LG TRRIP
Local Government Transport & Roads Research & Innovation Program

An initiative by:

WALGA

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Practitioners Guideline: Low-cost safety improvements for rural Local Government roads in WA

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1.0

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About LG TRRIP

The Local Government Transport and Roads Research and Innovation Program (LG TRRIP) is an initiative between Main Roads Western Australia and the Western Australian Local Government Association.

LG TRRIP has a strategic commitment to the delivery of collaborative research and development that positively contributes to the design, construction and maintenance of safe, sustainable transport infrastructure in Western Australia.

Summary

This practitioners guideline provides guidance for the implementation of low-cost road safety improvements on rural local government roads in Western Australia (WA). In WA, the majority of the road fatalities occur on regional roads, with an estimated cost of $4.6 billion for fatalities on regional roads in WA out of a total $7.1 billion for road fatalities on all WA roads during the 5-year period between 2018 to 2022. The guideline is based on research and analysis of existing guidance documents, case studies and best practice.

The guideline provides a list of low-cost safety treatments, including engineering guidance on the selection of suitable treatments and calculation of unit rates. It is designed to help local governments save time and costs associated with road safety improvements on their local road networks. In addition to the practitioner's guideline, the project outputs include a presentation providing an overview of the guideline and its use and a technical report.

The literature review, provided in the *Technical Report: Low-cost road safety improvements for rural Local Government roads in WA*, found that while general guidance on the design of low-cost road safety improvements is available in various guidance documents, little context-specific guidance exists to support the implementation of these improvements for rural local government roads in WA. The review identified several low-cost safety treatments that are discussed in this guideline, including shoulder sealing, lane widening, longitudinal linemarking, audio-tactile linemarking, speed limit review and zoning, guide posts, warning signs, guide signs, vehicle activated signs, raised reflective pavement markers, surface corrections, road safety barriers, improving skid resistance and flag lighting.

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1 Introduction

1.1 Background

These documents on the Low-cost road safety improvements for rural Local Government roads in WA have been developed by the National Transport Research Organisation (NTRO) for the Western Australian Local Government Association (WALGA) with the support of Main Roads Western Australia (MRWA) under the Local Government Transport and Roads Research and Innovation Program (LG TRRIP).

LG TRRIP was established in 2022 by MRWA and WALGA as a research and innovation program dedicated to the needs of the local government road network in WA. The objective of the program is to achieve better implementation of innovative practice by improving the specialist capability of local government through a collaborative program of projects which deliver advanced technology and cost-effective solutions to roads and transport issues for the people of Western Australia.

By providing this guidance, local governments will be better equipped to identify and implement the most appropriate and cost-effective solutions to improve road safety on their local road networks. This will not only reduce the risk of crashes and fatalities but will also create a safer and more comfortable road environment for all road users.

1.2 Purpose

Road safety affects everyone who uses the road network. While general guidance on the design of low-cost road safety improvements is available in various guidance documents, little context-specific guidance exists to support the implementation of these improvements on rural local government roads in WA.

Local governments have the responsibility of ensuring the safety of their local road networks. However, in some cases, the selected materials for implementing these safety improvements are not readily available. To support the delivery of safety projects, local governments may benefit from guidance on the relative benefits, selection, and implementation of low-cost road safety improvements.

Such improvements may include but are not limited to:

- guide posts
- warning signs (curve, intersection, and advisory speed)
- guide signs (chevron alignment markers)
- raised reflective pavement markers
- surface corrections
- speed limit review and zoning
- longitudinal linemarking (centre/edge)
- shoulder sealing
- lane widening
- audio-tactile linemarking (centre/edge)
- road safety barriers
- improving skid resistance
- vehicle activated signs
- flag lighting.

By providing this guidance, local governments will be better equipped to identify and implement the most appropriate and cost-effective solutions to improve road safety on their local road networks. This will not only reduce the risk of crashes and fatalities but will also create a safer and more comfortable road environment for all road users.

The objective of this document is to provide a Guideline for practitioners for the selection of low-cost safety treatments on rural local government roads in WA, roads primarily situated in regional or peri-urban locations, predominantly characterised by both sealed or unsealed surfaces and typically without kerbs.

1.3 Structure

The following documents have been prepared:

- **Practitioners Guideline** (this document)
- Technical Report.

The content and relationship between these 2 documents are summarised in Table 1.1.

Table 1.1: Structure of the documents

Document	Content
Practitioners Guideline	The Guideline is presented in a user friendly format and provides key information needed for practitioners to select the appropriate improvements.
Technical Report	The technical report contains the background research and supporting technical information.

1.4 How to use this Guideline

The following text and Figure 1.1 outline a step-by-step process that local government practitioners can follow when using this Guideline to implement low-cost safety treatments on rural local government roads in WA:

1. **Consider the context of the road project:**

- Assess the road, such as traffic volume, speed limits, crash history, and road geometry.
- Identify any specific safety concerns or areas that require improvement.

2. **Review the treatment matrix:**

- Consult treatment selection matrix in Table 2.1, which outlines various low-cost safety treatments available.
- Identify treatments that are suitable for addressing the safety concerns based on the characteristics of the road project.

3. **Reference the fact sheets:**

- Refer to Section 2.2 for the fact sheets provided of each selected treatment.
- The fact sheets contain detailed engineering guidance, including design considerations, installation requirements, and maintenance recommendations.
- Use the information in the fact sheets to ensure proper implementation of the selected treatments.

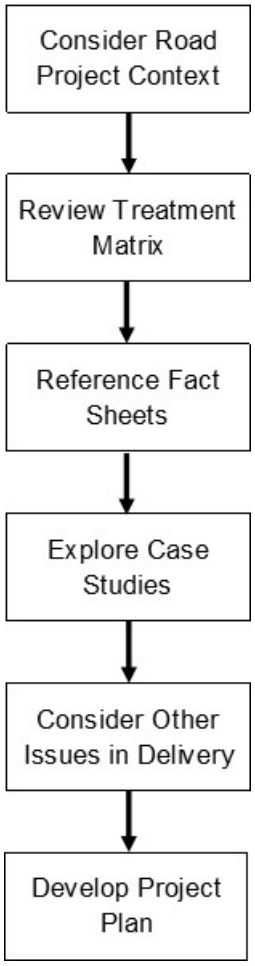
4. **Explore the case studies:**

- Review the case studies included in Section 3 of the Guideline.
- Examine the success and effectiveness of the low-cost treatments discussed in the case studies.
- Take note of any challenges encountered during implementation and consider strategies to overcome similar obstacles.

5. **Consider other issues in project delivery:**

- Evaluate additional factors that may impact the implementation of low-cost safety treatments, such as budget constraints, resource availability, and stakeholder engagement.
- Develop a project plan that addresses these issues and outlines the necessary steps for implementation.
- Consider the long-term sustainability and maintenance requirements of the selected treatments.

Figure 1.1: Process Flowchart



2 Low-cost Treatment Factsheets

This section provides the necessary details to guide practitioners in the appropriate selection and implementation of low-cost safety improvements on rural roads.

2.1 Matrix for Treatment Selection

In this section, a matrix (Table 2.1) is presented to assist in selecting appropriate low-cost safety treatments for local rural roads with anticipated low traffic volumes. The matrix is designed to allow for a logical selection based on crash risk, hierarchy and cost. This can help identify treatments that address specific crash risks while also considering their relative cost-effectiveness.

By using this matrix, Local Governments can make informed decisions about which treatments are most appropriate for their specific needs, which will help to improve road safety and efficiency on local rural roads in WA.

