduction on departure, across all sites in all directions and test conditions (Cairney et al 2019b). Significant reductions in vehicles travelling above the 50^{th} percentile speed, travelling above the speed limit, travelling above 30 km/h, and above 40 km/h were also shown.

Overall, installation of RSPs at these sites has resulted in a significant 25% overall reduction in approach speeds prior to entering the treated intersections, and 10% reduction in exit speeds from these intersections. Speed distributions were also shown to be more normally distributed following the installation of the RSPs. The speed reductions were also considerably greater than the reductions at the control sites.

It is clear RSPs used to date by jurisdictions at signalised intersections result in significant speed reductions. Key considerations for future designs are whether the target safe system speed of 40 or 50 km/h is being achieved, and whether any speed reductions are likely to have safety benefits for pedestrians and cyclists.

3.4.3 Safety

Recent Austroads research on achieving Safe System speeds on urban arterial roads assessed all the vertical deflection treatments in the study - Raised Intersections, Humps/ Platforms, and Wombat Crossings – as having a Crash Modification Factor (CMF)[7] of .60 (Austroads 2016a).

In a Dutch study of 10 raised platforms in urban areas with modest vehicle flows (3000–6000 daily), Van der Dussen (2002) showed that raised platforms at 10 intersections (daily traffic volumes 3000–6000) reduced crashes by 70%. The platforms were especially effective at reducing the severity of crashes, with casualty crashes reduced by 80%, while property damage only crashes were 60% lower. In another Dutch study, Fortuijn, Carton, and Feddes (2005) reported significant reductions in total and casualty crashes following the installation of RSPs at 40 signalised and 29 priority (unsignalised) intersections (accompanied by 50 km/h intersection speed limits) (see Table 3.7). Total collisions were reduced by a third and rear collisions by around a quarter (23%). Corben (2014) reports that when two highly congested intersections were removed from the sample of 40 intersections being evaluated, the reduction in casualties increased from 40% to 50%.

[7] The crash effects of treatments are expressed in terms of crash modification factors (CMFs). CMFs are defined as a ‘representation of the relative change in crash frequency that occurs due to a specific change in the road or its immediate environments’ (Austroads 2015). The relationship of CMFs to crash reduction factors (CRFs) is defined as an ‘indication of the expected percentage reduction in road crashes following the introduction of a countermeasure’ (Austroads 2015).

Table 3.7: Reductions in total/casualty crashes following installation of RSPs

	Signalised intersection with Safety Platform		Priority intersection with Safety Platform	
	#casualty crashes/ intersection/year	# crashes (total)/ intersection/year	# casualty crashes/ intersection/year	# crashes (total)/ intersection/year
Before	1.23	7.01	0.31	1.60
After	0.74	4.50	0.20	0.90
Safety effect	-39.6%	-35.8%	-35.0%	-44.0%
Chi squared test of difference	12.0	54.5	1.51	13.1
Significance level	0.05%	0.00%	22% (non-significant)	0.03%

Source: Fortuijn, Carton, and Feddes 2005

Candappa and Colobong (2015) used post-crash kinetic energy (KE) levels as a surrogate measure of the likelihood of injury crashes before and after the Belmont RSP. Prior to treatment, the authors estimated that KE levels of approximately 190 kJ could be expected for vehicles travelling at 70 km/h. Following the treatment and reduced speeds through the intersection, KE levels at the treated site were estimated to be just above the Safe System recommendation of 96.5 kJ. In comparison, 85th percentile speeds in both control sites equated to KE levels closer to double (189 kJ) tolerable levels (Candappaa, Colobong, and Buib 2016). It was concluded that the approximately 50% reduction in estimated KE in the event of a crash at the intersection would correspond to a reduction in serious injury crashes at the site (Candappa and Colobong 2015).

Drawing on evidence that reduced speed corresponds to reduced crash frequency and outcomes (Elvik 2005), and a predicted 5% reduction in crashes for every 1.6 km/h reduction in speed (Taylor et al, 2000), Candappa and Colobong (2015) also estimated the speed reductions achieved by the RSP would correspond to a 44% reduction in casualty crashes at the intersection (an estimate revised to 30% once accounting for the additive effect of traffic signals and posted speed limit reduction).

Taking a Safe System approach reducing deaths and serious injuries is the priority. Over time experience with RSPs will yield a greater understanding of how they reduce higher severity crashes.

3.4.4 Road User Responses to RSPs

Previous evaluations have considered whether RSPs could increase the risk of other crash types, particularly rear end crashes due to sudden, late, or erratic braking (Mackie et al, 2019; Candappa and Colobong 2015). Typically, these studies have used cameras to record motorist behaviours on approach to and travel over the RSPs. Braking and stopping behaviour have been commonly evaluated, with braking used as a surrogate measure for driver confusion, uncertainty, or misjudgement upon approach (Mackie et al, 2019; Candappa and Colobong 2015).

Braking on approach

A total of 1625 driver behaviours were filmed in the Candappa and Colobong (2015) evaluation. Motorcyclists and cyclists were more likely to initiate braking at the RSP itself, while 51% of cars and 56% of trucks had already initiated braking when first visible in the video footage. This suggests initial braking approximately 35-40 m prior to the RSP and earlier braking than the 6-7 m required to traverse the RSP at 50 km/h (Scully and Corben 2007, cited in Candappa and Colobong 2015). The authors suggested that early braking reflected road users' unfamiliarity with the RSP and expected the incidence to decrease as familiarity increased (Candappa and Colobong 2015).

Approximately five percent of drivers in the Candappa and Colobong (2015) evaluation braked twice on approach and one forceful stop was observed. Some heavy braking was observed, suggesting these drivers had not seen or anticipated the stopline being in advance of the signals. However, most braking was consistent and concluded as unlikely to be hazardous.

Mackie et al (2019) reported similar braking findings to Candappa and Colobong (2015). The greatest proportion (52%) of vehicles observed demonstrated consistent, sustained braking during the immediate approach. Five percent of vehicles demonstrated late braking, evidenced by braking only being initiated in proximity to the RSP. The authors interpreted this behaviour as suggesting a minority of drivers may have experienced some uncertainty upon approach. Over time, late braking may have diminished as drivers become more familiar with the intersection, but this would need to be confirmed.

Stopping behaviour

Candappa and Colobong (2015) observed the stopping behaviour of 813 vehicles at the Belmont RSP. The majority (81%) stopped before the RSP, at the defined stop-line, while a limited number stopped on the RSP. The incidence of overshooting the stop line was again predicted to decrease with increased driver familiarity.

Mackie et al (2019) again reported similar findings, with only 0.7% of vehicles stopping at the RSP stopping on the RSP itself. This result was interpreted as indicating that most drivers understood the layout and stopping requirements, and that the minority of drivers not complying precisely with the yield line was unlikely to present a safety risk.

3.4.5 Noise and Vibration

Noise pollution may be a potential concern with raised intersections (Wewalwala and Sonnadara 2011). However, a UK study showed that noise levels produced by light vehicles driving over speed humps were lower than vehicles driving over a flat section of road given the differences in mean speed (Daniel 2012).

Staff involved in the construction of a compact rural roundabout with raised platforms at Lance Creek, Victoria reported that adjacent landowners had initially been concerned about potential noise generated by the platforms, particularly by heavy vehicles at night. However, feedback from residents following completion of the roundabout indicated that the initial concerns about noise had not been realised (VicRoads 2018).

The specific noise impact of the RSP was not formally measured in the Hamilton, New Zealand evaluation as field observations determined that impacts were negligible and were unlikely to be isolated from the general intersection noise (Mackie et al 2019). At the time of writing, no noise related complaints had been received from the public, however, this will continue to be monitored (Mackie et al 2019).

3.4.6 Large Vehicle Stability

Beyond the simulation work that has been carried out in New Zealand and Australia, the authors could not find any post installation evaluation of vehicle stability. Impacts on large vehicle stability were considered further in the site visits reported later.

3.4.7 Traffic Flow and Capacity

Vertical deflection devices such as raised stop bars, speed platforms, and raised intersections may potentially lead to slower clearance times and therefore marginally increased inter-green time (Austroads 2015). Contrary to this, Fortuijn, Carton, and Feddes (2005) reported that raised stop bars at very busy intersections enhanced intersection capacity and the ability to negotiate intersections.

Concurring with Fortuijn, Carton, and Feddes (2005), a senior transport engineer saw little initial evidence the Hamilton RSP was impacting intersection capacity (Mackie et al 2019). There had been no requirement to alter existing traffic signal timing settings (e.g. inter-green times) following installation. Driver behaviour at the intersection when accelerating from stopped (i.e. from green) appeared similar to non-RSP sites in terms of acceleration rate and headway. It was observed that higher-speed platform profiles, as used in Hamilton, are likely to help with avoiding effects on intersection delay, compared to more abrupt platforms that seek more significant speed reduction (e.g. 25-30 km/h). It was also observed the RSPs might replicate the effect of the way limiting motorway speed during times of high volume can increase throughput (i.e. reducing the operating speed somewhat at the intersection may not necessarily have any effect on throughput during times of high volumes).

Intersection efficiency was considered further in the site visits reported later.

3.4.8 Vehicle Acceleration

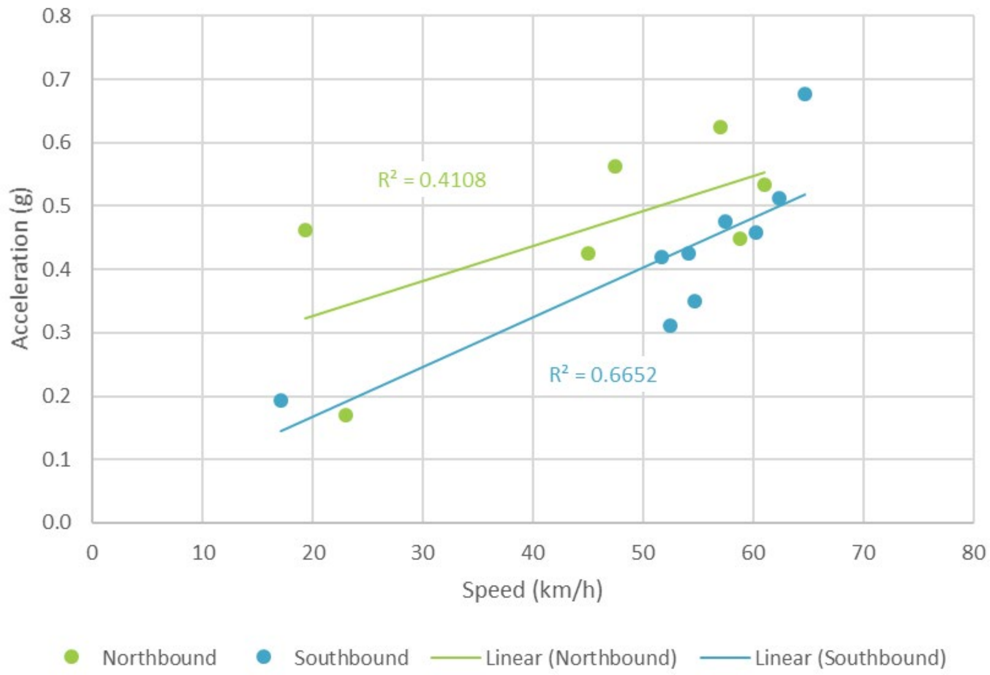
To estimate driver comfort and potential risk for loss of control, the Hamilton evaluation measured vertical acceleration while travelling over the RSPs in a light passenger vehicle (Mackie et al 2019). Peak vertical acceleration at a range of realistic approach speeds was well within the accepted range for safety and driver comfort (i.e. 0.5-0.7 g). Table 3.8 shows the peak acceleration recorded at different speeds. Figure 3.7 plots the recorded relationship and shows speeds of 50 km/h equalling 0.4-0.5g.

Table 3.8: Peak vertical acceleration (Hamilton RSP)

Direction	Speed (km/h)	Peak acceleration (m/s)	Peak acceleration (g)
Northbound	57	15.94	0.62
Northbound	59	14.21	0.45
Northbound	19	14.34	0.46
Northbound	45	13.99	0.43
Northbound	61	15.05	0.53
Northbound	23	11.48	0.17
Northbound	47	15.34	0.56
Southbound	65	16.45	0.68
Southbound	60	14.30	0.46
Southbound	62	14.84	0.51
Southbound	54	13.99	0.43
Southbound	53	12.86	0.31
Southbound	55	13.24	0.35
Southbound	52	13.93	0.42
Southbound	17	11.70	0.19

Source: Mackie et al 2019

Figure 3.7: Relationship between speed and peak vertical acceleration (Hamilton RSP)



Source: Mackie et al 2019

3.4.9 Public Transport and Emergency Services Vehicles

A US study identified that RSPs at intersections significantly impacted on emergency response times (Schulthiess 2006, cited in Candappa and Corben 2011). Austroads (2015) also report that vertical deflection devises could potentially lead to slower clearance times and therefore marginally increased inter-green time. However, it is not clear whether the raised platforms referred to in the literature are similar to the designs which are the focus of this report, or whether they are more conventional speed humps/tables commonly used in low speed environments. Further there appears to be limited measured impact from the available literature. Consultation and seeking advice from emergency services, when planning and designing vertical deflection treatments, is therefore recommended (Austroads, 2015, VicRoads 2018). It is understood that emergency services and a local bus company took part in early trials at GunDog Lane in Victoria, with accelerometer readings taken for most vehicle types, and the outcomes from this work could be used in further engagement with these stakeholders.

3.4.10 Community/Jurisdiction Acceptability

Project team members from the Korumburra-Wonthaggi Rd/West Creek Rd/Glen Alvie Rd RSP reported initial community concerns about potential noise generated by the platforms, particularly by heavy vehicles at night. However, subsequent feedback from resident post completion has not identified this to be an issue. Further noise evaluation will take place at the site (VicRoads 2018).

Anecdotally, the design of the Belmont RSP was accepted by the community and generally there was a positive response to it (Candappa and Colobong 2015).

A similar response to the Hamilton design was reported by Mackie et al (2019). A project close-out report (Hamilton City Council 2019) described high levels of engagement and support for the project by local authority politicians and overall, high levels of stakeholder satisfaction. Further, there had been no significant complaints about the project from the community during the installation and initial operation of the RSP. A review of the local council's online and telephone customer service channels throughout the project duration and initial operation revealed one safety related submission from a member of the public. The submission raised concerns about the visibility of the RSP particularly the change in height when approaching from the north. While not considered a safety critical risk, the authors recommended that consideration be given to increasing the salience of the approach ramp profile (e.g. through a colour treatment on the platform) (Mackie et al 2019).

South Australian researchers conducted an online survey of driver perceptions of safety at metro and rural intersections with different types of control (Stokes, Raftery, and Woolley 2019). Perceptions of safety were high for roundabouts while a raised intersection design was perceived as less safe compared to a similarly controlled intersection without a platform. The authors recognised that the latter finding was counter to professional understanding and suggested it could indicate a lack of public understanding of more innovative designs.

3.4.11 Pedestrian and Cyclist Amenity

Amenity for pedestrians and cyclists will continue to be examined in the literature review and during the future site visits of existing applications. We are currently unclear as to whether any applications have been designed specifically for these road users. Design solutions will be challenging with the Safe System speed for vehicle crashes involving pedestrians and cyclists ≤ 30 km/h, which is significantly lower than the 40-50 km/h target speeds for high speed signalised intersections used to date. As is described later, 40 km/h has been applied as a reasonable trade-off between Safe System speeds for vulnerable road users and vehicle side impacts.

3.4.12 Constructability (Including Drainage)

Raised Intersections are generally more expensive compared to Approach Platforms due to the increased footprint and greater potential impact upon services and drainage (VicRoads 2019).

A 'lessons learned' workshop conducted after the completion of the Hamilton RSP did not identify any significant construction or delivery issues specifically associated with the RSP treatment itself (Mackie et al 2019).

Construction methodology issues and learnings identified from the installation of RSPs at different sites in Victoria[8] (VicRoads 2018) included the following:

- Designing and installing platforms in three layers (base layer, intermediate layer, wearing course) was found to be effective, particularly enabling right sized machinery to be used for each layer.
- Construction of platforms in half widths required for some sites to cater for necessary traffic flow. Single lane sites may require contraflow or detours to reach a balance between required operation and speed of delivery.
- Construction was aided when kerb and channel followed the same profile as the ramps themselves (e.g. asphalt placement followed the same profile and grade of kerb and channel).
- The importance of ensuring that surveyors identify all the high and low points on site. Gridding the site out at ~5 m intervals assisted this. This was considered pivotal to capturing existing conditions and ensuring the desired profile is achieved.

[8] Surf Coast Hwy / Kidman Ave, Belmont; Dalton Rd / Childs Rd, Lalor; Korumburra-Wonthaggi Rd / West Creek Rd / Glen Alvie Rd, Lance Creek (ER); City of Whittlesea Council.

Some sites being investigated have locations where existing kerbing is quite low. Looking to apply RSPs or raise an entire intersection by ~100mm therefore resulting in need for the entire intersection to reconstructed which in turn impacts on the feasibility of the project.

When designing RSPs to marry into existing kerb and channel, need to consider:

- aligning platform to existing kerb (i.e. flush with kerb)
- feathering platform into existing kerb
- raising the kerb to follow profile of platform.

The preferred approach depends on the context of each site, including whether the site is a ‘new build’ or a retrofit.

The potential for a different material, such as a concrete plinth, to be used for the approach and departure ramps to help with delineation and potential maintenance moving forward was suggested. But it’s interesting that Hamilton has discounted this approach and proceeded with full asphalt RSPs.

There is a need to consider how changes to kerb and channel will impact on delineation for road users - e.g. where an intersection is being raised and platforms are to be constructed flush with kerb, and how RSP’s flush with kerb and footpath may be attractive to pedestrians looking to cross the road. Measures should be taken to delineate pedestrian space from the roadway – e.g. improved line marking, RRPM’s, bollards, etc. There is a need to be conscious of an RSP creating a new pedestrian desire line and if considered undesirable adopting measures to deter pedestrians from crossing (e.g. vegetation).

Project team members from the Belmont RSP also reported that the asphalt platforms have held their shape and have maintained the design profile (albeit being positioned in the braking and acceleration zones) (VicRoads 2018).

Staff involved in commissioning contractors for recently installed RSPs in Victoria stressed the need to ensure that quality and reputable contractors were awarded the works (VicRoads 2018). A pre-tender meeting with contractors was recommended to ensure that bidders fully understood the intent and design of the treatment and, for the treatment to be effective, how critical it was to build the specified design profile. This understanding was important so contractors could carefully consider and propose the methodology required to construct the works to required standards. This approach has also been adopted by Hamilton and has proved successful.

Greenfield vs retrofitting

Constructability unique to a greenfield development or retrofitting existing infrastructure will continue to be examined in the literature review and during the future site visits of existing applications.

3.4.13 Evaluation Considerations

Raised safety platforms are typically implemented with other safety measures and determining the performance impact of RSPs specifically can be difficult (Mackie et al 2019; VicRoads 2018). While a combination of treatments is likely to have the greatest impact on safety (Tariro, Makwasha, and Hillier 2017), evaluation of specific impacts and contribution to overall outcomes is often required.

In addition to the establishment of control (non-treatment) sites when determining the impact of treatments, isolating the effect of RSPs from other confounding factors generally requires staggered implementation of RSPs and other safety measures (VicRoads 2018). It requires the collection of performance data before and after the installation of each measure, with the cycle repeated at each stage of installation. There are often practical and logistical barriers to achieving such a design when working in applied settings, and final evaluation designs may not always be optimal (Mackie et al 2019).

Pratt and Aumann (2014) also noted the need to consider evaluation of any wider network impacts a specific or more localised set of treatments might have. For example, drivers may choose a different route to avoid a treatment, with corresponding impacts on traffic volumes and potentially speed.

The design of the evaluation of the RSPs being deployed in proximity along two routes in the Melbourne metropolitan area is seeking to understand impacts at a project (treatment specific), route (series of treatments), and overall investment program level (Cairney et al 2019a). In addition to the impact of the treatments on traffic speeds through each treated intersection, the evaluation is also examining impact on speeds along the entirety of the route that treatments have been installed.

3.5 Other Raised Safety Platform Applications

3.5.1 Midblock Applications

Warrants/Design

Raised safety platforms at mid-block sections are most suitable for local and lower speed arterial roads (VicRoads 2019). They are typically used to create a lower speed environment along a route or at locations of specific risk such as a high number of vulnerable road users (Turner, Jurewicz, and Makwasha 2017). In settings of high pedestrian activity, midblock treatments generally include pedestrian crossing facilities (Turner, Jurewicz, and Makwasha 2017).

There is ongoing debate about the appropriateness of vertical deflection devices for arterial mid-block applications including crossings. As shown below in Figure 3.8 there is the potential to challenge conventional practice and, in the same way as RSPs at signalised intersections, explore lower profile ramps that are acceptable to bus passengers, and potentially supporting safety treatments, to improve safety on arterial roads.

Safe System assessment

Moving midblock speeds closer to Safe System compliant speeds requires speed reductions while maintaining mobility, accessibility, and overall safety of all road users (Austroads 2016a).

Safety performance

In a study of seven midblock RSP sites in Australia, Hawley et al (1993) reported that following installation, 85th percentile speeds dropped from 66 km/h to 49 km/h; a 26% reduction. This study also showed that shorter platforms and greater ramp gradients resulted in lower speeds. A more recent study of midblock applications in Australia and New Zealand reported a statistically significant reduction of 5.4 km/h in 85th percentile speed and a 47% reduction in casualty crashes (Makwasha and Turner 2017).

Figure 3.8: Example of a midblock raised pedestrian crossing (Auckland, New Zealand)

Source: Google maps 25 November 2019 ©Google, New Zealand.

3.5.2 Urban Priority-Controlled Raised Intersections

Warrants/Design

The urban priority-controlled raised intersection generally has a conventional layout with the intersection itself raised by 75–100 mm. Approach ramps provide vertical deflection for moderating entry speeds, with the intent of reducing the severity and likelihood of collisions. The relocation of underground services may be required, meaning the design is likely to provide a moderate-cost solution compared to conventional intersections (Austroads 2017).

While they are typically used in other countries very deliberately within a road hierarchy, such as in the Netherlands, they are less common in Australia and New Zealand.

Safe System assessment

The Safe System Assessment Framework (SSAF) (Austroads 2016b) was used to assess the Safe System alignment of the urban priority-controlled raised intersections design under assumed conditions[9] (Austroads, 2017) (See Figure 3.9). While moderate alignment was concluded overall, the design was assessed as 31% more aligned compared to an equivalent non-raised intersection. It should be noted that while vehicle-vehicle risks were very low, alignment was moderate to poor for pedestrians, cyclists and motorcyclists, due to large volumes and impact speeds above the Safe System threshold. The design could achieve moderate alignment for vulnerable road users, mainly by reducing the speed limit and installing pedestrian and cyclist safety provisions (Austroads 2017).

9 Moderate traffic volumes; 60 km/h approach speeds; high volumes of pedestrians and cyclists; intersection entry speeds reduced to 40 km/h.

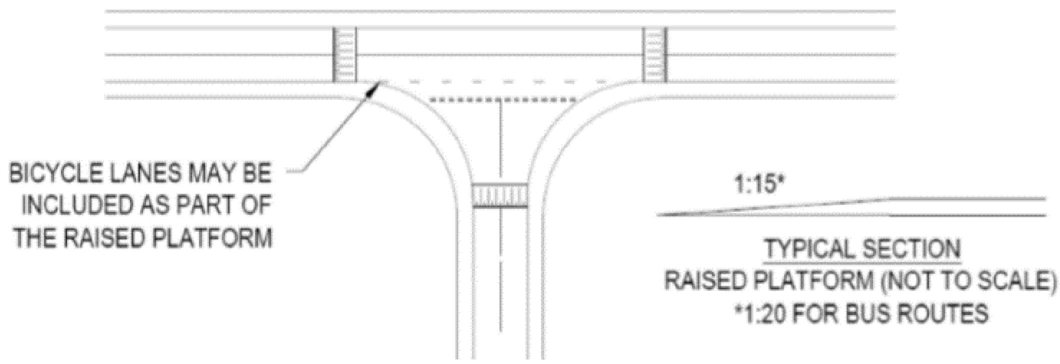
Crash likelihood and severity for the urban priority-controlled raised intersection design was assessed using the Extended Kinetic Energy Management System for Intersections (X-KEMM-X) method[10]. The assessment concluded a low possibility of FSI outcomes in vehicle-vehicle crashes due to the reduced speed of approaching vehicles, with half falling below the nominal FSI threshold of 0.1 (Austroads 2017). Pedestrian-vehicle conflict points recorded a high risk of FSI outcomes for pedestrians as impact speeds would be above the FSI threshold. Overall, the analysis concluded the design was highly aligned with Safe System objectives for vehicle occupants and moderately aligned for pedestrians (Austroads 2017).

Safety performance

In 2015, a raised safety platform was installed at the T-junction intersection of Rundle Street and The Parade West in Kent Town, South Australia (Austroads 2018) (See Figure 3.10). Ramped approaches (1:12) were added to all three legs of the intersection along with pavement marking and advisory speed signs of 20 km/h (prevailing 50 km/h speed zone). There had been 29 reported crashes at the nine years (2004-2013) prior to installation; following installation, only one minor injury crash has been reported.

The Makwasha and Turner (2017) evaluation included ten priority-controlled raised intersections in Australia and New Zealand. This study reported that the treatments resulted in a 7.5 km/h reduction in 85th percentile speed and a casualty crash reduction factor of 55% (statistically significant at $p = 0.100$). While the results for FSI crashes were not significant, this was most likely due to a small sample size. Pedestrian casualty crashes were reduced by 58%, with low statistical significance of the finding ($p = 0.26$) still indicating a strong safety effect.

Figure 3.9: Concept functional design of a raised intersection



Source: ARRB Group in Austroads 2017

10 The X-KEMM-X is used to analyse severe injury probability for crashes at intersections. Focused on impact speeds and angles, and different crash types (e.g. side, frontal, rear, pedestrian), the methodology estimates minimum, average and maximum severe injury probabilities for different intersection designs (Austroads, 2017). The method calculates a probability that at least one person will be severely injured when a vehicle-to-vehicle or vehicle-pedestrian collision occurs at each relevant conflict point.

Figure 3.10:Rundle St/The Parade West, Adelaide, South Australia

Source: Google Maps (2016), 'South Australia', map data, Google, California, USA.

3.5.3 Rural Priority-Controlled Intersections

Warrants/Design

Priority-controlled rural intersections with safety platforms provides a low-cost Safe System solution for high-risk rural intersections on low volume roads, and when higher costs are difficult to justify. They are routinely used in the Netherlands (Figure 3.11) where the default rural speed limit is 80 km/h on undivided roads. When combined with reduced speed limits and rumble strips, the design responds to multiple factors in rural intersection crashes, including failing to stop on the minor road, lack of driver attention, and error at the give way line. Lower entry speeds should also reduce conflict likelihood and severity (Austroads 2017). Applications in Australia or New Zealand are unknown at this stage.

Figure 3.11:RSPs at a rural priority-controlled intersection in The Netherlands

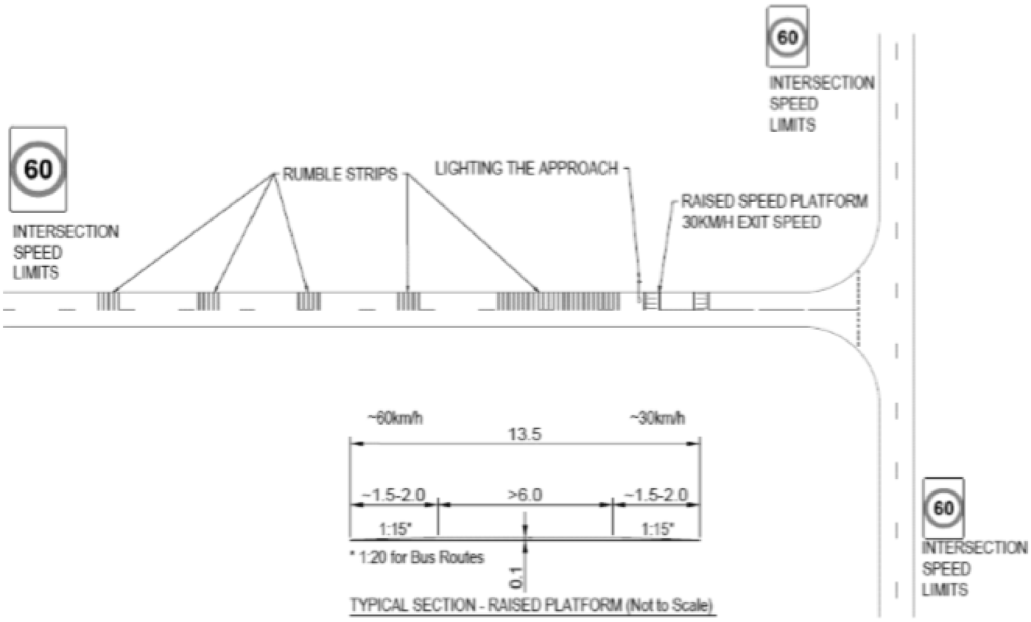
Source: Google Maps 17th June 2020. ©2020 Google, New Zealand

Safe System assessment

The alignment of a side road RSP design (Austroads 2017; Figure 3.12) with Safe System objectives was assessed as low due to very low traffic volumes yet moderate to high crash likelihood and severity (e.g. run-off-road and head-on crash types are not addressed) (Austroads, 2017). While the conclusion of moderate to high Safe System alignment overall was primarily due to low traffic volumes, rather than concept design, the design was still assessed as 21% more aligned compared to an equivalent non-raised rural T-intersection. The design could be improved through infrastructure such as roadside barriers and narrow medians, although these are inconsistent with the low-cost intent (Austroads 2017).

