The hurdles of introducing innovative road safety infrastructure solutions – a case study on raised Safety Platforms

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Abstract

It will be very difficult to achieve a perfectly Safe System on our road network (i.e. zero fatalities or serious injuries) without the introduction of new and innovative road infrastructure treatments. There are treatments that exist overseas and have proven effectiveness; however the uptake of these solutions in Australia has been limited in many cases. This is due to a number of issues, including lack of knowledge on their use and effectiveness, lack of experience with design and implementation, and risk aversion.

This paper will discuss issues relating to the future uptake of innovative infrastructure solutions through the case study of raised Safety Platforms on approach to signalised intersections on arterial routes – a new road infrastructure treatment that VicRoads has been in the process of researching, trialling and implementing on Victorian roads. The aim of this treatment is to achieve Safe System vehicle speeds through intersections (50 km/h). Although this infrastructure is used extensively overseas (e.g. in the Netherlands), it has yet to be introduced on arterial roads in Australia. ARRB undertook a comprehensive literature review on the likely benefits of these treatments, performed trials to establish vertical accelerations and driver comfort levels in a variety of vehicle types and performed modelling to assess the effects of road slope on effectiveness. VicRoads is currently in the process of installing the raised Safety Platforms at an intersection near Geelong, Victoria, and is due for completion in July 2015.

Introduction

The Safe System approach focuses on eliminating fatal and serious injuries as a result of crashes and promotes a shared responsibility between road agencies, the driver and car manufacturers to create a safe road environment for all road users (ATC 2011). This approach emphasises the need for a ‘forgiving’ system, where road users do not face the risk of serious injury or death while adhering to the road rules (Elvik et al. 2004).

Australian road authorities have adopted the Safe System approach; however it is understandable that achieving zero fatal and serious injuries on the Australian road network is not a task that can be done overnight. Current road safety treatments, regardless of expense, result in some reduced serious crash outcomes, but do not achieve a completely Safe System. For example, a roundabout or signals can be installed at an intersection to improve road safety, but each only attains a crash reduction of 55% and 30% respectively in an urban setting (Austroads 2013a). There is a need to develop new innovations and to adapt existing treatments so that better crash risk reduction can be obtained.

There are also a number of highly effective treatments that already exist, but are currently not being utilised in Australia. There is still reluctance to incorporate new treatments due to a lack of knowledge, existing evidence of a treatment’s effectiveness, and issues with public acceptance and legal liability. This paper will discuss how some of these issues can be negotiated through a case study on raised Safety Platforms at signalised intersections on arterial routes – a new road infrastructure treatment that VicRoads has been developing, trialling and implementing on

Victorian roads – as well as the need for an innovation framework to help agencies fast track the introduction of new treatments in future.

The structure of this paper is as follows:

- introduction
- case study (problem identification, literature review, off-road trial and current status)
- discussion of issues relating to innovation
- concluding remarks.

Note that the term 'Safety Platform' is used throughout to describe a raised platform just prior to an intersection, in accordance with VicRoads' definition.

Case Study – Problem identification

Intersections are often the source of major fatal and serious injury crashes and are often a challenge for road safety practitioners. At intersections, there are a high number of conflict points which create opportunities for vehicles to collide. When the vehicles collide, the impact forces influence the likelihood of a fatality or serious injury. The goal at intersections should be to reduce these impact forces to levels that do not result in a fatality or serious injury.

One method to achieve these lower impact forces is to reduce vehicle speeds through the intersection. Research has indicated that vehicle speeds over 50 km/h dramatically increases the chances of death and serious injury in the event of a crash between two vehicles at an intersection (Fildes et al. 2005). When vehicle speeds are kept at or below 50 km/h through intersections, the chance of death is less than 10%. For side-impact collisions, particularly at 90 degree angles, the likelihood of injury greatly increases above 50 km/h.

The aim of VicRoads' study was to install vertical displacement treatments (i.e. speed humps) in order to reduce vehicle speeds to 50 km/h through a signalised intersection in a 70 km/h speed environment. In the context of this paper, raised Safety Platforms specifically refers to a flat top speed hump.

