

## **Risk-based approach to speed limits – a step towards Safe System**

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### **Abstract**

Safer speeds are recognised as an integral tool in reducing road trauma, also they are a key pillar of the Safe System philosophy. The current national guidance on speed limits recognises this at the conceptual level but the approach for practical implementation has not been developed to date.

This paper aims to stimulate discussion around the emerging concept of setting speed limits on basis of severe crash risk (fatal and serious injury outcomes). It draws on recent Austroads research to propose several alternative approaches based on crash history, assessment of inherent crash risk due to the road environment, or both. The presented approaches also recognise the intended road function within the network as an indicator of the mobility level expected by the public. The paper explores the possible application of established network-level risk assessment tools such as AusRAP in risk-based approach to speed limits.

### **Keywords**

Speed limit, Safe System, risk assessment, crash rates

### **Introduction**

This paper aims to stimulate discussion around the emerging concept of setting speed limits on basis of severe crash risk (fatal and serious injury outcomes). This concept has been the subject of informal discussions among road authorities and road safety researchers for some time. A forthcoming Austroads research project on risk-based approach to speed limit setting will investigate this field further. This paper collects the existing threads of the discussion to date.

### **Background**

The Safe System approach seeks to regulate driver speeds so that they are appropriate for the level of protection offered by the road infrastructure and for the road user mix<sup>1</sup>. Under Safe System, speed limits should be set to maximise mobility consistent with safe travel, i.e. to achieve safe mobility.

The traditional approach of speed limit setting is based on various road environment features related to operating speed and sources of traffic flow interruption. These include road features such as roadside development level, frequency of access points and turning lanes. While these clearly focus on mobility aspects, they are also proxies for crash likelihood arising from vehicle-to-vehicle conflict. Notably, the traditional approach does not account for crash severity.

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<sup>1</sup> The Safe System places importance of improving vehicle safety, but recognises that not all vehicle types can offer adequate protection to their occupants (e.g. bicycles and motorcycles).

Austroroads investigation of speed limits and safety relationships, combined with industry consultations, produced in a set of four new principles for setting speed limits based on the Safe System principle of harm minimisation<sup>2</sup> (Jurewicz and Turner 2010). These principles include consideration of both the likelihood and severity of crashes in consideration of speed limits. A broader range of road features is considered than under the traditional approach. The aim of speed limit setting becomes minimisation of death and serious injury due to road environment factors, including speed.

The proposed principles involve a process of consideration of safety and mobility, and the practical reconciliation of any gaps between them to arrive at a set of speed limit options. The principles are as follows:

Mobility	What speed limits does the community expect for each road class and function? For example, undivided urban arterials are typically 60 km/h.
Harm minimisation	What are the safe speed limits for a given road given the existing conditions? Safe speed limits are defined by the biomechanical tolerance to crash impact forces, e.g. 30 km/h for roads where vulnerable road users are exposed to vehicular traffic.
Gap analysis	Evaluation of the existing level of protection offered by the road to identify speed limit and/or infrastructure improvement options. A preliminary checklist of primary and supporting Safe System road features was developed to match speed limit to existing conditions, or to propose infrastructure improvements, so that harm minimisation could be achieved.
Driver perception	Management of the road environment and traffic speeds if necessary. In some cases further infrastructure changes would be desirable to lower actual speeds to support a lower speed limit.

Consideration of each principle is a separate step in an iterative process. The result is one or more speed limit options, some of which may require changes to the infrastructure to provide safe travel at a recommended speed limit. The lowest cost option would almost always be adoption of the very low safe speed limit. Jurewicz (2010) presents this process in more detail.