Crash likelihood and severity of the design was assessed using the X-KEMM-X and assuming a reduced speed limit of 60 km/h (Austroads 2017). While vehicle-vehicle conflict points were the same, the probabilities of FSI decreased by 0.3 on average compared with the original 100 km/h design. While crash severity for pedestrians remains high due to speeds in excess of 20 km/h, the rural environment reduces the presence of pedestrians.

Figure 3.12: Concept functional layout of a rural priority-controlled intersection with safety platforms



Source: ARRB Group in Austroads 2017

3.5.4 Urban Compact Roundabout

Warrants/Design

The urban compact roundabout with raised safety platforms is designed to provide a lower cost Safe System alternative to a conventional roundabout or retrofit solution to smaller existing roundabouts under-performing due to inadequate geometric deflection or higher than expected approach speeds (Austroads 2017). In both cases, the speed platforms act to moderate approach and entry speeds similar in function to the approach curves and central island at a conventional roundabout.

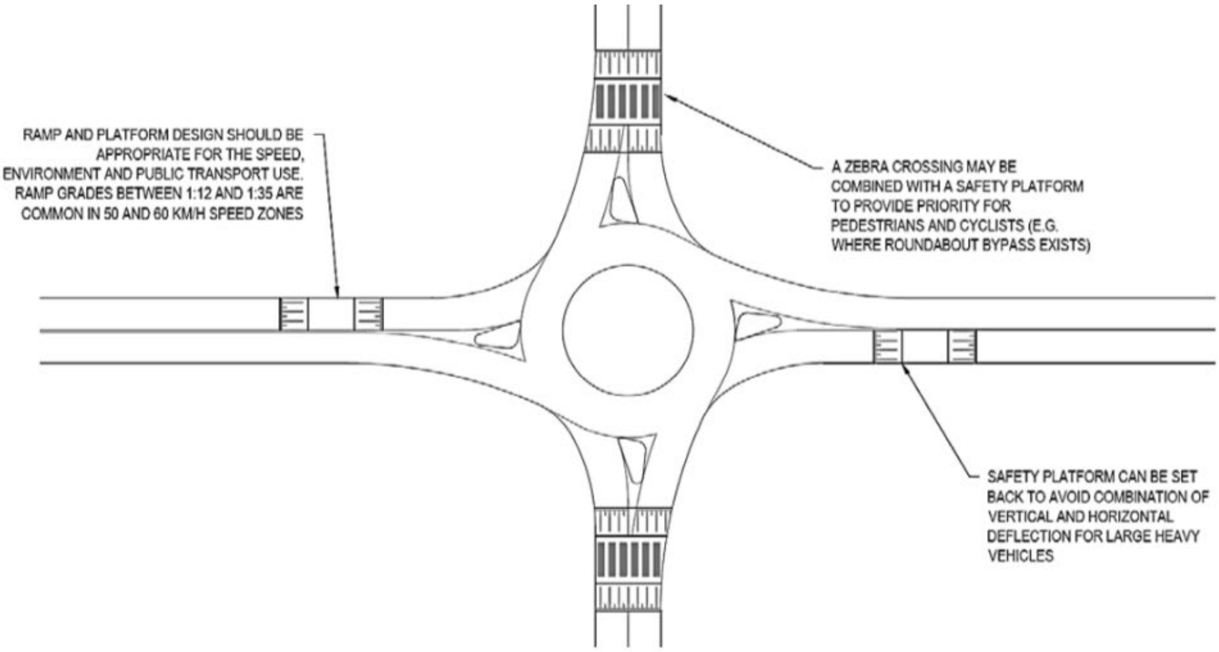
The design may be used at signalised or priority controlled arterial or local intersections. Raised zebra (Wombat crossings) and cyclist crossings may be added in appropriate environments, with these designed to address any potential confusion regarding the intent of the raised pavement area (Austroads 2017).

Safe System assessment

Assessment of the urban compact roundabout design using the SSAF, and under assumed conditions[11], concluded moderate to high Safe System alignment (Austroads 2017). While vehicle-vehicle crash types were highly aligned, off-path, cyclist and motorcyclist crash types had lower performance. Pedestrian impact severity was scored as moderately high due to impact speeds > 20 km/h however, staged crossings act to reduce the likelihood of these impacts. Overall, the design was assessed as 56% more aligned with Safe System objectives compared to an equivalent non-raised urban signalised intersection. Alignment could be improved mainly through advanced warning signs, rumble strips, and a roundabout bypass for cyclists (Austroads 2017).

Crash likelihood and severity assessment using X-KEMM-X assumed an urban three-leg roundabout, a 60 km/h speed environment and 40 km/h entry and circulating speeds (Austroads 2017). Reduced entry speeds due to the safety platforms removed the possibility of FSI outcomes greater than 0.1 for vehicle-vehicle conflicts, however, severity was assessed as just below moderate for vehicle-pedestrian conflicts (due to impact speeds of 40 km/)h. Overall, however, the analysis confirmed enhanced safety benefits compared to a conventional roundabout (Austroads 2017; Figure 3.13).

Figure 3.13: Concept design for urban compact roundabout with raised safety platforms



Source: ARRB Group in Austroads 2017

An innovative low-cost safe roundabout has been implemented in Mildura, Victoria (Figure 3.14 and Figure 3.15). It includes low-cost speed platforms on approach and was very inexpensive to install. Although this does not represent an RSP as discussed in this report, the example demonstrates how the principles of speed reduction at an intersection can be cost effectively implemented.

11 60 km/h approach speeds; 40 km/h entry speeds and moderate traffic flows (15 000 and 11 000 veh/day per approach); moderate pedestrian and cyclist flows (Austroads 2017).

Figure 3.14: Compact roundabout with low cost raised platforms in Mildura, Victoria

Source: Davis 2019

Figure 3.15: Urban compact roundabout at Irymple Avenue and 15th Street, Calder Highway, Mildura, Victoria

Source: Regional Roads Victoria https://regionalroads.vic.gov.au/map/western-improvements/deakin-avenue-calder-highway-17th-street-roundabout-mildura. n.d.

3.5.5 Rural Compact Roundabout

Warrants/Design

The rural compact roundabout is designed to provide a comparatively low-cost solution in a low-volume, high-speed (> 80 km/h) rural context (Austroads 2017). It seeks to address cost barriers to rural roundabouts (e.g. cost of land acquisition, service relocation, construction) as well as contributing factors to a higher FSI crash rate compared to urban roundabouts (e.g. high approach and entry speeds). Cost savings can be achieved if safety platforms are able to be retrofitted without major changes in intersection geometry (Austroads 2017).

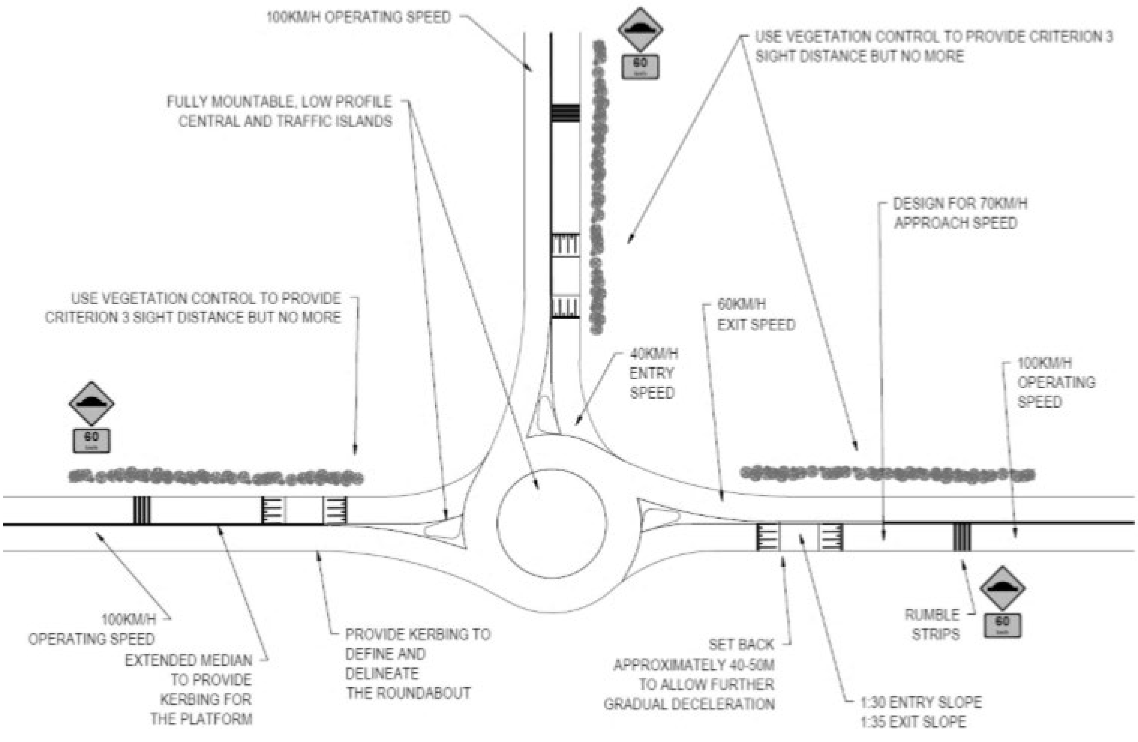
The design intent is to reduce approach speeds from 80–100 km/h range towards 60 km/h range, with the approach deflection leading to ≤ 40 km/h entry speeds. A localised intersection speed limit reduction from 100 km/h to 80 km/h or less could also be applied (Austroads 2017).

Safe System assessment

Assuming low entry speeds are achieved, it is estimated compact roundabout should have similar Safe System effectiveness to regular rural roundabouts (Austroads 2017). Assessment using the SSAF concludes high alignment with Safe System objectives, in part due to low traffic volumes. While risks remain for run-off-road, intersection and other crashes, the design is assessed as 62% more aligned with Safe System objectives compared to a conventional T-intersection without platforms (Austroads 2017).

Crash likelihood and severity assessment using X-KEMM-X assumed an 80 km/h speed environment and entry speeds of 40 km/h (Austroads 2017). While reduced entry speeds eliminate the possibility of FSI outcomes greater than 0.1, vehicle-pedestrian conflict points remain high due to the crash severity for pedestrians with speeds of 40 km/h. However, the rural context again means there are likely to be low pedestrian numbers. A very high level of Safe System alignment is concluded overall for vehicle-vehicle and vehicle-pedestrian crashes (Austroads 2017; Figure 3.16).

Figure 3.16: Concept functional design of a low-cost rural roundabout



Source: ARRB Group in Austroads 2017

Safety performance

A modified roundabout treatment with raised safety platforms was recently installed at a high-risk intersection in the eastern region of Victoria (Korumburra-Wonthaggi Road/Glen Alvie Road, Lance Creek). Completed in 2018, the project involved converting a previous stop-controlled intersection to a single lane roundabout with single curves, raised platforms on approach, and a central raised platform (Goodsell et al 2019). The project aimed to deliver a lower cost solution that still achieved the safety benefits of roundabouts and high alignment with Safe System principles (Austroads 2018; Figure 3.17; Figure 3.18).

Figure 3.17: Compact rural roundabout with raised platforms (Lance Creek, Victoria)

Source: Moon 2017

Figure 3.18: Compact rural roundabout with raised platforms (Lance Creek, Victoria)

Source: Moon 2017

Using a before/after evaluation design, a recent evaluation of the Lance Creek roundabout assessed the impact of the treatment on the approach speed for each leg, traffic volumes, and speed limit compliance (Goodsell et al 2019). The evaluation reported an overall decrease in post-construction speeds as vehicles approached the intersection. Differences between pre- and post-installation unimpeded speeds were statistically significant for all approach legs. Post-construction, all approaches also recorded a statistically significant increase in speed limit compliance, while three recorded a statistically significant decrease in per day traffic volumes. Assessment using the SSAF and X-KEMM-X methods concluded that while cyclists and motorcyclists were still exposed to risks, primarily due to operating speeds, the treatment had delivered significant benefits in aligning the intersection with Safe System objectives and by limiting the opportunity and/or severity outcome for motor vehicle crash types.

In response to resident concerns, noise surveys were also conducted on two approaches to the roundabout before and after construction of the raised platforms (Ahmed and Marshall Day Acoustics 2019). Baseline noise monitoring was also conducted at the site. Noise measurements were taken at 16 locations pre-construction and 15 locations post-construction. At each location, measurements were taken for three vehicle types (passenger, utility, articulated). For analysis purposes, the 15 post-construction measurement points were clustered into four groups based on location. Post-construction, A-weighted noise levels were higher for articulated compared to passenger and utility vehicles. However, for all vehicle types and across all groups of measurement locations, A-weighted Lmax noise levels were lower in the post-construction period than the pre-construction period. While the construction of the roundabout and the raised safety platforms will have reduced approach speeds and hence noise, the Asphalt resurfacing is also estimated to have reduced noise by 5-6 dB.

3.5.6 Urban Cycle-Friendly Roundabout

Design

Taking inspiration from conventionally designed roundabouts in the Netherlands, cycle friendly roundabouts are an emerging concept in Australia and New Zealand. In late 2018, Moray Street, South Melbourne was upgraded with high quality pedestrian and cycling facilities. An example of the infrastructure installed is a cycling and pedestrian friendly roundabout at the Moray/Dorcas St roundabout (Figure 3.19), and Thomas/Orly roundabout in Māngere Auckland Figure 3.20. This included raised crossings on all four legs, including integrated bicycle crossings continuous with circulating separated cycle lanes. This means that cyclists have priority at the intersection in the same way as pedestrians, separated from vehicle traffic.

Figure 3.19: Raised crossings at roundabout (Moray/Dorcas Street, South Melbourne)

Source: Melbourne Bicycle Users Group in Department of Transport and Main Roads 2019

Figure 3.20:Thomas/Orly Roundabout, Māngere, Auckland

Source: Fabian Marsh

Performance evidence

Two evaluations of the performance of the South Melbourne roundabout layout have been carried out. The perceptions of cyclists and pedestrian perceptions were carried out (ASDF Research 2019) for the City of Port Phillip before and after the changes to evaluate the impact the new roundabout has had on perceptions of safety. The perceptions of vehicle drivers following the upgrade were also collected. Following the upgrade, the perceptions of safety of the roundabout improved significantly for pedestrians and cyclists and a higher proportion of cyclists reported they would recommend the route to inexperienced cyclists. Two areas of concern, however, were whether motorists would see and give way to cyclists on the roundabout, and whether some cyclists would use the crossings (as opposed to riding on the carriageway), as it seemed less convenient. An evaluation of vehicle, pedestrian, and cyclist traffic flow was also carried out (Tan 2019). This evaluation found that most pedestrians and cyclists used the new facilities, but with some cyclists preferring the less bumpy and more direct route offered by the traffic lane. Up to 2% of vehicles did not yield to cyclists and there were very few examples of conflicts, although one near miss was observed within the observation period. The speed reducing effects of the new layout, or the safety performance is unknown at this stage.

Other applications

In New Zealand, a similar concept has been adopted as part of the project Te Ara Mua – Future Streets (Mackie et al 2018, Figure 3.20), also adopting raised platforms for pedestrians and cyclists. Although no movement, speed, or perceptual data is available for this intersection there have been no injury crashes as this intersection in the two-year period since the new roundabout has been established.

3.5.7 Raised Priority Crossings for Cyclists

Design

A bicycle path crossing at Somerset Street, Windsor, Brisbane was implemented where cyclists have priority over traffic on Somerset Street. The ramp gradients were constructed with a 17% slope, steeper than accepted practice for the Brisbane City Council (BCC) which would normally use a 10% slope for this purpose (Cairney and Steer 2018; Figure 3.21).

Figure 3.21:View of Somerset Street Bikeway crossing from observation camera, Brisbane

Source: Cairney and Steer 2018

Performance evidence

Given the unique design and departure from standard practice, a safety review (Troutbeck 2017) and series of evaluations of user behaviour have been carried out (CDM Research 2016; Cairney and Steer 2018) to understand likely safety outcomes, usability, and comfort considerations. Eighty interactions between cyclists and motorists as well as pedestrians and motorists (CDM Research 2016) found a strong majority of motorists giving way as required, with a minority of cyclists and pedestrians waving the motorist through. Six interactions involved some confusion and one incident required a major adjustment to a vehicle path – where a motorist braked late and suddenly for cyclist who had also slowed as a precaution. No design issues were attributed to the interactions noted.

Cairney and Steer (2018) determined whether the treatment performed satisfactorily in terms of: (a) catering for pedestrian and cyclist interactions with motor vehicles, (b) providing a comfortable crossing experience for vehicle occupants, and (c) not increasing the risk of damage to motor vehicles. This evaluation found that the steeper ramps met the criteria for success: there were no serious conflicts between cyclists/pedestrians and motor vehicles during the observation period and, although the ramps were judged to be less comfortable than other ramps tested in the study, there were very few 'very uncomfortable' ratings. There also appeared to be no risk of vehicle grounding.

Other applications and design guidance

Another application of a raised priority crossing in Queensland is shown below in Figure 3.22.

Figure 3.22: Raised priority crossing for a shared pathway (Mooloolaba, Queensland)

Source: Department of Transport and Main Roads 2019.

The Department of Transport and Main Roads in Queensland (Department of Transport and Main Roads 2019) has created a Technical Guideline for Raised priority crossings for pedestrians and cycle paths (Department of Transport and Main Roads 2019), covering a range of applications including local side roads, slip lanes, and mid-blocks, and capturing design elements that have been identified from existing facilities, particularly the priority cycle crossing outlined above. The Guidance also draws on the findings of a range of evaluations of bicycle priority facilities, which have shown positive outcomes, and indicates essential, important, highly desirable, and supportive attributes of crossings. A range of applications are also showcased from Australian cities.

3.6 Summary

The literature review has shown that RSPs are a promising road safety countermeasure with emerging practice and evidence in Australia and New Zealand. For urban signalised intersection case studies in Australia and New Zealand, evaluation of intermediate outcomes is positive, although it will take longer to capture the actual safety benefits. In the meantime, in addition to the positive emerging outcomes, earlier positive safety benefits from the Netherlands are useful to help justify further development and roll-out. A range of design parameters in these applications may still need consolidating, although the VicRoads Guidance provides a very helpful start.

Raised safety platforms are also showing potential or demonstrated benefit at roundabouts, cycling facilities, priority-controlled intersections, and crossings on arterial roads. The demonstration projects or applications for these that exist need to be further interrogated and replicated so that design guidance can ultimately be established and used by the sector. Guidance already exists for some of these, such as raised priority crossings for cycleways.

4. RSP Site Investigations - Method

In the second stage of the raised safety platform research, the research team undertook a series of site visits to selected existing RSP treatments in Australia and New Zealand. This chapter details the purpose and objectives of the visits, the methodology used to select and investigate the treatments visited and presents the findings from each investigation.

The research team would like to thank all local staff and other stakeholders who helped to arrange and facilitate the site visits and who took part in data collection.

4.1 Purpose and Objectives

The purpose of the RSP site investigations was to investigate the design and performance of a sample of existing RSP treatments, covering treatments of both primary and secondary interest in the current research.

The research objectives were:

- select and examine a sample of existing RSP treatments on design and performance dimensions of focus in the research
- collect further evidence on local design and performance where this exists, beyond existing literature, for each selected treatment
- compare local design and performance outcomes against existing practice identified in the literature
- identify areas where further or revised RSP design guidance is warranted.

4.2 Site Sample Selection

A list of existing RSP treatments in Australia and New Zealand was collected as they were identified through the literature review and stakeholder consultation. The derived list included treatments of both primary and secondary interest in the research and provided the population sample from which the jurisdictions and treatments included in the research were selected.

While a range of criteria were used to select the treatments, priority was given to treatments that met the definition of primary interest to the research (i.e. RSPs at signalised intersections on arterial roads).

The selection criteria used were as follows:

- existing RSP treatments of primary interest to the research
- existing RSP treatments of secondary interest to the research (including RSP treatments providing specific innovation over and above existing routine RSP applications)
- mix of urban and rural contexts
- extent of existing evidence and understanding[12]
- convenience and accessibility – this included consideration of site locations that would enable multiple treatments to be visited in each site visit.

12 For example, less priority was given to the Belmont RSP as this treatment has had a high level of previous evaluation.

The initial derived list of proposed treatments was presented to the research Project Reference Group (PRG) and finalised through subsequent discussions and evaluation against the criteria. A total of two jurisdictions were selected, these being Victoria (Australia) and Hamilton/Auckland (New Zealand). While the research design had allowed for up to three jurisdictions to be visited, the treatment identification process confirmed that most local examples at arterial signalised intersections are currently in Victoria. While the Netherlands also provides many examples of this application, visiting these sites was beyond project feasibility.

Seven intersection treatment locations were visited in Victoria with five of these being RSPs at arterial signalised intersections and two being RSP treatments of secondary interest. While the Belmont treatment is of primary interest, and was visited, limited primary data was collected as there is a high level of existing evaluation data for the site (see literature review).

Two treatment locations were visited in Hamilton with these being treatments of secondary interest; therefore limited primary data was collected for each treatment. While the Thomas/Gordonton Road RSP in Hamilton is a treatment of primary interest, it was not visited as it was recently subject to a comprehensive evaluation (see literature review). Any further reporting in this chapter on the design and performance of this treatment draws from the previous evaluation.

Auckland does not currently have any RSPs at arterial signalised intersections, however, two examples of raised priority-controlled intersections with roundabouts were included in Auckland site visits. Auckland also provides an opportunity to learn from the significant amount of planning work that has been undertaken in the city in preparation for the future installation of RSPs. There has also been a considerable amount of internal operational research by Auckland Transport (AT) to determine optimal platform design, and an example of accelerometry measurements over a mid-block raised zebra crossing that has been designed to be effective yet comfortable to buses is presented.

Table 4.1 shows the final sample of treatments visited and the key selection criteria for each.

Table 4.1: RSP treatments visited and their selection criteria

Location	RSP treatment type	Other selection criteria or innovation
Victoria/Melbourne (AUS)		
Treatments of primary interest		
Thomastown (High Street intersections with Spring Street; Station Street; Main Street; Cooper Street)	+50 km/h arterial signalised intersection	Multiple intersections route treatment in more pedestrianised area
Thomastown (Dalton Road intersections with Spencer Street; Alexander Avenue; The Boulevard; Childs Road)	+50 km/h arterial signalised intersection	Multiple intersections route treatment in less pedestrianised area
Whittlesea (Plenty Road/Wallan Road/Macmeikan Street/Laurel Street)	+50 km/h arterial signalised intersection	School adjacent to important regional intersection
Wonthaggi, South Gippsland	+50 km/h arterial signalised intersection	Recent raised intersection
Belmont (Surf Coast Highway/Kidman Avenue)	RSP at arterial signalised intersection	Longest established RSP application (Oct 2015)
Treatments of secondary interest		
Lance Creek, Victoria (Korumburra-Wonthaggi Road/Glen Alvie Road/West Creek Road/Lance Creek Road)	Compact rural roundabout with RSPs	Alternative to full sized rural roundabout
Moray St, City of Port Philip, South Melbourne (Moray/Coventry Street; Moray/Dorcas Street; Moray (between Cobden/Raglan Street)	Cycle roundabouts with RSPs	Urban roundabout with much higher level of service for cyclists than usual

Location	RSP treatment type	Other selection criteria or innovation
Hamilton/Auckland (NZ)		
Treatments of secondary interest		
Anglesea/Bryce Street, Central City, Hamilton	RSP at signalised intersection (50km speed environment)	Unique raised intersection in 50 km/h city centre location, with adjacent bus terminal
Two suburban locations, Hamilton	RSPs at signalised mid-block crossings	Safe System midblock pedestrian crossing on arterial roads
Suburban and central city, Auckland	Raised priority-controlled intersections with raised intersection roundabout	Safe System priority-controlled intersection
Arterial road, Auckland	Mid-block zebra crossing	Bus friendly ramp profile

4.3 Site Investigation Method

The site investigation methods used for each site and treatment visited are detailed in the following section.

4.3.1 Development of Investigation Framework Matrix

For the applications of primary interest, a generic framework matrix was developed to guide the design, focus and implementation of all investigation methods used at each site. In overview, the framework specified the following:

- Summarise the key design and performance outcomes identified in the literature review.
- Investigate the design and performance of each local treatment using the design and performance dimensions focused on in the research.
- Compare local design and performance against the literature and identify any differences, advances or gaps in knowledge regarding RSP design and performance.
- Suggest principles for guidance adjustments and assess the level of certainty[13] around best practice on key design and performance dimensions.

4.3.2 Victoria Site Visits

The Victoria site visit was conducted over 24-26 February 2020. In addition to the treatment site visits, a stakeholder workshop and conversation with a Signals Officer from the Victoria DOT, was also held (see later detail).

Treatment site visits

Site visits were planned in conjunction with a local host from Victoria DOT and the regional PRG member for this project. An itinerary was designed and all safety procedures and logistics were addressed.

The following data were collected at each RSP treatment visited, with more time and data collection undertaken at each site of primary interest. For these sites, the goal was to add to the pool of information that will ultimately influence design guidance. For the sites of secondary interest, the goal was to highlight these relatively innovative applications and to collate any readily available information of value. Exceptions included relatively more data collection at Lance Creek and the Moray St cycle roundabouts, given they represent particularly innovative practices.

13 Established; emerging; contested/uncertain.

Measures carried out at the sites of primary interest (60 km/h or greater signalised intersections) included:

- Site inspection via drive-throughs and roadside observation.
- Video of traffic behaviour through intersection and via drive-through to capture the sign and marking layout on approach.
- Photos (roadside and drive-through).
- Accelerometry (using the same method described by Mackie et al 2019), with multiple measures from various directions. This involved using the accelerometer feature from a Samsung Galaxy A5 smart phone, via opensource software SensorLab, sampling at 25 Hz. The phone was placed horizontally on the leading edge of the front passenger seat as a driver passed over the RSPs at various approaches and speeds. Care was taken to avoid hard braking, however there were variations in the time available to collect sufficient high-quality data among the other information being collected at these multiple site visits. Apart from site related causes of data variability, there was variation in the vehicle used and the driver. At Wanthaggi, Lance Creek, and the Melbourne cycle friendly roundabouts a recent model Subaru Liberty was used and at other sites a recent model Holden Astra was used. In New Zealand a recent model Honda Odyssey was used. We found that with sufficient time and a lack of other traffic to constrain driving behaviour, the Lance Creek measurements provided the most numerous and repeatable measures. For other sites, it needs to be remembered that the data provides a reasonable indication of the characteristics of each site, but a larger set of repeated data in very controlled conditions would be needed for any site to achieve a robust understanding of the accelerations experienced whilst travelling over the RSPs.
- Key informant conversations as available (e.g. local resident Wonthaggi, local pedestrian Moray Street).

Stakeholder workshops

In each jurisdiction (Victoria and Hamilton/Auckland) a two-hour workshop was carried out to further understand the design and performance dimensions of local RSP applications.

The design of each workshop followed the general structure of the site investigation framework, that is:

- a summary of literature review findings for each design and performance dimension of interest
- a discussion of design and performance dimensions of local treatments, existing evidence, and local lessons
- identification of any differences between the local treatments and literature review.

More weight was given to aspects of RSP design/performance as per the expertise and issues raised by the group. The goal was to cover as many of the design/performance dimensions as possible while giving weight to areas of interest identified by the group. Detailed notes were taken throughout each workshop and additions made to the design/performance matrix (as show in Section 6).

Follow-up validation

Validation of the information from the site visits was carried out through peer review of this report by local Victoria and Hamilton/Auckland personnel along with the project control group. Hence, this report incorporates the feedback of those people.

5. Site Investigation Findings

This section provides an account of the site investigation findings from the sites outlined in the previous section.

5.1 RSPs at Arterial Signalised Intersections Above 50 km/h

5.1.1 Thomastown (High Street)

Description

High Street is a major arterial road in Thomastown that has changing land use along its extent. At a location that includes a shopping strip, new train station facilities, and 60 km/h speed limit, a series of RSPs were installed at three signalised intersections in 2019 (Spring St, Station St, Main St), as shown below in Figure 5.1. RSPs were also installed at a less pedestrianised intersection further north (Cooper St).

Figure 5.1: Raised safety platforms on High Street, Thomastown, Melbourne

Design features

Advisory speed: 40 km/h, with raised intersection warning sign.

Marking layout: Stop line in advance of ramp (2) and on ramp (2).

A range of signs are employed on approach including speed limit and school zone signs, and unique raised intersection advisory signage with a platform symbol (see Figure 5.1 above). There is therefore potential for confusion around appropriate speeds with the mix of advisory and speed limit signs. Different layouts have been employed for stop line location.

Variable Message Signs (VMS) were used to warn traffic when the RSPs were newly installed.

Table 5.1 below provides further detail of the site and design features of each of the High Street applications.