Case Study – Literature review

In early 2014, VicRoads commissioned ARRB Group to undertake a literature review and present recommendations for ideal profile and dimensions for a vertical displacement treatment at signalised intersections. A brief summary of the literature review findings are presented in this paper; the full details of the literature review will be provided in a published report. A literature review was undertaken to explore the different uses and design profiles of three types of vertical displacement treatments, as nominated by VicRoads:

- Watts profile road humps
- flat top road humps
- raised intersections.

The review also brought attention to additional design types, such as sinusoidal profile road humps, road cushions, and raised pedestrian crossings.

The review sought to draw conclusions on how to achieve the Safe System vehicle speeds of 50 km/h through an intersection whilst considering different vehicle types (including bus services), passenger comfort, and emergency services access. Literature review searches revealed that although there is a great amount of available information on road hump performance, there is limited information on hump performance for a 50 km/h crossing speed or road hump implementation at intersections. Consequently, the review initially presented some information on design standards for local roads (i.e. lower speed environments) and road hump effectiveness at midblock locations to provide further background on overall hump performance. VicRoads provided some material for review, and input was also sought from councils as to their experiences with implementation, community acceptance and any other issues encountered.

There is also limited information on road humps and platforms with a design speed of 50 km/h. The literature review revealed that although current Austroads guidelines state that road humps and raised intersections are not suitable for locations where speed limits are posted above 60 km/h (Austroads 2008), a number of studies showed that 50 km/h vehicle speeds can be achieved whilst maintaining some level of driver comfort.

The literature review also considered:

- the impact on emergency and bus service operation
- catering for pedestrian activity at intersections
- noise pollution
- the impact on neighbouring streets/service lanes
- damage to vehicles/pavement
- difficulties that may be encountered when retrofitting to existing intersections.

In general, the flat top profile was seen as the least restrictive in terms of ease of installation and replication, benefits to different road users and lower cost.

Effectiveness of raised treatments at intersections

Raised Safety Platforms are a common instalment at both signalised and unsignalised intersections in the Netherlands (Candappa & Corben 2011). Safety Platforms are sometimes used on the approach to an intersection, rather than through the intersection itself. A number of studies around the world have shown raised intersections to be effective in achieving vehicle speed reduction and crash reduction. Table 1 provides a summary of the findings from these studies.

Table 1. Summary of the effectiveness of raised Safety Platforms at intersections

Reference	Site	Key treatment(s)	Effects on speed and crash reduction
Austroads (2011)	Mahoe Street, Hamilton, New Zealand	Raised intersection (traffic volume 3,000 vpd)	• 85th % speed: -1.1 km/h
Watkins (2000)	Cambridge, Massachusetts, USA	Raised intersection (2 sites: 8,100 and 4,400 vpd)	• 85th % speed: -5 mph (8 km/h) & -4 mph (6.4 km/h) • % drivers exceeding 25 mph (40 km/h): 57% to 17% & 39% to 14%
Reekmans et al. (2004)	The Netherlands & Australia	Raised intersections	• 20–60% crash reduction • 25–80% casualty reduction
Van der Dussen (2002)		82 intersections, 10 treated with raised plateaus	• 80% crash reduction (in comparison to 57% at roundabouts and 46% at traffic signals) • 80% injury crashes reduction

			• 60% property damage only crash reduction • Cheaper to install over roundabout/signals conversion

Source: Austroads (2013b); Harms & Turner (2013).

The UK Mixed Priority Routes Road Safety Demonstration Project (Gordon & Barrell 2008, in Austroads 2013b) assessed raised intersection tables at four locations in combination with other speed management treatments. These were primarily high volume bus routes with posted speed limits of 30 mph (48 km/h). Table 2 provides a summary of the project results, including percentage changes in mean and 85th percentile speeds, and percentage change in casualties. Note that because in some cases multiple treatments have been applied, it is therefore not possible to determine the effect of the raised intersection component.

