
Peer-reviewed papers

Original Road Safety Research

Safety solutions on mixed use urban arterial roads

Blair Turner¹, Rob Partridge², Shane Turner², Bruce Corben³, Jeremy Woolley⁴, Chris Stokes⁴, Jennifer Oxley⁵, Karen Stephan⁵, Lisa Steinmetz¹

¹*Australian Road Research Board, Melbourne, Australia*

²*Stantec, Christchurch, New Zealand*

³*Corben Consulting, Melbourne, Australia*

⁴*Centre for Automotive Safety Research, Adelaide, Australia*

⁵*Monash University Accident Research Centre, Melbourne, Australia*

Corresponding Author: Blair Turner, 80a Turner St, Port Melbourne, Vic 3207, Australia, blair.turner@arrb.com.au, +613 9881 1661.

Key Findings

- A significant proportion of fatal and serious injury crashes occur on urban arterial roads with a mixed use function
- There are effective infrastructure solutions that when used as part of a comprehensive package can deliver significant safety improvements
- Further innovation and broader application of infrastructure solutions is required to deliver Safe System outcomes, and these need to be supported by other pillars of the Safe System approach
- A clear functional classification for urban roads is needed before substantive improvements can be made on urban arterial roads, and this requires greater levels of community consultation.

Abstract

Urban arterials and intersections account for a large proportion of high severity crashes in Australia and New Zealand, particularly involving vulnerable road users. Safety gains appear to be slower in these ‘mixed use’ environments than in other areas. Austroads commissioned research to help identify solutions that might be applied on mixed use arterial roads to improve safety through the provision of Safe System infrastructure.

The project involved assessment of six case studies around Australia and New Zealand. Concept designs were developed for each of the routes based on analysis of safety issues and the likely safety benefits were assessed. This paper presents information on the safety solutions identified, as well as the broader issues that need to be considered when addressing safety on mixed use urban arterial roads.

Keywords

Safety, urban, arterial, mixed use, crash reduction

Introduction

Urban arterial roads account for a large proportion of high severity crashes, particularly involving vulnerable road users (Austroads 2015a). In these environments there are often different types of road users mixing and interacting within limited road space. These road users include car drivers, pedestrians, cyclists, motorcyclists, as well as the drivers of commercial vehicles, buses, and other forms of public transport. Safety gains appear to be slower in this

mixed use environment than in other areas. For example, the casualty crash rate on arterial strip shopping road segments in metropolitan Melbourne was around 46 per 100 million vehicle kilometres travelled (VKT) (Stephan 2015) compared to an average of 24 per 100 million VKT in urban Melbourne (Jurewicz & Bennett 2008; note that these crash rates are from different time periods and so are only broadly comparable). Vulnerable road users are often

highly-represented in these busy urban environments. In the five year period from 2005 to 2009, the median rate of police-reported crashes on strip shopping road segments was 20.8 crashes per km. More than a quarter (26.6%) of the crashes involved pedestrians and almost half of these crashes (45%) resulted in a pedestrian death or serious injury. Approximately one-sixth of these police-reported crashes involved cyclists, although the true size of the problem is likely to be underestimated (Stephan 2015).

Austrroads commenced this project to help identify safety solutions, particularly those based on infrastructure improvements that might be applied to help achieve Safe System outcomes in these road environment types. The objective of the project was to better understand how the Safe System approach can be applied to mixed use urban arterials. The project used a case study approach to identify solutions that might be applied. Based on workshops, issues relating to safety were explored and safety solutions identified. Full results from this work were published in a report by Austrroads (2017), while this paper summarises information on effective treatments as well as broader implementation issues to move towards Safe System objectives on mixed use urban arterial roads.

Methods

In order to meet the key objectives, the project involved identifying a range of case study sites across Australia and New Zealand. These case study locations were selected following an application process. 36 applications were received, with each evaluated against an assessment criteria. The following six sites were eventually included in the study:

- Grey Street, Hamilton East (New Zealand)
- Glen Huntly Road, Elsternwick (Victoria)
- Unley Road, Unley (South Australia)
- Bondi Road, Bondi Junction (New South Wales)
- Melrose Drive, Woden (Australian Capital Territory)
- York Street, Launceston (Tasmania).