Table 5.1: Site and design features of High Street RSP applications

Location		Existing signals	Speed limit		Profile				Platform location
Road 1	Road 2		Before	After	RSP Type	Approach	Departure	Height	
High St	Spring St	Yes	60 km/h, with time-based 40 km/h through majority of day	60 km/h, with time-based 40 km/h through majority of day	Raised Intersection	1:20	1:20	100mm	Existing signalised T-intersection (located nearby Station St)
High St	Station St	Yes			Raised Intersection	1:20	1:20	100mm	Existing signalised T-intersection (located nearby Spring St)
High St	Main St	Yes			Raised Intersection	1:20	1:20	100mm	Existing signalised T-intersection
High St	Cooper St	Yes	60-70 km/h	60 km/h	Approach Platforms	1:20	1:35	100mm	Existing signalised X-intersection

Performance

See acceleration data later in section 5.1.6, and speed data in Cairney et al (2019a). There has been a reduction in 85th percentile speeds on approach to the three southern intersections from 54 km/h to 43 km/h, a result very close to the advisory speeds for the intersections.

Stakeholder and community acceptance: No ongoing negative feedback, based on stakeholder workshop described later.

Other: Where the stop line is on the raised intersection, some people stop before the ramp, but this isn't seen as problematic. There have been minor drainage issues at Main/High. No unusual or concerning behaviour was detected in video footage and through site observations.

5.1.2 Thomastown (Dalton Road)

Description

Dalton Road is a major north/south arterial road also in Thomastown, but with a lower level of 'place' function, less pedestrian activity, and with a greater number of traffic lanes. The speed limit is 60 km/h and approach platforms (3) or raised intersections (1) have been installed at four intersections along Dalton Road. Spencer Street, Alexander Avenue, and The Boulevard are all closely spaced and were completed in 2019, while Childs Rd is located further north with the raised intersection installed in late 2017 (Figure 5.2).

Figure 5.2: Raised safety platforms on Dalton Road, Thomastown, Melbourne

Design features

Advisory speed: 40 km/h, with a conventional speed hump warning sign. 50 km/h dip advisory signs are located on departure for the Dalton/Childs site only (Figure 5.3). Note that this signage is not used at the newer sites further south, as it was considered the signage was not needed. Truck tilting signage was also present at Dalton/Childs (but not the rest of the more recent intersections).

Table 5.2 below provides further detail of the site and design features of each of the Dalton Road applications.

Table 5.2: Site and design features of Dalton Road RSP applications

Location		Existing signals	Speed limit (km/h)		Profile				Platform location
Road 1	Road 2		Before	After	RSP Type	Approach	Departure	Height	
Dalton Rd	Childs Rd	No	60	60	Raised Intersection	1:30	1:35	100mm	Two safety platforms with setback and fully raised intersection being considered
Dalton Rd	Spencer St	No	60	60	Approach Platforms	1:20	1:35	100mm	Un-signalised T-intersection
Dalton Rd	Alexander Ave	Yes	60	60	Approach Platforms	1:20	1:35	100mm	Existing signalised X-intersection
Dalton Rd	The Boulevard	Yes	60	60	Approach Platforms	1:20	1:35	100mm	Existing signalised X-intersection

Figure 5.3: Raised intersection departure ramp and signage on Dalton Rd, Thomastown, Melbourne

Source: Google maps 27 November 2019 ©2019 Google, New Zealand.

Marking layout: Stop line on platform with piano keys in advance, except for Dalton/Childs which as these located in advance of the platforms.

A range of ramp profiles, but all with the intention of 1:25 (except for Dalton/Childs). All RSPs were retrofits, except for Dalton/Spencer which was previously a priority-controlled intersection. This means any analyses are mostly able to isolate the impacts of the RSPs, depending on what other intersection and traffic changes have happened over the analysis period.

As per the High St sites, variable Message Signs (VMS) were used to warn traffic when the RSPs were newly installed.

Performance

Acceleration: See acceleration data in section 5.1.6. There is large variation in the data, with Dalton/Childs (raised intersection) having significantly less profile and vertical acceleration than Dalton/Spencer in particular. A paving machine was used for the Childs intersection, whereas the later Dalton/Spencer (and other Dalton Road intersections) was hand-formed.

Speed: See earlier review of literature (Cairney et al 2019a). The mean speed along three Dalton intersections (excluding Dalton/Childs) decreased from 60 km/h to 43 km/h, which is again very close to the advisory speed for these intersections. Some of this speed reduction could also be the result of changes in traffic patterns.

Stakeholder and community acceptance: No ongoing negative feedback based on stakeholder workshop mentioned later, but still some stakeholder resistance to RSPs at signalised intersections. No negative feedback about noise.

Other: Occasional heavy braking before the platforms has been observed.

Based on observation of video at Dalton/Spencer (which has the most aggressive ramps in the suite of intersections on Dalton), it was noted that generally the traffic responded well to the ramps with a mixture of slight slowing and deliberate braking for the ramps. Vehicles that tended to brake more, to around 30 km/h, included laden trucks, lowered cars, and emergency vehicles (Figure 5.4). There was one instance of a van braking hard before the ramps.

Figure 5.4: An ambulance and van braking at the Dalton/Spencer RSP in Thomastown, Melbourne

5.1.3 Whittlesea

Description

The RSPs forming a raised intersection at Whittlesea (northern extremity of Melbourne) are part of a new intersection that has recently been constructed (Figure 5.5). The speed limit on the major road approaches is 60 km/h, but a variable 40 km/h school zone applies during school commuting times. School crossing supervisors are present during these times. This is also a major junction for the area.

Figure 5.5: Raised intersection at Plenty/Whittlesea-Yea/Wallan Rds in Whittlesea, Melbourne

Design features

Ramp type: Raised intersection.

Ramp profile: 1:25 on approach.

Advisory speed: 40 km/h, with raised intersection warning and tilting truck signs.

Marking layout: Stop line ahead of platform and piano keys.

Other features: Bollards on corners, signs on approaches for various purposes including for navigation and a variable speed limit sign for the school zone (Figure 5.6), but no speed limit signs. The array of signage located immediately on approach to the intersection from Wallan Road may make the raised intersection warning signage less conspicuous.

Figure 5.6: School variable speed limit sign on approach to Whittlesea raised intersection, Melbourne

Performance

Acceleration: See data in section 5.1.6.

Speed: None available.

Stakeholder and community acceptance: Seen as a vast improvement on previous intersection; some local views that speed may have crept up again over time, according to crossing supervisors who are present during school commuting times.

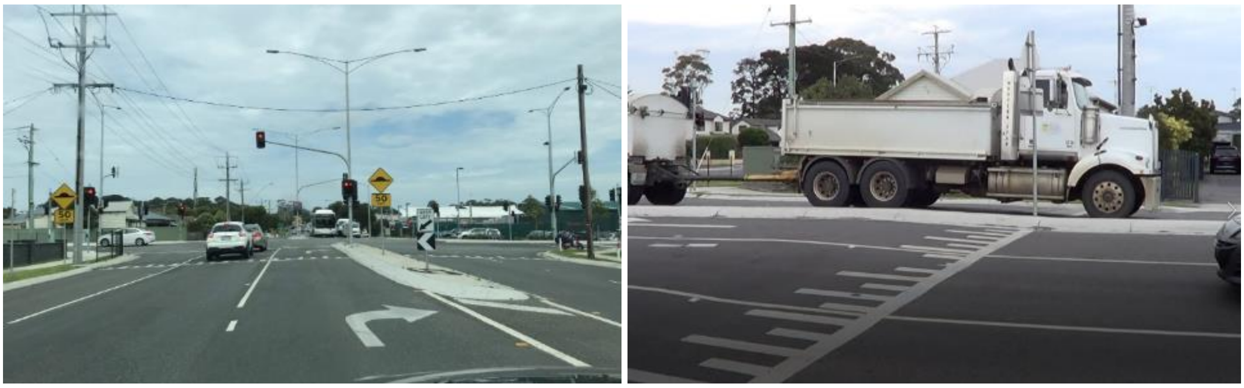
Other: Significant congestion and pedestrian presence at the end of the school day.

5.1.4 Wonthaggi

Description

In Wonthaggi, a 1.5 hour drive southeast of Melbourne, a new intersection was installed at Bass Highway/Korumburra-Wonthaggi Road (Figure 5.7) to upgrade a previous priority-controlled crossroad. The speed limit on three of the four approaches is 60 km/h.

Figure 5.7: RSPs at Bass Highway (McKenzie St) intersection in Wonthaggi, Victoria



Design features

Ramp type: Raised intersection.

Ramp profile: 1:25 on approach; 1:30 on departure (more severe than the typical 1:35 used at other sites).

Advisory speed: 50 km/h, with conventional speed hump warning signs.

Marking layout: Stop line ahead of platform and piano keys.

Other features: 60 km/h speed limit signs on approach.

Performance

Acceleration: See acceleration data in section 5.1.6.

Speed: 85th percentile speeds along Bass Highway (McKenzie Street) have decreased from 55-57 km/h to 41-44 km/h, which is well below the 50 km/h speed advisory (unpublished traffic data, soon to be reported by ARRB).

Stakeholder and community acceptance: According to regions surveillance officer it is generally seen as a vast improvement on the previous intersection. However, there has been some negative feedback about the platforms also, although no evidence of significant community concern.

Other: There have been reports of noise from trucks and other vehicles with trailers or loose loads, which was verified by a conversation and observation with one local resident who lives next to the intersection. A key issue seemed to be the severity of the southbound departure ramp and several examples of noisy vehicles leaving the ramps were noted. However, this was in the context of overall appreciation for the intersection upgrade.

5.1.5 Belmont (Geelong)

Description

This intersection at Surf Coast Highway/Kidman Avenue was the first RSP application in Victoria and has previously been comprehensively evaluated (see literature review; Figure 5.8).

Figure 5.8: RSPs at Surf Coast Highway/Kidman Ave intersection in Belmont, Geelong

Design features

Ramp type: Raised platforms on approach.

Ramp profile: 1:30 on approach; 1:35 on departure

Advisory speed: 50 km/h, with conventional speed hump warning signs.

Marking layout: Stop line ahead of platform, yellow piano keys, and bicycle markings (Figure 5.8).

Other features: 60 km/h speed limit signs on approach, otherwise relatively 'clean' (i.e. little signage).

Performance

Acceleration: See some limited acceleration data in section 5.1.6.

Speed: See Candappa and Corben (2015), summarised in literature review, with 85th percentile speed reducing by 13 km/h following the introduction of the RSPs.

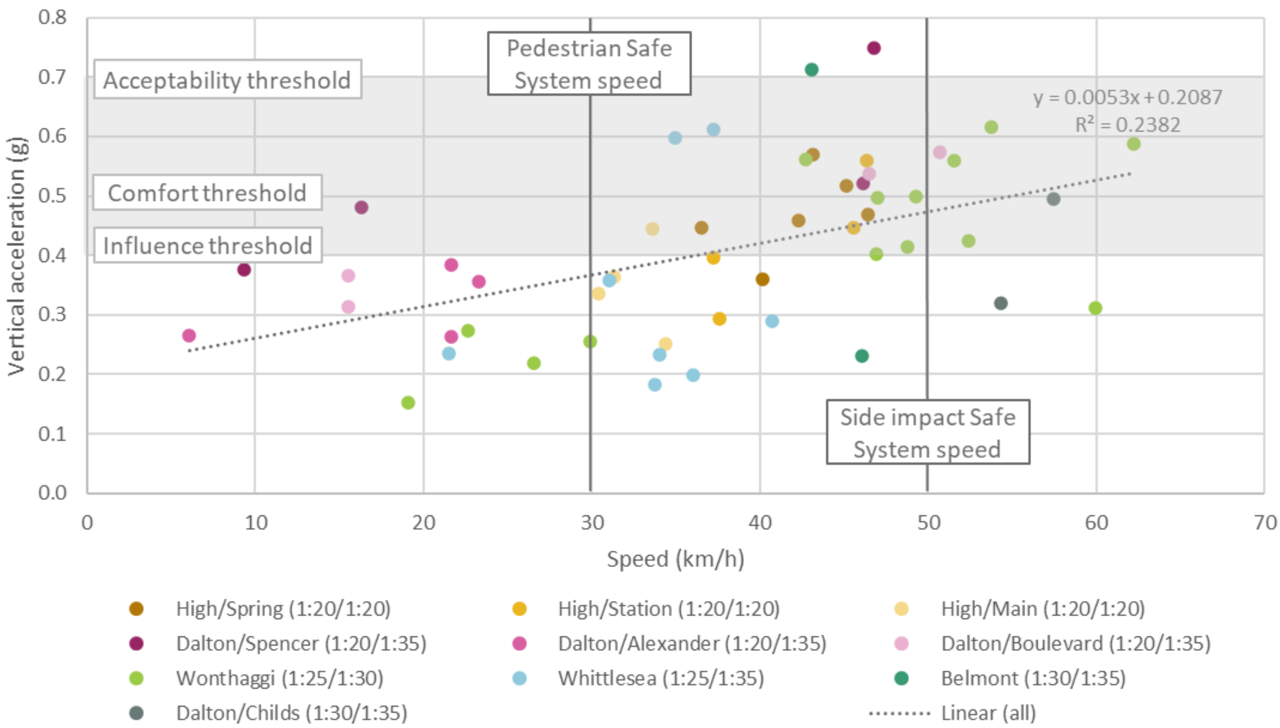
Stakeholder and community acceptance: No lasting community resistance from information collected.

Other: RSPs were included in the intersection re-build that included associated and significant stormwater works.

5.1.6 Summary of Acceleration Data

Accelerometer data were collected as described in the method earlier. A summary of the vertical acceleration readings at primary interest sites in Victoria (all described earlier) are shown below in Figure 5.9. The plot includes peak acceleration for both approach and departure measurements at the different intersections.

Figure 5.9: Vertical acceleration data for all signalised arterial RSP sites visited in Victoria

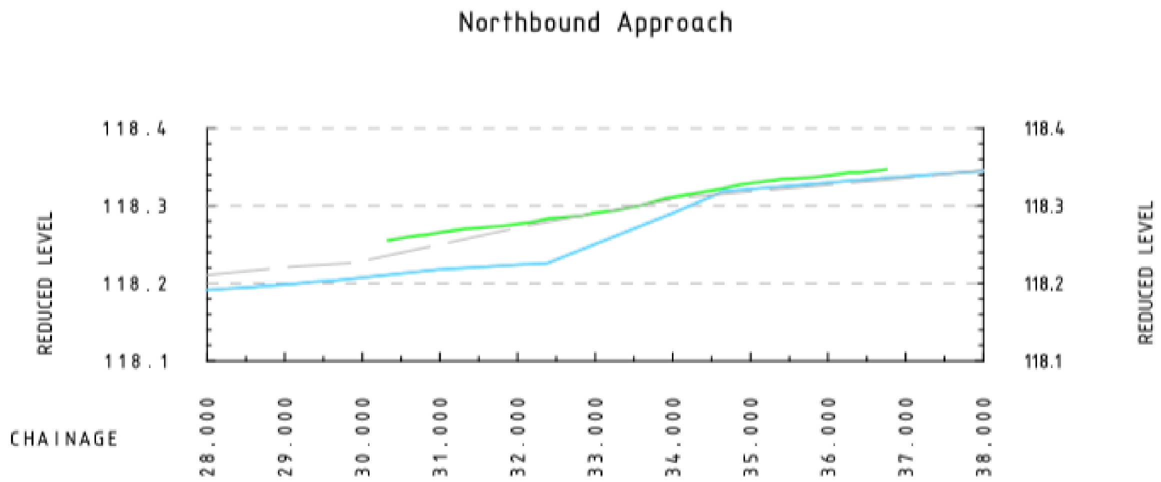


There are some notable trends in the data:

- There is considerable variation in the data given the various conditions that were measured. There were some unexpected outliers (e.g. Belmont has a very high acceleration reading of 0.71 g at 43 km/h), which seems unrealistic and may have resulted from some sudden movement by or within the vehicle. The case studies and earlier reported literature suggests that the 0.4-0.7g range is likely to be most effective in reducing speeds, with 0.5g being an important comfort threshold for speed reduction.
- There are clear differences in the aggressiveness of the ramps at different intersections. For example, the approach ramp acceleration for Dalton/Childs (approximately 0.32 g at 54 km/h, interestingly with a stronger departure) had a very low response, while Dalton/Spencer had vertical accelerations well above 0.5 g for speeds over 40 km/h.
- There are different outcomes from different designs, e.g. 1:20 profiles with a 40 km/h advisory speed at High Street, Thomastown, compared with the 1:25 profiles and 50 km/h advisory speed at Wonthaggi. However, Dalton/Spencer, as mentioned above, had very high vertical accelerations with 1:20 ramps and 40 km/h advisory speed, which interestingly isn't shown for some lower speed applications later in the report. This effect may have resulted from as-built ramp grades being slightly more severe than what was designed.
- The overall trend, while highly variable, shows increasing vertical acceleration at increasing speeds.

There may be several reasons for the variation in the data. Actual constructed profiles may have differed from specified profiles, as was the case at Dalton/Childs. Figure 5.10 is an example of how the designed profile differs substantially from the built profile. It is understood this occurred as a result of limitations in the construction machinery used to form the ramps. There is likely to be some limitations on the accuracy of the data collected, but the main point of more shallow as-build profiles is likely to remain.

Figure 5.10: Example of designed profile (blue), vs 'as built' profile (green) for Dalton Childs Intersection.



Source: Dalton Rd Childs intersection post construction ramp feature survey results, VicRoads, 11/2/2019

Other measurement factors may include different vehicles being used for some of the data, and slight variations in forward acceleration depending on whether the vehicle was speeding up or slowing down. In addition, different lanes may have slightly different gradients. All effort was made to have the vehicle pass over the RSPs at a constant velocity and in the same lane, but this wasn't always possible in the actual traffic situations the data was collected in.

5.1.7 Victoria RSP workshop

A workshop was held at the DOT Footscray office, with DOT staff who have been involved with RSP planning and delivery (Table 5.3 below).

Table 5.3: Attendees at Victoria RSP workshop

Name	Title	Business Area
Aura Gina Dimacali	Team Leader Development	Safer Roads
Evan Goulden	Team Leader Road Design West	Road and Traffic Engineering
Ibrahim Younes	Projects Engineer	Metro North West
Madeleine Kastner	Communications and Engagement Lead	Metropolitan Communications and Engagement
Radie Maliki	Senior Program Coordinator	Safer Roads
Russell Gardner	Senior Officer - Road Design	Road and Traffic Engineering
Tandy Pok Arundell	Senior Evaluation Officer	Safer Roads
Sarah Morris	Senior Program Coordinator	Safer Roads
Sean Yates	Lead Engineer - Road Design and Safe System Engineering	Road and Traffic Engineering
Hamish Mackie	Director	Mackie Research
Rebekah Thorne	Researcher	Mackie Research

The purpose of the workshop was to introduce the Austroads project, share key findings from the literature review, and then discuss the design and performance dimensions that have been developed for RSPs. The discussion and issues raised were used to further populate the design/performance matrix (Table 6.1) during the workshop itself. In addition, the following key points were discussed:

- Lance Creek is generally perceived through evaluations and by the project teams to be very successful and more people are being encouraged to consider this kind of design. Several million dollars were saved by taking this approach over a conventional roundabout approach.
- Compact roundabouts (more compact than conventional and very compact within existing road geometry) are increasingly being considered a viable solution in Australia and New Zealand.
- Community engagement could be further improved around RSP applications.
- Funding levers are available and have been used to encourage installation of RSPs (e.g. at the Belmont site, SSRIP funding for traffic signals was contingent on installation of RSPs).
- In Thomastown, a range of different site characteristics were chosen to learn more about the effectiveness of the treatments in different situations.
- There appears to be variable outcomes in terms of platform shape, with some intersections having insufficient vertical deflection because of the construction process.
- It seems easier to construct new intersections, with retrofit intersections much harder.
- RSPs at signalised urban arterials cost approximately $800-900K for retrofits and $300k for new. However, there are likely to be costs related to services and signal hardware that is likely to be attributed to retrofits, whereas these are probably not attributed to the RSP within a whole intersection upgrade.
- Considerable attention is needed to correctly construct ramps; small deviations from design can lead to ineffectiveness or conversely a severe response.
- The Thomastown RSPs initially attracted considerable public feedback (e.g. 175 mostly negative emails) as well as ministerial requests. Emails from the public have since reduced to about four to five per month. Most emails received have related to Dalton Road rather than High Street suggesting RSPs are perceived by the public as more credible in the High Street context.
- Having design guidance moved upwards into Austroads Guides will be useful in establishing sector credibility.
- It is important to provide evidence that Safe System speeds are being achieved, rather than simply that speed reduction has occurred. Safe System speeds are the critical measure of success.

As representation at the workshop was impossible, an online meeting was later held with a member of the signal operations team. Several points were noted:

- Signal phase lengths are adjusted at RSP intersections which extend the inter-green time and reduce the green time: red and amber phases have been extended to provide more time for vehicles travelling at the RSP advisory speed (40 km/h) to travel through the intersection. In addition, along Dalton Road, one right-turn signal has been reduced in frequency to occur only every other phase.
- The stop line at some RSP intersections is further back than would otherwise be the case, which increases the size of intersections and the time needed for vehicles to travel through it, as well as resulting in some motorists getting 'stuck' beyond the stop line (and detector loops) during a red phase. The newer design with vehicle stop lines marked on top of the platform is preferred as it minimises this impact. Consideration of detector loop location depending on stop line location is also important.
- Comparing throughput data from before and after the RSPs were installed shows there may be some reduction in the number of vehicles travelling through the Dalton Road intersections during peak times, particularly for right-turning. However, for free-flowing conditions, off-peak SCATS data also provided suggests there is no overall reduction in vehicle volumes between 2018 and 2019. This suggests that traffic volume changes may relate to factors other than the RSPs, except for right-turning vehicles where there may be some impact.
- Ramp grades are a little inconsistent across intersections, and relatively steeper departure ramp grades, such as those on High Street, have resulted in some pavement gouging.
- The increased intersection sizes associated with RSPs and encouragement of motorists to slow down as they enter intersections are at odds with signals operations objectives around maximising intersection capacity/operational time and reducing congestion.

In addition, observations of the Dalton Road intersections included that motorists have mixed responses to the RSPs, with some vehicles observed braking heavily to go over the platforms rather than slowing gently. Vehicles with cabins directly above the front axles (e.g. trucks) and those carrying equipment have been observed going over the platforms especially slowly, while other vehicles go relatively quickly, which may increase the risk of rear-end crashes. Differences in motorist responses may be exacerbated by one or two intersections with lower grades across the intersections (e.g. Dalton/Childs as mentioned earlier). It is also thought this has contributed to increased congestion and reduced flow during peak periods between Alexander Avenue and The Boulevard, particularly for motorists turning right.

These observations raise a number of points related to construction consistency, road safety risk, and traffic efficiency. The construction consistency issue is clear throughout this project, whereas road safety risk and traffic efficiency issues are not evident from other sources. The speed reductions shown by evaluations should translate into reductions in death and serious injury crashes, the focus of safe system treatments, and further evaluation should check that this has happened. For traffic efficiency, this points to a need for a clear strategic approach to managing traffic at intersections. Historically, traffic efficiency has been the dominant factor determining intersection design, but moving towards a Safe System approach, the safety of the intersection and its efficiency, may need to be considered together with a minimum level of safety that is expected for any intersection.

5.1.8 Workshop and Meeting in Hamilton and Auckland

Hamilton workshop

A workshop was held in Hamilton, New Zealand to discuss progress with RSPs since the installation of the initial Thomas Gordonton Intersection (see literature review). The dimensions outlined in Table 14 in Section 6 were again the focus, and most time was spent on areas of particular experience or interest to participants. Workshop participants were listed in Table 5.4 below.

Table 5.4: Attendees at Hamilton RSP workshop

Name	Title	Business Area
Robyn Denton	Network Operations and Use Leader	City Transportation Unit, Hamilton City Council
Simon Crowther	Road Safety Engineer	City Transportation Unit, Hamilton City Council
John Kinghorn	Transport Systems Engineer	City Transportation Unit, Hamilton City Council
Dharmendra Singh	Program Delivery Engineer	City Transportation Unit, Hamilton City Council
Irene Tse	Technical Lead Road Safety Engineering	Network Management, Auckland Transport
Hamish Mackie	Director	Mackie Research

For this workshop there was considerable focus on construction and contracting methods, along with various other matters. The key points from the workshop are outlined below:

- There has been no obvious reduction in intersection performance at Thomas/Gordonton but this is based on operational experience rather than objective data at this stage. The need to tweak signal timing can often be evidence of an impact, however, this has not eventuated for this intersection suggesting any effects are likely to be negligible.
- A new RSP has been installed at the intersection of Anglesea and Bryce Streets in the Hamilton central city. This is a major arterial road with a speed limit of 50 km/h. It has much shorter approach ramps, the whole intersection is raised, and it has approach ramp grades of 1:15 (see case study later).
- A key feature of the Anglesea/Bryce treatment was that the intersection was closed for three weeks to accelerate and simplify the construction process. This reduced health and safety risk, meant no after-hours work was required, and was much easier to deliver. The closure also challenged the notion that vehicle access must be maintained at any cost. Overall, the approach was considered to have been highly successful.
- Another feature of the construction was a close working relationship with the contractor throughout the life of the project, and close cooperation with local business who were potentially significantly affected.
- All RSPs in Hamilton are constructed from asphalt although some have cobblestone paving as well.
- Several other RSP applications in 50 km/h environments are emerging around Hamilton. These included midblock signalised pedestrian crossings, compact roundabouts, and priority controlled intersections.
- New RSPs are being considered on higher speed roads (e.g. Wairere Drive) with an 80 km/h speed limit, so there will be opportunities to feed best practice back into continuing practice in Hamilton

Auckland meeting

A further workshop was held in Auckland with Irene Tse (Road Safety Engineering Technical Lead) and Fabian Marsh (Austroads Project Manager), to discuss Auckland's RSP developments. Key plans for delivery include:

- RSPs planned for 70 km/h signalised intersections.
- Advanced approach platforms on major arterial roads (50 km/h).
- A recently installed raised intersection and compact roundabout in a suburban town-centre.

Auckland Transport also has a program of testing for various RSP ramp profiles to estimate the effects on bus and car passengers.

5.2 Other RSP Applications

5.2.1 Rural Compact Roundabout – Lance Creek, Victoria

Description

A site visit to the new Lance Creek compact rural roundabout (Figure 5.11) was undertaken to complement the existing evaluation data (see literature review). Video, photos, and acceleration data were collected to get a more nuanced understanding of design characteristics and performance. The research team were joined by a DOT surveillance officer, who was able to provide local insights into the construction process, and community engagement and feedback

The roundabout is an important intersection for regional traffic, and one used by a number of trucks, including those from a nearby quarry. Although the intersection isn't heavily trafficked (around 40 vehicles per hour), at times multiple vehicles can converge on the intersection simultaneously.

The design was $2-3 million less expensive than a full-sized rural roundabout for which significantly more land would have been needed.

Figure 5.11:Raised compact roundabout at Lance Creek, Victoria

Design features

The intersection is compact in nature and features a mountable central apron and side road islands to accommodate trucks. This provides a compact geometry largely within the existing road reserve. There are a range of signs and road surface treatments on the approaches from various directions including rumble transverse lines and 'dragons teeth'. As mentioned earlier, there are instances where repeated speed limit signs are posted on approach to the intersection, which appear, from a driver's perspective, to conflict with the advisory signs accompanying the RSPs (Figure 5.12 below).

Figure 5.12:Speed limit signs on approach to Lance Creek roundabout

Performance

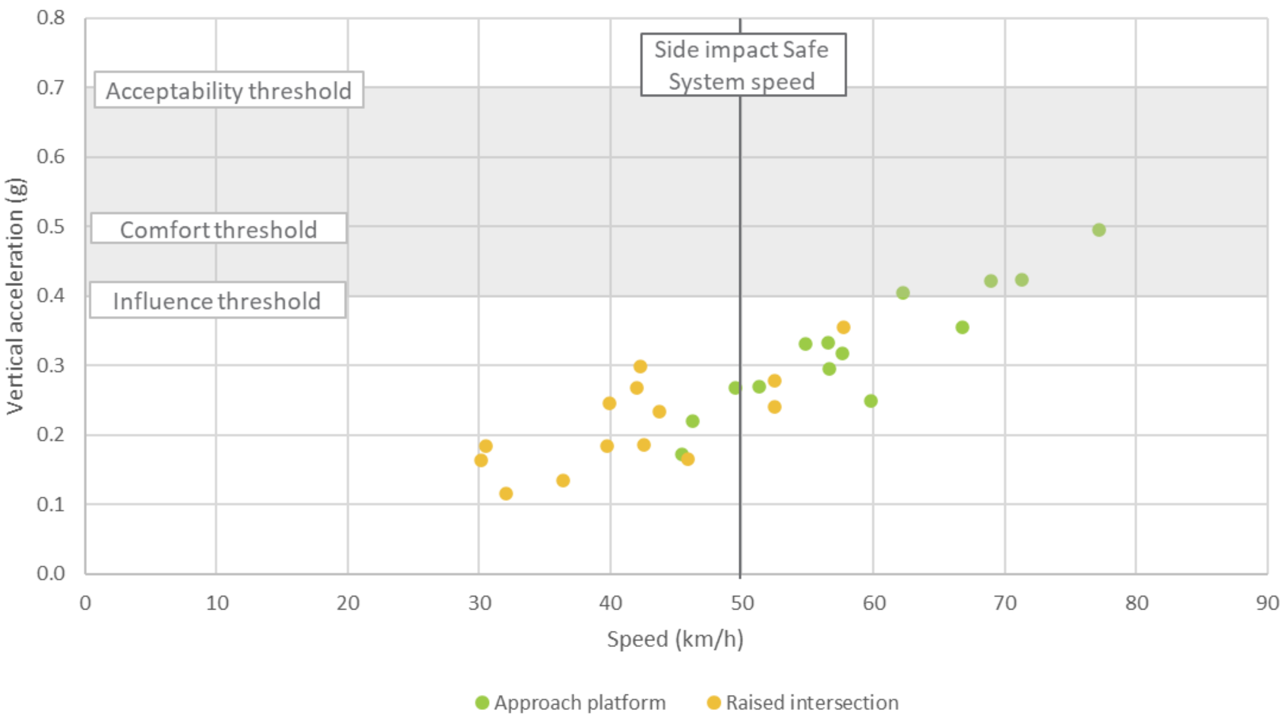
Overall, there is agreement across stakeholders and in evaluation reports that the innovative intersection design, including RSPs, has been well constructed and performs excellently. Data collected onsite revealed the following:

- A range of vehicle types appear to easily and intuitively slow for the intersection and negotiate its geometry.
- The advanced 60 km/h RSPs seem to be effective at slowing traffic on approach to the intersection, with two distinct braking phases shown for many motorists (Figure 5.13).
- There was no noise noticed from a range of trucks travelling over the platforms and there have been no complaints from residents.