Table 2. Summary of project results for UK Mixed Priority Routes Road Safety Demonstration Project 2008

Site	Key treatments	Change in mean speed	Change in 85th % speed	Crashes
The Parade/ Victoria Tce, Leamington Spa	Lower speed limit, road narrowing, raised junctions, cycle lanes	-5–19% (to under 20 mph (32 km/h) speed limit)	-5–17% (to between 19–23 mph (30–37 km/h))	• Average annual casualties dropped from 14 to 8.6 • 0% reduction in speeds (possibly skewed by major bus crash involving many passengers)
Cowley Rd, Oxford	Raised carriageway and junctions, additional crossings, extended kerbs	-10% (2.7 km/h)	-10% (3.4 km/h)	• 36% reduction in crash frequency • 55% reduction in cyclist crashes • 18% reduction in pedestrian crashes
Walworth Rd, Southwark	Raised crossings at junction, wider footpaths, improved signalling	N/A	N/A	• 46% reduction in slight casualties • 0% reduction in serious injuries • 42.5% overall crash reduction
St Peters St, St Albans	Raised table with crossings, gateways, carriageway shift	-8% (3.2 km/h)	-4%	• 38–50% reduction in injury crashes

Source: Austroads (2013b); Harms & Turner (2013).

It should be noted that three of the sites experienced reductions in traffic due to the treatment implementation (Harms & Turner 2013).

Fortuijn, Carton and Feddes (2005) assessed the safety effects of raised Safety Platforms at 29 intersections in the Netherlands. At a controlled intersection, the Safety Platforms were typically 120 mm high with a 6 m long plateau and 1:30 ramps. From a safety viewpoint, the authors stated that a reduction in speed to 30–35 km/h was desirable. The authors studied 40 signalised intersections and 29 priority (unsignalised) intersections for a three-year period (where data was available) before and after the installation dates of Safety Platforms. The resultant safety effects are shown in Table 3.

Table 3. Safety effects of raised Safety Platforms at signalised and priority intersections

	Signalised intersections with Safety Platform		**Priority intersections 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 & Feddes (2005).

Optimal performance design

A linear inverse relationship has been previously established between the perception of comfort and vertical acceleration (Kjemtrup 1988). In other words, as vertical acceleration increases, so does discomfort for drivers and passengers. Vertical acceleration is not only dependent on the geometric design of the hump and the vehicle speed as it travels over the hump, but also vehicle characteristics such as the suspension system, tire pressure and seat softness. Callaway, Roper and Germanchev (2010) noted that comfort was also affected by pitch, roll and steering wheel feedback. Kjemtrup (1988) and Callaway et al. (2010) both identify 1.0 g as being internationally considered the appropriate maximum vertical acceleration that one should withstand, and that vertical acceleration of above 0.5 g (0.7 g recommended) should achieve effective speed reduction. Kjemtrup also notes that the driver of a bus is subjected to a higher level of vertical acceleration than their passengers. According to Kjemtrup's trials cars were able to traverse the same road hump consistently 15–20 km/h faster than buses.

ARRB was previously commissioned by the Department of Transport to assess the effectiveness of platform-style tram stops at kerbside, which allow vehicles in the left lane to traverse the tram stop platforms (Callaway, Roper & Germanchev 2010). The platform style ramps were 290 mm high with a plateau of 6 m and ramps at various grades from 1:12 to 1:55. The study measured maximum vehicle travel speeds, adverse effects while braking, and the acceptable distance for parked cars on the ramp approach and departure for a variety of different ramp grades. The vertical acceleration threshold was set at 0.5 g as the platforms were not designed to reduce vehicle speeds, but aimed at maintaining consistent traffic flow. The resultant speeds for various vehicle types and ramp grades are shown in Table 4.

Table 4. Highest recommended posted speed limit (based on a maximum vertical acceleration of 0.5 g)

Vehicle	**Highest recommended comfortable speed (km/h)**			
	1:12	**1:20**	**1:40**	**1:55**
Motorcycle	20	50	80+	80+
Passenger car	20	50	70	80+

Medium rigid truck	20	30	60	70
Low floor bus	10(2)	20	60	70+(1)
Heavy rigid truck	20	30	60	70+(1)
B-double	20	30	60	70+(1)
Overall	10	20	60	70

1 Due to the limited approach distance, the test vehicle was not able to reach a speed of 80 km/h. The highest speed reached is listed.
2 Result based on ground clearance considerations rather than occupant comfort.
Source: Callaway, Roper & Germanchev (2010).

The braking tests indicated that vehicle stopping distances increased by 1–5 m when an emergency braking manoeuvre was performed on the off-ramp to the platform; however there were no negative effects on vehicle stability (Callaway, Roper & Germanchev 2010).