### **Harm reduction**

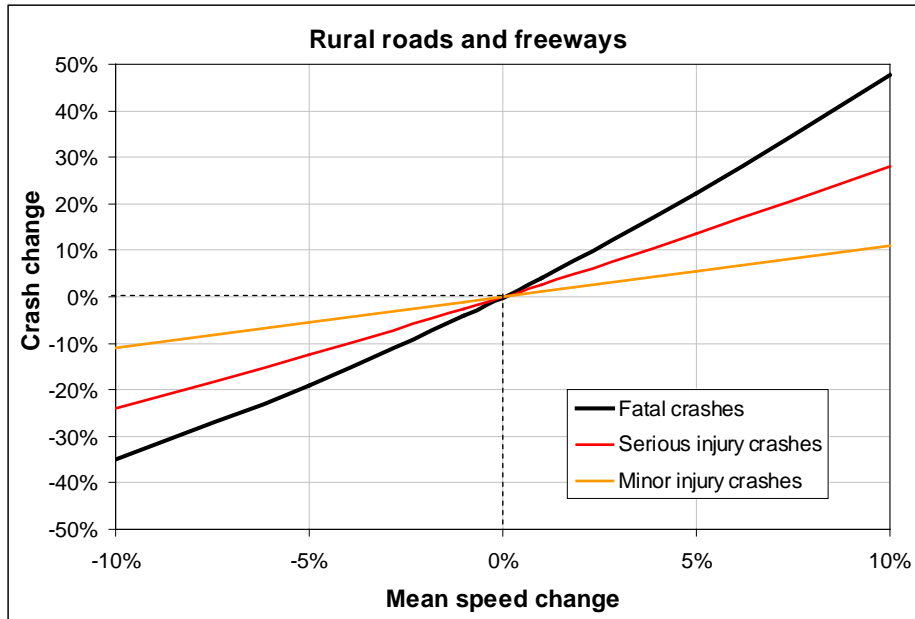
At the time of writing, the agreement as to which road infrastructure features would be required to provide safe travel in the Safe System framework was still a subject of ongoing discussion among road safety experts. Even if this fundamental issue was resolved promptly, provision of Safe System infrastructure would be prioritised and delivered over many years. In the mean time, public acceptance of very low speed limits compensating for the absence of Safe System road features would be limited to certain road types, e.g. congested shopping strips, school zones. Thus, in the short to mid-term, a harm reduction approach to speed limits could be implemented while road authorities gradually move towards implementation of the Safe System infrastructure.

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<sup>2</sup> i.e. avoidance of death and serious injury due to road environment factors. This version of vision zero depends on integration of benefits of Safer Roads and Safer Speeds with Safer Vehicles and Safer Road Users. This includes minimising harm through providing a road environment forgiving of human error. Grave harm may still occur if one of the key elements fails, e.g. road users choose not to comply safer speed limits.

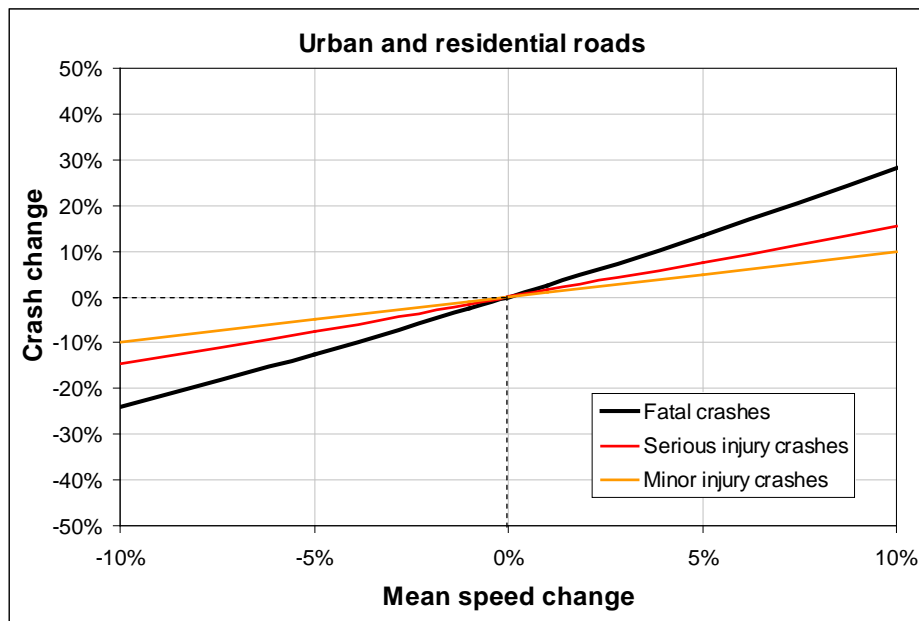
The harm reduction approach to speed limit setting involves adopting a limit somewhat lower than that suggested by the road class and function but above the harm minimisation speed limit. It is intended to be applied to roads where severe crash risks are unacceptable.