Figure 5.13: Braking on approach to Lance Creek roundabout

Vertical acceleration data was collected on the approach to both the approach platform and the raised roundabout treatments (Figure 5.14). Most was collected on the eastbound and westbound approaches, as well as once each on the northbound and southbound approaches.

Figure 5.14: Vertical acceleration data for mounting the approach platforms and the raised intersection at Lance Creek



5.2.2 Urban Cycle-Friendly Roundabout – South Melbourne, Victoria

Description

Two cycle-friendly roundabouts (Figure 5.15) have been installed in South Melbourne (see literature review), to help provide a parallel route for cyclists who might otherwise use a busy arterial road.

Figure 5.15: Cyclist using the raised cycle lane around the Moray St/Dorcas St roundabout in South Melbourne

Performance

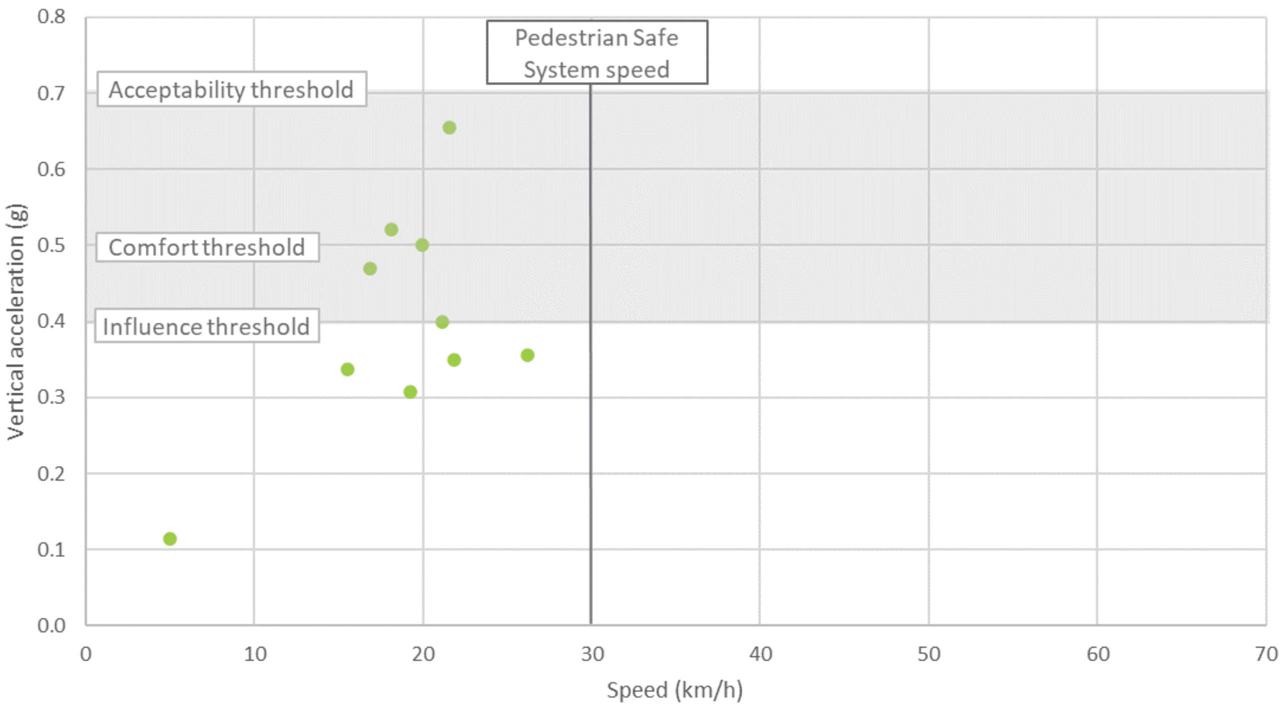
Observations made during the site visits indicated that the roundabouts were generally performing well, with a few minor operation issues, largely in support of the evaluations outlined earlier. Some key points of note are listed below:

- The circulating priority cycle lanes were well used, even by more experienced-looking commuter cyclists on fast bicycles.
- The RSPs on approaches seemed critical to the success of the roundabout, ensuring slow speeds on roundabout entry.
- A ‘dilemma zone’ exists where cyclists entering the crossing converge with motorists exiting the roundabout on the same leg (Figure 5.16). In some cases, there appeared to be uncertainty about right of way. Cyclists were also observed to stop proactively in cases where the driver may not have seen them.
- Some cyclists did not use the circulated lane and instead opted to use the traffic lane within the roundabout, as reported in earlier evaluations.
- Occasional conflicts between cyclists and pedestrians were mentioned by locals who we spoke with on the street, and the potential for this was also observed in various situations.

Figure 5.16: Cyclist-vehicle interaction at the Moray St/Dorcas St roundabout in South Melbourne

Accelerometry data are shown for the Moray Street round about platforms below (Figure 5.17). The plot shows that these platforms are very aggressive, which may be necessary to produce very slow vehicles speeds given the complex nature of the intersection and the various road users drivers need to beware of. In this example it was difficult to approach the platforms at much more than 20 km/h as any higher speed would have felt unsafe given the cognitive workload involved.

Figure 5.17: Accelerometry data for Moray street approach platforms.



5.2.3 50 km/h Signalised Intersection – Hamilton, New Zealand

Description

As previously noted, a signalised intersection in the Hamilton central city with a 50 km/h speed limit has been re-built with a raised intersection (Figure 5.18).

Figure 5.18: Raised intersection at Anglesea St/Bryce St in Hamilton

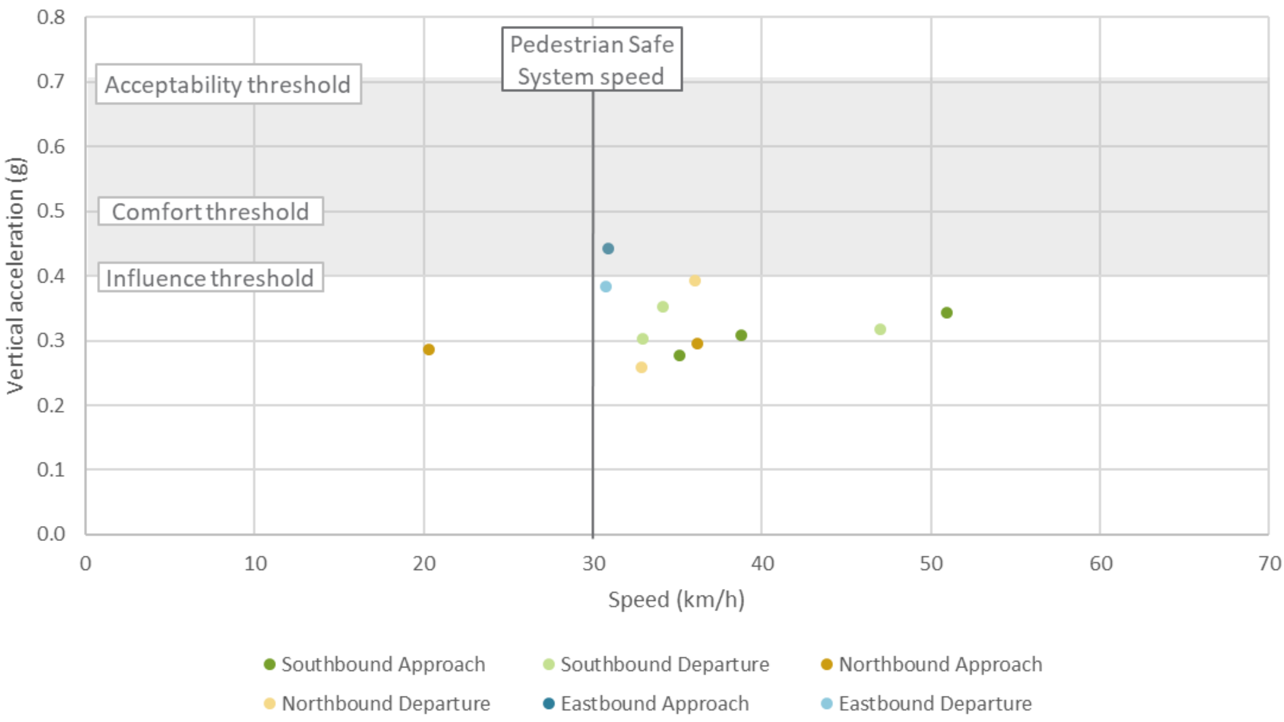
Design features

- Next to city bus terminal.
- Ramps are located closer to intersection than in the higher-speed examples described earlier. The approach gradient is 1:15.
- Designed for 30 km/h travel speed through intersection, with 25 km/h speed hump advisory speed signs.
- Cycle advanced stop boxes immediately ahead of ramps.

Performance

While speed data is not yet available for this intersection, the intersection sits within the City's Bluetooth network measure system and average travel speed between nodes on either side of the intersection on Anglesea Street could be measured immediately before and after construction. Accelerometry data collected reveals an interesting pattern, however, there is not enough data to deduce any strong trend (Figure 5.19). The main finding from this data is that passes at various speeds resulted in vertical acceleration of no more than 0.45g. Although the ramps were designed at 1:15, they felt less aggressive than this when travelling over them.

Figure 5.19:Vertical acceleration data for Anglesea St/Bryce St in Hamilton



5.2.4 Urban signalised mid-block applications – Hamilton, New Zealand

Description

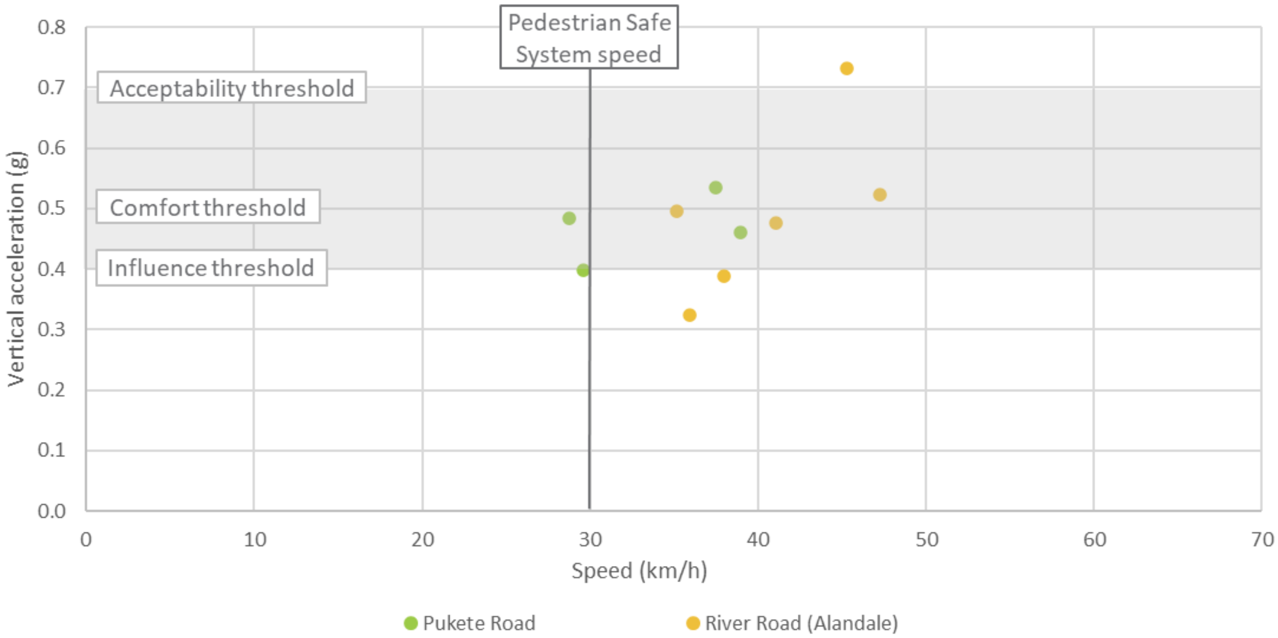
Midblock crossings of various kinds in Hamilton are being upgraded to raised signalised crossings (Figure 5.20). Previous zebra crossings or even zebras with flush painted pedestrian areas have proved to be inadequate in cases, and the move to raised midblock crossings represents a safe system solution. As with most Hamilton RSPs in 50 km/h, these applications have a 1:15 gradient.

Figure 5.20: Raised table signalised crossings on Pukete Rd and River Rd in Hamilton

Performance

Speed data was not available for these sites, however, the vertical acceleration data suggests the raised tables are able to be comfortably driven over up to around 40 km/h.

Figure 5.21: Vertical acceleration data for raised table signalised crossings on Pukete Rd and River Rd in Hamilton



5.2.5 Raised Priority-Controlled Intersections with Raised Intersection and Roundabout

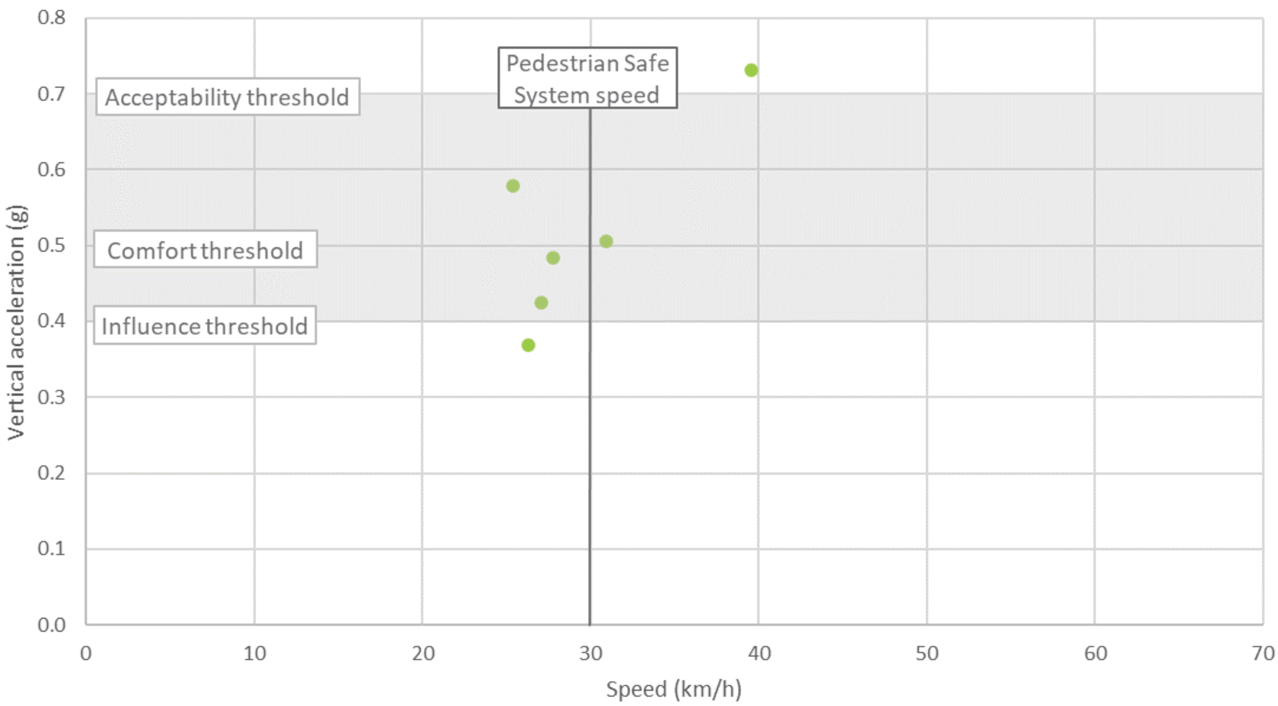
An emerging practice in Auckland is installation of roundabouts on priority-controlled raised intersections (Figure 5.22). Applications on higher volume roads have zebra crossings. while examples on lower volume roads tend to have informal crossing facilities.

Figure 5.22: RSPs at Victoria St/Church St roundabout in Onehunga and Pakenham St/Customs St W in Auckland Central, Auckland

Performance

Vertical acceleration data at the raised crossings on approach to the Victoria/Church roundabout indicates the ramps quickly become uncomfortable at vehicle speeds over 30 km/h (Figure 5.23).

Figure 5.23: Vertical acceleration data for raised table crossings at Victoria St/Church St roundabout in Onehunga, Auckland



5.2.6 Bus-Friendly Mid-block Zebra Crossing, Auckland

Internally, Auckland Transport have been testing various ramp profiles and their comfort for buses. On arterial roads with frequent bus services (Figure 5.24), the standard 1:10 profile that is used for pedestrian facilities is potentially too uncomfortable for bus passengers, and buses need to slow much more than other passenger vehicles to maintain similar levels of passenger comfort. At such locations, lower profile platforms have been installed and are being evaluated, as part of work to understand the effectiveness of speed tables (GHD, 2018).

Following an initial literature review, the authors concluded the literature supported ramps of 100mm in height (75mm for buses to mitigate driver and passenger discomfort) with a 1v:15h slope. It was estimated this slope would achieve approximately 24 km/h mean crossing speeds and 28 km/h 85th percentile crossing speeds. Typical driver comfort limit was concluded to be 5 m/s^2 (0.5g) vertical acceleration, with 7 m/s (0.7g) being the maximum threshold for comfort. Driver perceptions of discomfort were confirmed as generally increasing with crossing speeds towards 40 km/h. The authors concluded that the findings from both the literature review and the field tests supported the recommendation that speed table ramps should be 100 mm in height (with 75 mm for buses), with a 1:15 slope. This design was considered to achieve a good compromise between discomfort for bus passengers and grounding risk, balanced with safety improvements through speed reduction effectiveness.

Figure 5.24: Bus-friendly zebra crossings, Auckland

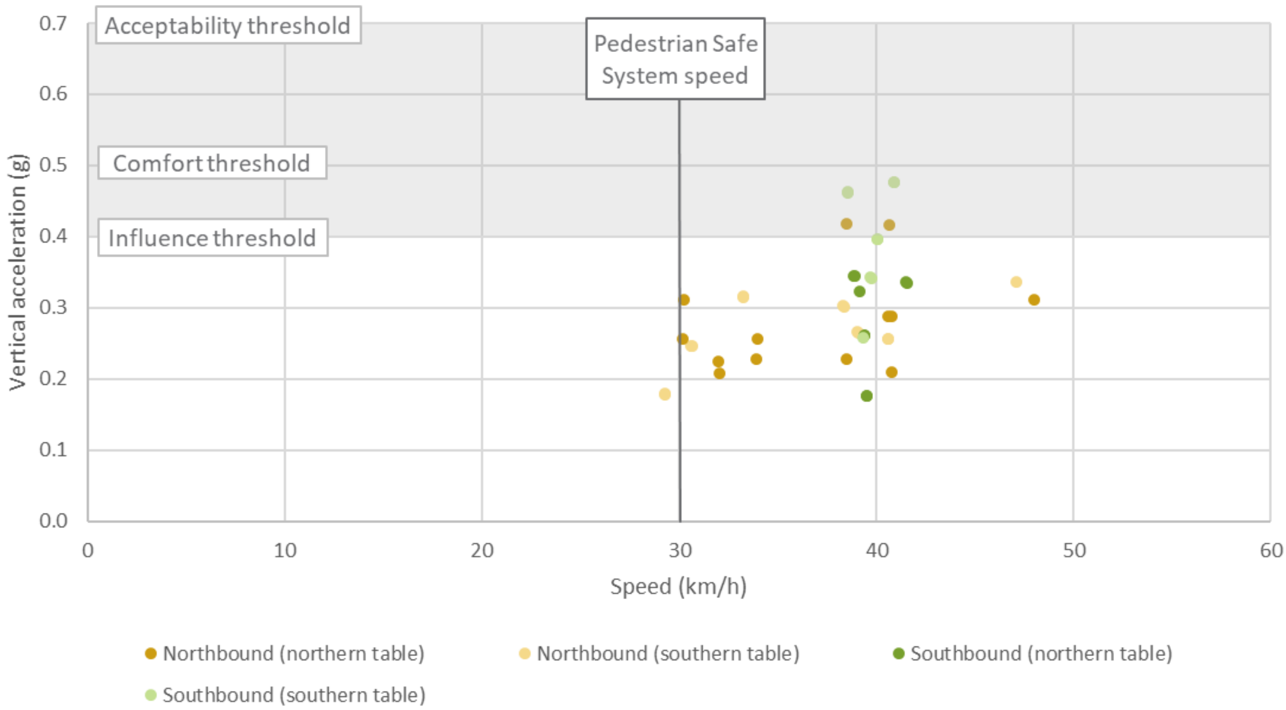
Source: Google maps 25 November 2019 ©Google, New Zealand.

Performance

In addition to the Auckland Transport testing, a number of vehicles passes were made in a car to evaluate the vertical acceleration caused by the more modest than usual platforms. This was also an opportunity to test the repeatability of the acceleration data and so a number of repeated passes were made at a target speed of 40 km/h.

The data (Figure 5.25) shows how generally the platforms are much less severe than the Auckland ones described earlier, as would be expected, with only a few readings showing that they are likely to be severe enough to make much difference to traffic speed. There is also some variation in the data around 40 km/h, reflecting slight differences in ramp gradient for each of the two crossings. Interestingly, although more data would need to be collected to show any strong trend, in a similar way to the Hamilton Anglesea Street raised intersection, there doesn't seem to be a substantial increase in vertical acceleration at higher speeds.

Figure 5.25: Vertical acceleration data for raised table crossings at Victoria St/Church St roundabout in Onehunga, Auckland



It is also interesting that, anecdotally, there has been a considerable improvement in safety since the platforms were installed, which raises questions about the ramp dimensions, vertical acceleration, vehicle speeds, and ultimately safety of platforms that are more forgiving than typcial 1:10 – 1:15 platforms. These 'bus-friendly' platforms have achieved 85% speeds of around 33 km/h. It is likely that context is important at this location and a combination of platforms and a more pedestrianised environment at this tourist attraction combine to create overall safe speeds and this is supported by the Auckland Transport (GHD 2018) research. More consideration is needed of the combined effect of treatments in different environments.

5.2.7 Tables at Speed Thresholds

Raised tables are increasingly being used for transitions from higher to lower speed zones, as shown in the Auckland example below (Figure 5.26). In this example the table also serves as an RSP for traffic approaching a major signalised intersection in the other direction. At village centres, these applications are more likely to include zebra crossings.

Figure 5.26: RSP on Market Place located between 30 km/h zone and major intersection, Auckland

6. Gap Analysis and Principles for Guidance Changes for Raised Safety Platforms at Arterial Signalised Intersections Above 50 km/h

The following table (Table 6.1) summarises, for key design and performance dimensions for RSPs: the key points from the literature; further findings from our Sample investigations; and the knowledge gap raised through this research. In the final column **key principles for guidance changes** are also suggested for each dimension where appropriate. Note this applies only to arterial signalised intersections above 50 km/h i.e. the applications of primary interest in this study.

Table 6.1: RSP design and performance dimension for signalised intersections above 50 km/h

Dimension	Key findings from the literature review	Local application lessons	Identified knowledge gap and implications for Guidance
Warrant considerations and site selection.	• Sites that have potential for collisions at non-Safe System speeds. • Signalised intersections on arterial roads generally have poor Safe System alignment. • RSPs are a tool to better align existing signalised intersections with the Safe System. • Existing Guidance, applications should be no more than 70 km/h.	• A range of sites including variable pedestrian volumes (Thomastown). All applications to date have maximum approach speed limit of 60 km/h. • Initial concerns around rear-ending with slowing in high-speed environments (hence 70 km/h cut-off). • In principle higher speed applications possible but few applications to date.	Existing trials suggest applications could proceed on a less conservative basis than currently suggested in the literature or guidance, with correct parameters. **Implications for Guidance:** • Key principle is that the gap between the operating speed in advance of an intersection and the desired operating speed at the intersection should not be greater than 20 km/h. In practice, at higher speed locations, the difference between the speed limit and intersection advisory speed should be no greater than 20 km/h. However, where approach speed is constrained and operating speeds are much lower than the speed limit, then greater step downs in intersection advisory speed may be appropriate. E.g. 80 km/h speed limit step down to an intersection advisory of 40 km/h before any lower advisory speed, if the operating speed on approach was no greater than 60 km/h. If the difference between the operating speed and the intersection advisory speed is greater than 20 km/h then speed management needs to be added to meet this principle.
Site features to avoid.	• Tram routes; high volumes of heavy vehicles; horizontal/vertical curves; restricted vertical clearance.	• Current parameters based on first sites chosen – conservative start, concentrate on 60 km/h and non-tram, non-HV routes (or high freight but low HV turning) initially, and avoiding high ped areas (strip shopping etc). • Increasingly confident about use on all routes (except tram routes), if treated carefully. No	Existing trials suggest applications could proceed on a less conservative basis than currently suggested in the literature or guidance. Tram routes will continue to be problematic however. **Implications for Guidance:** • Appropriate to use on routes with higher number of heavy vehicles as long as careful design and placement of ramps is considered to mitigate noise, load shifting, and vehicle instability.

<table>
<thead>
<tr><th>Dimension</th><th>Key findings from the literature review</th><th>Local application lessons</th><th>Identified knowledge gap and implications for Guidance</th></tr>
</thead>
<tbody>
<tr><td></td><td></td><td>evidence for heavy vehicle roll-over risk, but some evidence of noise for more severe ramp profiles.</td><td></td></tr>
<tr><td>Ramp/platform design.</td><td>

100mm, min 6m (7m if ped crossing on ramp) for approach platforms.
Approach gradient 1:25-1:30, departure 1:35, for 50 km/h advisory speed

</td><td>

Conservative start at first intersections (e.g. 1:30 at Belmont). Settling on 1:20-1:25 approach gradients (but still variation for ‘as builts’), with 40 km/h advisory speeds. Where lower speed more pedestrianised environments exist within 50 km/h environments, a 1:15 ramp profile designed for 30 km/h may be appropriate.
Some ‘as builts’ vary from specifications due to construction process, lessening for recent applications.
Auckland Transport is planning signalised four lane intersection with tables further in advance of the intersection.

</td><td>
<table>
<tr><th rowspan="2">Pedestrian/ cyclist activity</th><th rowspan="2">Heavy vehicle activity</th><th rowspan="2">Speed advisory (km/h)</th><th colspan="2">Divided carriageway</th><th>Undivided carriageway</th></tr>
<tr><th>Approach ramp grade</th><th>Departure ramp grade</th><th>Approach/ departure ramp grade</th></tr>
<tr><td>High (e.g. town or activity centre)</td><td>Low (e.g. buses only)</td><td>30*</td><td>1:15 (6.7%)</td><td>1:35 (3%)</td><td>1:15 (6.7%)</td></tr>
<tr><td rowspan="2">Medium (e.g. urban arterial)</td><td>Low (e.g. buses only)</td><td rowspan="2">40+</td><td>1:20 (5%)</td><td>1:35 (3%)</td><td rowspan="2">1:25 (4%)</td></tr>
<tr><td>Medium</td><td>1:25 (4%)</td><td>1:35 (3%)</td></tr>
<tr><td>Low</td><td>Medium-high (e.g. truck route)</td><td>50^</td><td>1:25** (4%)</td><td>1:35 (3%)</td><td>1:25 (4%)</td></tr>
</table>
*Safe System maximum survivable impact speed for pedestrians and cyclists
+Note that while 40 km/h may be a reasonable compromise in some circumstances, a Safe System speed of 30 km/h should be sought for pedestrian safety whenever possible
^Safe System maximum survivable impact speed for side-impact vehicle-only crashes
**Where there is very heavy truck volumes or stock trucks, a 1:30 approach grade may be considered
Recent experience suggests care needed to construct ramps accurately to the design, including working closely with contractors.
Implications for Guidance:

Recognise current practice and reinforce the need for close supervision of contractors and the importance of achieving the correct profile as per the design.