Weber and Braaksma (2000) tested vehicle speeds across a variety of Watts and Seminole profiles in Canada and the USA (see Figure 1 for hump profiles). The 75 mm high Seminole profile (6.7 m long) had the closest results to the target of this project (50 km/h), with 85th percentile speeds for passenger vehicles of 44 km/h and bus mean speeds of 30 km/h. It is also worth noting that for all tests, the peak vertical acceleration was generally between 0.5 to 0.7 g.

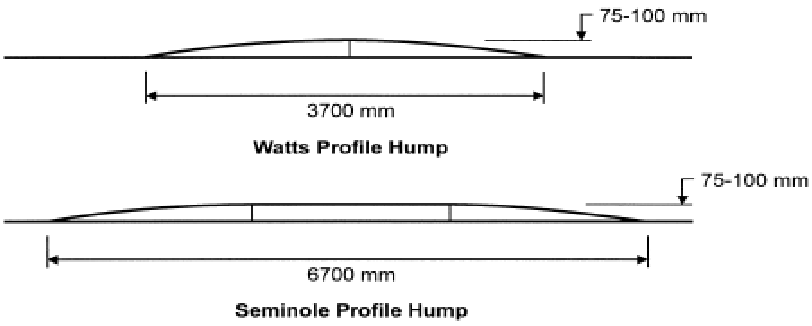


Figure 1. Watts and Seminole profile road humps

Design issues and limitations

A study in the US identified that raised Safety Platforms at intersections significantly impacted on emergency response times (Candappa & Corben 2011). Bus route timetables can also be affected by the introduction of road humps (Department of Transport 1992).

Locating raised Safety Platforms at an existing intersection can create quite a few issues, including:

- Care must be taken to ensure road humps or raised intersection ramps do not impact on vehicle turning movements. Vehicle stability could be compromised if vehicles travel up or down a ramp at an angle.
- Orientation of stop lines should preferably be at 90 degrees to the direction of travel to ensure vehicles do not travel across the ramps at an angle.
- The platform of flat top humps can act well as pedestrian crossing points; however these points must be clearly line-marked and signed to ensure there is no confusion as to when pedestrians have priority (for example, ensure that the platform is not confused for wombat crossing at a signalised intersection) and the platform must be flush with the footpath to prevent tripping hazards.
- The Safety Platform should be raised across the whole intersection if the road is undivided to prevent additional hazards to both vehicles and pedestrians in the middle of the carriageway.

- For intersections with left turn slip lanes and/or median splitter islands, hump length may be limited by the length of the islands.
- If road shoulders are present, the design should prevent vehicles bypassing the raised pavement and maintaining a higher speed.
- Drainage of the pavement should be taken into account in the design of the treatment.
- Warning signs and linemarking should alert road users to the treatment to ensure they slow down accordingly.
- Longitudinal grade of the road has not been the subject of research, and local road treatments are suggested to be placed on roads preferably with a 3% longitudinal grade (Austroads 2008).

Case Study – Off-road trial

Late in 2014, VicRoads commissioned ARRB Group to undertake on-site testing and simulation modelling of Safety Platform designs to determine expected vehicle speeds as a result of comfort levels. A brief summary of the off-road trial process is presented in this paper; the full details of the trial will be provided in a published report. The testing program focussed on three key areas:

- maximum acceptable speed to traverse each installed platform
- the vertical acceleration and pitch experience by each vehicle type at different speeds
- how this compares to the sensation of a passenger vehicle travelling over other vertical deflection devices.

In the previous literature review, it was identified that comfort is a key criteria for performance effectiveness, and road user discomfort can reduce vehicle speeds and thus improve overall safety.

VicRoads had installed two flat top Safety Platforms along Gundog Lane, Belmont, with profiles as described in Table 5 and locations as shown in Figure 2.