A team of Safe System infrastructure researchers and experts led a series of workshops to identify the issues and challenges at each site, and develop potential initiatives to address these. Participants at these workshops varied, but included road agency staff, public transport providers, pedestrian and cycle groups and local traders. Indicative solutions were developed, and the likely safety benefits estimated. The Safe System Assessment Framework (SSAF) (Austrroads 2016a) was used to assess the safety benefits, and more specifically to determine the Safe System alignment of existing locations as well as the concept designs for each of the case study sites. This approach allocates a rating to the key sources of risk (exposure, likelihood and severity) and to the key causes of fatal and serious injury outcomes (run-off-road, head-on, intersections, other – typically rear-end crashes, pedestrians, cyclists and motorcyclists). A total risk score is derived based on this assessment. Although subjective, the assessment provides an indicative

level of risk for an infrastructure project. Relative risks for alternative designs can then be compared against current levels of risk.

An estimation of the severe crash reduction benefits for each option was also made using the method outlined in national guidelines (Austrroads 2015b). This guidance caters well for simple road safety improvements, and involves an assessment of the baseline situation (i.e. the current situation) in terms of current crash numbers and the costs of these and an estimate of the likely benefits (crash reduction) from the suggested improvements. The process is based on generating a likely crash reduction based on findings from previous research for individual infrastructure treatments. Crash Modification Factors (CMFs) for each treatment were based on a previous review of relevant literature (Austrroads 2017).

A second round of workshops was held to discuss the potential solutions and outcomes. Finally, a report was prepared that showcased a number of indicative design examples of how urban arterials could be designed or retrofitted to better achieve Safe System outcomes. Also included was information on the benefits from specific road safety interventions. This information was based on existing literature, including trials conducted in Australia and New Zealand as part of previous Austrroads work. As well as these benefits, other key results included process-related guidance for road agencies and others on effective implementation of safety improvements on mixed use arterials. These results are presented in the following section.

Results

Results for case study locations

A large number of treatments were used across the six case study locations. These treatments varied for each of the routes based on local conditions and requirements identified during the workshops. However, there were some commonalities between routes. Key treatments included those that helped to manage vehicle speeds. Reduced design speed was considered in each case, and this typically involved lower speed limits (either on a full or part-time basis) supported by infrastructure, including safety platforms, gateway treatments, road narrowing, textured surfacing and additional measures. Other treatments to improve vulnerable road user safety were also considered including pedestrian crossing facilities, and cycle lanes and separated pathways.

In all cases, packages of treatments were seen as necessary to address the road safety issues. Table 1 provides a summary of the most common treatments, and also demonstrates the reliance on treatment packages at each location.

Based on the installation of these and other more minor treatments, it was estimated that fatal and serious injuries would be substantially reduced at the case study locations. Estimates of safety benefits were calculated based on application of the Safe System Assessment Framework

Table 1. Packages of treatment options for each route

	Grey St	Glen Huntly Rd	Unley Rd	Bondi Rd	Melrose Dr	York St
Reduced speed environment	✓	✓	✓	✓	✓	✓
Gateway	✓	✓	✓	✓	✓	
Safety platform	✓	✓	✓	✓	✓	✓
Raised pedestrian crossing	✓		✓	✓	✓	✓
Roundabout	✓				✓	
Narrowing	✓	✓	✓		✓	✓
Colour or texture surface	✓	✓	✓	✓	✓	
Cycle path	✓		✓	✓	✓	
Access management	✓	✓	✓	✓	✓	

Table 2. Expected fatal and serious injury risk reduction

Route	Location	Expected FSI risk reduction – all road users	Expected FSI risk reduction – pedestrians and cyclists
Grey Street	Hamilton, New Zealand	55%	75%
Glen Huntly Road	Melbourne, Victoria	65%	55%
Unley Road	Adelaide, South Australia	65%	50%
Bondi Road	Sydney, New South Wales	40%	35%
Melrose Drive	Canberra, ACT	40%	35%
York Street	Launceston, Tasmania	55%	50%

(SSAF; Austroads 2016a) as well as traditional analysis of crash reduction (based on Austroads guidance on the treatment of crash locations; Austroads 2015b). Table 2 provides the results from the SSAF assessment. Figures are rounded to the nearest 5%.

Crash analysis revealed broadly consistent results with expected reductions in fatal and serious injury of between 40 and 75% for vehicle occupants, and between 50 and 70% for vulnerable road users.

Results: individual treatments

This section provides a summary of the most commonly used treatments across the routes, and the likely safety benefits of these. The safety benefits are based on an extensive review of existing literature which is documented in previous Austroads work (Austroads 2017; Austroads 2016b). A summary of the treatments, including a description of the treatment, the Crash Modification Factor (CMF) and an image is provided in Table 3. The CMF is a multiplier that is applied to the number of crashes in the 'before' period to indicate likely crash numbers in the 'after' period (once the treatment has been installed). For instance, if there are 10 crashes in the three year period before the treatment is installed, and the CMF is 0.6, it could be

expected that there would be 6 crashes in the after three year period ($10 \times 0.6 = 6$). CMFs generally relate to the safety impact on all road users (i.e. not specific road user groups such as pedestrians) and are typically based on casualty crash reductions i.e. not fatal and serious crash reduction). Although it would be desirable to provide information for specific road user groups, and for impacts on fatal and serious injury outcomes, the evidence base typically does not provide this detail.