Table 2.1: Treatment selection matrix table

		Longitudinal linemarking	RRPMs	Guide posts	Curve warning signs	Intersection warning signs	Advisory speed signs	Guide signs (i.e. CAMs)	Audio-tactile linemarking	Speed limit review and zoning	Skid resistance	Flag lighting	Shoulder sealing	Surface corrections	Road safety barriers	Vehicle activated signs	Lane widening
Cost		Low	Low	Low	Low	Low	Low	Low	Low	Low to medium	Low to medium	Low to medium	Medium	Medium	Medium	Medium to high	Medium to high
Road	Sealed	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Unsealed	✗	✗	✓	✓	✓	✗	✓	✗	✗	✗	✓	✗	✗	✓	✓	✗
Location	Mid-block	✓	✓	✓	✓	✗	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓
	Intersection	✓	✓	✓	✗	✓	✗	✗	✗	✗	✓	✓	✗	✓	✗	✓	✗
Hierarchy	Change road user behaviour	✗	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗	✗	✗	✓	✗
	Reduce the risk	✓	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✓	✓	✓	✗	✓
Crash type	Head on																
	Hit animal																
	Hit object																
	Hit pedestrian																
	Non-collision																
	Off carriageway hit object																
	Off carriageway non-collision																
	Other																
	Rear end																
	Right angle																
	Right turn thru																
	Sideswipe																

Legend:

Yes - ✓; No - ✗

Reduction in crash type:

- Likely to be effective: Green;
- Somewhat effective: Yellow;
- Unlikely to be effective: Red

2.2 Fact Sheets

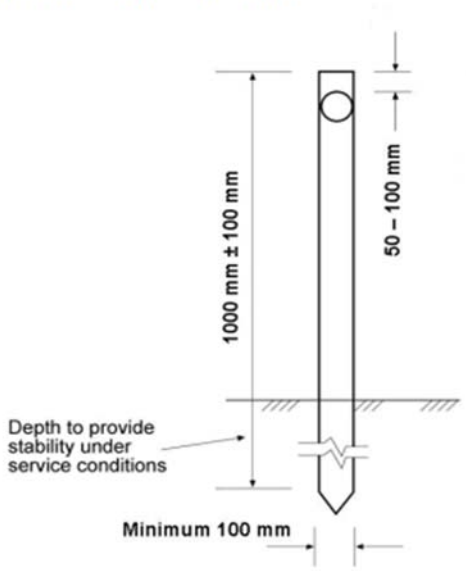
This section provides details for identified low-cost road safety treatments, including the following: crash reduction benefit, hierarchy, warrants, cost estimates, case study reference, and design and construction guidance.

Note that indicative costs provided are applicable to time of publishing.

2.2.1 Guide Posts

Guide Posts
 Source: WALGA  Source: WALGA.
Description Guide posts are roadside markers that are installed on the edge of the road in order to improve the delineation of the road's path for drivers. Guide posts are generally one metre1 m high, are installed at a uniform distance from the edge of the road and are fitted with reflectors near the top to enhance their effectiveness during night-time driving. Guide posts assist drivers by indicating the alignment of the road ahead, especially at horizontal and vertical curves. Guide posts with reflectorised delineators are placed in pairs on both sides of the road in a series. The longitudinal spacing of the guide posts may vary along different alignments.
Crash reduction factors 10% to 25% (iRAP 2022)
Potential locations • Sealed road: Yes • Unsealed road: Yes Guide posts are effective at locations where existing delineation is poor and are also commonly used on horizontal and vertical curves.

Figure 7.1: A typical guide post



Source: Austroads.

Guide Posts

Considerations

- The spacing requirements for guide posts will vary depending on the type of roadway and the location of the guide posts (e.g. on straight sections, curves, crests, bridges and culverts). Follow the guidelines outlined in AS 1742.2 to ensure the guide posts are placed in optimal locations for visibility.
- The colour of the reflective delineator should be consistent throughout the area, with white reflectors used on the right side of two-way roads, yellow reflectors used on the right side of one-way roads (including divided roads) and red reflectors used on the left side of the road facing oncoming traffic. The mounting height of the guide posts should also be consistent.
- It may also be beneficial to consider the use of flexible (self-correcting) guide posts, which can help reduce damage to the posts and surrounding infrastructure in the event of a collision and may reduce maintenance costs.

Warrants

The following guidance is provided for rural sealed roads:

- Sealed pavements less than 5.5 m wide: Guide posts with delineators are normally the only devices used on undivided rural roads with pavements less than 5.5 m wide. Where used, guide posts shall be provided at, or near, the edge of the road formation at a constant distance (generally between 1.2 m and 3.0 m) from the pavement edge.
- Sealed pavements between 5.5 m and 6.8 m wide: Guide posts shall be provided at, or near, the edge of the road formation at a constant distance (generally between 1.2 m and 3.0 m) from the pavement edge.
- Sealed pavements 6.8 m wide or greater: Guide posts shall be provided at, or near, the edge of the road formation at a constant distance (generally between 1.2 m and 3.0 m) from the pavement edge.

Hierarchy

- Road safety audit risk control method: Change road user behaviour.
- Safe System assessment framework: Supporting treatment.

Other supporting treatments

- Linemarking and warning signs at substandard curves to provide additional guidance to drivers.
- Shoulder seal to improve traction and reduce the risk of run-off road crashes.
- Road safety barriers can be installed in areas with high risk of collision.

Pros

- Help drivers maintain a safe and consistent lateral vehicle position within the travel lane.
- Assist drivers in changing the driver behaviour by highlighting upcoming changes in road alignment.
- Provide effective long-range delineation for night driving, particularly in low visibility conditions or fog-prone areas.
- Can help reduce pavement deterioration by preventing vehicles from driving on the shoulder of the roadway.

Cons

- Ongoing maintenance required.
- Poorly maintained guide posts can become a hazard to road users.
- Poorly designed or located guide posts may add to crash risk.

Types (Material)

Wood, metal and plastic.

Installation methods

Vary depending on shoulder materials:

- Formed compacted shoulders: typically use buried (cored, placed & re-compacted) or driven method (using pneumatic drill/jackhammer).
- Unformed shoulder: typically buried or driven with a pneumatic drill/jackhammer.

Installation considerations

Where roads are kerbed or near electrical installations (lights, rail crossings etc) underground power needs to be considered. Driven method is typically more cost-effective once equipment is purchased.

Cost

Low (approximately $80 per guide post, including installation)

Life expectancy

5 years

2.2.2 Curve Warning Signs

Curve Warning Signs
 W1-5: Left or Right  W1-1: Left or Right  W1-5: Left or Right  W1-7: Left or Right  W1-4: Left or Right  W1-2: Left or Right Source: AS 1742.2:2022.
Description Curve warning signs are used to inform drivers of an upcoming curve in the road. These signs are particularly useful for substandard curves where additional signage may be necessary to convey the severity and nature of the curve to motorists, giving drivers time to react and adjust their driving behaviour accordingly. Warning signs are an effective measure to reduce crashes for a relatively small cost where more expensive interventions cannot be achieved.
Crash reduction factors 10% to 30% (Main Roads Western Australia 2021)
Potential locations • Sealed road: Yes • Unsealed road: Yes • Areas where the alignment of the road changes, such as when the road transitions from a straight to a curved section.
Considerations • Consider whether the horizontal and vertical alignments of the road are suitable for the 85th percentile traffic speed. If not, consider installing warning signs and advisory speed signs, and ensure that the posted advisory speed for each curve is appropriately assessed. • The type and size of the warning sign. • Ensure signage is consistently applied on other roads with similar road geometry.