Table 5. Installed Safety Platform profiles

Trial	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

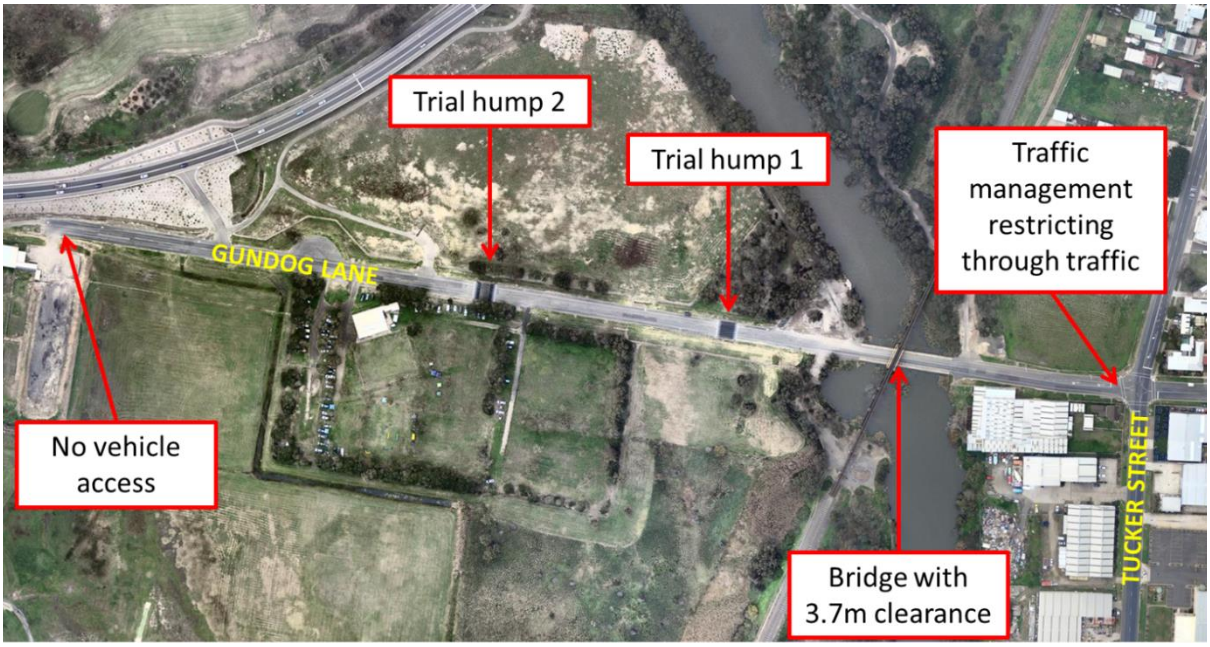


Figure 2. Trial Safety Platform locations along Gundog Lane, Belmont

A range of vehicle types were included in the study to account for differences in vehicle performance and to ensure that there was no significant negative impact on the majority of road users at potential Safety Platform sites. The vehicles selected in this study were:

- bicycle
- motorcycle (with pillion and without)
- passenger car
- heavy rigid truck
- semi-trailer
- airbag suspension bus
- spring suspension bus.

The comfort levels were measured by vertical acceleration and pitch. Ride quality data was collected for a passenger car, rigid truck, semi-trailer, airbag suspension bus and spring suspension bus. Driver/passenger feedback was collected for bicycles and motorcycles. Comparison data was also collected for typical vertical displacement treatments (i.e. conventional road humps and Safety Platforms) in the passenger car.

Based on the literature review previously undertaken, it was established that speed reduction occurred when vertical acceleration exceeded the comfort threshold (i.e. 0.5 g). Vertical accelerations exceeding 0.7 g was considered dangerous and has the potential to cause damage to a vehicle. Considering this, a range of 0.5 to 0.7 g was considered to achieve noticeable speed reduction without causing vehicle damage (see Table 6).

Table 6. Typical driver speed responses to vertical acceleration

Magnitude of vertical acceleration (g)	Typical driver response
0.1 – 0.5	No speed response
0.5 – 0.7	Some speed reduction
0.7+	Possible damage to vehicle (bottoming out)

In the on-site testing, Profile 1 (1:30 on-ramp, 7 m platform and 1:35 off ramp) was shown to be the more effective of the two profiles installed. This profile showed the smallest speed differential between vehicle types, with the following expected speed results if the treatments were to be deployed on public roads (see also Figures 3 and 4):

- 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 red line in Figures 3 and 4 indicate the comfort threshold (0.5 g), as determined from the previous literature review. The x-axis (‘target speed’) indicates the speed that the driver was trying to achieve as the vehicle passed over the Safety Platforms.