Results: Other key learnings

As well as identifying viable safety solutions on mixed use arterial roads, the Austroads project highlighted a number of 'process' issues that need to be addressed when implementing safety improvements in these environment types. This section highlights some of the key learnings relating to implementation of safety improvements in mixed use environments.

Table 3: Example mixed use arterial treatments

Treatment	Brief description	CMF	Image
Raised intersections	Either the entire intersection is raised, acting as a type of speed platform, or raised sections can be placed in advance of the intersection (sometimes referred to as raised stop bars).	0.60	
Roundabouts	Intersection control measure implemented in order to reduce speeds and reduce road user conflict points.	0.25	
Reduced speed limit	Involves managing posted speed limits, revising them towards Safe System levels.	0.75	
Lane narrowing	Narrowing lane through perceptual and physical measures, e.g. kerb extensions, wide medians or shoulders.	0.70	
Road diet	Road narrowing measure typically involving the conversion of a four-lane road (two each way) into a road with only one lane in each direction, and a central two-way right-turn lane.	0.65	
Humps/platforms	Vertical deflection treatments used to control speed, with various forms of speed humps available for different road types.	0.60	
Wombat crossings	Similar profile and speed reduction effect as flat-top speed humps but differ by giving priority to pedestrians rather than motorists.	0.60	
Gateway treatments	Use of signs with other techniques to create a threshold or gateway between high and low-speed environments.	Unknown (up to 0.60 for rural)	

Source: Austroads 2017

Functional Classification/Movement and Place

A key finding from this study was that assignment of function for roads is critical in planning for safety on urban arterials. This assignment requires a clear understanding around the intended use of routes within the broader urban context. This includes the need to identify different road user groups as well as time of day, day of week and seasonal considerations. It also requires agreement from all of the key stakeholders, including governmental, political and public endorsement. Tools have been developed to assist in this engagement task, including the movement and place framework (Austroads 2016c). This framework can assist with identifying options that best meet and balance strategic objectives. This includes graphical representation of different scenarios to highlight the implications for different decisions relating to road use.

Until the function has been decided and agreed upon by stakeholders, it is difficult to firm up speed and infrastructure requirements. This was clearly demonstrated at a number of the case study locations. In those cases where there had been agreement around function (or at least where these discussions have been had) there was a greater ability to seek transformational solutions. Conversely, it was clear in other locations that there was no such agreement and that the priority for competing road user types had not been set. In these cases the capacity for substantial change was far more limited, and agreement only possible on minor improvement programs. A more detailed discussion on this important issue, including gaps in knowledge, is provided in Turner et al. (2018).

Processes for Assessment of Risk

Crash data formed a basis for the assessment of risk for most of the case study locations. This is a key source of information relating to safety performance. In some cases this source of information on its own is adequate to help assess risk. These cases exhibit substantial crash numbers and clear crash patterns. However, it is typically the case that additional information is required to determine the full extent of risk. This is because crash locations remain scattered. Crashes can occur at locations where no previous crashes have occurred, and so a complete reliance on crash data alone is not sufficient. In addition, many of the routes assessed were facing substantial changes in traffic use and roadside development. For example, some routes were experiencing increases in residential development. It could be expected that in future the number of vulnerable road users would increase, and therefore the risk profile is likely to change.

It is also important to recognise the need for assessment of systemic risk as opposed to relying on risk assessment at specific locations. Crash risk is at elevated levels for much of the route in these mixed use urban environments, especially for unprotected road users. It is therefore important that sustainable, holistic treatments be applied that deliver Safe System outcomes on a route basis.

For this project, the SSAF was used to assess risk in a proactive manner. As highlighted, this allows an assessment of potential risks for different road user groups, including pedestrians, cyclists and motorcyclists. As indicated previously, ratings within this tool are quantitative but subjective, but provide a broad indication of risk. Other tools exist to allow proactive assessment (e.g. the Australian National Risk Assessment Model or ANRAM). The outcome from these assessments is a better understanding of where potential fatal and serious injury risks lie on the network. This allows better targeting of interventions to address not only the types of crashes that may have occurred previously, but also those that are likely to happen in the future.