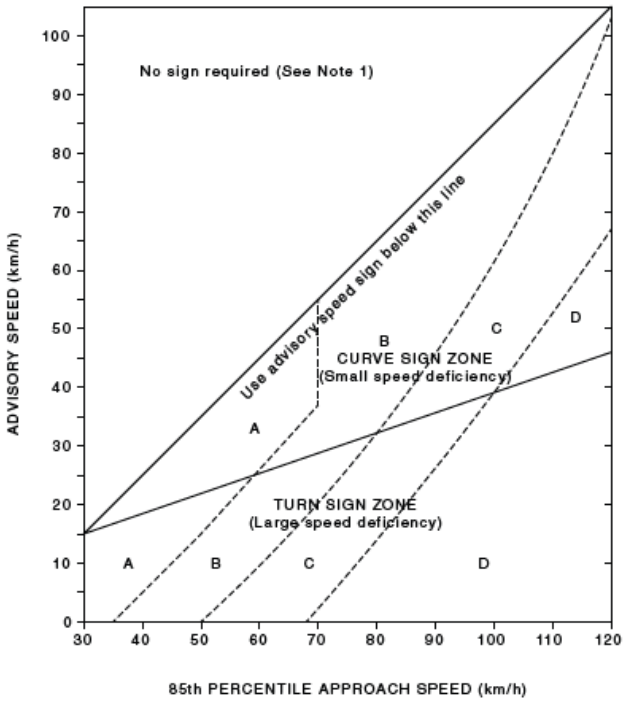
Curve Warning Signs

Warrants

Curve warning signs shall be used in advance of a substandard curve.

The use of supplementary Advisory Speed signs (W8-2) in conjunction with Curve Warning signs is determined by the following chart.

AS 1742.2:2022 78



NOTE 1 No sign is required in this zone unless otherwise indicated by Clause 4.3.2.

NOTE 2 A, B, C and D indicate the size of the sign. B size is the minimum size recommended for arterial roads. Increase one size where either the sign is cantilevered over the roadway, there are two or more lanes in one direction or the sign is more than 6 m from edge of the travel lane.

Figure 4.1 — Guide to the signposting of substandard horizontal curves

Source: AS 1742.2:2022.

Hierarchy

- Road safety audit risk control method: Change road user behaviour.
- Safe System assessment framework: Supporting treatment.

Other supporting treatments

- Edge lines to help delineate the edge of the road and provide guidance to drivers.
- Guide posts and RRPMs can provide additional guidance to drivers, particularly in areas where visibility may be limited.
- Flattening of batters to provide a more stable road surface and reduce the risk of run-off-road crashes.
- Advisory speed signs can ensure drivers are aware of the appropriate speed for travelling.
- Superelevation changes of the road for horizontal curves.

Pros

- Change road user behaviour by providing appropriate warning and advice, reducing the likelihood of crashes caused by driver error.
- Improved curve delineation, reducing the likelihood of run-off-road crashes on curves.
- Cost-effective at improving road safety.
- Able to alert drivers to hazardous or potentially hazardous conditions that may not appear apparent due to road geometry or environmental conditions.

Cons

- Regular maintenance is required to ensure signs remain visible and effective, which can be costly and time consuming.
- Warning signs do not eliminate the hazard itself, and poorly maintained or installed signs can add to the risk of crashes.
- Overuse of warning signs can be confusing for drivers and can reduce their effectiveness due to inconsistency.
- Warning signs are prone to vandalism.

Curve Warning Signs
Types (material) Typically made of reflective sheeting and aluminium substrate that is shaped into the appropriate curve warning sign configuration. It provides a durable and long-lasting material for the sign that can withstand adverse weathering conditions.
Installation methods Typically involves mounting the sign on a post or pole, which is buried in a hole that is dug into the ground. For additional stability, the hole is then backfilled with concrete which helps to prevent the post from leaning or falling over. Once the post or pole is anchored into the ground, the sign is then attached to post or pole using bolts or other fasteners, which are tightened securely. The installation process must adhere to AS 1742 to ensure the sign is properly positioned and visible to drivers approaching the curve.
Installation considerations When installing the warning signs, it is important to position them effectively without restricting lateral clearance or sight distance. Typically, a curve warning sign will be erected on the left side of the carriageway, but a duplicate sign may be installed on the right side if necessary to effectively convey the message to motorists.
Cost Low (approximately $350 per sign, including installation)
Life expectancy 5 years

2.2.3 Guide Signs (Chevron Alignment Markers)

Guide Signs (i.e. Chevron Alignment Markers)

Source: WALGA.

D4-6

Source: AS 1742.2:2022.

Guide Signs (i.e. Chevron Alignment Markers)

Description

Chevron alignment markers (CAMs) are a type of enhanced delineation treatment used to improve road safety by alerting drivers to the presence and severity of upcoming curves.

CAMs are typically located along the outside edge of a curve and consist of a series of chevron-shaped markers pointing in the direction of the curve. CAMs are designed to provide continuous reminders and guidance to drivers, helping them to position their vehicles and adjust their driving behaviour while negotiating the curve.

Crash reduction factors

10% to 25% (iRAP 2022)

Potential locations

- Sealed road: Yes
- Unsealed road: Yes

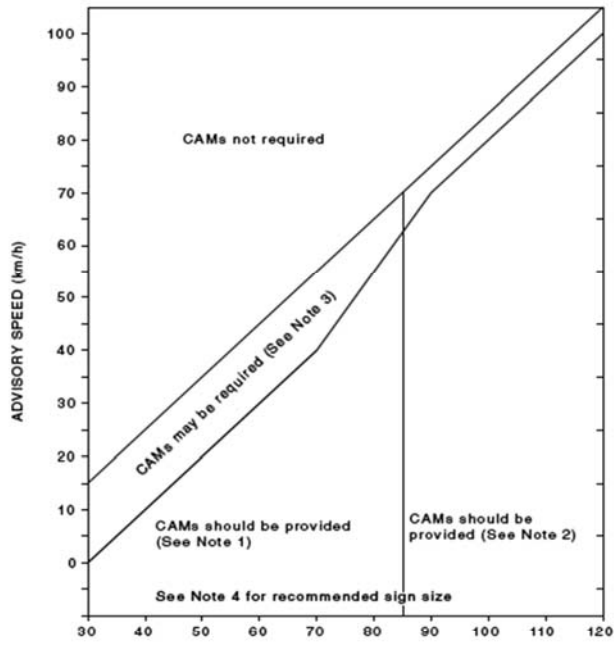
CAMs are typically used on substandard curves with a radius of 200 m to 500 m, where other forms of delineation such as pavement markings and guide posts may not be sufficient to adequately inform drivers of the severity of the curve. CAMs should only be used to augment other delineation treatments and not for delineation of traffic islands or other obstructions.

Considerations

CAMs should be reserved exclusively for the delineation of curves. The application of CAMs and other types of delineation treatments should be consistent on a route basis. This helps to establish appropriate driver expectancy and can help drivers anticipate changes in the road ahead accordingly.

Warrants

The requirements for the use of CAMs are found in the following chart.



NOTE 1 CAMs should be provided at curves in this region in accordance with Clause 4.3.6.1 and the spacing given for V_{85} – Less than 85 km/h in Table 4.3.

NOTE 2 CAMs should be provided at curves in this region in accordance with Clause 4.3.6.1 and the spacing given for V_{85} – 85 km/h and greater in Table 4.3.

NOTE 3 Curves in this region will not normally require CAMs, but they may be used where the existence or direction of the curve may not be clear to approaching drivers (e.g. where the curve is just beyond a crest) or the locality is subject to frequent fogs or other adverse weather conditions, also see Clause 4.3.2.

NOTE 4 Generally, B size CAMs should be used for all installations, including on multi-lane roads. However, in urban situations where the speed limit is less than 70 km/h, use of A size CAMs may be appropriate. It is recommended that C size CAMs are used on expressways.