Pitch data was also collected during each test, which measures the rate of change in angle of the vehicle as it traverses a Safety Platform. This can cause additional discomfort to vehicle occupants. However, the pitch angles measured during travel over all of the ramps were no more than 10 degrees per second. Anything under approximately 15 degrees per second is unlikely to be noticed as a pitching movement, especially in combination with the vertical accelerations that are occurring at the same time. Accordingly, it is the vertical accelerations which are considered more important when measuring comfort during travel over these ramps.

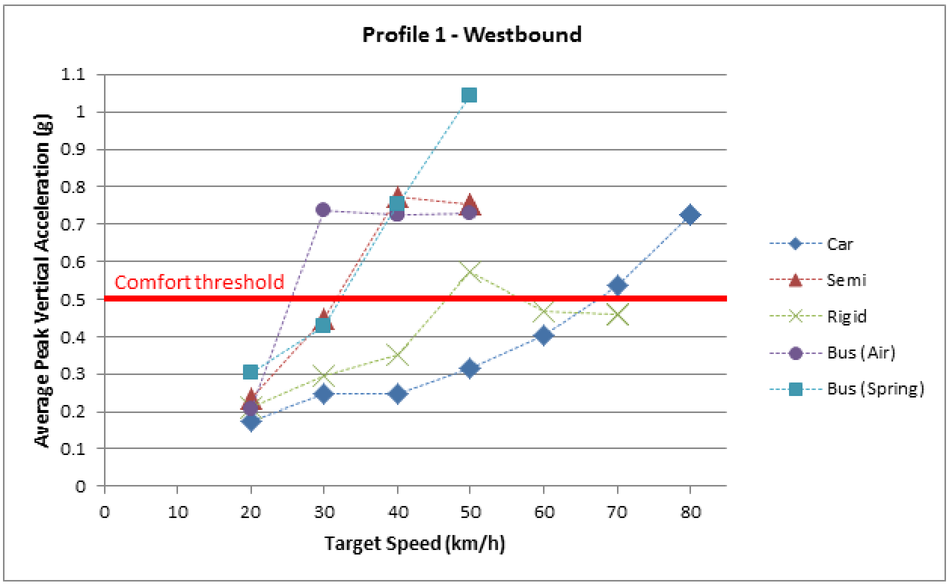


Figure 3. Average peak vertical accelerations measured at passenger seat for Profile 1 Safety Platform (travelling westbound)