Safety Benefits of Solutions and Residual Risk

As identified above, reductions in risk of fatal or serious injury crashes were likely to be substantial for each of the case study locations. However, despite the comprehensive safety improvements suggested for each of the sites, and the significant improvements expected, it is clear that the maximum benefit that can be obtained from the provision of infrastructure alone in these types of environments is up to around a 60% reduction in fatal and serious injury, with an indicative maximum of 75% reduction for pedestrians and cyclists at one site. This still leaves substantial residual risk of fatal and serious injury crashes.

Consideration should be given to this residual risk. Where possible, more substantive interventions may be required. However, it is clear that combinations of speed management and supporting infrastructure solutions alone will not typically lead to the complete elimination of death and serious injury, and this is consistent with Safe System thinking, where a broader systems approach across multiple pillars is required. Vehicle-based safety improvements are likely to provide substantial benefits into the future in these mixed use environments (e.g. pedestrian and cyclist warning, and braking systems), although it should be recognised that full implementation across the whole vehicle fleet is still some time off. Post-crash care improvements (e.g. increased community training in first aid, and faster access to specialist trauma care) may also contribute to reductions in fatal and serious injury outcomes.

Impact on Traffic Operations

Detailed modelling of the impact of treatments on traffic was outside the scope of the study. However, in most cases there is existing evidence to help understand the impact of different treatments on traffic operations. The impact on traffic operations from some of these interventions can be significant, however, this is often the intention. There may be a need to change the function of a road based on broader network objectives, and therefore change the priority for different road user groups. This may include the need to reduce the amount or type of motorised traffic entering the route, and/or the speed of traffic to give higher priority to vulnerable road users. In other cases, vulnerable road users may be redirected to alternative paths and greater priority

given to the movement of motorised traffic. This highlights the importance of understanding vehicle mix/classification on routes and the surrounding network. In several of the case studies there was a demand to reduce traffic volumes along the route. The approach to meeting this demand included reductions in speed (e.g. lower speed limits supported by infrastructure such as safety platforms) and reduced traffic lanes (e.g. using a road diet). However, overseas and local experience has shown that such measures can be used while also maintaining current levels of traffic (Gordon 2011). Care should be taken so as not to displace traffic on to collector or local roads, but rather on to alternative routes with a more defined arterial traffic function.

Synergies

Although the focus of this project was on improving safety outcomes, there were other benefits that would derive from the designs. Synergistic benefits include a better environment to support active travel modes (walking and cycling), and this would have the dual benefit of reducing traffic as well as potential population health improvements. Other benefits from well-executed designs include increased social connection, improved liveability and greater vibrancy of the area. These in turn bring other social benefits including improved health and wellbeing and increased economic activity through support for local businesses. Although the evidence base is less well documented for these elements, there are likely benefits deriving from these areas. It would be useful that in future, information is collected to assess and quantify such benefits.

Consultation

As already indicated, a variety of stakeholders attended the workshops for each case study location. This included road agency staff (local government and state/territory) from planning, design, safety, and traffic management teams. In some cases, experts from other departments also attended (e.g. sustainable travel modes). There was also input from public transport agencies, pedestrian and cycle groups, and local traders. Road agency representation varied greatly between workshops. In some cases there was a strong representation from road safety and traffic management personnel, and less input from planners. At others, the workshops comprised predominantly planners. This seemed to matter less than the amount of groundwork and prior consultation that had been undertaken. It was very apparent that the most productive discussions were in locations where strategic planning had been undertaken, and there was a firm agreement on the form and function of the route. A number of locations had undertaken this prior to the workshops. This planning took the form of Masterplans, Network Operating Plans or Road Planning Framework. In others, this discussion had not been undertaken or no firm decision or agreement had been reached. In these cases there was much less consensus about the desired nature of the route, and therefore what infrastructure might be appropriate to meet the needs of all road users.

One positive by-product from this project was increased levels of engagement between key stakeholders. In many cases it was clear that the stakeholders had not recently met to address common issues. Discussion on case study locations provided a very useful opportunity to bring stakeholders together and address not only issues at the specific sites, but also broader transport-related issues.

Conclusions and recommendations

A significant proportion of fatal and serious injury crashes occur on urban arterial roads. Mixed use arterials (where there are different types of road users including motorised and non-motorised) are particularly high risk. This paper provides a synthesis of key safety solutions as well as issues that need to be considered when effectively addressing safety on urban mixed use arterial routes.