</td></tr>
</tbody>
</table>

Dimension	Key findings from the literature review	Local application lessons	Identified knowledge gap and implications for Guidance
Speed reduction.	• Evidence of Safe System speed reductions to 50 km/h with currently used profiles (e.g. Hamilton, NZ).	• 7-16 km/h reduction at Thomastown sites (preliminary data), median speeds dropping to 29-36 km/h – greatest reduction at new signalised site (Spencer). Some sites advisory 40 km/h. • Limited evidence of speeds creeping up again over time at Belmont; however, note that this site has a conservative ramp grade.	Establishing evidence of tangible speed reductions (and hence likely safety benefits). Consistent literature and more recent experience. **Implications for Guidance:** • Reinforce the importance of speed reduction to avoid deaths and serious injuries, and hence design speeds that approach safe system. Advisory speed of 40 km/h may be a vehicle side impact/pedestrian collision compromise. 30 km/h design speeds used in highly pedestrianised areas such as town centres (e.g. Hamilton)
Vehicle accelerations and occupant comfort levels.	• Consensus: 1.0 g = maximum vertical acceleration able to be withstood driving speed humps. • 0.5 g should be effective in reducing speed and is considered a comfort threshold. • Vertical accelerations exceeding 0.7 g is considered dangerous; may damage vehicles although TRL research suggested 0.6-0.8 would be approaching 'Uncomfortable'.	• Variable depending on a range of factors including site, approach/departure, and potentially lane (left lane may be less effective in some instances as ramp tapers to kerb, vehicle type. • For signalised intersections with advisory speeds of 40-50 km/h, most vertical accelerations at 40-50 km/h range between 0.4-0.6g. There are some significant unexplained outliers however.	Recent applications have variable acceleration performance based on a range of factors, which is not yet reflected in the literature. **Implications for Guidance:** • For RSPs on higher speed arterial roads with 40 km/h advisory speed at the intersection, ramp designs that cause vertical acceleration of approximately 0.5g is desirable, and no lower than 0.4g for routes with many heavy vehicles, and no higher than 0.6g for all vehicles. More comprehensive testing should be carried out on recent applications to test and compare their performance.
Large vehicle stability.	• Must not present undue dynamic stability (or roll-over) risk for 'critical unstable'/'low performing' vehicle (VicRoads) • Initial modelling for a corridor of RSP applications in Metro Melbourne suggests under some conditions there is a risk of roll-over (not yet clear whether RSPs contribute) (Cairney et al, 2019a). • Vertical deflection devices may reduce roll-over risk given they are likely to reduce turning speed before the turn (Campbell et al, 2012). • NZ and Australian modelling indicated negligible performance impacts for heavy vehicles from RSPs specifically	• Need to take pedestrian crossings into account, ensure ramps are not too far into intersection. • Issues around advisory signage for trucks encouraging them to travel at 15-20 km/h when not necessary. Not examples of truck roll-over due to RSPs yet. • Better to avoid truck roll-over signage (as per current guidance) at most applications	Recent applications suggest a less conservative approach to truck roll-over could be taken than currently suggested in the literature or guidance to avoid excessive sign clutter, and hence increase awareness of the RSP. **Implications for Guidance:** • Truck roll-over signage only to be used where some demonstrated risk exists. Not needed for flat and conventional layouts.

Dimension	Key findings from the literature review	Local application lessons	Identified knowledge gap and implications for Guidance
Noise and vibration issues.	• No reported issues at existing sites, limited data. • Lance Creek showed less noise following the new intersection (but may be a result of new surface and slower approach speeds).	• Wonthaggi and Dalton some minor noise issues, but overall difficult to differentiate from impact of traffic signals (engine braking/Accelerating). • Departures should be milder than approaches on separated roads – where necessary, and guidance specifies 1:35 (Wonthaggi an exception). • Careful construction needed to ensure ramp profiles as designed.	Specific noise issues do exist in some circumstances and not yet reflected in literature or guidance. **Implications for Guidance:** • Design needs to consider situations where noise issues have been demonstrated such as heavy and trade vehicles departing from RSPs where departure is more aggressive than expected. Ensure that construction is built as per designs.
Traffic flow and intersection capacity.	• Possible implications for emergency vehicles, but no data. Negligible impact on traffic flow but information limited.	• Signals operations personnel have adjusted signal phases slightly to adjust for lower advisory speed and perception that RSPs have slightly affected capacity. • SCATS data suggests any delays or reduced capacity complicated with other factors such as increasing congestion. Set back stop line for right turning vehicles is likely to affect right turning capacity though. So stop line further forward improves this.	There may be some influence of RSPs on capacity issues under some circumstances, but it’s still not known whether in general these are caused by the RSPs or other factors. A more robust study of this is suggested, as well as a strategic position on this, comparing with safety. **Implications for Guidance:** • Need strategic messaging on the rationale for reducing speed at intersections and the prioritisation of this over minor capacity issues. Design guidance to mitigate capacity issues such as having stop lines closer to intersection to help with right turning vehicle capacity.
Wider network considerations.	• Consider impacts along corridor and throughout network. No data yet.	• No strong views at this stage, analyses haven’t been carried out at an aggregated network level, except for recent speed analyses at Thomastown.	Still need evidence for this to steer guidance, including strategic direction on the application of RSPs for various intersections, road types, and hence the wider network. **Implications for Guidance:** • Need general comments for considering the strategy for use at a network level and not only for individual or corridor applications.

Dimension	Key findings from the literature review	Local application lessons	Identified knowledge gap and implications for Guidance
Constructability and construction.	• Range of local experiences to be learned (materials, methods, services, drainage).	• Detailed oversight of construction is needed to get ramp profiles right. • Get delivery team and designers on board early so they understand the concept and objective, design and delivery process is very different to the staged contracting processes usually used – have pre-tender meetings to emphasise the intent and importance of RSPs and critical need to get ramp profiles right. • Retrofits more difficult to get right and are more expensive than newbuilds. • Difficult at large intersections to raise the entire intersection – better to do approach platforms at these. • Building platform first, removing excess, and then adding ramps is effective for getting grades right (Victoria). • Precision of grades is crucial – if too steep, complaints and hard braking could undermine project, but if not big enough, then impact is reduced; a lack of public complaints may indicate that the grade is not enough; there is evidence that precise grade is hard to achieve without close supervision. • Variability in contractor quality; contractor appointments needs careful consideration. • The time it takes to close roads is an issue; RSPs need to be built quickly on busy arterials (little time to check). • Barrier kerbs are easier to fill, semi-mountable are difficult because of slope (and can't saw-cut) – relevant to retrofit sites. • RSPs are not possible at some sites due to drainage issues (e.g. large pipes). • Asphaltic concrete is used for most applications.	Local applications suggest a range of important issues that are not addressed by literature or guidance. **Implications for Guidance:** • Add important design/construction considerations to guidance, particularly the importance of building the profiles accurately, and for cross-fall and drainage.

Dimension	Key findings from the literature review	Local application lessons	Identified knowledge gap and implications for Guidance
Signs and delineation.	• Advanced warning and stop line conspicuity important. • Practices depend on jurisdiction. • Stop line may be place prior to or on platform. • Pedestrian facilities must be clearly delineated from ramp markings. • If RSPs are installed near pedestrian facilities, ramp and pedestrian space must have a minimum of 1m separation. • Higher speed arterial applications typically have 50 km/h design speed (based on side impact survivability).	• Currently variable signage and marking approaches for different jurisdictions. .eg. shark's teeth (NZ) vs piano keys (Australia), speed hump vs raised intersection signs (different applications in Victoria). • Signage based on different guidance (e.g. speed zoning guidelines). Following letter of law leads to confusion for motorists, with sign clutter in some circumstances. • Should promote consolidation of signs. Often looks fine on plans then doesn't work on site (e.g. truck stability signs provide substantial clutter). • Issue of mixing speed limit signs with advisory signs. Confusing speed messaging for motorists approaching intersection. • Guidance needs upgrading based on the specific requirements of RSPs. • A-size signs are too small, B-size should be used at all multilane/divided intersections. Gating may not be enough on wide roads. Frequent complaints early on around not seeing signage. • Sign layouts could be more intuitive. Human Factors audits could be carried out. • VMS signage during and immediately following construction has been important and will continue in Victoria.	Local applications suggest variable delineation and signage configurations, which are not outlined in literature and which need consolidation in guidance. Further work is needed to agree on typical signage layout. **Implications for Guidance:** • Importance of reducing sign clutter and getting the order of signs right (e.g. directional signs in advance, more immediately functional signs closer to the intersection). Speed limits and advisory speeds should not be in conflict with each other (e.g. higher speed limit on approach to intersection with lower advisory speed). • Use VMS boards informing public of new layout when first installed.

Dimension	Key findings from the literature review	Local application lessons	Identified knowledge gap and implications for Guidance
Organisational barriers/ enablers.	• No literature on organisational or stakeholder acceptability of RSPs.	• Still not automatically considered by designers, still needs to be actively proposed. Safe System thinking is not automatic. • Safe System assessments promote RSPs. • Many do not see RSPs as appropriate for high freight routes or on busy arterial networks. • There is a perception that RSPs are a trial, and therefore reluctance to use as they are not standard practice. • Development and further uptake is not helped by early intersections not being very effective due to overly conservative ramps. • Some people in RSP development are not fully informed about effectiveness, uses, and issues. There can be inadequate sector communication. • Funding practices – can incentivise with funding for signals that include RSPs (but first need evidence to create general consensus). • Greater acceptance of RSPs on quieter or more mixed-use routes, however, ongoing pushback on busier arterials. Emphasis still on flow/capacity. Design constraints are sometimes used to justify not implementing RSPs.	Local applications suggest a range important factors not currently raised in the literature or guidance. There is a need for continued and targeted communication and education around the strategic purpose of RSPs. **Implications for Guidance:** • Emphasise the importance of well-designed engagement, communication, and education, as the concept of RSP is still very novel to many people.

Dimension	Key findings from the literature review	Local application lessons	Identified knowledge gap and implications for Guidance
Public and stakeholder acceptance.	• Understanding public attitudes and communicating with public is important. • Potential for community rejection. • Little documented evidence of dissatisfaction with current applications.	• Public acceptance of the Thomastown installations was initially low and there was a high level of negative feedback from the public. • Victorian applications had substantial local engagement but didn't necessarily reach all key stakeholders (e.g. commuters, people passing through). • The local community in Thomastown has become more supportive of the RSPs over time. There is also a supportive local government group. • High Street (40 km/h, shopping strip) was received much more positively than Dalton Rd (higher speed less pedestrianised arterial) probably because people are more used to concept of traffic calming in high pedestrian areas. • Concerns around different grades and designs. Dalton/Childs relatively flat example hasn't helped. • Importance of internal support for treatments when dealing with public concerns. • Value of early exploration of community attitudes to speeding. • Issue of responding to complaints around effectiveness (generic safety explanations not enough – the 'why' is difficult for the public – traffic signals perceived as already safe) – value of strong messaging around why RSPs are needed at higher speed signalised intersections. • Lack of understanding of how to approach RSPs. They can still be confused with speed bumps, but they operate quite differently. • Good local government support, several wanting to adopt – but can be turned off by local complaints – important to disseminate effectiveness findings	Local applications suggest a range important factors that are not raised in the literature or guidance. **Implications for Guidance:** • As above, need for well designed, engagement, communications and education. Use VMS boards when first installed.

Dimension	Key findings from the literature review	Local application lessons	Identified knowledge gap and implications for Guidance
Road user behaviour and driver perceptions.	• Evaluations find low risk of unsafe/erratic responses. • Some evidence drivers perceive raised platforms as less safe than roundabouts.	• Little evidence of unsafe or erratic responses. • Infrequent observed and reported cases of motorists braking hard ahead of platforms on Dalton Rd examples. This was also observed at the first installation at Belmont but has since subsided.	Local applications confirm acceptable road user behaviour, with isolated cases of erratic behaviour in some instances. **Implications for Guidance:** • Ensure RSPs are visible and appropriately signed. More education is needed to explain how RSPs operate differently to traditional speed humps (i.e. foot off the accelerator in advance rather than braking at the platform).
Considerations for public transport.	• Bus comfort important consideration. Ramps above should provide acceptable comfort.	• No indication of discomfort for buses, not mentioned specifically.	Lack of evidence from local applications suggest bus comfort continues to be important but not a large issue. **Implications for Guidance:** • With correct design RSPs should function appropriately for buses. Further, more detailed internal research is being carried out by Auckland Transport, which can inform future guidance.
Considerations for other road users.	• Site specific risk assessment and design considerations are required for emergency services, heavy vehicles, low floor vehicles, motorcyclists, cyclists, and the vision impaired. • Potential delay to emergency services needs to be considered. • RSPs should not be installed if the treatment presents an unacceptable risk for other road users.	• 40 km/h advisory is being used in higher pedestrian areas. • Some anecdotal concern that Police may not favour RSPs, but little evidence. • Project officials agree that emergency vehicles should be slowing for intersections anyway. • Little project evidence for adverse effects on other road users.	More evidence is needed to determine impacts on other road users. Local practices suggest risks for other road users may be less than stated in literature. Care is needed to ensure pedestrians do not mistake the RSP for a crossing facility unless it is designed and intended to perform that function. **Implications for Guidance:** • Where pedestrians present but not dominant, 40 km/h RSPs appropriate balance between side impact and pedestrian safe system speed. Highly, pedestrianised areas should have a 30 km/h design/advisory speed. • Important to engage with emergency services about new applications to discuss any issues and agree on strategy • Safe locations for crossing should be clear and intuitive
Sustainability (maintenance).	• Belmont has held up well. Potential for addition intersection maintenance costs.	• Confirmed that the Belmont ramps were still in good condition and were performing well.	More literature/guidance needed based on established applications. **Implications for Guidance:** • Consider whole of life cost and any potential for ramp deformities due to heavy vehicles. • Important that marking and signage is kept in good condition to warn motorists of platforms.

Dimension	Key findings from the literature review	Local application lessons	Identified knowledge gap and implications for Guidance
Cost.	• No literature identified to date on typical costs.	• Retrofit might add approximately $700-900K to new intersection. New intersection RSP costs might add $300K.	More information needed to establish order of cost estimates for RSP applications. **Implications for Guidance:** • Adding into new intersections or re-built intersections most cost-effective way to install them.

7. Discussion, Limitations and Further Research and Evaluation

Through the course of the literature review and the site Investigation findings, a range of issues warrant further consideration and are presented below. The limitations of the research and its scope are then discussed, and suggestions are made for further research.

7.1 Discussion

A developing community of practice

A community of practice for the use of RSPs is clearly emerging, particularly in Victoria, and lessons learned from early RSP installations have now been incorporated into the most recent installations. New Zealand and other Australian states are yet to establish multiple RSP applications at higher speed signalised intersections, although there are plans for these.

With growing confidence in the use of RSPs, a further wave of RSP applications are warranted, with the issues described earlier and in this report being addressed. Cooperation between jurisdictions could accelerate their adoption, building on guidance (such as this report and Austroads Guides), and the evaluations and lessons learned from various recent installations. The evaluation program for the Thomastown sites represents the most comprehensive evaluation effort to date (the early part of which has been described earlier). The estimates for safety improvement provide a compelling case for pursuing RSPs further, and effort should now be made to initiate evaluations of safety performance, particularly for multiple installations.

Optimising design and achieving construction consistency

Another key finding from the research is that, despite a consolidating approach to the use of RSPs, there are still minor design and construction inconsistencies. Some of this simply represents the evolution of RSPs (e.g. from the less aggressive ramps at Belmont and Dalton/Childs at Thomastown to the more aggressive 1:20-1:25 ramps in the most recent installations). However, there is also a theme of needing to ensure that ramps are constructed to designs. A range of methods have been suggested such as using a template to shape the design (Hamilton) or building up the table first in layers and then adding ramps carefully to design (recent Thomastown installations).

In settling on an optimal ramp design, it is interesting that some intersections with shallower than usual ramps (secondary interest applications Lance Creek and Auckland bus friendly platforms), are achieving safe speeds at potential collision points. At Lance creek a gradual stepping down of speed over a relatively long distance appears affective and for the bus-friendly pedestrian crossings in Auckland the wider context works together with the platforms to achieve Safe System speeds. There is the potential for vertical devices to become annoying to motorists if over-used, and on the other hand a consistency of use is likely to reinforce a road type and provide a greater overall safety benefit. Settling on optimal ramp dimensions may consider supporting contextual factors that are helping to slow traffic, in which case a shallower ramp may achieve Safe System speeds, minimise annoyance to road users, and maximise stakeholder buy-in. For higher speed arterial intersections however, there are minimal supporting environmental cues and so ramp dimensions are likely to need to be finely tuned to achieve Safe System speeds.

Considering a full range of road users

Further work is needed to consolidate the impacts of RSPs on a range of road users including bus passengers, truck drivers, emergency vehicles and motorcyclists. The lack of vigorous objection to RSPs by these user groups where RSPs have been installed (at least from the activities carried out in this research), suggests they may not be problematic, although it appears there has been isolated negative feedback. It would be useful to purposefully engage with these user groups to better understand the usability of RSPs, but with a clear framework for considering the feedback. There should be evidence for any problems mentioned and risks should also be weighed against the wider safety benefit that RSPs are likely to bring. For example, and hypothetically, deeper conversations with emergency services may reveal that although RSPs cause police, fire or ambulance vehicles to slow, the slowing may be in line with policies or rules around safe emergency driving.

Strategic positioning and scaling up

The potential for RSPs to cause traffic delay has been raised through this research. Framing RSPs within Safe System strategy (e.g. Road to Zero Road Safety Strategy in New Zealand) and setting a national or State-wide agenda for their use would be more useful than debating the merits of RSPs locally and every time they are proposed. Stakeholder buy-in across the system would still be needed, but at least an informed conversation could be carefully crafted to set an agenda, perhaps more so, than the variable experiences that are likely to play out if they are only advocated for at local levels.

Within a road safety strategy, a position on intersection design could be established. For example, intersection performance could be assessed from a Safe System starting point; intersections should be designed to promote Safe System travel speeds. Rather than being seen as efficiency problems for otherwise satisfactory intersections, RSPs might then be seen as a necessary intervention for harm minimization – an essential characteristic for any intersection under a Safe System.

As RSPs are increasingly positioned as a Safe System tool, principles for scaling up should be considered, including multi-level leadership, addressing system and design barriers, building capability and capacity, strengthening stakeholder support, and defining the pace of implementation with associated resources.

7.2 Limitations

The scope of this research was to provide clarity around the design and operation of RSPs and deepen understanding of leading practice across a range of performance dimensions. The information collected is not intended to represent an in-depth evaluation of any RSP installation. Hence the information and data collected should be seen as supporting information rather than original or definitive data upon which research questions are answered.

Apart from the original applications of RSPs in the Netherlands, the literature on the use of RSPs globally was very limited, reflecting their novelty. However, this has been countered by some very targeted and in-depth evaluations from Australia and New Zealand, which have provided a crucial early evidence base.

In order to contain the size of the investigation, a sample of jurisdictions and installation locations were chosen for the study, and this means that the outcomes of the report are based on the experiences of Victorian and Hamilton/Auckland New Zealand. There may be RSPs at higher speed arterial roads in other jurisdictions, and lessons from them can be added to these findings to further practice in Australia and New Zealand.

7.3 Further Research and Evaluation

The current program of evaluation at the Thomastown RSPs should provide further certainty regarding the efficacy of RSPs. As a community of practice develops, evaluation should track the adoption of RSPs by jurisdictions and consistency in application between sites and between jurisdictions. Preliminary evaluations of safety performance could also begin to understand their impact on improving road safety, but also to systematically address any issues (such as rear end crashes) which could then be mitigated through extra signage or public education.

Research and evaluation could also advance other promising concepts such as the Lance Creek roundabout, South Melbourne cycling friendly roundabout, and other innovative applications.

8. Conclusions and Considerations Forward

This research project has examined the current state of development for Raised Safety Platforms in Australia and New Zealand, primarily focussing on applications at urban arterial intersections above 50 km/h, but also in other innovative contexts. The literature has shown that, outside of the Netherlands where RSPs have been used extensively, a ‘community of practice’ is developing in Australia and New Zealand, with the majority of applications at signalised intersections above 50 km/h to date being in Victoria.

There is emerging agreement about the pavement, marking, and signage designs for RSPs, although some inconsistencies remain, including differences between design and ‘as-built’ profiles. However, more recent applications appear to be settling on more consistent designs in Victoria. Stakeholder and public understanding of why RSPs exist and how people should negotiate them is also developing, and there is no evidence of any significant safety issues associated with RSPs at this stage.

It seems there is also a need to reinforce RSPs within a wider Safe System or Vision Zero conversation in jurisdictions, so that a strategic context for their use filters down to project level investment decisions. However, there is enough certainty now about various aspects of RSPs at higher speed signalised intersections that clear guidance direction can be updated and promoted, building on earlier effort in Victoria, and specific changes to the Austroads Guide to Traffic Management and Guide to Road Design have been suggested accordingly. The suggested changes to the Austroads Guide to Traffic Management are outlined in Appendix A. The suggested changes to the Austroads Guide to Road Design have been provided to the Road Safety & Design Program for future incorporation in the Guide to Road Design.

Raised Safety Platforms are also showing their worth in a range of other rural and urban contexts. The compact rural roundabout at Lance Creek is particularly impressive, as are the cycling priority roundabouts on Moray Street, South Melbourne. The new Hamilton city centre 30 km/h raised intersection and Auckland compact roundabouts on raised intersections and bus friendly speed tables also show innovation. For these various other applications, there is a need to progress the innovation journey that has been demonstrated for RSPs at higher speed signalised intersections.

8.1 Considerations Forward

The following captures considerations forward for practitioners, jurisdictions and Austroads, expanding on the research findings presented in this report:

1. Continue to consolidate designs and practices for RSPs at signalised intersections on arterial roads, with increasing consistency as well as practice across jurisdictions, while continuing to address residual concerns regarding design and construction consistency, and intersection efficiency and safety.
2. In addition to Austroads Guide changes, update technical guidance (e.g. the VicRoads Raised Safety Platform Design Note).
3. Build sector capability and stakeholder support so Safe System intervention programs can roll-out RSPs at scale at suitable locations.
4. In addition to RSPs at signalised urban arterial roads, further develop and implement their use at other innovative applications such as rural intersections, urban roundabouts, and pedestrian mid-block crossings.

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Appendix A Recommended Edits to Austroads Guide to Traffic Management

Table A.1 Recommended edits to Austroads Guide to Traffic Management

Section/Page	Description	Current Content	Edited Content
Part 1: Introduction to Traffic Management (2019)			
No changes.			
Part 2: Traffic Theory (2015)			
No changes.			
Part 3: Traffic Studies and Analysis (2017)			
No changes.			
Part 4: Network Management (2016)			
No changes.			
Part 5: Road Management (2019)			
AGTM Part 5 Section 4.2.5 Bus Routes on Urban Local Roads (page 33)	Amend to include RSPs/vertical deflection devices/speed management devices in addition to LATM devices	Bus routes on urban local roads: • provide direct access to public transport for residents • can take more time because of the progressive implementation of LATM measures • need to be managed to achieve a balance between efficiency and environmental quality of residential roads (e.g. impacts of increased noise, bus stops removing residential parking spaces) • need appropriate LATM devices that are safe and comfortable for passengers and do not cause damage or turning problems for the bus. Bus lanes may also be provided on urban local streets.	Bus routes on urban local roads: • provide direct access to public transport for residents • can take more time because of the progressive implementation of LATM measures • need to be managed to achieve a balance between efficiency and environmental quality of residential roads (e.g. impacts of increased noise, bus stops removing residential parking spaces) • need appropriate LATM and RSP vertical deflection devices that are safe and comfortable for passengers and do not cause damage or turning problems for the bus. Bus lanes may also be provided on urban local streets.

Section/Page	Description	Current Content	Edited Content
AGTM Part 5 Section 6.8 Physical Speed Management Devices (page 77)	Add RSPs as option for higher speed speed control	Physical devices may be used to achieve a speed environment that is compatible with the road activity (e.g. concentrated roadside activities, high number of vulnerable road users) and often require alteration of the road geometry to change the perspective of drivers to one of a slower speed environment. Some of the treatments available are listed in Table 6.7. [Table 6.7] Where speed limits of 40 km/h or less are applied to local streets they should generally be supported by physical design features or local area traffic management (LATM) devices. The way the safety objective is achieved along residential streets is comprehensively provided in the *AGTM Part 8* (Austroads 2016c). The Guide describes LATM as a 'tool for traffic calming' and details the processes and designs that can be applied. The management of traffic in business areas (e.g. activity centres) is covered in the *Guide to Traffic Management Part 7: Traffic Management in Activity Centres* (Austroads 2019a).	Physical devices may be used to achieve a speed environment that is compatible with the road activity (e.g. concentrated roadside activities, high number of vulnerable road users) and often require alteration of the road geometry to change the perspective of drivers to one of a slower speed environment. Some of the treatments available are listed in Table 6.7. [Table 6.7] Where speed limits of 40 km/h or less are applied to local streets they should generally be supported by physical design features or local area traffic management (LATM) devices. The way the safety objective is achieved along residential streets is comprehensively provided in the *AGTM Part 8* (Austroads 2016c). The Guide describes LATM as a 'tool for traffic calming' and details the processes and designs that can be applied. Along roads with higher operating speeds or traffic volumes, speed management devices such as raised safety platforms can be used to manage speeds at intersections and crossings (refer to the *Guide to Traffic Management Part 6 (Austroads [date]*). The management of traffic in business areas (e.g. activity centres) is covered in the *Guide to Traffic Management Part 7: Traffic Management in Activity Centres* (Austroads 2019a).
AGTM Part 5 Section 6.8 Physical Speed Management Devices Table 6.7: Speed control treatments (page 78)	Add RSPs to definition of 'Physical speed management devices'	**Treatment**: Speed constraining treatments **Comment:** • Make excessive speed physically uncomfortable. • Include vertical displacement devices such as road humps, speed cushions, rumble strips. • Include horizontal displacement devices such as roundabouts, slow points.	**Treatment**: Speed constraining treatments **Comment**: • Make excessive speed physically uncomfortable. • Include vertical displacement devices such as road humps, speed cushions, rumble strips, and raised safety platforms. • Include horizontal displacement devices such as roundabouts, slow points.
AGTM Part 5 References (page 79)	Add reference to current Austroads report (Austroads 2020, cited in Appendix A1 Table A5)		Austroads 2020[x], *Effectiveness and Implementation of Raised Safety Platforms*, NTM6187, Austroads, Sydney, NSW.

Section/Page	Description	Current Content	Edited Content
AGTM Part 5 Appendix A1 Urban Arterial Intersections – Table A5 Raised Intersections (page 89)	Update with technical info/findings	**Table A5 Raised Intersections** **Description:** Raised intersections (also known as platform intersections, raised junctions or plateaus) are a speed management device, typically with the aim of reducing the speed of vehicles to 50 km/h or less. The entire intersection can be raised, with the pavement surface sometimes flush with the adjoining footpath. Alternatively, raised sections can be placed in advance of the intersection (sometimes referred to as raised stop bars) to achieve a similar effect. Raised intersections can be painted or paved in a manner such that they serve to further increase driver awareness of the intersection. The results include outcomes from an evaluation conducted through Austroads (2016e). Further research may be undertaken in the future. **Effectiveness** ***Speed reduction:*** • 3 km/h reduction in mean speed. • 8 km/h reduction in 85th percentile speed. ***Crash reduction:*** • 40% reduction in casualty crashes. ***Road user effects (delays, congestion, consistency of travel time):*** • ‘Downgrading’ of functionality of road – e.g. urban arterial potentially becomes a lesser road. • Inconvenience and delay to buses and emergency vehicles. • Increased noise levels. • Pedestrians confusing ramp markings for crossing facilities. **Implementation issues:** • Increased height and a steeper ramp gradient lead to a greater level of speed reduction. Austroads classifies a 1:30 gradient as bus friendly. However, this grade may result in less speed reduction for other vehicles. • Need to consider the impact on drainage. • Require appropriate delineation. • Traffic volume, composition and geometry should be taken into considerations when determining the suitability of this treatment.	**Table A5 Raised Safety Platforms ~~Intersections~~** **Description**: Raised safety platforms (RSPs) ~~intersections (also known as platform intersections, raised junctions or plateaus)~~ are a speed management device, typically with the aim of reducing the speed of vehicles to 30-50 km/h, ~~or less~~depending on the level of pedestrian activity in the area. The entire intersection can be raised to create a raised intersection (also known as platform intersections, raised junctions or plateaus), with the pavement surface sometimes flush with the adjoining footpath. Alternatively, raised sections can be placed in advance of the intersection in the form of approach platforms (sometimes referred to as raised stop bars) to achieve a similar effect. Raised ~~intersections~~ safety platforms can be painted or paved in a manner such that they serve to further increase driver awareness of the intersection. The results include outcomes from an evaluation conducted through Austroads (2016e). Further research may be undertaken in the future. **Effectiveness** **Speed reduction (depends on RSP design and target speed):** • Preliminary data from Victoria suggests mean speed reductions of 7-16km/h for RSPs designed with 40km/h target speeds on 60km/h urban arterials (1:20 to 1:25 approach ramp gradients) • 8 km/h reduction in 85th percentile speed (1:30 approach ramp gradients with 50km/h speed advisory on 60km/h arterial). ***Crash reduction:*** • 40% reduction in casualty crashes. ***Road user effects (delays, congestion, consistency of travel time):*** ~~• ‘Downgrading’ of functionality of road – e.g. urban arterial potentially becomes a lesser road.~~ • Minor i~~I~~nconvenience ~~and delay~~ to buses and emergency vehicles. • Increased noise levels where there is a high proportion of heavy and trade vehicles and ramps that are more aggressive than recommended in guidance. • Pedestrians confusing ramp markings for crossing facilities.