Even a small reduction in speed limits and in traffic speeds has the potential to deliver measurable road trauma savings over time. Figure 1 shows how small reductions in mean speeds can reduce crashes on rural roads and freeways. Figure 2 presents a similar relationship for urban and residential roads. It is clear that fatal and serious injury crashes can be effectively targeted by speed reductions. The differences between the two figures indicate that the same percentage mean speed reduction would be more effective on high speed and rural roads than on urban roads.



Source: based on Elvik (2009)

**Figure 1: Change in mean speed vs. change in crashes, high speed roads**



Source: based on Elvik (2009)

**Figure 2: Change in mean speed vs. change in crashes, lower speed roads**

Initially only well known high risk locations could be targeted with harm reduction speed limits. Gradually, assessment of the entire road network could be undertaken to reduce speeds at all high risk locations.

### **Risk-based approaches**

There are a number of possible approaches to the risk-based approach to speed limit setting. The following four are described in the following sub-sections:

- issue-driven
- crash history
- crash risk assessment
- combined approach.

Where possible, examples of each approach were provided.

#### *Issue-driven*

Speed limits were occasionally lowered on case-by case basis to address unacceptably high crash levels for a particular user group (e.g. motorcyclists). Typically, such speed limit reductions were not considered as part of a systematic approach, but rather as ad-hoc departures from the guidelines to address extraordinary conditions. Several examples of issue-driven speed limit changes included the 100 km/h to 80 km/h speed limit reduction on Melba Highway at Black Spur, Victoria, to address recreational motorcyclist crashes in a mountainous terrain. Similar reductions were implemented along winding sections of Great Ocean Road (personal communication Kenn Beer, VicRoads).

#### *Crash-history*

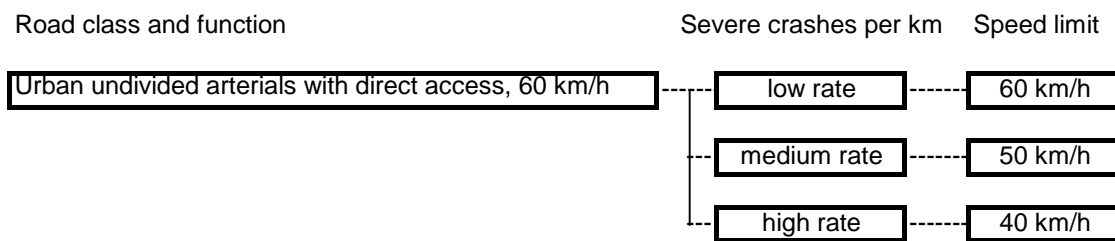
Speed limits were also reduced on the basis of significant crash history or high crash rate. Most speed zoning guidelines in Australian jurisdictions allowed crash history to be taken into account when reviewing speed limits, although it was rarely the leading factor in the decision. Typically speed limit reductions due to crash history were approved after consultation with the road safety department in the head office, on case-by-case basis. In Queensland there were examples of speed limit reductions on a number of 'black links' (personal communication Rohit Singh, Queensland Transport and Main Roads). These include:

- Bruce Highway, Cooroy to Curra section, from 100 km/h to 90 km/h
- Bruce Highway, Innisfail to Cairns, from 100 km/h to 90 km/h
- Warrego Highway, from Toowoomba to Dalby, from 100 km/h to 90 km/h
- Noosa – Eumundi Road, from 90 km/h to 80 km/h
- Mt Cotton Road, from 90 km/h to 80 km/h
- state roads on Kuranda Range, from 80 km/h to 60 km/h.

In Victoria, there were also recent examples for speed limit reductions from 100 km/h to 80 km/h due to significant crash history:

- Cape Paterson–Inverloch Road, ~15 km section
- Princess Highway East / Kooweerup–Longwarry Road intersection.

This ad-hoc approach could be developed into a risk-based speed limit setting system focussing predominately on crash history. A process similar to black length analysis could be implemented to identify road sections with history of severe injury crashes with a view to reduction of speed limits. Trigger levels could be set for roads of different class and function (e.g. severe crashes per km in 5 years). Figure 3 shows an example of such a process. The speed limit expected by the community for a given road class and function is defined first, then it is either retained or lowered accordingly to severe crash rate.