Figure 4.2 — Guide for the use of Curve Alignment Marker signs (CAMs)

Source: AS 1742.2:2022.

Hierarchy

- Road safety audit risk control method: Change road user behaviour.
- Safe System assessment framework: Supporting treatment.

Guide Signs (i.e. Chevron Alignment Markers)

Other supporting treatments

- Guide posts help to highlight the curve and guide drivers along the correct path.
- Use additional signage, such as advisory speed signs, to allow drivers to adjust the driving behaviour when negotiating through the curve.

Pros

- Improve the lateral positioning of vehicles, moving them away from the edge of the carriageway. This reduces the likelihood of run-off-road crashes.
- Effective at controlling speed to and through substandard horizontal curves.
- Provide warning and advice to drivers, informing them of the upcoming change in road conditions.

Cons

- Do not eliminate the hazard. Drivers may still encounter sharp curves.
- Require regular maintenance to ensure effectiveness.
- If installed too close to the edge of the road, the signs can be hazardous to drivers due to the proximity.
- Incorrect spacing of the signs can be confusing for drivers.
- Signs are prone to vandalism.

Types (material)

Typically made of reflective sheeting and aluminium substrate that is shaped into the appropriate chevron alignment marker configuration. It provides a durable and long-lasting material for the sign that can withstand adverse weathering conditions.

Installation methods

Typically involves mounting the sign on a post or pole, which is buried in a hole that is dug into the ground. For additional stability, the hole is then backfilled with concrete which helps to prevent the post from leaning or falling over. Once the post or pole is anchored into the ground, the sign is then attached to post or pole using bolts or other fasteners, which are tightened securely.

The installation process must adhere to the AS 1742 to ensure the sign is properly positioned and visible to drivers approaching the curve.

Installation considerations

AS 1742.2:2022 86

Table 4.3 — Spacing of Curve Alignment Marker signs (CAMs)

Curve radius, m	CAM spacing, m (see Note 1)	
	V_{85} Less than 85 km/h	V_{85} 85 km/h and greater
< 50	10	6
50 – 99	12	8
100 – 149	18	12
150 – 199	24	16
200 – 249	30	20
250 – 300	36	24
> 300	40	26
NOTE The spacings in this Table are subject to a tolerance of ± 10 %		

Source: AS 1742.2:2022.

In addition to the spacing requirement detailed above, the mounting height should not be more than 1.2 m to the underside of the sign from the ground and should be consistent throughout a curve. This helps to ensure that the markers are visible to drivers.

Cost

Low (approximately $315 per sign, including installation)

Life expectancy

5 years

2.2.4 Raised Retroreflective Pavement Markers

Raised Retroreflective Pavement Markers
 Source: WALGA.  Source: ARRB Group.
Description Raised retroreflective pavement markers (RRPMs) are small reflective devices that are installed on the road surface to provide enhanced visibility to motorists, especially in low light or adverse weather conditions. RRPMs are commonly used to mark the edge of lanes, indicate change in alignment and delineate areas such as median and traffic islands. RRPMs are especially useful in rural areas where road lighting is limited. The reflective properties of RRPMs are achieved through the use of specialised materials that reflect light back to its source. When headlights shine on the markers, they appear to glow and are highly visible to drivers. Also, the raised design of the RRPMs provides an audible and tactile signal when a vehicle passes over them. This further enhances their effectiveness in providing warning and guidance.
Crash reduction factors 15% (Main Roads Western Australia 2021)
Potential locations • Sealed road: Yes • Unsealed Road: No RRPMs can be used to supplement painted lines, particularly in areas where the painted lines may not be clearly visible or where additional guidance is needed. As a guide, RRPMs may be used to augment painted barrier linemarking.

Raised Retroreflective Pavement Markers

Considerations

- RRPMs should be installed in accordance with relevant guidelines and standards. This ensures that the markers are correctly spaced and positioned to provide effective guidance.
- RRPMs are available in different colours to match the type of painted linemarking they are intended to supplement. It is critical to select the correct colour of RRPMs to ensure they are easily distinguishable and will not cause confusion for motorists.

NOTE Blue RRPMs are typically used to assist with locating water points on, or adjacent to, the road. While located on road pavements, they are not applicable to the situations as set out below.

Table 5.6 — Colour of retroreflective raised pavement markers to augment painted lines

Application	RRPM colour
Dividing lines	Yellow
Lane lines (excl. tram lane lines)	White
Right hand edge line, divided road	Yellow
Left hand edge line, divided road	Red
Left hand edge line, two-way road	Red
Tram lane lines	Yellow
Small channelizing island outline, painted or raised — all sides (see Note 1)	White
Median island outline, painted or raised — all sides	Yellow
Roadway diverge outline, including expressway exit nose, and approach end of large island	
Left side (see Note 2)	Yellow
Right side (see Note 2)	Red
Step-out markings at expressway exit ramps	Green
NOTE 1: A small island should generally be regarded as one with no side, including approach and departure markings, longer than 12 m.	
NOTE 2: Left or right when viewed in the direction of travel.	

Source: AS 1742.2:2022.

Warrants

- When traffic volume exceeds a certain threshold, RRPMs may be used to improve visibility and delineation.
- Roads with poor lighting or roads subject to fog or other environmental conditions that reduce visibility.
- To address specific safety concerns, such as high crash locations.
- RRPMs may be used in designs to meet specific standards and guidelines, such as the Manual of Uniform Traffic Control Devices.
- To mark specific road features, such as fire hydrants.

Hierarchy

- Road safety audit risk control method: Change road user behaviour.
- Safe System assessment framework: Supporting treatment.

Other supporting treatments

RRPMs are used to augment linemarking.

Pros

- Improve the visibility of linemarking, particularly at night-time and during adverse weather conditions.
- Audible and tactile warnings to drivers when they depart from their lane help to reduce the risk of lane departure crashes.

Cons

- As RRPMs are designed to provide an audible warning to drivers when crossing over them, RRPMs can produce a noise that can be heard by nearby residents.
- Regular maintenance/replacement may be required.

Types (material)

Typically made of durable materials such as ceramic or plastic that are designed to withstand the weight and pressure of vehicular traffic.

Installation methods

Adhesive installation using a two-part adhesive to attach the RRPM to the pavement surface. The adhesive is applied to the bottom of the marker, which is then pressed firmly onto the pavement. Or, the adhesive is applied to the pavement, then the RRPM is pressed onto the adhesive.

Raised Retroreflective Pavement Markers
Installation considerations • RRPMs should be placed 25 mm to 50 mm from the linemarking they are intended to augment. • Should only apply on a clean, dry pavement surface to ensure good adhesion. • RRPMs should be installed uniformly to ensure consistency and visibility for motorists.
Cost Low (approximately $12 per RRPM, including installation)
Life expectancy 5 years

2.2.5 Surface Corrections (rutting, cracking, pot holes)

Surface Corrections
 Source: WALGA.
Description Surface corrections refer to the process of fixing or restoring pavement defects that can negatively impact the safety, durability and performance of roadways. Surface corrections may be required due to environmental factors or traffic loads that affect the condition of the pavement. In locations that are prone to surface water and flooding events, the pavement must be designed to withstand the effects of weather and provide adequate skid resistance. The pavement characteristics of a road are influenced by the traffic load, which may determine the chosen pavement material. The choice of pavement material may also have the whole-of-life cost implications (taking into in maintenance and asset life). Some pavement characteristics influenced by traffic levels include the pavement structural design, required performance criteria and functionality requirements. Surface defects that may need correction include cracking, potholes, flushing, roughness, shoving, rutting, soft spots and oil spills.
Crash reduction factors 25% to 40% (iRAP 2022)
Potential locations • Sealed road: Yes • Unsealed Road: Yes Any roadway that is subject to surface defects and where maintenance is required to ensure safe and reliable use by road users.