Section/Page	Description	Current Content	Edited Content
		• Confusion of priorities may occur; therefore, proper pedestrian crossings should be designed with raised intersections. **Cost**: Medium to high. **Treatment life:** 20 years+. **Applicability:** • Recommendation that raised intersections and raised stop bars are not utilised on roads with posted speed limits of above 60 km/h. • Should not be used where there is limited or restricted sight distance. [After table] *Source: Based on Austroads (2016e).*	**Implementation issues:** • Approach platforms are more suitable for large multi-lane intersections with a divided carriageway, where the device can be installed in a single direction of travel. Raised intersections are often more appropriate for relatively compact, pedestrianised intersections. • Increased height and a steeper ramp gradient lead to a greater level of speed reduction. Approach ramp gradients are typically between 1:15 and 1:25 depending on the target intersection speed. Shallower departure ramp gradients are recommended where possible, especially on roads with a high proportion of heavy and trade vehicles. Departure gradients of 1:35 are typical. ~~Austroads classifies a 1:30 gradient as bus friendly. However, this grade may result in less speed reduction for other vehicles.~~Construction should be closely monitored to ensure correct profiles achieved. • Need to consider ~~the~~ impacts on drainage. • Require appropriate delineation such as piano keys (Australia) or shark teeth (New Zealand). • Signage clutter on approach to intersections should be avoided; speed limit and advisory speed signs should not conflict with one another. • Marking stop lines on top of raised safety platforms (rather than in advance) helps to maintain sightlines and signal phase efficiency. Detector Loops should be cut into platform in advance of stop line accordingly. ~~• Traffic volume, composition and geometry should be taken into considerations when determining the suitability of this treatment.~~ • Confusion of priorities may occur; therefore, proper pedestrian crossings should be designed with raised safety platforms~~intersections~~. • VMS signage should be used to inform public of new layout post-installation, in addition to other engagement and education activities. **Cost:** Medium to high. New intersection installations are more cost-effective than retrofits. **Treatment life:** 20 years+.

Section/Page	Description	Current Content	Edited Content
			Applicability: • Recommendation that raised ~~intersections and raised stop bars~~safety platforms are not utilised on roads with ~~posted speed limits of above 60 km/h.~~operating speeds of 20km/h above the target intersection speed. However, additional speed management devices may be used to create a staged speed reduction. • Should not be used where there is limited or restricted sight distance. • Not appropriate on tram routes, unless trams are entirely separated from vehicle traffic. • Where existing truck rollover risk exists, rollover advisory signage or avoiding the use of RSPs should be considered depending on site characteristics. [After table] *Source: Based on Austroads (2016e) and Austroads (2020).*
AGTM Part 5 Appendix A2 Urban Arterial Mid-blocks – Table A 15: Humps/platforms (page 97)	Update with technical info/findings	**Description:** Humps/platforms refer to vertical deflection treatments used to control speed, with various forms of speed humps available for different road types. Speed humps are around 100 mm high and 3–4 m wide and are generally recommended for use on local roads. Speed tables and platforms consist of an approach transition of approximately 1.8 m, rising to a height of 70–100 mm above the road surface, with a flat section of around 3–6 m in between. The exact length and grade of entrance and exit ramps and the length of the table will differ depending on the function of the road. The results include outcomes from an evaluation conducted through Austroads (2016e). Further research may be undertaken in the future. **Effectiveness** ***Speed reduction:*** • Up to 25 km/h reduction in 85th percentile speed. • 25 km/h reduction in mean speed.	**Description:** Humps/platforms refer to vertical deflection treatments used to control speed, with various forms of speed humps available for different road types. Speed humps are around 100 mm high and 3–4 m wide and are generally recommended for use on local roads. Speed tables and platforms consist of an approach transition of approximately 1.8 m, rising to a height of 70–100 mm above the road surface, with a flat section of around 3–6 m in between. The exact length and grade of entrance and exit ramps and the length of the table will differ depending on the function of the road. The results include outcomes from an evaluation conducted through Austroads (2016e). Further research may be undertaken in the future. **Effectiveness** ***Speed reduction:*** • Up to 25 km/h reduction in 85th percentile speed. • 25 km/h reduction in mean speed.

Section/Page	Description	Current Content	Edited Content
		• 5–15% reduction in 85th percentile speeds at Seminole humps (e.g. flat top speed hump) and 11–18% at Watts humps (e.g. rounded speed hump). ***Crash reduction:*** • 40% reduction in serious injury and minor injury crashes. ***Road user effects (delays, congestion, consistency of travel time):*** • Increase in vehicle delay and travel time. • Increase in emissions. **Implementation issues:** • At higher speeds, aggressive humps/platforms can cause significant driver discomfort and damage to some vehicles. Milder ramp profiles of 1:12 used on roads ≤ 60 km/h and 1:30 or 1:35 on 70 km/h roads. • There also needs to be consideration for heavy and emergency response vehicles. • Through traffic and overall traffic volumes, and traffic mix should be considered before application. • Adequate provision of drainage should be considered. • Should be applied with associated advance warning signs. • Priority issue – pedestrians interpreting raised platform as pedestrian crossing. • Inconsistency in design (colour/texture etc.) across the road network may affect user perception. • Potential noise concerns. **Cost:** Medium. **Treatment** life: 10 years+. **Applicability**: • Suitable for lower-tier arterial roads with limited emergency and heavy vehicle volumes. • Typically applied in environments of up to 60 km/h.	• 5–15% reduction in 85th percentile speeds at Seminole humps (e.g. flat top speed hump) and 11–18% at Watts humps (e.g. rounded speed hump). ***Crash reduction:*** • 40% reduction in serious injury and minor injury crashes. ***Road user effects (delays, congestion, consistency of travel time):*** • Increase in vehicle delay and travel time. • Increase in emissions. **Implementation issues**: • At higher speeds, aggressive humps/platforms can cause significant driver discomfort and damage to some vehicles. Milder ramp profiles of 1:15-20 used on roads ≤ 60 km/h and 1:30 or 1:35 on 70 km/h roads. • There also needs to be consideration for heavy and emergency response vehicles. • Through traffic and overall traffic volumes, and traffic mix should be considered before application. • Adequate provision of drainage should be considered. • Should be applied with associated advance warning signs. • Priority issue – pedestrians interpreting raised platform as pedestrian crossing. • Inconsistency in design (colour/texture etc.) across the road network may affect user perception. • Potential noise concerns. **Cost**: Medium. **Treatment** life: 10 years+. **Applicability**: • Suitable for lower-tier arterial roads with limited emergency and heavy vehicle volumes. • Typically applied in environments of up to 60 km/h. • Raised safety platforms may be appropriate on signalised urban intersections with speeds greater than 50km/h.

Section/Page	Description	Current Content	Edited Content
AGTM Part 5 Commentary 10 (page 137)	Add advice around RSPs as more bus-friendly alternative to road humps. Add speed mgmt to LATM devices.	The turning envelope of a long wheelbase bus (e.g. a tag-axle coach) can be extremely large and care should be taken to ensure the swept path does not encroach on pedestrian areas and cycle paths. The types of LATM devices that can affect the operation of buses are: • Bus boarders: Kerbside parking (often illegal) causes consistent problems for bus operation and can lead to significant cumulative delays, especially in busy central business districts and suburban town strips. A device for alleviating this problem is the construction of a bus 'boarder' or 'reverse embayment' where the kerb is built out into the roadway. General traffic is required to stop behind a bus that is loading/unloading passengers. • Bus stop relocation: Locating new bus stops adjacent to traffic calming devices, and at sites immediately before intersections, especially in conjunction with selective vehicle detection priority measures, can assist in minimising delays for buses. • Road humps: Road humps have a detrimental effect on bus passenger comfort. Overuse of road humps on a route will impact on route times and discourage public transport use. • Speed cushions: Speed cushions can permit buses to straddle the cushion and maintain reasonable speeds while causing cars to slow. Parking should be prohibited near a speed cushion so that buses can position themselves correctly when straddling. • Slow points: A series of slow or pinch points can cause significant delays for buses. Where used, slow points should be coordinated with bus stops to minimise delays. To maintain both passenger and bus safety, it is recommended that the following design of slow points should not be used on roads with bus routes: – one-lane, two-way slow points (parallel or angled) – one-lane, angled and double-angled slow points. • two-lane, parallel, and angled slow points are the preferred forms of slow points for use on roads with bus routes. The following minimum widths are recommended for buses: • parallel slow point – minimum road width 7 m • angled slow point – minimum of 5 m per traffic lane – not preferred on bus routes.	The turning envelope of a long wheelbase bus (e.g. a tag-axle coach) can be extremely large and care should be taken to ensure the swept path does not encroach on pedestrian areas and cycle paths. The types of LATM and speed management devices that can affect the operation of buses are: • Bus boarders: Kerbside parking (often illegal) causes consistent problems for bus operation and can lead to significant cumulative delays, especially in busy central business districts and suburban town strips. A device for alleviating this problem is the construction of a bus 'boarder' or 'reverse embayment' where the kerb is built out into the roadway. General traffic is required to stop behind a bus that is loading/unloading passengers. • Bus stop relocation: Locating new bus stops adjacent to traffic calming devices, and at sites immediately before intersections, especially in conjunction with selective vehicle detection priority measures, can assist in minimising delays for buses. • Road humps: Road humps have a detrimental effect on bus passenger comfort. Overuse of road humps on a route will impact on route times and discourage public transport use. • Raised safety platforms: Raised safety platforms can be designed to have minimal impact on bus passenger discomfort. • Speed cushions: Speed cushions can permit buses to straddle the cushion and maintain reasonable speeds while causing cars to slow. Parking should be prohibited near a speed cushion so that buses can position themselves correctly when straddling. • Slow points: A series of slow or pinch points can cause significant delays for buses. Where used, slow points should be coordinated with bus stops to minimise delays. To maintain both passenger and bus safety, it is recommended that the following design of slow points should not be used on roads with bus routes: – one-lane, two-way slow points (parallel or angled) – one-lane, angled and double-angled slow points. • two-lane, parallel, and angled slow points are the preferred forms of slow points for use on roads with bus routes. The following minimum widths are recommended for buses: • parallel slow point – minimum road width 7 m • angled slow point – minimum of 5 m per traffic lane – not preferred on bus routes.

Section/Page	Description	Current Content	Edited Content
		• T-intersection deviation: The design at T-intersections should allow for bus turning movements. Recommended widths are discussed in the AGTM Part 8 (Austroads 2016c) and the AGRD Part 3 (Austroads 2016a). • Splitter islands at intersections: Designs should allow for bus turning movements. A frequent problem on bus routes is the failure to provide adequate clearance and road space for buses to complete their turns. This is particularly problematic for buses entering a road with a splitter island for left or right-turns. It is essential that the bus overhang be confined to the roadway and be clear of the kerb and splitter island. Recommended road and lane widths are discussed in Austroads (2016c) and Austroads (2016a).	• T-intersection deviation: The design at T-intersections should allow for bus turning movements. Recommended widths are discussed in the AGTM Part 8 (Austroads 2016c) and the AGRD Part 3 (Austroads 2016a). • Splitter islands at intersections: Designs should allow for bus turning movements. A frequent problem on bus routes is the failure to provide adequate clearance and road space for buses to complete their turns. This is particularly problematic for buses entering a road with a splitter island for left or right-turns. It is essential that the bus overhang be confined to the roadway and be clear of the kerb and splitter island. Recommended road and lane widths are discussed in Austroads (2016c) and Austroads (2016a).
Part 6: Intersections, Interchanges and Crossings (2019)			
AGTM Part 6 Section 2.3.1 Introduction (2.3 Intersection Selection) (page 34)	Add RSPs as example of speed management treatments at signalised intersections	Many Safe System intersection treatments are still being developed, while others are well established. Roundabouts, for example, are very commonly used in Australia and New Zealand to manage vehicle conflicts but have often been overlooked in some applications because unbalanced entry flows can result in long delays. Rather than seeking to improve capacity at existing roundabouts, many over saturated roundabouts have been replaced with signalised intersections that solve the delay problems but introduce road safety problems. Practitioners are encouraged to adopt intersections that achieve the following principles: • Where side impacts can occur, speeds must be kept to 50 km/h or below; or • In areas of high pedestrian or cyclist activity, or where collisions with pedestrians or cyclists are likely, speeds must be kept to 30 km/h or below; or • Impact angles are as small as possible (i.e. as close to parallel as possible).	Many Safe System intersection treatments are still being developed, while others are well established. Roundabouts, for example, are very commonly used in Australia and New Zealand to manage vehicle conflicts but have often been overlooked in some applications because unbalanced entry flows can result in long delays. Rather than seeking to improve capacity at existing roundabouts, many over saturated roundabouts have been replaced with signalised intersections that solve the delay problems but introduce road safety problems. Practitioners are encouraged to adopt intersections that achieve the following principles: • Where side impacts can occur, speeds must be kept to 50 km/h or below; or • In areas of high pedestrian or cyclist activity, or where collisions with pedestrians or cyclists are likely, speeds must be kept to 30 km/h or below; or • Impact angles are as small as possible (i.e. as close to parallel as possible).

Section/Page	Description	Current Content	Edited Content
		Roundabouts generally achieve both the speed and impact angle principles, which is why they are considered Safe System treatments. When a signalised intersection is considered to be the most appropriate intersection form, or crash problems at an existing signalised site are being addressed, the first two principles can be achieved by various types of speed management treatments and/or road safety cameras to assist with road user behaviours. In general, there is little scope to reduce impact angles at signalised intersections.	Roundabouts generally achieve both the speed and impact angle principles, which is why they are considered Safe System treatments. When a signalised intersection is considered to be the most appropriate intersection form, or crash problems at an existing signalised site are being addressed, the first two principles can be achieved by various types of speed management treatments such as raised safety platforms and/or road safety cameras to assist with road user behaviours. In general, there is little scope to reduce impact angles at signalised intersections.
AGTM Part 6 Section 2.3.2 Selection Process Table 2.3 Intersection treatment hierarchy and selection (page 37)	Update terminology	Hierarchy: Safe System options ('primary' or 'transformational' treatments); Treatment: • Grade separation • Close intersection • Low speed environment/speed limit • Roundabout • Raised platform.	Hierarchy: Safe System options ('primary' or 'transformational' treatments); Treatment: • Grade separation • Close intersection • Low speed environment/speed limit • Roundabout • Raised ~~platform~~safety platforms.
AGTM Part 6 Section 2.5.4 Road Lighting (page 69)	Add speed management treatments alongside LATM	Intersections are locations where the driving task is generally more complex than elsewhere along a route. In urban areas they are the source of most crashes, and lighting of urban intersections to appropriate standards is usually justified even with low traffic volumes. In urban areas the need for other road users (such as pedestrians and cyclists) to see and be seen should be taken into account, as well as the lighting of physical devices (e.g. channelisation, roundabouts, local area traffic management (LATM) treatments).	Intersections are locations where the driving task is generally more complex than elsewhere along a route. In urban areas they are the source of most crashes, and lighting of urban intersections to appropriate standards is usually justified even with low traffic volumes. In urban areas the need for other road users (such as pedestrians and cyclists) to see and be seen should be taken into account, as well as the lighting of physical devices (e.g. channelisation, roundabouts, local area traffic management (LATM) and speed management treatments).
AGTM Part 6 Section 4.2 Functional layout Table 4.2: Factors affecting signalised intersection capacity and safety (page 97)	Add raised platforms as suggestion for dealing with speed of approaching vehicles at signalised intersections	**Factors**: Speed of approaching vehicles **Issues** • Drivers difficulty at estimating the speed of approaching vehicle (perception distance). • Contribution to impact speed.	**Factors**: Speed of approaching vehicles **Issues** • Drivers difficulty at estimating the speed of approaching vehicle (perception distance). • Contribution to impact speed.

Section/Page	Description	Current Content	Edited Content
		Comment: • At rural sites, consider use of warning signs (advance or vehicle activated), enhanced line marking, perceptual countermeasures, lane-narrowing, reduced speed limits on approach and through intersections, variable speed limits, high friction coloured surfacing, speed and red light cameras. • At urban sites, consider use of speed discrimination equipment, provide separate right-turn phase, align opposing right turns, speed and red light camera. Refer to High Risk Intersection Guide (NZTA 2013a) and Methods for Reducing Speeds on Rural Roads: Compendium of Good Practice (Austroads 2014a).	**Comment:** • At rural sites, consider use of warning signs (advance or vehicle activated), enhanced line marking, perceptual countermeasures, lane-narrowing, reduced speed limits on approach and through intersections, variable speed limits, high friction coloured surfacing, speed and red light cameras. • At urban sites, consider use of speed discrimination equipment, provide separate right-turn phase, align opposing right turns, install speed and red light cameras, install raised safety platforms. Refer to High Risk Intersection Guide (NZTA 2013a) and Methods for Reducing Speeds on Rural Roads: Compendium of Good Practice (Austroads 2014a).
AGTM Part 6 Section 4.6 Speed Management (page 107)	Add new Speed Management and RSPs section (insert after 4.5 Traffic Signal Operations, page 107)		**4.6 Speed Management** Speed is a critical factor in providing safe intersections. Physical speed management devices may be installed at signalised intersections to achieve safe operating speeds through the intersection. **4.6.1 Raised Safety Platforms** Raised safety platforms can be used as a speed management treatment to achieve Safe System speeds (i.e. ≤ 50 km/h for vehicle to vehicle side impacts, or ≤ 30 km/h for collisions involving pedestrians or bicyclists) at signalised intersections along arterial urban roads. They are typically applied on roads with speed limits of 50 km/h or more and are appropriate along routes with high proportions of heavy vehicles, provided ramp design mitigates noise, load shifting, and vehicle instability risks. A raised safety platform is a raised section of roadway 75-100 mm high and at least 6 m long, with a ramp up and a ramp down (Figure 4.5). It can take the form either of approach platforms on the vehicle approaches to an intersection or of a fully raised intersection.

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			The length of the platform enables a standard passenger vehicle to bring both sets of wheels up onto the platform at the same time. This produces less vertical acceleration than most LATM vertical deflection devices. Raised safety platforms work by reducing vehicle approach speeds down to a comfortable level based on the target speed for that intersection, compared with the more pronounced braking that is needed to comfortably negotiate steeper LATM devices. This makes them more appropriate for higher-speed, higher-volume roads. **Considerations** Approach platforms are more suitable for large multi-lane intersections with a divided carriageway, where the device can be installed in a single direction of travel. Raised intersections are more appropriate at relatively compact, pedestrianised intersections. Raised safety platform design and advisory speeds should generally not be more than 20 km/h below the intersection speed limit. However, where approach speeds are constrained and operating speeds much lower than the speed limit, a difference of no more than 20 km/h between the existing operating speeds and the intersection speed advisory may be acceptable. The use of additional speed management devices to create a staged speed reduction may also be appropriate where operating speeds are greater than 20 km/h above the intersection advisory speed. Raised safety platforms may have a minor impact on intersection capacity for right-turning vehicles. Placement of the stop line on top of the platform is recommended as this minimises the impact of raised safety platforms on sightlines and signal phase efficiency. Stop lines placed before the raised safety platform can also cause vehicles to become 'stranded' beyond the stop line, particularly in right-turn lanes. Raised safety platforms have typically been applied at individual sites and corridors where speed issues have been identified. However, they may also be appropriate for use at a network level.

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			Emergency vehicle services should be engaged during the planning process to discuss potential issues and agree appropriate approach. Though there is no evidence of truck rollover risk from RSPs to date given careful attention to appropriate design principles, it is important to consider site factors that may affect vehicle stability. Motorcyclist safety should also be considered due to the risk of losing concentration or balance under severe vertical acceleration. Approach platforms are less expensive than raised intersections and, for both types, installation of raised safety platforms at new intersections is generally more cost-effective than retrofitting existing intersections. The placement of raised safety platforms on arterial roads is relatively novel, so consideration should be given to appropriate public engagement, communication, and education to promote correct usage. In particular, drivers should be encouraged to gently decelerate on approach, rather than braking suddenly, to reduce noise and the risk of rear-end collisions. VMS boards on approach to the intersection are recommended to be used for 1-2 months following installation. Ramp and platform design Raised safety platforms have a flat top platform and ramps with a consistent grade between the top and bottom of the ramp. The extent of speed reduction is determined by the ramp gradients (Table 4.7). The ramp gradient and speed advisory should be determined based on the level of pedestrian and cyclist activity at the intersection, as well as the volume and type of heavy vehicles using it. Gradients of up to 1:15 at intersections with a target operating speed of 30 km/h have been used along bus routes with few reported issues. Gradients of 1:15 are also considered to be bicycle and motorcycle friendly. Where possible (i.e. on roads with divided carriageways), gradients should be shallower on departure than approach. A departure gradient of 1:35 is typical, though even shallower gradients such as those used in Swedish speed tables could be adopted.

Table 4.7 Typical ramp gradients

Pedestrian/ cyclist activity	Heavy vehicle activity	Speed advisory (km/h)	Divided carriageway		Undivided carriageway
			Approach ramp grade	Departure ramp grade	Approach/departure ramp grade
High (e.g. town or activity centre)	Low (e.g. buses only)	30*	1:15 (6.7%)	1:35 (3%)	1:15 (6.7%)
Medium (e.g. urban arterial)	Low (e.g. buses only)	40+	1:20 (5%)	1:35 (3%)	1:25 (4%)
	Medium		1:25 (4%)	1:35 (3%)	
Low	Medium-high (e.g. truck route)	50^	1:25** (4%)	1:35 (3%)	1:25 (4%)

**Safe System maximum survivable impact speed for pedestrians and cyclists*

+Note that while 40 km/h may be a reasonable compromise in some circumstances, a Safe System speed of 30 km/h should be sought for pedestrian safety whenever possible

^Safe System maximum survivable impact speed for side-impact vehicle-only crashes

***Where there is very heavy truck volumes or stock trucks, a 1:30 approach grade may be considered*

Platform heights of 100mm are desirable, though 75 mm may be more appropriate along bus routes to minimise the risk of scraping.

Raised safety platform ramps should be at right angles to the direction of traffic and be a consistent height to minimise vehicle instability due to uneven vertical acceleration.

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			Ramp and platform design and selection of materials should also take into consideration: • traffic mix, particularly the volume of heavy, trade, and emergency vehicles using the road • vehicle stability • load shifting • noise, particularly on departure ramps • bicycle and motorcycle stability and skid resistance • the potential for ramp deformities due to heavy vehicle use • drainage. Asphalt is the most common material used for platform construction Close supervision of construction is advised to ensure ramps and platforms are built to specification. **Signage and delineation** Piano keys (Australia) or shark teeth (New Zealand) should be applied to approach ramps. Use of a different colour on top of the platform can help to further increase raised safety platform visibility, though the risk of priority confusion for pedestrians should be carefully considered. Signage should include at least one approach sign which advises drivers of the vertical deflection and provides an advisory speed. Truck rollover signage should only be used where there is a demonstrated risk. Sign clutter on approach to raised safety platform intersections should be minimised and conflicting signage avoided. In particular, speed limit repeater signs should be placed after the intersection to avoid conflict with raised safety platform speed advisories. Signage should also be arranged so that guide (directional) signs are in advance of the intersection, with regulatory signage relating to use of the intersection placed closer to the intersection. All markings and signage should be maintained in good condition to warn motorists. This is of particular importance along higher-speed routes. **Applicability:** • Recommendation that raised safety platforms are not utilised on roads with operating speeds of 20km/h above the target intersection speed. However, additional speed management devices may be used to create a staged speed reduction.

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			• Should not be used where there is limited or restricted sight distance. • Not appropriate on tram routes unless trams are entirely separated from vehicle traffic. • Where existing truck rollover risk exists, rollover advisory signage or avoiding the use of RSPs should be considered depending on site characteristics. **Examples of raised safety platforms** Examples of raised safety platforms at signalised intersections are illustrated in Figure 4.2. Example layouts are shown in Figures 4.3 and 4.4. Typical dimensioned details are given in Figure 4.5. **Figure 4.2 Raised safety platforms in Victoria and New Zealand**  City of Melbourne (Thomastown), Victoria

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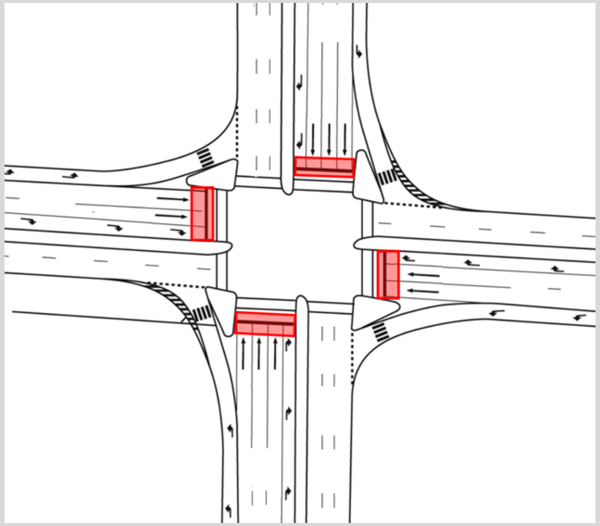
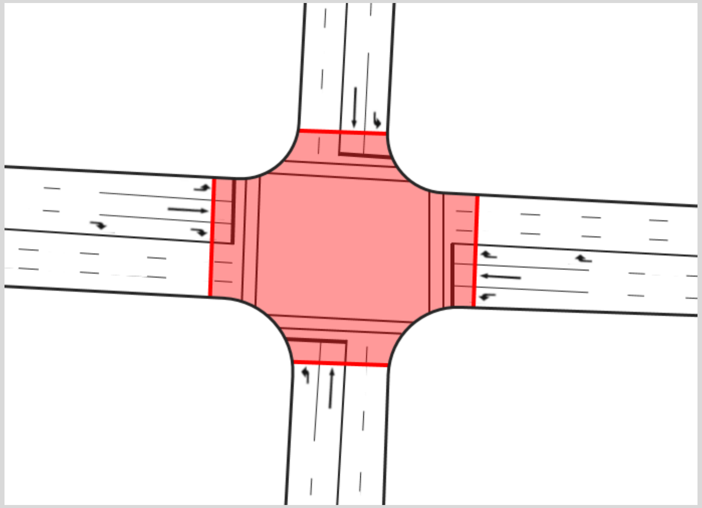
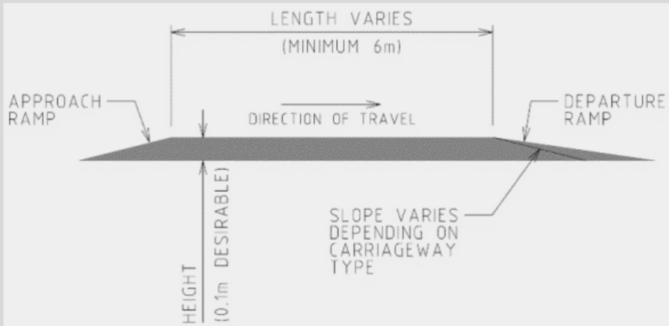
			 City of Whittlesea, Victoria  City of Hamilton, New Zealand

Section/Page	Description	Current Content	Edited Content
			 *City of Geelong, Victoria* **Figure 4.3 Example of a raised safety platform layout at an intersection with divided carriageways** 

Section/Page	Description	Current Content	Edited Content
			Figure 4.4 Example of a raised safety platform layout at an intersection with undivided carriageways  **Figure 4.5 Typical raised safety platform dimensions**  *Source: VicRoads (2019)* For further guidance and detailed design advice, refer to VicRoads (2019) and Austroads (2020).

Section/Page	Description	Current Content	Edited Content
AGTM Part 6 Sections 4.6 Signs and Road Markings and 4.7 Road Lighting (page 107)	Adjust numbering to accommodate new section 4.6 Speed Management	**Section 4.6 Signs and Road Markings** … **Section 4.7 Road Lighting**	**Section 4.7~~6~~ Signs and Road Markings** … **Section 4.8~~7~~ Road Lighting**
AGTM Part 6 References (page 180)	Add new references in appropriate places		Austroads 2020[x], Effectiveness and implementation of raised safety platforms, NTM6187, Austroads, Sydney, NSW. Metro Tunnel 2018, *Victorian-First Roundabout Opens on Moray Street*, viewed 30 April 2020, >https://metrotunnel.vic.gov.au/about-the-project/news/2018/moray-street-roundabout>. Safe System Solutions 2020, *Safe System Snippet #2*, viewed 30 April 2020, <https://safesystemsolutions.com.au/safe-system-snippet-2/>. VicRoads 2019, *Raised Safety Platforms (RSPs)*, Road Design Note RDN 03-07, VicRoads, Kew, Vic.
AGTM Part 6 Commentary 6 Unconventional and Innovative Intersection Designs (page 198)	Remove RSPs ('divided arterial with speed humps') from this section	The separation of conflicts in space has been investigated in a number of less conventional or innovative designs of intersection not common in Australia or New Zealand. Some designs are considered 'unconventional' due to their lack of use in a particular road network. However, in many cases they have been in existence for some time and used in other parts of the world. A number of emerging and innovative designs are also included, which include relatively new designs that may not yet be fully evaluated. Most unconventional signalised intersection designs are based on the theory of repositioning the right-turn movement in order to: • reduce the delays experienced by turning-traffic signal phases • reduce the number of conflict points through separation. The benefits of various unconventional designs are dependent on site-specific characteristics such as road reserve width and traffic volumes. Unconventional designs have been found to be beneficial in a number of instances (Austroads 2007). However, their implementation has been limited to site-specific studies balancing considerations of right-of-way and local roads. Driver confusion may also be an issue, especially during the early stages of operation, due to unfamiliarity with uncommon intersection configurations.	The separation of conflicts in space has been investigated in a number of less conventional or innovative designs of intersection not common in Australia or New Zealand. Some designs are considered 'unconventional' due to their lack of use in a particular road network. However, in many cases they have been in existence for some time and used in other parts of the world. A number of emerging and innovative designs are also included, which include relatively new designs that may not yet be fully evaluated. Most unconventional signalised intersection designs are based on the theory of repositioning the right-turn movement in order to: • reduce the delays experienced by turning-traffic signal phases • reduce the number of conflict points through separation. The benefits of various unconventional designs are dependent on site-specific characteristics such as road reserve width and traffic volumes. Unconventional designs have been found to be beneficial in a number of instances (Austroads 2007). However, their implementation has been limited to site-specific studies balancing considerations of right-of-way and local roads. Driver confusion may also be an issue, especially during the early stages of operation, due to unfamiliarity with uncommon intersection configurations.