**Figure 3: Risk-based approach 1 – crash history**

Since high crash sections do not form a significant percentage of the road network, this approach would cover only small proportion of the road network. A high level of communication with road users would be required to explain the reason for localised speed limit reductions. Also, such approach could become an economically attractive alternative for addressing localised road safety problems in lieu of proven engineering treatments.

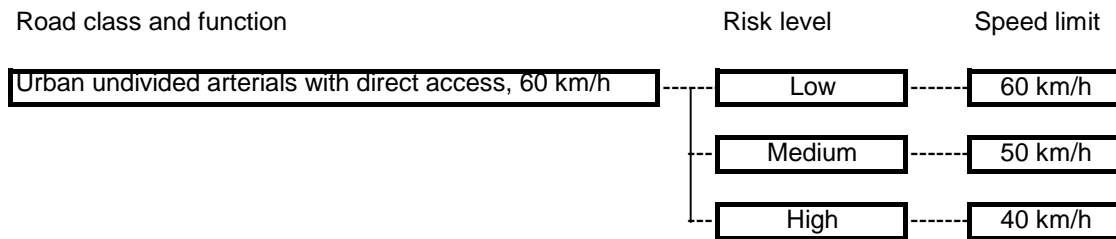
There are several additional reasons why the use of crash data alone may not be sufficient to identify high risk sites. There is a relatively low reporting rate for crashes in rural areas. Although it is assumed that all fatal crashes are recorded, it is likely that a large proportion of the serious and minor injury type crashes do not make it to the crash database. Information from overseas indicates only around 60% of serious crashes are reported, with a significantly lower percentage for minor injury crashes (Alsop and Langley 2001, Ward et al., 2006). Australian based research has also identified under-reporting of injury crashes (Roy Morgan Research 1994, Cercarelli 1998). The reporting rate is likely to be even lower in rural areas.

In addition, in rural areas crashes are often dispersed, including those involving vehicles running off the road. Analysis by ARRB showed that only around a half of all crashes in Victoria occurred at sites defined as black spots, while the figure was only a third for rural areas. The rest were distributed across the network. Due to this phenomenon a large proportion of low standard – low volume rural roads may never meet the criteria for a lower speed limit and retain high speed limits. At the same time, higher volume and better designed highways would attract speed limit reductions. Such inconsistency would be difficult to communicate to the public.

*Crash risk assessment*

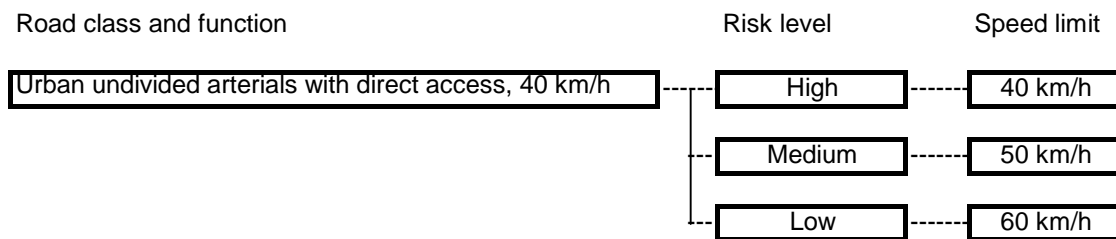
Alternative approach to risk-based speed limit setting could be developed using crash risk assessment of road features and operating conditions (various methodologies are described in the following section). Such approach would promote self-explaining roads, i.e. those of poor

design standard would consistently attract lower speed limits, regardless of reported crash history. One example of such an approach is illustrated by the example in Figure 4. The typical speed limit for urban undivided road would remain unchanged if the risk of future crashes, based on assessment of road features and operational risk factors, remained low.



**Figure 4: Risk-based approach 2 – risk level**

An alternative process proposes a low default speed limit which could be raised only if the road was demonstrated to have low crash risk. This approach is illustrated in Figure 5. As there would be an onus on the reviewer to demonstrate low crash risk, a more conservative application of this approach could promote lower speed limits.