Surface Corrections

Considerations

- The design of the pavement should be appropriate for the expected traffic volume and the surface should be designed to withstand the loads it is subjected to.
- Surface water can increase the risk of aquaplaning; pavement should be designed to allow for proper drainage to reduce this risk.
- The surfacing materials used should be carefully chosen to provide the required skid resistance, durability and resistance to weather and environmental factors.
- The individual aggregate properties, such as polished stone value and skid resistance value should be suitable for the location and the expected traffic usage.
- The surface correction should be acceptable to the local community in terms of noise, dust and aesthetics.

Warrants

- High-speed condition surveys and reactive visual condition assessments are 2 ways of identifying the need for surface corrections.
- Surface corrections can be completed as part of a larger project or through maintenance requirements.
- Main Roads Western Australia and Austroads specifications, as well as individual shire's construction specifications, are used as warrants or guidelines for selecting the treatment.

Hierarchy

- Road safety audit risk control method: Reduce the risk.
- Safe System assessment framework: Supporting treatment.

Other supporting treatments

Installing appropriate warning signs to alert motorists to changing road conditions. This can help drivers to adjust their speed and driving behaviour accordingly.

Pros

- Can provide a level surface free from major defects and hazards, reducing the risk of crashes and improving driving comfort.
- Increase the pavement strength and weatherproofing, extending the pavement life.
- Improve the skid resistance of the pavement.
- Provide the opportunity to fix other road surface problems, such as crossfall and drainage issues.
- Provide the opportunity to add or enhance road delineation, such as pavement markings.

Cons

- May not necessarily be the most economical treatment, as the cause of the pavement defect may be related to geometric or operating deficiencies.
- Can cause temporary inconvenience to road users, such as traffic delays and detours due to lane closures when works are being undertaken.
- The process of surface corrections may be disruptive to adjacent properties and may have environmental impacts because of the heavy machinery and construction materials required. This may include issues such as noise, vibration, dust and temporary loss of access to adjacent properties.

Types (material)

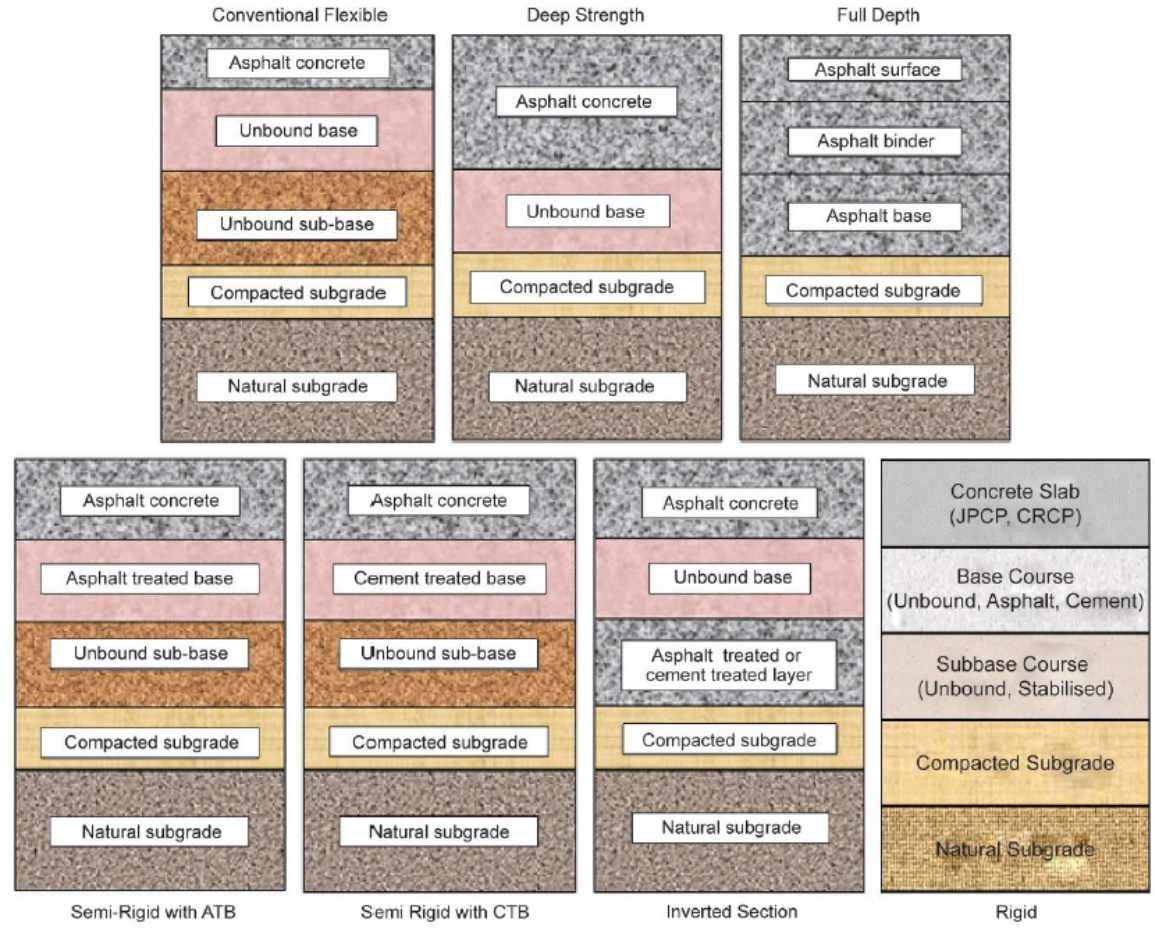
A pavement structure is made up of various layers of materials.

Pavement layer	Material options
Wearing course	• Hot mix asphalt • Bituminous spray seal • Bituminous slurry seal (micro-surfacing) • Unsealed
Basecourse	• Hot mix asphalt intermediate course or basecourse • Concreate • Unbound granular • Modified unbound granular • Lightly bound or bound stabilised granular
Subbase	• Concrete • Unbound granular • Modified unbound granular • Lightly bound or bound stabilised granular
Subgrade	• In situ granular • Stabilised granular

Surface Corrections

Installation methods

There are various types of pavement structures which utilise different material types at different layers of the pavement system. Choosing a suitable pavement type depends on design traffic, functionality and serviceability requirements, budget constraints, material availability, local climatic conditions and a range of other factors. The figure below presents common sealed pavement types used throughout Australia.



Source: Rice et al. (2020).

Installation considerations

- Weather conditions during the construction of the road surface can affect the laying operation and subsequent performance of the surface. Temperature, humidity and wind can all have an impact on the installation process and quality of the surface.
- Temporary traffic management at work sites must be designed and managed to ensure the safety of all those affected.
- Quality control measures must be in place during the installation process to ensure the correct materials are used and the installation procedure is carried out to the required standards. This may require regular testing of the materials used.
- Environmental considerations, including measures to reduce noise and dust pollution.

Cost

Medium

- Road reconstruction with double seal – $250,000 per km.
- Road gravel re-sheet – $40,000 per km
- Road re-seal – $50,000 per km
- Maintenance grading – $12,000 per km

2.2.6 Speed Limit Review and Zoning

Speed Limit Review and Zoning

Source: WALGA.

Source: AS 1742.2:2022.

R4-1 series

Description

Effective management of speed on the road network requires careful consideration of various factors, including speed limit review and zoning. The appropriate setting of speed limits can communicate the function of the road and regulate traffic speed based on factors such as road user types, vehicle types, road environments and community needs. This is critical to ensure the desired safety, mobility, traffic management and local amenity, and to meet the expectations of road users.