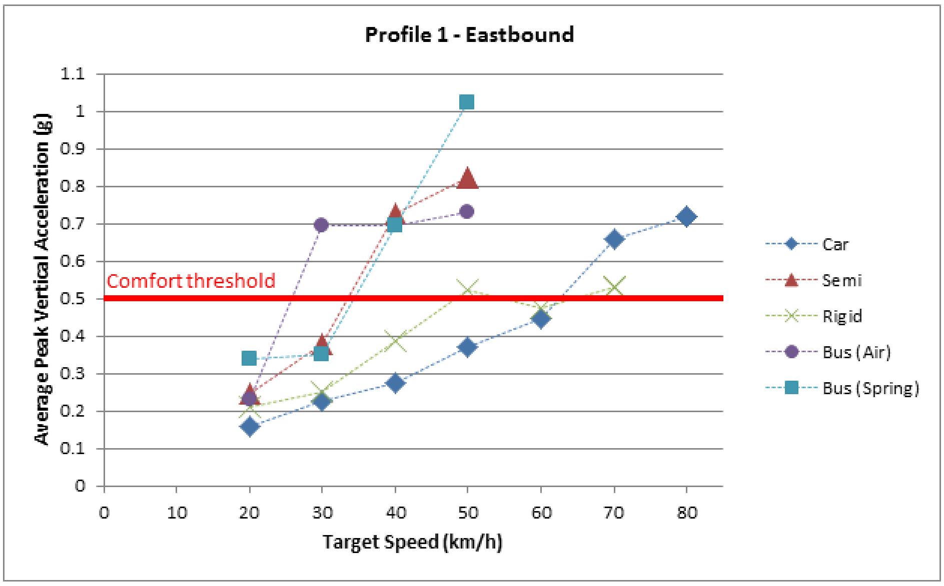


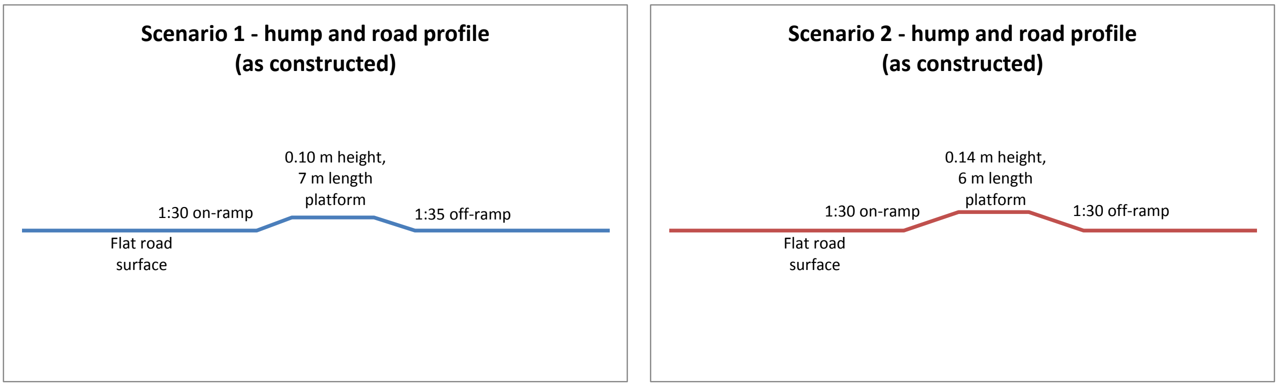
Figure 4. Average peak vertical accelerations measured at passenger seat for Profile 1 Safety Platform (travelling eastbound)

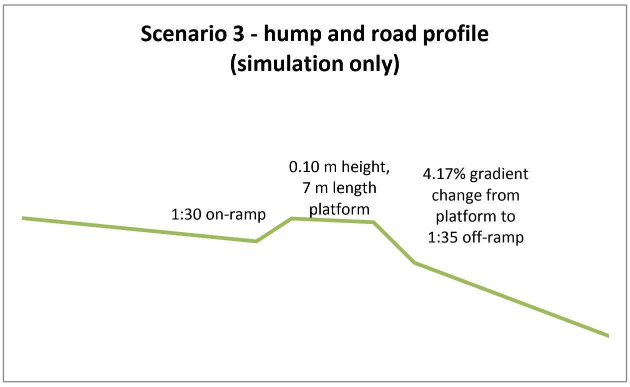
Previous work (Callaway et al. 2010) showed that Safety Platforms of this height and grade should have no adverse effects on vehicle stability in braking or wet weather conditions.

An additional assessment was required to determine comfort levels for different vehicle types when the Safety Platforms were installed under varying vertical displacement conditions. The two road conditions specified by VicRoads were the Profile 1 platform 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%.

The simulation model was set up based on the vertical acceleration test data collected from the trials at Gundog Lane, Belmont, and conducted using vehicle models constructed in Mathworks Simulink. The test data was also used to calibrate the models, allowing simulation of the operation of the tested two-axle vehicles on any combination of Safety Platform and road profile.

The simulation testing showed that should a downhill road gradient be present, maintaining a 4.17% gradient change (as in Scenario 3 in Figure 5) from the raised platform to the off-ramp is more likely than the other designs to allow maintenance of speed by larger vehicles while encouraging lower speeds in smaller vehicles.





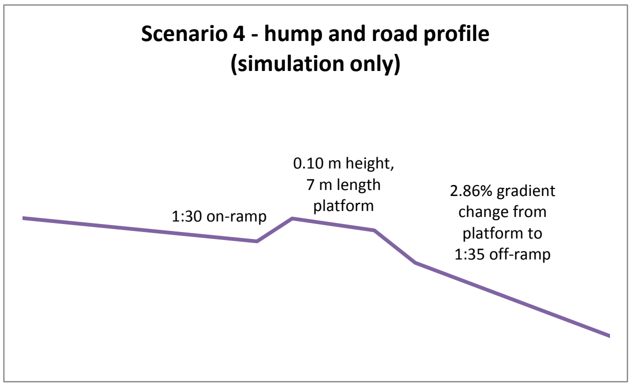


Figure 5. Scenarios used for modelling

The simulated road gradient (as seen in Scenarios 3 and 4) was found to generally lessen the vertical accelerations expected to be felt by passengers as a result of the Safety Platforms. Scenario 4 was consistently the most gentle of the four scenarios. Scenario 3 was generally closely matched with Scenario 1, which suggests that buses and other heavy vehicles would be able to achieve higher speeds over the platform without experiencing severe discomfort (i.e. closer to 50 km/h) whilst also limiting the speeds of smaller vehicles (particularly for Scenario 3). Scenarios 1 and 3 consequently had the smallest speed differentials compared to Scenarios 2 and 4. This is ideal for safety purposes.