Section/Page	Description	Current Content	Edited Content
		The safety performance of a number of innovative intersection designs were evaluated as part of a recent Austroads project (Austroads 2017g). Some of these have been used successfully internationally, but often not in Australia and/or New Zealand. Innovative designs that were assessed as having a low probability of a FSI crash included: • signalised – signalised 3-leg roundabout, cut-through roundabout, divided arterial with speed humps • unsignalised – flower roundabout, two-lane roundabout (3 or 4 leg). Unconventional and/or innovative intersection designs include those described in Table C6 1 . For further guidance on these and other unconventional intersection designs and overseas applications refer to Austroads (2007), Arup (2004), Hughes et al. (2010), Austroads (2015c) *(Improving the Performance of Safe System Infrastructure)* and Austroads (2017g).	The safety performance of a number of innovative intersection designs were evaluated as part of a recent Austroads project (Austroads 2017g). Some of these have been used successfully internationally, but often not in Australia and/or New Zealand. Innovative designs that were assessed as having a low probability of a FSI crash included: • signalised – signalised 3-leg roundabout, cut-through roundabout~~, divided arterial with speed humps~~ • unsignalised – flower roundabout, two-lane roundabout (3 or 4 leg). Unconventional and/or innovative intersection designs include those described in Table C6 1 . For further guidance on these and other unconventional intersection designs and overseas applications refer to Austroads (2007), Arup (2004), Hughes et al. (2010), Austroads (2015c) *(Improving the Performance of Safe System Infrastructure)* and Austroads (2017g).
AGTM Part 6 Commentary 6 Table C6 1: Types of unconventional intersection designs (page 201)	Remove RSPs from Table C6 as they are no longer 'unconventional'	**Intersection type:** Vertical deflections at intersections and/or on approaches **Comments:** This solution encompasses various designs such as raised stop bars, speed platforms and raised intersections. The solution may have different design parameters, depending on location and road function, and could cater for very low entry speeds, e.g. in pedestrian areas. For high-speed arterial roads, the design needs to more sensitive to operation and comfort, and may not be able to provide low speeds (e.g. was designed for a 60 km/h traverse on a 70 km/h road with buses). This consideration is also important for safety of motorcyclists, who may lose concentration or balance under severe vertical acceleration.	~~Intersection type:~~ ~~Vertical deflections at intersections and/or on approaches~~ ~~Comments:~~ ~~This solution encompasses various designs such as raised stop bars, speed platforms and raised intersections. The solution may have different design parameters, depending on location and road function, and could cater for very low entry speeds, e.g. in pedestrian areas. For high-speed arterial roads, the design needs to more sensitive to operation and comfort, and may not be able to provide low speeds (e.g. was designed for a 60 km/h traverse on a 70 km/h road with buses). This consideration is also important for safety of motorcyclists, who may lose concentration or balance under severe vertical acceleration.~~
AGTM Part 6 Commentary 6 Table C6 1: Types of unconventional intersection designs (pages 198-203)	Add new row in table: rural compact roundabouts with RSPs		**Intersection type:** Rural compact roundabout with vertical deflections on approaches **Comments:**

Section/Page	Description	Current Content	Edited Content
			A compact roundabout that may be installed at the intersection of low-volume, high-speed rural roads where a conventional roundabout is not feasible due to space or cost constraints. Two sets of raised safety platforms including piano keys on the approaches (approach platforms and a raised intersection), as well as rumble strips/dragon's teeth are used to progressively slow motorists to achieve the 40km/h roundabout advisory speed. Mountable central aprons and side road islands accommodate trucks.  Source: Safe System Solutions (2020)
AGTM Part 6 Commentary 6 Table C6 1: Types of unconventional intersection designs (pages 198-203)	Add new row in table: cycle-friendly roundabouts		**Intersection type:** Cycle-friendly roundabout with raised cyclist and pedestrian crossings on all approaches **Comments:** Provides raised unidirectional priority crossings for both pedestrians and cyclists on all four roundabout legs and incorporates a continuous off-road cycle lane around the roundabout perimeter.

Section/Page	Description	Current Content	Edited Content
			 Source: Metro Tunnel (2018)
Part 7: Traffic Management in Activity Centres (2019)			
AGTM Part 7 Section 3.5.3 Implications for Practice (page 36)	Add RSPs as option for sharing street cross-section in activity centres	Sharing the street cross-section can typically involve: • widening footways • reducing the number of lanes for moving traffic • perhaps converting the street to one-way operation so that only one lane total is required • providing a median, frequent refuge islands, or intermittent streetscape features such as planter boxes, seating, lamp posts, rubbish bins and so on • creating parking lanes (often intermittent rather than continuous) separate from the through lanes • considering designated cycle lanes • providing kerb build-outs at pedestrian crossing points • separating turning vehicles from through vehicles at intersections. Design guidance for these elements is found in the *Guide to Road Design*.	Sharing the street cross-section can typically involve: • widening footways • reducing the number of lanes for moving traffic • perhaps converting the street to one-way operation so that only one lane total is required • providing a median, frequent refuge islands, or intermittent streetscape features such as planter boxes, seating, lamp posts, rubbish bins and so on • creating parking lanes (often intermittent rather than continuous) separate from the through lanes • considering designated cycle lanes • providing kerb build-outs at pedestrian crossing points • separating turning vehicles from through vehicles at intersections • slowing moving traffic using speed management treatments such as LATM devices on local roads and raised safety platforms at arterial road intersections.

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		…	Design guidance for these elements is found in the *Guide to Road Design*. Design guidance on speed management treatments is provided in the *Guide to Traffic Management Part 6* and *Part 8 (Austroads [date] and Austroads [date]).* …
AGTM Part 7 Section 3.6 Traffic Calming and Speed Management (page 38)	Add reference to TM Part 6 for speed management guidance	An overview of the Safe System approach and the importance of speed management within activity centres is discussed in Section 2.2.1. A low-speed traffic environment is essential in a pedestrian-dominated street, whether or not other rules or measures have been introduced to facilitate safe and pleasant walking. Pedestrians and cyclists are particularly vulnerable road users. For vehicle-pedestrian collisions, the equivalent survival speed is about 30 km/h (refer to the *Guide to Road Safety Part 3: Speed Limits and Speed Management*, Austroads 2008). A conceptual basis for acknowledging streets within activity centres as 'places' as well as 'links' is presented in Section 2.3.6. The implications of this emphasis form the basis of traffic calming in centres. The principal Austroads source of guidance on traffic calming is the *Guide to Traffic Management Part 8* (Austroads 2016b). Although Part 8 describes mainly applications in residential neighbourhoods, the guide can be applied to circulatory and access roads within activity centres. The intention of traffic calming in this context is to adapt the road to the environment that it serves. The purpose and techniques of 'environmental adaptation' and the specific case of centres straddling arterial roads is dealt with in Section 3.7 of this part.	An overview of the Safe System approach and the importance of speed management within activity centres is discussed in Section 2.2.1. A low-speed traffic environment is essential in a pedestrian-dominated street, whether or not other rules or measures have been introduced to facilitate safe and pleasant walking. Pedestrians and cyclists are particularly vulnerable road users. For vehicle-pedestrian collisions, the equivalent survival speed is about 30 km/h (refer to the *Guide to Road Safety Part 3: Speed Limits and Speed Management*, Austroads 2008). A conceptual basis for acknowledging streets within activity centres as 'places' as well as 'links' is presented in Section 2.3.6. The implications of this emphasis form the basis of traffic calming in centres. The principal Austroads source of guidance on traffic calming is the *Guide to Traffic Management Part 8* (Austroads 2016b). Although Part 8 describes mainly applications in residential neighbourhoods, the guide can be applied to circulatory and access roads within activity centres. For busier roads such as arterials, guidance on speed management treatments can be found in the *Guide to Traffic Management Part 6* (Austroads [date]). The intention of traffic calming in this context is to adapt the road to the environment that it serves. The purpose and techniques of 'environmental adaptation' and the specific case of centres straddling arterial roads is dealt with in Section 3.7 of this part.
AGTM Part 7 Section 3.6.2 Ways to Influence Vehicle Speeds in Centres (page 39)	Amend traffic calming reference to include RSPs	There are several overlapping design and management concepts that may be considered as part of a strategy to reduce vehicle speeds (among other things), such as: • 'Main Street' treatments (environmental adaptation – see Section 3.7) • traffic calming (local area traffic management) devices and treatments • pedestrian priority areas • pedestrian malls and transit malls • legislated 'shared zones' (streets and places)	There are several overlapping design and management concepts that may be considered as part of a strategy to reduce vehicle speeds (among other things), such as: • 'Main Street' treatments (environmental adaptation – see Section 3.7) • speed management~~traffic calming (local area traffic management)~~ devices and treatments such as those used in local area traffic management (LATM) and at signalised arterial intersections, including raised safety platforms. • pedestrian priority areas • pedestrian malls and transit malls

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		• 'road diets' • 'shared spaces' by design (so-called 'naked streets'). These are briefly discussed in Appendix E. They are related concepts and differ mostly in degree and in the mix of urban design and traffic management measures that are employed. Section 3.7 expands on the underlying intention in all these strategies to achieve environmental adaptation.	• legislated 'shared zones' (streets and places) • 'road diets' • 'shared spaces' by design (so-called 'naked streets'). These are briefly discussed in Appendix E. They are related concepts and differ mostly in degree and in the mix of urban design and traffic management measures that are employed. Section 3.7 expands on the underlying intention in all these strategies to achieve environmental adaptation.
AGTM Part 7 Section 3.6.3 Implications for Practice (page 39)	Add reference to RSPs for guidance on speed management at intersections on arterials through activity centres	• Practitioners, whether urban designers, planners, architects or engineers, have a wide range of traffic management/urban design techniques from which to choose. • Most experience has been with traffic calming (or 'local area traffic management') – Part 8 of the guide (Austroads 2016b) – and with environmental adaptation of main streets (Roads and Traffic Authority NSW 2000). These sources provide guidance on appropriate speed management techniques to maximise benefits and minimise dis-benefits for bus operation, in particular. • Specific issues, such as pedestrian facilities, are dealt with in the relevant sections of this part and in other parts of the guide. Lower vehicle speeds are essential if increased integration of the street space, involving greater pedestrian-vehicle mixing, is envisaged. • Speeds of on-street public transport and bicycles will need to be moderated where they are intended to share the street space with pedestrians. • Refer to Section 3.7 for more specific guidance in terms of generic environmental adaptation.	• Practitioners, whether urban designers, planners, architects or engineers, have a wide range of traffic management/urban design techniques from which to choose. • Most experience has been with traffic calming (or 'local area traffic management') – Part 8 of the guide (Austroads 2016b) – and with environmental adaptation of main streets (Roads and Traffic Authority NSW 2000). These sources provide guidance on appropriate speed management techniques to maximise benefits and minimise dis-benefits for bus operation, in particular. • Specific issues, such as pedestrian facilities, are dealt with in the relevant sections of this part and in other parts of the guide. Lower vehicle speeds are essential if increased integration of the street space, involving greater pedestrian-vehicle mixing, is envisaged. • Treatments including raised safety platforms, for reducing traffic speeds at signalised intersections without causing significant inconvenience or delay on arterial roads are dealt with in Part 6 of the guide (Austroads [date]). • Speeds of on-street public transport and bicycles will need to be moderated where they are intended to share the street space with pedestrians. • Refer to Section 3.7 for more specific guidance in terms of generic environmental adaptation.
AGTM Part 7 Section 3.8.4 Cycling Implications for Traffic Management Practice (page 47)	Add reference to Part 6 for speed management	***Interaction with other traffic*** • Include design elements that legitimise and elevate awareness of the presence of cyclists, particularly at intersections. • Create slow-speed conditions on streets where cyclists mix with traffic within the centre. • Exploit opportunities to use streetscaping, pedestrian and cycling facilities, and parking layouts to help restrain vehicle speeds.	***Interaction with other traffic*** • Include design elements that legitimise and elevate awareness of the presence of cyclists, particularly at intersections. • Create slow-speed conditions on streets where cyclists mix with traffic within the centre. • Exploit opportunities to use streetscaping, pedestrian and cycling facilities, and parking layouts to help restrain vehicle speeds.

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		• Manage traffic volumes and lower speeds through traffic calming, parking design and intersection design measures (see Part 8 of the guide, Austroads 2016b). • Where appropriate, introduce shared zones (see Section 3.6). • As noted above, separate bicycle lanes can be considered where it is unsafe for cyclists to share the road with motorised traffic. • Whatever arrangement for integration with, or separation from, vehicular traffic is adopted, there should be no ambiguity about where the cyclist and other road users are situated on the road and what their mutual obligations and expectations are. • Safe crossing points across busier roads may be necessary to minimise the disruption of cyclists travelling to activity centres. Cycle road crossings are an integral part of cycle routes, and intersection and crossing design should favour cyclists' convenience and safety within centres.	• Manage traffic volumes and lower speeds through traffic calming, parking design and intersection design measures (see Part 6 of the guide, Austroads [date], and Part 8 of the guide, Austroads 2016b). • Where appropriate, introduce shared zones (see Section 3.6). • As noted above, separate bicycle lanes can be considered where it is unsafe for cyclists to share the road with motorised traffic. • Whatever arrangement for integration with, or separation from, vehicular traffic is adopted, there should be no ambiguity about where the cyclist and other road users are situated on the road and what their mutual obligations and expectations are. • Safe crossing points across busier roads may be necessary to minimise the disruption of cyclists travelling to activity centres. Cycle road crossings are an integral part of cycle routes, and intersection and crossing design should favour cyclists' convenience and safety within centres.
AGTM Part 7 Section 4.3.2 Key Issues and Cross-references Table 4.3 Key issues in arterial shopping strips (page 61)	Add reference to Parts 5 and 6 for reducing traffic speed	***Issue:*** Lowering of traffic speed ***Traffic management response discussed*** ***GTM 7(1):*** Section 3.6 ***Other resources 7(1):*** GTM 8 and GTM 13 (Austroads 2016b and 2017c)	***Issue:*** Lowering of traffic speed ***Traffic management response discussed*** ***GTM 7(1):*** Section 3.6 ***Other resources 7(1):*** GTM 5, GTM 6, GTM 8 and GTM 13 (Austroads [date], [date], 2016b and 2017c)
AGTM Part 7 Appendix C.3 Arterial Roads (page 119)	Add reference to use of RSPs as treatment option	Arterial roads constitute a major problem in pedestrian mobility and safety, as the provision for pedestrians on the arterial road system will be in conflict with the principal function of moving traffic. While a satisfactory balance may be achieved in environments with a low incidence of pedestrian demand, problems occur where arterial roads pass through the older strip shopping developments commonly encountered along arterial or sub-arterial roads.	Arterial roads constitute a major problem in pedestrian mobility and safety, as the provision for pedestrians on the arterial road system will be in conflict with the principal function of moving traffic. While a satisfactory balance may be achieved in environments with a low incidence of pedestrian demand, problems occur where arterial roads pass through the older strip shopping developments commonly encountered along arterial or sub-arterial roads.

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		There is scope for the use of grade (spatial) separation techniques on arterial roads. These are essential where pedestrians need to cross freeways and high-speed high-volume roadways. Elsewhere they are used where the expected pedestrian flow is high enough to justify the high costs involved, e.g. near a large school or a railway station. General treatments such as footpath (kerb) extensions and/or central refuge islands can be used to assist pedestrians to cross arterial roads. These may be combined with time separation techniques to provide the next best level of assistance to pedestrians. The most common pedestrian crossing facilities on non-freeway arterial roads include zebra crossings, pedestrian operated signals, and pelican crossings (which include a flashing amber sequence for the motorist, commonly used in Perth, Sydney, Darwin, and the UK). Another type of signalised pedestrian crossing, a puffin crossing, includes pedestrian sensor mats and infra-red pedestrian detectors. Pelican and puffin crossings can significantly reduce vehicle delays compared with standard pedestrian operated signals by allowing the pedestrian crossing time to be reduced when pedestrians cross more quickly. Pedestrian safety is also expected to be enhanced with puffin crossings due to the ability of the installation to detect pedestrians late crossing the roadway and hold the vehicular traffic on a red signal. On the other hand, zebra crossings on arterial roads have been shown to be associated with higher pedestrian accident frequency and are now not favoured on this class of road. Treatments available to assist pedestrians at crossings of roads are further discussed in Section 8 of the *Guide to Traffic Management Part 6* (Austroads 2019c).	There is scope for the use of grade (spatial) separation techniques on arterial roads. These are essential where pedestrians need to cross freeways and high-speed high-volume roadways. Elsewhere they are used where the expected pedestrian flow is high enough to justify the high costs involved, e.g. near a large school or a railway station. General treatments such as footpath (kerb) extensions and/or central refuge islands can be used to assist pedestrians to cross arterial roads. These may be combined with time separation techniques to provide the next best level of assistance to pedestrians. The most common pedestrian crossing facilities on non-freeway arterial roads include zebra crossings, pedestrian operated signals, and pelican crossings (which include a flashing amber sequence for the motorist, commonly used in Perth, Sydney, Darwin, and the UK). Another type of signalised pedestrian crossing, a puffin crossing, includes pedestrian sensor mats and infra-red pedestrian detectors. Pelican and puffin crossings can significantly reduce vehicle delays compared with standard pedestrian operated signals by allowing the pedestrian crossing time to be reduced when pedestrians cross more quickly. Pedestrian safety is also expected to be enhanced with puffin crossings due to the ability of the installation to detect pedestrians late crossing the roadway and hold the vehicular traffic on a red signal. On the other hand, zebra crossings on arterial roads have been shown to be associated with higher pedestrian accident frequency and are now not favoured on this class of road. Treatments available to assist pedestrians at crossings of roads are further discussed in Section 8 of the *Guide to Traffic Management Part 6* (Austroads 2019c). More recently, raised safety platforms have been applied at signalised intersections on arterial roads. These reduce the speed of vehicles travelling through the intersection and can be designed for speeds of 30 km/h to create a safer environment for pedestrians to cross the road. For further guidance, refer to the *Guide to Traffic Management Part 6* (Austroads [date].
AGTM Part 7 Appendix E.1 Traffic Calming Treatments in Activity Centres (page 124)	Add RSPs as traffic calming device option and reference to Part 6	Traffic calming is essentially about speed management.	Traffic calming is essentially about speed management.

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		Traffic calming techniques, as most widely applied, include vertical and horizontal speed control devices, intersection treatments such as roundabouts, pavement and kerb realignments, pedestrian treatments and variations in materials and colours. The *Guide to Traffic Management: Part 8* (Austroads 2016b) discusses these treatments and their application in detail. Not all of these treatments will be applicable in activity centres. For example, there are limitations in many jurisdictions on the use of vertical speed control devices on bus routes. The practitioner will need to note the limitations of treatments specified in Part 8. Treatments that can find application in activity centres are noted in Section 3.7. Physical treatments that are compatible with (or form part of) the architecture of the street are likely to find most ready application and acceptance in activity centres.	Traffic calming techniques, as most widely applied, include vertical and horizontal speed control devices, intersection treatments such as roundabouts, pavement and kerb realignments, pedestrian treatments and variations in materials and colours. The *Guide to Traffic Management: Part 8* (Austroads 2016b) discusses ~~these~~local area traffic management treatments and their application in detail. Not all of these treatments will be applicable in activity centres. For example, there are limitations in many jurisdictions on the use of vertical speed control devices on bus routes. The practitioner will need to note the limitations of treatments specified in Part 8. Treatments that can find application in activity centres are noted in Section 3.7. Raised safety platforms are vertical deflection devices that can be used to lower speeds through signalised intersections on arterial roads, and which may be appropriate for use along bus routes. These are discussed in the *Guide to Traffic Management: Part 6* (Austroads [date]). Physical treatments that are compatible with (or form part of) the architecture of the street are likely to find most ready application and acceptance in activity centres.
AGTM Part 7 Appendix F.1.1 Measures to Achieve a Target Speed Profile Table F 1 Measures for environmental adaptation of streets through activity centres (page 129)	Add RSPs to table	Measures to achieve a speed profile ***Primary measures:*** Speed zoning Gateway Roundabouts Traffic signals Staggered roadway Carriageway/lane narrowing Raised pavement within intersection Raised pavement mid-section Shared/raised pedestrian crossing Two lane entry threshold Pedestrian crossings Cross pavement markings Variable carriageway pavement Management of on-street parking Management of on-street loading	Measures to achieve a speed profile ***Primary measures:*** Speed zoning Gateway Roundabouts Traffic signals Staggered roadway Carriageway/lane narrowing Raised safety platforms Raised pavement within intersection Raised pavement mid-section Shared/raised pedestrian crossing Two lane entry threshold Pedestrian crossings Cross pavement markings Variable carriageway pavement Management of on-street parking

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		Off-line bays Tree planting in median strip Tree planting in road shoulder	Management of on-street loading Off-line bays Tree planting in median strip Tree planting in road shoulder
Part 8: Local Area Traffic Management (2016)			
AGTM Part 8 Section 1.1 Scope of this Guide (page 1)	Add reference to TM Part 6: Intersections	Part 8 of the Austroads *Guide to Traffic Management* has the title *Local Area Traffic Management* (LATM) to define the limitations on its scope within the context of: • the 13 different Parts of the Guide to Traffic Management • the 9 different Guides spanning the range of Austroads publications. The structure and content of the *Guide to Traffic Management* is discussed in *Part 1: Introduction to Traffic Management*. The 13 Parts are listed in Table 1.1. In the context of the *Guide to Traffic Management,* Part 8 is restricted to measures for traffic (especially speed) management and physical changes to the environment of streets within local areas. Whilst Part 8 refers to issues covered in other parts, it is distinguished from: • Part 4 – covers issues considered at the network level such as provisions for specific road users in the network • Part 5 – refers to related management issues but in the context of the broader network • Part 6 – deals with traffic management issues relating to the use and design of intersections, interchanges and pedestrian, bicycle and other crossings • Part 7 – includes reference to the needs of road users in activity centres • Part 9 – covers traffic operational matters such as traffic signals and incident management • Part 10 – provides guidance on the design and use of traffic control and communication devices • Part 12 – deals with issues related to development impacts • Part 13 – provides guidance on road environment and safety in a broader context.	Part 8 of the Austroads *Guide to Traffic Management* has the title *Local Area Traffic Management* (LATM) to define the limitations on its scope within the context of: • the 13 different Parts of the Guide to Traffic Management • the 9 different Guides spanning the range of Austroads publications. The structure and content of the *Guide to Traffic Management* is discussed in *Part 1: Introduction to Traffic Management*. The 13 Parts are listed in Table 1.1. In the context of the *Guide to Traffic Management,* Part 8 is restricted to measures for traffic (especially speed) management and physical changes to the environment of streets within local areas. Whilst Part 8 refers to issues covered in other parts, it is distinguished from: • Part 4 – covers issues considered at the network level such as provisions for specific road users in the network • Part 5 – refers to related management issues but in the context of the broader network • Part 6 – deals with traffic management issues relating to the use and design of intersections, interchanges and pedestrian, bicycle and other crossings • Part 7 – includes reference to the needs of road users in activity centres • Part 9 – covers traffic operational matters such as traffic signals and incident management • Part 10 – provides guidance on the design and use of traffic control and communication devices • Part 12 – deals with issues related to development impacts • Part 13 – provides guidance on road environment and safety in a broader context.

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		The scope of this Guide is therefore **traffic management within localities** and thus it focuses on local streets, which are primarily the responsibility of local government. The primary emphasis is on physical changes to the local street environment, with associated traffic management and enforcement, on an area-wide or at least whole-of-street basis to improve the community space, amenity, and safety within a residential precinct. Some standard traffic management measures, such as signs and road markings, have LATM application and may be included in the LATM 'tool box'. Where not referred to here, the reader should consult other parts of the *Guide to Traffic Management*, the general traffic engineering literature and appropriate codes for guidance on these techniques. Additionally, the Guide does not deal with those wider aspects of 'traffic calming' that relate to traffic reduction or roads beyond local areas. Measures to reduce the total level of traffic in cities are discussed in Austroads (2007), and guidance on traffic management techniques suitable for arterial roads and other roads with a significant traffic function is given in Austroads (1998a, b). In the context of the other Guides within the Austroads range of publications, this Guide is restricted to traffic management advice specific to local streets, and refers only briefly to issues more appropriately addressed in other Guides. It is recognised that it is difficult, if not impossible, to discuss many aspects of local area traffic management without reference to road design and/or safety issues. Therefore the view is taken that within the *Guide to Traffic Management* any consideration of such issues should be brief and be supported by references to the *Guide to Road Design* and/or the *Guide to Road Safety*.	The scope of this Guide is therefore **traffic management within localities** and thus it focuses on local streets, which are primarily the responsibility of local government. The primary emphasis is on physical changes to the local street environment, with associated traffic management and enforcement, on an area-wide or at least whole-of-street basis to improve the community space, amenity, and safety within a residential precinct. Some standard traffic management measures, such as signs and road markings, have LATM application and may be included in the LATM 'tool box'. Where not referred to here, the reader should consult other parts of the *Guide to Traffic Management*, the general traffic engineering literature and appropriate codes for guidance on these techniques. Additionally, the Guide does not deal with those wider aspects of 'traffic calming' that relate to traffic reduction or roads beyond local areas. Measures to reduce the total level of traffic in cities are discussed in Austroads (2007), and guidance on traffic management techniques suitable for arterial roads and other roads with a significant traffic function is given in Austroads (1998a, b) and, for signalised intersections, in the *Guide to Traffic Management Part 6 [date]*. In the context of the other Guides within the Austroads range of publications, this Guide is restricted to traffic management advice specific to local streets, and refers only briefly to issues more appropriately addressed in other Guides. It is recognised that it is difficult, if not impossible, to discuss many aspects of local area traffic management without reference to road design and/or safety issues. Therefore the view is taken that within the *Guide to Traffic Management* any consideration of such issues should be brief and be supported by references to the *Guide to Road Design* and/or the *Guide to Road Safety*.
AGTM Part 8 Section 2.4.1 Road Function and Traffic Hierarchy (page 16)	Add references to RSPs as appropriate speed management on Type I traffic routes	Although the legal classification of a road may influence the administrative and financial responsibilities that apply to it, including the processes for approvals, it is the functional classification of a road, or its place in the traffic hierarchy and in relation to local non-traffic activity, which is most important in LATM. In essence, the functional classification indicates the relative importance of the traffic mobility function and the amenity/access functions of streets and roads.	Although the legal classification of a road may influence the administrative and financial responsibilities that apply to it, including the processes for approvals, it is the functional classification of a road, or its place in the traffic hierarchy and in relation to local non-traffic activity, which is most important in LATM. In essence, the functional classification indicates the relative importance of the traffic mobility function and the amenity/access functions of streets and roads.

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		The conduct of an LATM scheme presupposes that there is a community agreement on at least one fundamental point: that the streets in which these actions are proposed are different in nature and purpose from other roads where traffic is expected to pass without such constraints. While there may be broader categorisation and consistency of approach such as used in the New Zealand ‘One Network’ classification (NZ Transport Agency 2013), LATM programs require the identification of a road hierarchy comprising of at least two basic categories, using the definitions of street environments (corridor types) adopted in *Sharing the Main Street* (RTA 2000, p. 8): • those elements that exist to carry traffic reasonably efficiently, on which severe traffic restraint is inappropriate and frontage activities must be subordinate to the traffic function (i.e. Type I corridors or traffic routes) • those elements on which living and environmental conditions predominate, and on which physical speed management may be considered (i.e. Type II and III corridors, such as main streets and local streets). Road classification studies in consultation with the community and the state authorities should readily be able to allocate most roads into one category or another, in which process the functional needs of important traffic routes can be agreed. This should prove to be easier than trying to obtain accord on a more detailed and far-reaching road-hierarchy plan over a whole municipality or region. However, specific local studies will be needed to identify the types of treatments that are appropriate to a given street’s characteristics and local functions, and to deal with that difficult group of ‘intermediate’ streets which do not fall readily into the arterial or local categories. It is important that the adopted road and street types be consistent with state road and traffic authority functional designations (e.g. a local scheme should not unilaterally designate a recognised road as a local street for the purposes of LATM), and that there be consistency in the designation of roads that cross between areas or municipalities. In New Zealand, the One Network road classification should be used to determine the function, status and level of service performance measures of a road (NZ Transport Agency 2013).	The conduct of an LATM scheme presupposes that there is a community agreement on at least one fundamental point: that the streets in which these actions are proposed are different in nature and purpose from other roads where traffic is expected to pass without such constraints. While there may be broader categorisation and consistency of approach such as used in the New Zealand ‘One Network’ classification (NZ Transport Agency 2013), LATM programs require the identification of a road hierarchy comprising of at least two basic categories, using the definitions of street environments (corridor types) adopted in *Sharing the Main Street* (RTA 2000, p. 8): • those elements that exist to carry traffic reasonably efficiently, on which severe traffic restraint is inappropriate and frontage activities must be subordinate to the traffic function (i.e. Type I corridors or traffic routes) • those elements on which living and environmental conditions predominate, and on which physical speed management may be considered (i.e. Type II and III corridors, such as main streets and local streets). Note, however, that non-LATM speed management devices such as raised safety platforms may still be appropriate on Type I corridors or traffic routes. Road classification studies in consultation with the community and the state authorities should readily be able to allocate most roads into one category or another, in which process the functional needs of important traffic routes can be agreed. This should prove to be easier than trying to obtain accord on a more detailed and far-reaching road-hierarchy plan over a whole municipality or region. However, specific local studies will be needed to identify the types of treatments that are appropriate to a given street’s characteristics and local functions, and to deal with that difficult group of ‘intermediate’ streets which do not fall readily into the arterial or local categories.