**Figure 5: Risk-based approach 3 – risk level**

Risk-assessment approach has been used for identification of candidate sites for further investigation, road improvements, road safety program development and building public awareness of road safety issues (Jurewicz et al, 2011, Turner et al. 2011). Risk level would be more comparable to crash rate per vehicle-kilometre of travel, rather than to frequency of crashes per kilometre of road. It is thus limited to estimating the individual crash risk, rather than the collective crash risk.

One of the limitations the risk assessment approach to speed limits could be its reliance on the road environment data. However, the latest risk algorithms such as those used in iRAP also use environmental proxies for road user behaviour, e.g. roadside land use, residential, commercial, pedestrian demand and facilities (Jurewicz et al. 2011).

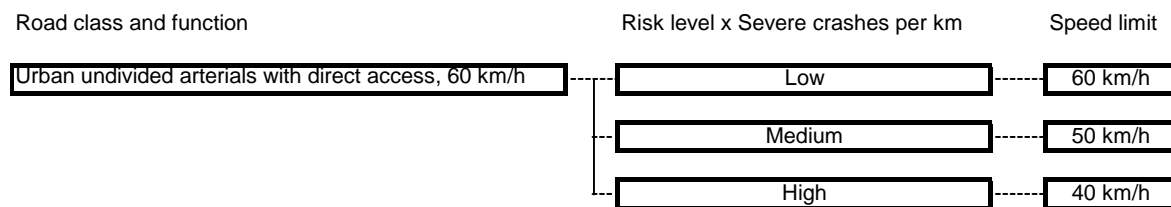
Typically, risk assessment does not include crash history in calculation of the risk level (score). The risk of future crashes is based on the aggregate of safety performance of various road environment elements such as curvature, road width, grade, roadside hazards, access/intersections, speed and presence of vulnerable users. Traffic flow is not taken directly into account in risk assessment algorithms. Hence, an individual low volume road section may score poorly but have no crash history due to lack of exposure. Conversely, the risk assessment approach would allow methodical consideration of lower speed limits on a low volume road network which collectively accrues a significant number of crashes over time.

To date crash risk methodologies have been based on casualty crashes rather than on severe crashes. This is being addressed via ongoing Austroads research (Jurewicz et al. 2011).

Crash risk levels based on road features and operational factors may be derived according to a number of methodologies as outlined in the following section.

### *Combined approach*

In many locations, road features and operational factors are not the only causes of severe crashes. Roads with high traffic volumes and low-risk features still accrue high crash numbers over time (e.g. freeways). An approach combining risk assessment and crash history may offer an optimal way of identifying high risk locations for the purpose of speed limit setting. A product of assessed risk level (score) and crash frequency rate could be used to produce a scale used in speed limit review. More complex algorithms could be developed which would weigh the influence of either factor and also introduce others such as assessment of observed speeds. Triggers could be established empirically for roads of different class and function. Figure 6 illustrates the process for undivided urban roads.



**Figure 6: Risk-based approach 4 – combined**

### **Methods of risk assessment**

Adoption of an optimal method for assessing severe crash risk would be crucial in developing a viable risk-based approach. Experience in risk assessment and speed limit setting systems suggests several criteria to be considered in selecting an appropriate method:

- it draws on local research and experience as much as possible
- it has the smallest amount of input data required for a robust risk level estimate
- it delivers logical and consistent results across a range of road environments
- the method/software should be easy to use
- input data is either already available or easy to collect.

There are several existing risk assessment models available in Australia and internationally. Some of them include:

- NetRisk – produces a crash risk score based on road features and speed environment. Incorporates speed as one of the variables which affect the risk score, so it is possible to view the impact of lower speed limit on the risk level. Comes as an Excel tool.