Given the mix of road users, a reduced speed environment was suggested for each case study locations, and this typically involved lower speed limits (either on a full or part-time basis) supported by infrastructure, including safety platforms, gateway treatments, road narrowing, textured surfacing and additional measures. Other treatments were also seen as necessary to improve vulnerable road user safety. Solutions included road narrowing, pedestrian crossing facilities, and cycle lanes and separated pathways. In each case, packages of treatments were suggested to provide comprehensive, route-based improvements. Individual treatments can bring about significant safety benefits (as indicated in Table 3), but greater benefits are likely, particularly over routes, when compatible combinations are used. It is recommended that greater use be made of these packages of treatments to help achieve significant safety improvements on mixed use arterials. One difficulty when applying packages of treatments is understanding the combined benefits of the treatments. Sometimes the different treatments act independently and address different crash risks while in other situations the treatments may act together to give a greater overall benefit. Some advice on how to calculate crash reductions for multiple treatments is provided in Austroads (2015b).

Although the proposed designs were not constructed as part of the Austroads project, estimates were made regarding the likely safety benefits. These were substantial, typically producing an estimated 60% reduction in fatal and serious injury crashes. However, it is clear that despite the significant improvements, the reductions fall short of Safe System objectives to completely eliminate death and serious injury. In many cases the benefits were variable for different road user groups, with vulnerable road users the most difficult group to treat. More substantive and innovative infrastructure solutions are required, as well as contributions from other Safe System pillars (particularly improved vehicle technologies).

In terms of implementation, a key recommendation is that formal assessment of routes be undertaken to determine and agree desired function by key governmental, political and public stakeholders. Without agreement on function, it is very difficult to make substantive safety improvements.

However, once function is agreed, the appropriate design can be achieved more easily, and conflicts between safety and mobility are removed (see Turner et al. 2018 for a detailed discussion on this).

Related to this issue of functional definition is the need for greater consultation, and a community-based strategic approach to defining urban road hierarchies. Greater community dialog and agreement is required to facilitate the changes required to improve not only safety on these road networks, but also issues such as social connection, liveability, and population health and wellbeing. Road agencies are encouraged to share good practice around successful community engagement strategies, as well as on effective infrastructure improvements.

There are a number of limitations to this study. The information provided on treatment effectiveness (FSI reductions) for each of the locations is based on an estimate, and not from evaluation of actual crash reductions. A Safe System Assessment was undertaken which by its nature is a subjective measure of risk reduction. This was supported by information on likely crash reduction for different individual treatments, which are combined to produce an overall estimate for each location. Errors can occur in deriving estimates for individual treatments, as well as when combining these treatments for each route. There is a scarcity of information on the impact of packages of treatments, and it is recommended that future evaluations be undertaken and information disseminated. In addition, the packages of treatments were included in concept designs, and have yet to be implemented. Further learning from this implementation phase is required to validate some of the conclusions from this study.

Acknowledgements

The authors would like to acknowledge the involvement of participants at workshops for each of the six case studies. Input by representatives of various Austroads Task Forces in the direction of the project and production of this report is also greatly appreciated.

References

- Austroads (2015a), *Road fatalities and serious injuries in Australia and New Zealand 2001–10*, AP-R478-15, Austroads, Sydney, NSW.
- Austroads (2015b), *Guide to road safety: part 8: treatment of crash locations*, 2nd edn, AGRS08-15, Austroads, Sydney, NSW.
- Austroads (2016a), *Safe system assessment framework*, AP-R509-16, Austroads, Sydney, NSW.
- Austroads (2016b), *Achieving safe system speeds on urban arterial roads: compendium of good practice*, AP-R514-16, Austroads, Sydney, NSW.
- Austroads (2016c), *Guide to traffic management: part 4: network management*, 4th edn, AGTM04-16, Austroads, Sydney, NSW.
- Austroads (2017), *Safe System Infrastructure on Mixed Use Arterials*, Austroads Sydney, Australia.
- Gordon, G (2011), *Mixed priority routes: results update and cost review*, Department for Transport, London, UK
- Jurewicz, C & Bennett, P (2008), ‘Casualty crash rates for Australian jurisdictions’, *Australasian road safety research policing education conference*, Adelaide, South Australia, Department for Transport, Walkerville, SA, 24 pp.
- Stephan, K. L. (2015). ‘A multidisciplinary investigation of the influence of the built urban environment on driver behaviour and traffic crash risk’, PhD thesis, Monash University, retrieved from <https://doi.org/10.4225/03/58b78d6fea3f1>
- Turner, B, Steinmetz, L, Han, C & Espada, I, (2018), Linking mobility and safety – Building on the mixed use arterials project. *28th ARRB International Conference – Next Generation Connectivity*, Brisbane, Queensland, Australia.