Speed plays a critical role in determining the likelihood and severity of crashes. Therefore, managing speed on the road network is essential in improving the safety of road users. However, effective speed management is not just setting the appropriate speed limits; it also involves educating drivers about the importance of adhering to speed limits. This can be achieved through driver education programs, targeted enforcement activities and technology such as speed cameras and other monitoring devices.

Overall, managing and setting appropriate speed limits is a comprehensive and coordinated task that requires the cooperation of various stakeholders such as government agencies, police services, road users and other relevant stakeholders. When speed limits are implemented correctly, they can ensure the safe and efficient operation of the road network.

Crash reduction factors

10 km/h reduction from a road with 100 or 110 km/h speed limit: 20%. (Austroads 2021)

Note: Reduction in speed limit can significantly reduce the risk of pedestrian-related crashes. Small reductions in operating speeds can exponentially increase the likelihood of survival in the event of a pedestrian-related crash.

Further details on crash reduction factors for specific speed limit changes can be found in the Main Roads Western Australia Treatment Resource Guide.

Speed Limit Review and Zoning

Potential locations

- Sealed road: Yes
- Unsealed Road: Yes

Consider the function and purpose of the road. Speed limits are likely to be higher on roads where movement is the primary function, while lower speed limits are important in creating a sense of 'place'. Place value influences the activity pattern along the roadway, which can have a significant bearing on naturalistic operational speed.

The setting of effective speed limits is dependent on various factors such as the road function, traffic movement, road infrastructure and roadside development and activity.

Considerations

It is essential to ensure that speed limits are consistent with the purpose and physical environment of the roadway. Arbitrary speed limits that are too low for the road, traffic and roadside environment may attract poor levels of compliance, regardless of the level of enforcement.

When setting a speed limit, several factors should be considered such as pedestrian and cyclist activity, crash history, road safety rating, land use, desired place value, intersection spacing, driveway density, geometry of the road, roadside conditions, road function, traffic volume and observed speeds.

Warrants

Main Roads WA Speed Zoning Policy and Application Guidelines provides guidance on the principles and objectives applied in setting regulatory speed limits for all public roads in WA.

When making changes to speed zones, it is necessary to consult with the relevant representatives from Main Roads WA. Additionally, any applications for general speed zones or changes to existing speed zones should be submitted to the appropriate speed management committee within Main Roads WA for review. Further information is detailed in AS 1742.4: *Speed Controls.*

Hierarchy

- Road safety audit risk control method: Change road user behaviour.
- Safe System assessment framework: Supporting treatment.

Other supporting treatments

Effective speed management requires a multi-faceted approach that considers road infrastructure design, traffic calming measures and enforcement activities.

Setting appropriate speed limits is one aspect of speed management and must be complemented with other treatments and measures to ensure compliance and promote safe travel speeds. Speed limits should be regularly reviewed and updated in response to changing road environments, land use and traffic conditions. Collaboration with relevant stakeholders and consultation with road safety experts and local transport planners are critical to ensuring effective speed management strategies.

Pros

- Applying appropriate speed management can reduce the likelihood of crashes.
- Reduced travel speeds can decrease emissions, enhance traffic flow and improve safety.
- Effective area-wide benefits may include reduced traffic volumes on local roads, improved accessibility and environment for vulnerable road users and encouragement of sustainable modes of transport.
- Reducing vehicle noise, acceleration and deceleration can create a more pleasant environment for adjoining land uses.

Cons

- Minor increase in travel time for motorists.
- Often additional treatments are required to reinforce the new reduced speed limit.
- Compliance with the new speed limit can be challenging and may only be possible over extended timeframes.
- Not an isolated treatment, must consider area-wide approach.

Types (material)

Typically, speed limit signs, pavement markings and variable message signs are used to inform motorists of the posted speed limits.

Speed Limit Review and Zoning

Installation methods

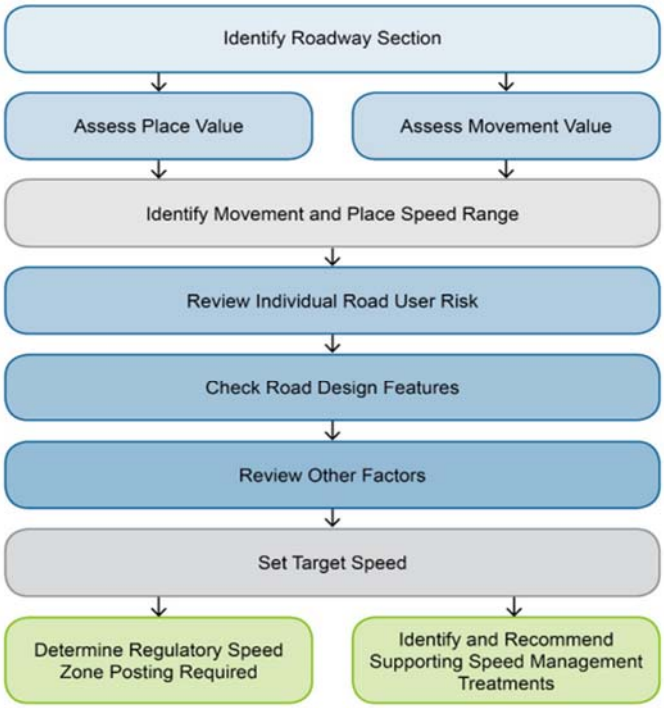


Figure 1: Procedure for setting a speed zone

Source: AS 1742.4:2020.

Installation considerations

- Ensure the location of the speed limit signs and pavement markings are compliant and visible to drivers.
- Consider additional traffic calming measures to support the change of the new speed limit.
- Engage in consultation with stakeholders such as the residents, businesses and community groups to ensure their needs and concerns are considered.
- Coordinate with other road maintenance and improvement projects to minimise disruptions. It is important to ensure that the new speed limit is integrated with other road safety projects and initiatives.

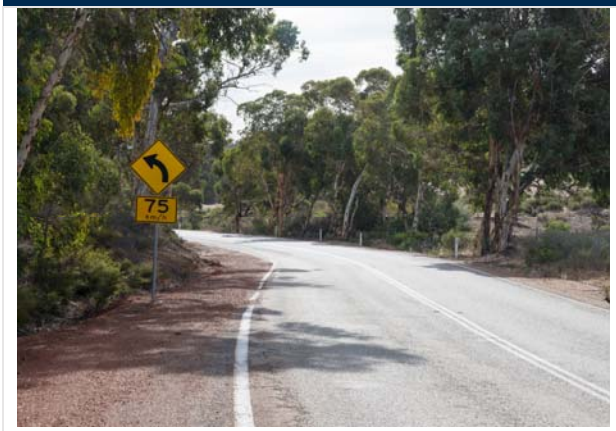
Cost

Low to medium (approximately $350 per sign, including installation)

Life expectancy

10 years

2.2.7 Advisory Speed Signs

Advisory Speed Sign (Supplementary Sign)	
	
Source: WALGA.	Source: Australian Standards.

Description

A speed advisory sign is a type of supplementary warning sign that is typically used in combination with a curve warning sign. The purpose is to provide motorists with information about the maximum safe speed that they should maintain when navigating a curve, based on the road geometry and environmental conditions.

The advisory speed displayed on the sign is determined by engineering measures, such as the road's horizontal and vertical alignment, as well as the potential hazards that may be encountered along the curve.

Advisory speed signs are designed to give drivers ample time to adjust their driving behaviour and reduce their speed before encountering the curve. This is particularly important for drivers who are unfamiliar with the road and for those who may be travelling at high speeds.