- Highway Safety Manual (US) – uses a hybrid crash prediction and risk assessment method to estimate the expected number of crashes for a given road segment. It uses risk factors for operating speed based on Nilsson’s Power Model (AASHTO 2010). It is based mainly on the US research and would need calibration to Australasian conditions. Interactive Highway Safety Design Model (IHSDM) is the associated software which performs many of the calculations of the Manual.
- iRAP – expresses the fatal and serious injury crash risk as a Road Protection Score (RPS). RPS is based on the risk associated with a combination of different road features and several operational factors. The iRAP 2.2 version requires 47 input variables for each 100 m road segment. This requires a dedicated road network survey and data coding. iRAP provides an online tool free of charge. Speed limit is used as a broad measure of the operating speed environment and is used in the algorithm. Future versions of iRAP software plan to accommodate speed limit changes as a potential treatment and thus will provide a visible change in risk rating as a result of speed management initiatives (iRAP 2009).
- AusRAP – Australian version iRAP.
- KiwiRAP – similar to iRAP but based on a different software platform. Utilises New Zealand research on the effects of horizontal alignment and operating speeds through curves to better model the fatal and serious injury crash risk on rural roads (KiwiRAP 2010).
- Austroads National Risk Assessment Model (ANRAM) prototype – utilises iRAP’s RPS approach to risk assessment, but incorporates a fatal and serious injury crash prediction module based on actual crash data to better estimate the risk level. Under the ANRAM model, changes in speed will be reflected in the expected number of fatal and serious injury crashes. ANRAM is intended to be adopted by all Australian jurisdictions (Jurewicz et al. 2011).

It is likely that a custom-built risk assessment module would be required for speed limit setting purposes, one based on a limited number of relevant road features and factors including traffic speed, vulnerable road users and special road uses.

### **Key risk factors**

Risk assessment and crash prediction modelling research by Austroads suggests that some risk factors have more significant influence on crash risk than others (McLean, Veith and Turner 2010, Jurewicz and Pyta 2010, Turner et al. 2011). The top risk factors for rural roads are as follows:

- traffic flow (AADT)
- road curvature
- road grade (when steep)
- presence of a median
- sealed pavement width (may be expressed as lane width and sealed shoulder width)
- frequency of intersection or access points
- clear zones



- mean speed and speeding levels.

For urban roads, the list is similar but the hierarchy is less clear due to many different road environments and road user mixes. It can be said that the following additional factors play an important role in crash risk on urban roads:

- pedestrian numbers and crossing activity
- pedestrian facilities
- presence of on-road cyclists
- intersection control types
- access control level.

These risk factors can be taken into account if a dedicated risk assessment model was to be considered as part of a future risk-based speed limit setting system.

### **Example: New Zealand trial**

In the mid 2000s, Land Transport New Zealand implemented a trial of a risk-based method for speed limit setting on rural roads (Edgar 2006; Land Transport New Zealand 2005).

The speed limit is derived initially on the basis of the 85<sup>th</sup> percentile speed. In addition, a risk calculation is made for the route. This provides information on the actual level of risk. This rating is based on three groups of features, activity total, roadside crash potential and traffic crash potential. The total for each of these scores is added together to provide a speed zone rating score which corresponds to an appropriate speed limit. The following variables are considered in the risk assessment:

- frontage development density
- presence of side roads
- speed change (variability) along the route
- seal width
- roadside hazards
- opposing traffic separation
- sight distance
- AADT and vehicle composition
- vulnerable users.

According to the draft speed zoning guidelines, the risk assessment is carried out for only short segments of the road section being reviewed (10% or less). This limits the amount of effort required in the review. Various evaluations are currently being conducted on the effect of this approach in New Zealand, but to date there was very little objective information available.

### **Discussion**

A risk assessment approach would be broadly consistent with the Safe System approach to speed limits outlined in Austroads (2008). It requires that crash history is to be considered in the form of individual road user crash risk (crash rate) and collective crash risk (crash frequency). When completed, ANRAM will provide estimates of both these risk types. Further, Austroads (2008) asks that road infrastructure, the surrounding environment and speeds be considered in the speed limit setting process. This would be done via the risk assessment methodology. The final requirement of Austroads (2008) is consideration of the road's planned and actual functions, including presence of vulnerable road users. This would be recognised as illustrated in Figures 3 to 6 by assigning an expected speed limit as a starting point for the speed limit setting process.

A key speed limits issue for road traffic authorities is the frequency of speed zone changes road users face. Further development of the risk based approach to speed limit setting would need to consider two questions related to this issue:

1. Is there an increased crash risk attached to having frequent changes in speed limits than currently exist?
2. How important is consistency of speed limits (i.e. lack of frequent changes) to community acceptance and compliance?

The issues raised in this paper will be explored in far greater detail in the forthcoming research on risk-based speed limits for Austroads. It is hoped that this paper will stimulate discussion within road authorities and road user groups. Inputs and ideas arising from these discussions will be sought during the consultation phase of the Austroads study.

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