Case Study – current status

VicRoads have selected a site to install the raised Safety Platforms in Victoria's west. The signalised intersection has a speed limit of 70 km/h along its primary road, and, as researched, the aim of the platforms is to reduce vehicle speeds down to 50 km/h through the intersection. The platforms are due to be installed in August 2015.

Discussion – issues relating to innovation

To get to this point in the process of introducing new infrastructure onto Victorian roads has required considerable dedication from VicRoads and has already taken a number of years to achieve. This highlights the need for a process, or some form of innovation framework to fast-track the process.

As previously mentioned, there are a number of reasons that some highly effective interventions are not introduced, even when these have been found to be highly effective in other countries. These include:

- a lack of knowledge regarding the treatment and its effectiveness
- lack of experience with treatment installation and maintenance
- issues regarding the transferability of some treatments and differing levels of effectiveness due to cultural/environmental influences
- concerns regarding legal liability should something go wrong
- concerns regarding public understanding and acceptability of the new treatment.

Road agencies should first be prudent in the selection of a new treatment. It should be rigorously tested and have documented safety benefits. A demonstration project can be an effective way of assessing a new treatment prior to wider rollout, much as VicRoads is doing now.

Based on the lessons from this current trial, as well as observation of similar approaches overseas, a methodological approach towards innovation should be adopted. It is suggested that this include the following:

- Identify the problem – in terms of target crash type, road user type and target locations.
- Identify possible solutions – including overseas examples or adaptations of existing treatments.
- Assess shortlist of solutions – research the treatments thoroughly to fully understand the likely beneficial safety outcomes as well as any other eaffects the intervention may have on the road network (e.g. changes in route capacity). This can include researching documented experiences from other road agencies, or the use of driver simulators to determine likely effects. Sometimes treatments can be installed in a controlled environment (such as the off-road trials done by VicRoads).
- Trial the selected solution – through a demonstration project in a controlled environment and specific context. This can be an effective way to test the intervention without the need for a full roll-out, as well as additionally strengthening institutional knowledge of the treatment and potential delivery partnerships.
- Monitor and evaluate the trial – ensuring that the outcomes are as predicted and that there are no unexpected (or unwanted) effects on road user safety or otherwise. The evaluation should comprise an assessment of the innovative treatment's cost effectiveness, including a comparison to the original 'do nothing' scenario.
- Roll out the solution on a wider scale – whilst continuing to monitor and evaluate the treatment sites. This should include crash analysis once sufficient data can be collected. Guidance documents should include design and operational information to ensure the treatment can be accurately reproduced each time.
- Inform others – including the public, and in particular the international road safety community. Regardless of whether the new treatment is effective or not, it is always important that this information is circulated for future reference. There are a number of road agency bodies that actively promote innovative treatments, including FHWA (2012).

It should be noted that guidelines are often slow to include innovative treatments, as it can take a number of years for these to be constructed and evaluated. Some Australian guides are still yet to incorporate the Safe System approach into their documents. Due to often infrequent updates of guidelines and a reluctance to change established practice, it is paramount that an evidence-based approach is used to facilitate the continual improvement and updates to guides.

Concluding remarks

It is acknowledged that achieving 'Vision Zero' will take more than the current selection of infrastructure treatments, and that there is a need for innovative and adapted solutions. The process to introduce new infrastructure into a road network is a complicated one, and this highlights the need for an innovation framework that takes an evidence-based approach. This should outline the process to identify, develop and fast track installation of treatments, but should also be tailored to each state road authority. Many potentially effective treatments have been identified from overseas, and these would most likely produce significant safety outcomes in Australia. Similarly, current research in Australia is focused on improvements to existing infrastructure to produce better reduction in fatal and serious injury. Without adoption of innovative infrastructure solutions it will be difficult to achieve Safe System outcomes.

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