Crash reduction factors

30% (Austroads 2021a)

Potential locations

- Sealed road: Yes
- Unsealed road: No

Curves in the road that have a sharper turn than the surrounding area may require drivers to slow down due to substandard horizontal alignment. Advisory speed signs should be provided in conjunction with curve warning signs.

It is important to note that advisory speed signs should only be used in locations where the safe operating speed is less than the speed limit. Advisory speed signs are not intended to be used to arbitrarily lower the speed limit, but rather to provide drivers with guidance on the safe speed for navigating through a section of road.

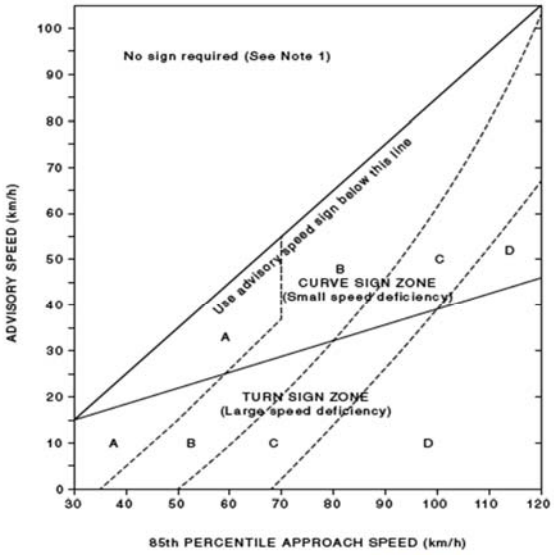
Considerations

- Type and size of the signage: Signs should be large enough and positioned effectively to be visible to drivers and convey the message clearly.
- The posted advisory speed should be appropriate for the road's design and potential hazards. Advisory speeds should be based on engineering measures such as the road's alignment, sight distance and potential hazards. It should also be based on the 85th percentile speed of the traffic when determining these factors.

Advisory Speed Sign (Supplementary Sign)

Warrants

AS 1742.2:2022 78



NOTE 1 No sign is required in this zone unless otherwise indicated by Clause 4.3.2.

NOTE 2 A, B, C and D indicate the size of the sign. B size is the minimum size recommended for arterial roads. Increase one size where either the sign is cantilevered over the roadway, there are two or more lanes in one direction or the sign is more than 6 m from edge of the travel lane.

Figure 4.1 — Guide to the signposting of substandard horizontal curves

Source: AS 1742.2:2022.

Hierarchy

- Road safety audit risk control method: Change road user behaviour.
- Safe System assessment framework: Supporting treatment.

Other supporting treatments

Advisory speed signs are to be used in conjunction with curve warning signs.

Pros

- Can be an effective way to alert drivers of potential hazards and encourage them to adjust their driving behaviour accordingly.
- Particularly effective at controlling speed through horizontal curves and helping to reduce the risk of crashes caused by excessive speed.
- Enhance safety and comfortability when negotiating through the curve.

Cons

- Regular maintenance is required to ensure that signs remain visible and effective, which can be costly and time consuming.
- Warning signs do not eliminate the hazard itself, and poorly maintained or installed signs can add to the risk of crashes.
- Overuse of warning signs can be confusing for drivers and reduce their effectiveness due to inconsistency.
- Warning signs are prone to vandalism.
- Incorrect determination of the speed guidance can increase the risk of crashes.

Types (material)

Typically made of reflective sheeting and aluminium substrate that is shaped into the appropriate advisory speed warning sign configuration. It provides a durable and long-lasting material for the sign that can withstand adverse weathering conditions.

Installation methods

To be installed underneath a curve warning sign.

Typically involves mounting the sign on a post or pole, which is buried in a hole that is dug into the ground. For additional stability, the hole is then backfilled with concrete which helps to prevent the post from leaning or falling over. Once the post or pole is anchored into the ground, the sign is then attached to the post or pole using bolts or other fasteners, which are tightened securely.

The installation process must adhere to AS 1742 to ensure the sign is properly positioned and visible to drivers approaching the curve.

Installation considerations

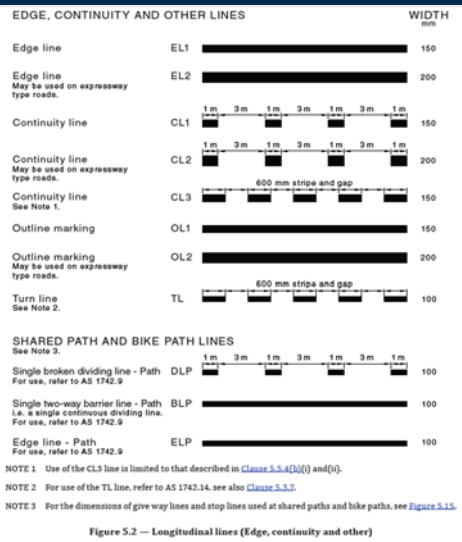
When installing the warning signs, it is important to position them effectively without restricting lateral clearance or sight distance. Typically, a curve warning sign will be erected on the left side of the carriageway, but a duplicate sign may be installed on the right side if necessary to effectively convey the message to motorists. The advisory warning sign will be installed underneath the curve warning sign. However, please note the required longitudinal clearance from the ground to the bottom of the sign.

Advisory Speed Sign (Supplementary Sign)
Cost Low (range between $120 and $1,000 per sign, including installation) Range between $2,500 and $3,000 for ball bank indicator to undertake assessment.
Life expectancy 5 years

2.2.8 Longitudinal Linemarking (Centre, Edge)

Longitudinal Linemarking

Source: WALGA.



Source: AS 1742.2:2022.

Description

Longitudinal linemarking is an essential aspect of road safety and driver guidance on sealed roads. It includes centrelines and edge lines that can run the entire length of a road or in selected sections and are generally marked parallel to the direction of travel. Centrelines separate opposing streams of traffic, while edge lines can delineate the outer limits of the travelled way and help drivers maintain a safe distance from the edge of the road. Both centre and edge delineation treatments can assist drivers in maintaining and judging their position on the roadway and provide guidance on approaching road conditions.

Crash reduction factors

10% to 25% (iRAP 2022)

Further details on crash reduction factors for centre and edge delineation can be found in the Main Roads Western Australia Treatment Resource Guide.

Potential locations

- Sealed road: Yes
- Unsealed road: No

It is important to take into account factors such as poor lighting, weather conditions of the area, road geometry and traffic volumes. Centrelines should be marked to separate opposing directions of traffic flow on sealed pavements that are at least 5.5 m wide. However, on narrower pavements, centrelines are not usually installed unless sight distance is deficient.

Edge lines are used to provide a continuous guide to the driver and discourage traffic from travelling on shoulders, and are generally installed on motorways, rural arterial roads and urban arterial roads with low-standard street lighting.

Centrelines and edge lines may not be required if traffic volumes are less than 300 vehicles per day (VPD) for rural roads or 2,500 VPD for urban roads, though the safety benefits of installing centrelines or edge lines apply regardless of traffic volumes. Please note, in high rainfall areas or where the road is subject to fog or wet conditions for significant periods, longitudinal linemarking may be necessary.

Longitudinal Linemarking

Considerations

Ensure the linemarking is traversable and conforms to AS 1742 and Main Roads Western Australia guidelines, and is consistent throughout the area.

Centrelines should not be used on pavements of insufficient width where it is not practicable for all vehicles to travel on their side of the travel lane. Edge lines should only be installed over a continuous length rather than isolated sites and should not be used unless a centreline is also marked. When provided, they should be placed on both sides of the roadway.

Consider the road geometry of the area of installation as vertical deflections may obscure the visibility of the markings. It is also important to note that longitudinal linemarking cannot be used on unsealed roads.