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		It would be expected that streets already allocated speed limits below the general urban limit would rationally be readily accepted as streets on which LATM may also be appropriate. There is mutuality between LATM and lower speed limits; lower speed limits give credibility to LATM measures, and LATM measures support lower speed limits. However, it cannot be assumed that LATM is **not** appropriate on some roads and streets with higher speed environments. For various reasons, many streets have retained higher speed limits, and these streets may require close inspection before it can be decided what, if any, LATM measures (including speed limit reductions) may be appropriate on them to ensure a Safe System. Given that these streets, which tend to be the more important local streets, usually suffer the worst safety, speed and amenity problems, they present the greatest challenge to a local road controlling authority contemplating LATM. Some streets of this type serve linear retail and other pedestrian activity centres, and can be dealt with as Type II corridors (Section 2.4.2). Others function as general urban roads, without any particular pedestrian concentrations but nevertheless may have sensitive abutting land uses with which higher speeds are not compatible. The potential for forms of traffic management that do not significantly degrade the traffic functionality of such roads became clear during the 1990s (e.g. Van den Dool & McKeown 1991), pointing the way for various types of intervention to reduce the conflict between traffic and land activity on such roads. These treatments are seen properly as sub-arterial traffic management rather than LATM. The following additional source material is recommended for reference on this topic: Brindle (1996: Chapter 6); Main Roads WA (1990: Appendix F); Pak-Poy and Kneebone (1987: Chapter 8); RTA (2000); NZ Transport Agency (2013).	It is important that the adopted road and street types be consistent with state road and traffic authority functional designations (e.g. a local scheme should not unilaterally designate a recognised road as a local street for the purposes of LATM), and that there be consistency in the designation of roads that cross between areas or municipalities. In New Zealand, the One Network road classification should be used to determine the function, status and level of service performance measures of a road (NZ Transport Agency 2013). It would be expected that streets already allocated speed limits below the general urban limit would rationally be readily accepted as streets on which LATM may also be appropriate. There is mutuality between LATM and lower speed limits; lower speed limits give credibility to LATM measures, and LATM measures support lower speed limits. However, it cannot be assumed that LATM is **not** appropriate on some roads and streets with higher speed environments. For various reasons, many streets have retained higher speed limits, and these streets may require close inspection before it can be decided what, if any, LATM measures (including speed limit reductions) may be appropriate on them to ensure a Safe System. Given that these streets, which tend to be the more important local streets, usually suffer the worst safety, speed and amenity problems, they present the greatest challenge to a local road controlling authority contemplating LATM. Some streets of this type serve linear retail and other pedestrian activity centres, and can be dealt with as Type II corridors (Section 2.4.2). Others function as general urban roads, without any particular pedestrian concentrations but nevertheless may have sensitive abutting land uses with which higher speeds are not compatible. The potential for forms of traffic management that do not significantly degrade the traffic functionality of such roads became clear during the 1990s (e.g. Van den Dool & McKeown 1991), pointing the way for various types of intervention to reduce the conflict between traffic and land activity on such roads. These treatments are seen properly as sub-arterial traffic management rather than LATM. The following additional source material is recommended for reference on this topic: Brindle (1996: Chapter 6); Main Roads WA (1990: Appendix F); Pak-Poy and Kneebone (1987: Chapter 8); RTA (2000); NZ Transport Agency (2013).

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			The need for speed management on Type I corridors where a high crash risk is present is also increasingly recognised, such as at intersections and crossings on urban arterial roads. Speed management devices at these locations are based on similar concepts as those used in LATM treatments but are designed to be comfortably navigated at higher speeds as well as by heavy and emergency vehicles. For further guidance, refer to the *Guide to Traffic Management Part 6 (Austroads, [date])*.
AGTM Part 8 Section 3.3.3 Developing Outline Schemes (page 40)	Add reference to RSPs as vertical deflection device option for higher-volume streets where LATM devices are not appropriate.	***More important local roads*** LATM choices are more limited on the more important local roads (often termed 'collectors' or 'local distributors'), but can still be effective. By definition, these roads carry higher volumes of traffic and are (or may become) bus routes. They help to break local areas into smaller land units and therefore provide the direct paths into the local area. Yet these roads also usually serve normal residential and community functions, including school access. Suitable LATM measures for these roads typically include (Daff & Wilson 1996): • roundabouts and/or mid-block splitter islands • median islands, intermittent planting islands or barrier lines to restrict overtaking and provide pedestrian refuges • carriageway narrowing or linemarking to provide one lane in each direction; this can also provide protected parking lanes and provide for cyclists. Vertical displacement devices with low operating speeds are not usually considered to be appropriate on higher-volume streets. Additional source material and more detail on this topic can be found in: Main Roads WA (1990: Section 7.6); O'Brien and Brindle (1999: Table 9-5); Transportation Association of Canada (1998: Table 3.2); VicRoads (1999a: Section 8.5).	***More important local roads*** LATM choices are more limited on the more important local roads (often termed 'collectors' or 'local distributors'), but can still be effective. By definition, these roads carry higher volumes of traffic and are (or may become) bus routes. They help to break local areas into smaller land units and therefore provide the direct paths into the local area. Yet these roads also usually serve normal residential and community functions, including school access. Suitable LATM measures for these roads typically include (Daff & Wilson 1996): • roundabouts and/or mid-block splitter islands • median islands, intermittent planting islands or barrier lines to restrict overtaking and provide pedestrian refuges • carriageway narrowing or linemarking to provide one lane in each direction; this can also provide protected parking lanes and provide for cyclists. Vertical displacement devices with low operating speeds are not usually considered to be appropriate on higher-volume streets. However, gentler vertical displacement devices with higher operating speeds, such as raised safety platforms, may be appropriate in these locations (refer to the *Guide to Traffic Management Part 6, Austroads [date])*. Additional source material and more detail on this topic can be found in: Main Roads WA (1990: Section 7.6); O'Brien and Brindle (1999: Table 9-5); Transportation Association of Canada (1998: Table 3.2); VicRoads (1999a: Section 8.5).

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AGTM Part 8 Section 7.2.3 Flat-top Road Humps (page 73)	Add info differentiating flat-top road humps from raised safety platforms	***Description of flat-top road humps*** A flat-top road hump or raised table is a raised surface approximately 75–100 mm high and typically with a 2 to 6 m long platform ramped up from the normal level of the street. The raised section (or platform) is flat instead of being curved as is the case with a (round profile) road hump described in Section 7.2.1. Where it is acceptable to install this device on bus routes, a minimum platform length of 6 m, a platform height of 75 mm, and a ramp gradient of 1:20 is recommended. Where the platform extends more than 6 m in length the device is likely to function as a raised pavement (see Section 7.2.5). Devices should be clearly visible to approaching drivers, illuminated by adequate street lighting, and enhanced by the use of signs, pavement markings, and other delineation. They should be installed at right angles to the direction of travel and should extend as close to the kerb as possible allowing sufficient opening for drainage. Flat-top road humps are a whole-of-street treatment and more than one device may be needed where speed reduction is required over the entire length of the street. The spacing of further devices should be as uniform as possible allowing for side roads and vehicle crossings. Consideration also needs to be given to providing bypasses for bicycles where the situation warrants it. Flat-top road humps with ramp gradients of 1:15 to 1:20 are generally regarded as bicycle friendly.	***Description of flat-top road humps*** A flat-top road hump or raised table is a raised surface approximately 75–100 mm high and typically with a 2 to 6 m long platform ramped up from the normal level of the street. The raised section (or platform) is flat instead of being curved as is the case with a (round profile) road hump described in Section 7.2.1. Where it is acceptable to install this device on bus routes, a minimum platform length of 6 m, a platform height of 75 mm, and a ramp gradient of 1:20 is recommended. Where the platform extends more than 6 m in length the device is likely to function as a raised pavement (see Section 7.2.5). Raised safety platforms are also similar to flat-top road humps but are optimised for use at signalised intersections with higher traffic speeds and volumes. They generally have gentler ramp gradients, a platform length of at least 6 m, and are constructed from different materials than flat-top road humps (see the *Guide to Traffic Management Part 6, Austroads, [date]*). Devices should be clearly visible to approaching drivers, illuminated by adequate street lighting, and enhanced by the use of signs, pavement markings, and other delineation. They should be installed at right angles to the direction of travel and should extend as close to the kerb as possible allowing sufficient opening for drainage. Flat-top road humps are a whole-of-street treatment and more than one device may be needed where speed reduction is required over the entire length of the street. The spacing of further devices should be as uniform as possible allowing for side roads and vehicle crossings. Consideration also needs to be given to providing bypasses for bicycles where the situation warrants it. Flat-top road humps with ramp gradients of 1:15 to 1:20 are generally regarded as bicycle friendly.
AGTM Part 8 Section 7.2.5 Raised Pavements (page 80)	Add info differentiating raised pavements from raised safety platforms	***Description of raised pavements*** A raised pavement is a raised section of roadway approximately 90 to 100 mm high ramped up from the normal level of the street with a platform extending over more than a standard car length (at least 6 m but typically more). It can be located either mid-block or cover the entire intersection.	***Description of raised pavements*** A raised pavement is a raised section of roadway approximately 90 to 100 mm high ramped up from the normal level of the street with a platform extending over more than a standard car length (at least 6 m but typically more). It can be located either mid-block or cover the entire intersection.

Section/Page	Description	Current Content	Edited Content
		It differs from a flat-top road hump both in terms of dimension and functionality. The raised pavement is longer than a flat-top road hump and is different in that it allows a vehicle to bring both sets of wheels up onto the platform at the same time. Flat-top road humps have more of a pitching action as one set of wheels comes up onto the platform and the other set goes down; this does not occur with raised pavements. Instead, the vertical deflection is generally less severe. Consequently, speed reduction may not be as substantial as with flat-top road humps although the zone of influence may extend over a longer street section. The extent of speed reduction that can be derived from this device is determined by the gradient and height of the ramp sections. A gradient of 1:12 is most commonly adopted in Australia and New Zealand. Steeper ramp gradients, which provide greater speed reducing benefits, can be employed. However, care should be taken to ensure that the ramp transition is not so severe that it will cause vehicles to bottom out. Raised pavements with ramp gradients of no more than 1:15 are generally regarded as bicycle friendly and 1:20 as bus friendly.	It differs from a flat-top road hump both in terms of dimension and functionality. The raised pavement is longer than a flat-top road hump and is different in that it allows a vehicle to bring both sets of wheels up onto the platform at the same time. Flat-top road humps have more of a pitching action as one set of wheels comes up onto the platform and the other set goes down; this does not occur with raised pavements. Instead, the vertical deflection is generally less severe. Consequently, speed reduction may not be as substantial as with flat-top road humps although the zone of influence may extend over a longer street section. Raised safety platforms are also similar to raised pavements but are optimised for use at signalised intersections with higher traffic speeds and volumes. They generally have gentler ramp gradients than raised pavements, are located in or extend into the throat of the intersection, and can incorporate appropriately marked crossing facilities (see the *Guide to Traffic Management Part 6, Austroads [date]).* The extent of speed reduction that can be derived from this device is determined by the gradient and height of the ramp sections. A gradient of 1:12 is most commonly adopted in Australia and New Zealand. Steeper ramp gradients, which provide greater speed reducing benefits, can be employed. However, care should be taken to ensure that the ramp transition is not so severe that it will cause vehicles to bottom out. Raised pavements with ramp gradients of no more than 1:15 are generally regarded as bicycle friendly and 1:20 as bus friendly.
AGTM Part 8 Section 8.13.1 Providing for Emergency Services Vehicles in LATM (page 135)	Amend advice around use of vertical displacement devices on ambulance routes	Emergency services commonly express concerns about the impacts of speed control devices on turn-out times. Reported research (e.g. Ewing 1999a) shows that the delay per slow point or road hump is generally well below 10 seconds. The delay at each road hump is reported to be between 3 and 5 seconds for fire trucks and up to 10 seconds for an ambulance with patient (ITE n.d.). It should be possible to calculate the increase in response times for a given proposal, and compare this with the current response time and with the target times. The issue is not whether the slow points add to the turn-out time, but whether the required turn-out time targets are met to all parts of the service area while improving general traffic safety and amenity for the neighbourhood. Other studies have shown that road humps caused less severe impacts.	Emergency services commonly express concerns about the impacts of speed control devices on turn-out times. Reported research (e.g. Ewing 1999a) shows that the delay per slow point or road hump is generally well below 10 seconds. The delay at each road hump is reported to be between 3 and 5 seconds for fire trucks and up to 10 seconds for an ambulance with patient (ITE n.d.). It should be possible to calculate the increase in response times for a given proposal, and compare this with the current response time and with the target times. The issue is not whether the slow points add to the turn-out time, but whether the required turn-out time targets are met to all parts of the service area while improving general traffic safety and amenity for the neighbourhood. Other studies have shown that road humps caused less severe impacts.

Section/Page	Description	Current Content	Edited Content
		Recommended elements of a process to address emergency services concerns are: • Consult with the responsible agencies, particularly at the early stages of investigation and planning. • Focus on the actual rather than claimed effects of speed control devices (i.e. have the factual evidence before you). • Recognise designated response routes and minimise restrictive devices on those routes where possible. • Ensure (by design template checks and so on) that essential vehicles can gain access to all properties at reasonable speed. This may involve wrong-way movements at roundabouts and displacement of signs and bollards in emergencies. • If possible, implement treatments in stages so that the impacts can be observed and modified if needed. • Select treatment types and designs, including innovative treatments such as road cushions that help to meet emergency services concerns. • Re-design treatments where possible in response to realistic emergency services submissions. • Create informed public opinion about the benefits that offset any marginal increases in turn-out times. Emergency response routes are likely to be potential or actual bus routes, be feeder routes to schools and other local facilities, and also are likely to be the more important traffic collector streets in the neighbourhood. They will therefore generally be among the streets with the greatest problems and challenges. While restrictive devices are generally inadvisable on streets with high emergency vehicle volumes such as an access to a fire station, doing nothing on these streets may not be an acceptable option. It may be appropriate to consider these streets for non-physical speed enforcement measures such as speed cameras (manned or unmanned), lane reduction and speed advisory devices. The effect of vertical displacements on patients is the main concern for ambulance operators. While vertical accelerations will be generally no greater than those encountered in normal operation on the road system if ambulances traverse devices at an appropriate speed, it is advisable not to place vertical displacement devices on streets frequently used by patient transport vehicles.	Recommended elements of a process to address emergency services concerns are: • Consult with the responsible agencies, particularly at the early stages of investigation and planning. • Focus on the actual rather than claimed effects of speed control devices (i.e. have the factual evidence before you). • Recognise designated response routes and minimise restrictive devices on those routes where possible. • Ensure (by design template checks and so on) that essential vehicles can gain access to all properties at reasonable speed. This may involve wrong-way movements at roundabouts and displacement of signs and bollards in emergencies. • If possible, implement treatments in stages so that the impacts can be observed and modified if needed. • Select treatment types and designs, including innovative treatments such as road cushions that help to meet emergency services concerns. • Re-design treatments where possible in response to realistic emergency services submissions. • Create informed public opinion about the benefits that offset any marginal increases in turn-out times. Emergency response routes are likely to be potential or actual bus routes, be feeder routes to schools and other local facilities, and also are likely to be the more important traffic collector streets in the neighbourhood. They will therefore generally be among the streets with the greatest problems and challenges. While restrictive devices are generally inadvisable on streets with high emergency vehicle volumes such as an access to a fire station, doing nothing on these streets may not be an acceptable option. It may be appropriate to consider these streets for non-physical speed enforcement measures such as speed cameras (manned or unmanned), lane reduction and speed advisory devices.

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		The following source contains additional material on this topic: VicRoads (1999a: Chapters 1, 8 and 10).	The effect of vertical displacements on patients is the main concern for ambulance operators. While vertical accelerations will be generally no greater than those encountered in normal operation on the road system if ambulances traverse devices at an appropriate speed, it is advisable not to place vertical displacement devices with low target operating speeds on streets frequently used by patient transport vehicles in locations where they would not normally be required to slow down. Note this does not exclude the use of appropriately designed vertical displacement devices in locations where ambulances would be expected to slow regardless of traffic management, such as at signalised intersections and crossings. The following source contains additional material on this topic: VicRoads (1999a: Chapters 1, 8 and 10).
Part 9: Traffic Operations (2019)			
AGTM Part 9 Section 6.2 Intersection Signals and the Safe System (page 56)	Add RSP reference as Safe System treatment for signalised intersections	Intersection signals should be designed and operated in a way that supports a Safe System. As intersections are where most conflicts between different traffic streams occur (including pedestrian and bicycle traffic) it is critical that geometry and operation of signalised intersections are designed so that, as far as is practically possible, the likelihood of serious crashes is minimised. Managing the likelihood and outcome of crashes at intersections by designing and operating the infrastructure in an appropriate manner is necessary to support the safe roads and roadsides pillar of the Safe System. Traffic signal design and operation must be considered from the road user perspective. For road users, traffic signals are essentially a communication device which, if well designed, will simplify decision making and foster safe behaviour. While intersection signals have generally been found to improve the safety performance of intersections compared to that of priority-controlled intersections (NZ Transport Agency, 2013), they have not been typically identified and promoted as a Safe System treatment (Austroads, 2015h). This is because the geometric design and operation of signalised intersection is generally not sufficiently forgiving in the event that a driver or other road user makes a mistake. A number of factors that increase the FSI crash risk at signalised intersections are outlined in Section 6.4.3. These factors should be taken into account when designing intersection signals and their operation.	Intersection signals should be designed and operated in a way that supports a Safe System. As intersections are where most conflicts between different traffic streams occur (including pedestrian and bicycle traffic) it is critical that geometry and operation of signalised intersections are designed so that, as far as is practically possible, the likelihood of serious crashes is minimised. For example, raised safety platforms can be incorporated into intersection design to reduce the risk and severity of crashes at urban arterial signalised intersections (refer to the *Guide to Traffic Management Part 6, Austroads, [date]*). Managing the likelihood and outcome of crashes at intersections by designing and operating the infrastructure in an appropriate manner is necessary to support the safe roads and roadsides pillar of the Safe System. Traffic signal design and operation must be considered from the road user perspective. For road users, traffic signals are essentially a communication device which, if well designed, will simplify decision making and foster safe behaviour.

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			While intersection signals have generally been found to improve the safety performance of intersections compared to that of priority-controlled intersections (NZ Transport Agency, 2013), they have not been typically identified and promoted as a Safe System treatment (Austroads, 2015h). This is because the geometric design and operation of signalised intersection is generally not sufficiently forgiving in the event that a driver or other road user makes a mistake. A number of factors that increase the FSI crash risk at signalised intersections are outlined in Section 6.4.3. These factors should be taken into account when designing intersection signals and their operation.
AGTM Part 9 Section 6.5.3 Phasing Design (page 69)	Add RSPs as factor influencing phasing design	***Factors to consider*** Phasing design is the combination of all necessary traffic movements into a plan that describes the way movements should interrelate. The choice of phasing system depends on: • **Layout** – the number of lanes and the length of left and right turn lanes available for each movement on the approach and departure of each intersecting road. • Alignment – the horizontal and vertical alignment in regard to the angle at which roads intersect and sight distance available to allow safe filtering of right turn movements. • Traffic flows – the amount of traffic including proportion of heavy vehicles in each through or turning movement. • Signal coordination – progression considerations for an intersection within a coordinated system. • Pedestrians – which pedestrian movements need to be controlled and how they will be catered for in the phasing system. • Special vehicles – whether or not buses, trams, bicycles, emergency vehicles or (rarely) trains need to be separately controlled, and how they will be catered for in the phasing system. • Speed environment – the operating speed of vehicles is a factor that affects both the likelihood and severity of crashes.	***Factors to consider*** Phasing design is the combination of all necessary traffic movements into a plan that describes the way movements should interrelate. The choice of phasing system depends on: • **Layout** – the number of lanes and the length of left and right turn lanes available for each movement on the approach and departure of each intersecting road. • Alignment – the horizontal and vertical alignment in regard to the angle at which roads intersect and sight distance available to allow safe filtering of right turn movements. • Traffic flows – the amount of traffic including proportion of heavy vehicles in each through or turning movement. • Signal coordination – progression considerations for an intersection within a coordinated system. • Pedestrians – which pedestrian movements need to be controlled and how they will be catered for in the phasing system. • Special vehicles – whether or not buses, trams, bicycles, emergency vehicles or (rarely) trains need to be separately controlled, and how they will be catered for in the phasing system. • Speed environment – the operating speed of vehicles is a factor that affects both the likelihood and severity of crashes. • **Speed management treatments** – the presence of speed management devices such as raised safety platforms can influence operating speeds and clearance times on some or all approaches.
Part 10: Traffic Control and Communication Devices (2019)			
No changes.			

Section/Page	Description	Current Content	Edited Content
Part 11: Parking (2017)			
No changes.			
Part 12: Traffic Impacts of Developments (2019)			
No changes.			
Part 13: Road Environment Safety (2017)			
AGTM Part 13 Section 4.4.3 Speed Management (page 25)	Add reference to RSPs	Effective speed management requires investment in three main areas: engineering, education (including community education and engagement) and enforcement. In addition, emphasis is placed on the importance of cross-agency collaboration and ongoing engagement with research and best practice. Brief details with respect to the contribution that engineering, education and enforcement has on speed management are outlined below: • Engineering – while speed management can be undertaken through applying speed limits only, outcomes are enhanced if the road environment is designed to naturally elicit an appropriate speed response. For example, long, wide, straight local streets lead to higher-speeds. Streets suitably altered by local area traffic management (LATM) treatments lead to lower-speeds. The same principles apply to highways. Curvilinear highways with appropriate radii curves may lead to lower, but not excessively slow speeds. Straight highways may lead to higher-speeds. Long, straight sections of highways also give rise to isolated curves, which may present problems for drivers. • Education – education is an important element of speed management. Education helps to communicate the inherent risks involved in speeding and allows road users to understand the importance of speed management and road safety, and how the measure seeks to contribute to these goals. Education should also include details with respect to enforcement (see below). This should include outlining the penalties associated with disobeying the speed limit, and the speed enforcement measures undertaken to discourage drivers. • Enforcement – to maximise the effectiveness of speed management engineering features, enforcement along with penalties for violating any regulatory control is required to discourage drivers from breaking the regulatory control (i.e. speed limit). This is intended to reduce the number of drivers exceeding the limit and consequently lower the mean and 85th percentile speeds.	Effective speed management requires investment in three main areas: engineering, education (including community education and engagement) and enforcement. In addition, emphasis is placed on the importance of cross-agency collaboration and ongoing engagement with research and best practice. Brief details with respect to the contribution that engineering, education and enforcement has on speed management are outlined below: • Engineering – while speed management can be undertaken through applying speed limits only, outcomes are enhanced if the road environment is designed to naturally elicit an appropriate speed response. For example, long, wide, straight local streets lead to higher-speeds. Streets suitably altered by local area traffic management (LATM) treatments lead to lower-speeds. The same principles apply to highways. Curvilinear highways with appropriate radii curves may lead to lower, but not excessively slow speeds. Straight highways may lead to higher-speeds. Long, straight sections of highways also give rise to isolated curves, which may present problems for drivers. Intersections are also an increasing focus for speed management treatments due to the relatively high proportion of crashes which occur at them. At signalised intersections with operating speeds above Safe System speeds, the use of appropriately designed engineering treatments such as raised safety platforms leads to lower speeds. • Education – education is an important element of speed management. Education helps to communicate the inherent risks involved in speeding and allows road users to understand the importance of speed management and road safety, and how the measure seeks to contribute to these goals. Education should also include details with respect to enforcement (see below). This should include outlining the penalties associated with disobeying the speed limit, and the speed enforcement measures undertaken to discourage drivers.

Section/Page	Description	Current Content	Edited Content
		The *Guide to Traffic Management Part 5: Road Management* (Austroads 2017e) provides guidance on the risk-based selection of speed limits for different road categories and functions.	• Enforcement – to maximise the effectiveness of speed management engineering features, enforcement along with penalties for violating any regulatory control is required to discourage drivers from breaking the regulatory control (i.e. speed limit). This is intended to reduce the number of drivers exceeding the limit and consequently lower the mean and 85th percentile speeds. The *Guide to Traffic Management Part 5: Road Management* (Austroads 2017e) provides guidance on the risk-based selection of speed limits for different road categories and functions.
AGTM Part 13 Section 5.2.5 Intersections and Crossings (page 40)	Amend RSP terminology	Austroads (2015h) investigated various approaches to make traditional intersections more aligned with the Safe System philosophy. The report found that the most effective and innovative way to make intersections align is to undertake geometric design changes, with the aim being to reduce crash severity through moderating both impact speeds and angles. These include: • low-speed signalised roundabouts • high-speed signalised roundabouts • horizontal deflections on approaches • vertical deflections on approaches (e.g. raised intersections) – where no changes to impact angles are intended.	Austroads (2015h) investigated various approaches to make traditional intersections more aligned with the Safe System philosophy. The report found that the most effective and innovative way to make intersections align is to undertake geometric design changes, with the aim being to reduce crash severity through moderating both impact speeds and angles. These include: • low-speed signalised roundabouts • high-speed signalised roundabouts • horizontal deflections on approaches • vertical deflections on approaches (e.g. raised ~~intersections~~safety platforms) – where no changes to impact angles are intended.
AGTM Part 13 Section 5.2.6 Traffic Controls (page 42)	Cross-reference speed management guidance to RSP guidance in AGTM Part 6	In the context of a Safe System, traffic control devices can be used to deliver both safe roads and safe speeds. Safe speeds may be delivered using regulatory (e.g. regulatory speed limit signage) and physical traffic control devices (e.g. local area traffic management devices that reduce the speed of vehicles). Safe roads can be delivered through traffic control devices that control road user movements and behaviour (e.g. traffic signals that control the movement of vehicles) and physical devices that directly influence the passage of vehicles (e.g. medians that control turning movements). Speed management is fundamental to the safe management of traffic. Guidance on the principles and practice of speed management, with reference to the application of speed limits, is given in the *Guide to Road Safety Part 3* (Austroads 2008a) and the *Guide to Traffic Management Part 5* (Austroads 2017e).	In the context of a Safe System, traffic control devices can be used to deliver both safe roads and safe speeds. Safe speeds may be delivered using regulatory (e.g. regulatory speed limit signage) and physical traffic control devices (e.g. local area traffic management devices that reduce the speed of vehicles). Safe roads can be delivered through traffic control devices that control road user movements and behaviour (e.g. traffic signals that control the movement of vehicles) and physical devices that directly influence the passage of vehicles (e.g. medians that control turning movements). Speed management is fundamental to the safe management of traffic. Guidance on the principles and practice of speed management, with reference to the application of speed limits, is given in the *Guide to Road Safety Part 3* (Austroads 2008a) and the *Guide to Traffic Management Part 5* (Austroads 2017e). Guidance on the use of speed management devices at intersections is given in the *Guide to Traffic Management Part 6* (Austroads [date]).

Section/Page	Description	Current Content	Edited Content
AGTM Part 13 Appendix A Safe Road Environment Elements – Standards and Guidelines Directory Table A5 Intersections (page 62)	Add reference to TM Part 6 to intersection guidance for managing speeds to table	Safe road environment features: **Control** road users at conflict points or areas of conflict, and manage their speed Road environment element: • GTM Part 8 Local area traffic management - Gives guidance on the selection of a management plan to control the road user at intersections	Safe road environment features: **Control** road users at conflict points or areas of conflict, and manage their speed Road environment element: • GTM Part 6 Intersections, Interchanges and Crossings - Gives guidance on speed management treatments (raised safety platforms) at signalised urban intersections • GTM Part 8 Local area traffic management - Gives guidance on the selection of a management plan to control the road user at intersections

Note ellipses ('…') indicate additional text from the section which has not been included in the table.

Page references generally refer to the page where the selected section of text begins and may not always align with the first page of the section.

The date of the version of each Guide Part that has been used is noted in the heading for each Part. Note this may not be the most recent version as some updates have been released in the last two months.

References to Guide Parts are followed by '[date]' so these can be replaced with the most up to date versions.

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