Warrants

Dividing line marking, including barrier lines where required should be used on sealed pavements 5.5 m or wider if the traffic volume on rural roads is in excess of 300 vehicles per day.

Notwithstanding the above traffic volume warrants, dividing lines shall be installed where the following conditions apply:

- approaches to intersections with significant turning (mostly leading to barrier lines at the intersection)
- between opposing traffic on sections of road with overtaking lanes
- approaches to Local Area Traffic Management devices
- on the terminating leg of intersections controlled by Stop or Give Way sign (meeting minimum width requirements as per Clause 5.3.9 AS 1742.2).

Requirements for edge lines are contained in AS 1742.2 and are summarised as follows:

- edge lines shall not be used unless a dividing line or lane line is also marked
- edge lines shall not be used if minimum lane widths of 3.0 m between edge lines and the nearest dividing line or lane line are not achieved
- edge lines shall not be used where heavy vehicles comprise 10% or more of the AADT and minimum lane widths of 3.2 m between edge lines and the nearest dividing line or lane line are not achieved.

General treatment for rural undivided roads is as follows:

- Two-lane sealed roads less than 5.5 m wide: Edge lines shall not be used, except for guidance through width transitions at a one-lane bridge on a two-lane roads.
- Two-lane sealed roads less than between 5.5 m and 6.8 m wide: Edge lines are not normally used; however, they may be considered where the alignment has consistently constrained geometry, frequent fog occurs, contrast between the pavement and shoulder is insufficient or roadside hazards occur close to the pavement edge.
- Two-lane sealed roads 6.8 m wide or greater: Edge lines should be provided.
- Multi-lane roads: Edge lines shall be provided.

Rural divided roads shall have edge lines provided.

Hierarchy

- Road safety audit risk control method: Reduce the risk.
- Safe System assessment framework: Supporting treatment.

Other supporting treatments

- Audio-tactile linemarking: Produces a sound and vibration when driven over, providing an additional sensory to drivers who may be drifting from their lane.
- Raised retroreflective pavement markers (RRPMs): Enhances visibility, especially during poor light conditions and weather conditions.
- Guide posts: Enhances visibility, especially during poor light conditions and weather conditions.

Pros

- Delineation for motorists.
- Effective at controlling speed through horizontal curves.
- Discourage travelling on road shoulder.
- Reduce lane departures, run-off-road and head-on crashes.
- Reduce road shoulder damage, leading to lower maintenance costs due to longer asset life.
- More comfortable and safer for drivers when travelling under adverse conditions and at night.
- Able to convey road delineation to drivers without diverting their attention from the road.

Cons

- Can cause confusion if not removed correctly.
- If poorly designed or installed, can increase crash risk.
- Frequent maintenance is required due to traffic wear and tear.
- Can be ineffective on wet roads, or when fallen vegetation or dust is present.
- Improper installation process or selection of material can create skidding concerns.

Types (material)

Longitudinal Linemarking
AS 4049 provides guidelines for various types of pavement marking, including longitudinal line marking. The materials used for the line marking should conform to the requirements specific in AS 4049, which include aspects such as durability, colour and reflectiveness. Also refer to Main Roads Western Australia (2016).
Installation methods • Paint: Applied by a linemarking machine or manually using a brush or roller. • Preformed tape: Applied by using a machine that heats and presses the tape onto the pavement surface. • Thermoplastic: Melted onto the pavement surface. Also refer to Main Roads Western Australia *Specification 6.4: Pavement Marking.*
Installation considerations • The thickness of the linemarking material should comply with Australian Standards and guidelines for consistency. • The road surface must be dry and clean before application. • The temperature and humidity should be within the recommended range during installation to ensure bonding of the material to the pavement. • Allow the linemarking to cure properly before opening the road to traffic; this can avoid smudging or damaging to the markings. • Regular maintenance should be planned to ensure continued effectiveness of the linemarking.
Cost Low (approximately $1,580 per kilometre for installation of centreline and edge line)
Life expectancy 1 to 5 years

2.2.9 Shoulder Sealing

Shoulder Sealing
 Source: Main Roads Western Australia website.
Description Sealing of shoulders, either wholly or partially, is frequently done to improve moisture conditions under pavements and reduce overall maintenance costs. However, there are safety benefits of sealing shoulders as it provides drivers with an appropriate surface to regain control of an errant vehicle, ultimately reducing the risk of run-off-road crashes when a driver accidentally travels onto the road shoulder.
Crash reduction factors • 14% at a speed limit of 100 km/h (Austroads 2021b) • 25% at 110 km/h (Austroads 2021) Further details on crash reduction factors for shoulder sealing can be found in the Main Roads Western Australia Treatment Resource Guide.
Potential locations • Sealed road: Yes • Unsealed road: No • Horizontal curves, especially on the outside of a curve should be targeted for shoulder sealing. • Locations of greatest risk, including those with a history of crashes, alignment issues, roadside hazards and road function should be considered for shoulder sealing.

Shoulder Sealing

Considerations

The width of the shoulder sealing should be dependent on factors such as traffic speed, volume, environmental conditions and the nature of roadside hazards. A minimum shoulder seal width of 1 m on each side of the road should be considered for future works, with most of the benefit achieved by a width of 0.5 to 1.5 m. However, the shoulder width can be up to 3 m on higher volume roads to ensure the shoulders are wide enough to allow drivers to regain control of errant vehicles and for broken-down or emergency vehicles to stop safely.

Before implementing shoulder sealing as a treatment, it is important to evaluate the superelevation and determine if it meets the required design standards. If the superelevation is insufficient, it may be necessary to make modifications to the road to improve the horizontal curve design, which could include realigning the road or widening the pavement.

Warrants

The table below is sourced from Austroads *Guide to Road Design Part 3: Geometric Design* and provides guidance on minimum shoulder widths for rural roads based on traffic volumes.

Element	Design AADT				
	1–150	150–500	500–1000	1000–3000	> 3000
Traffic lanes[1]	3.7 (1 x 3.7)	6.2 (2 x 3.1)	6.2–7.0 (2 x 3.1/3.5)	7.0 (2 x 3.5)	7.0 (2 x 3.5)
Total shoulder	2.5	1.5	1.5	2.0	2.5
Minimum shoulder seal [2],[3],[4],[5],[6]	0	0.5	0.5	1.0	1.5
Total carriageway	8.7	9.2	9.2–10.0	11.0	12.0

1 *Traffic lane widths include centrelines but are exclusive of edge-lines.*
2 *Where significant numbers of cyclists use the roadway, consideration should be given to fully sealing the shoulders. Suggest use of a maximum size 10 mm seal within a 20 km radius of towns.*
3 *Wider shoulder seals may be appropriate depending on requirements for maintenance costs, soil and climatic conditions or to accommodate the tracked width requirements for Large Combination Vehicles.*
4 *Short lengths of wider shoulder seal or lay-bys to be provided at suitable locations to provide for discretionary stops.*
5 *Full width shoulder seals may be appropriate adjacent to safety barriers and on the high side of superelevation.*
6 *A minimum 7.0 m seal should be provided on designated heavy vehicle routes (or where the AADT contains more than 15% heavy vehicles).*

Source: Austroads (2021c).

Hierarchy

- Road safety audit risk control method: Reduce the risk.
- Safe System assessment framework: Supporting treatment.

Other supporting treatments

Audio-tactile edge lines are commonly installed as part of shoulder sealing projects to improve driver awareness and reduce the risk of vehicles running off the road. Other support treatments may include centreline marking, guide posts, safety barriers and removal of roadside hazards. These measures all support enhanced road safety outcomes.

Pros

- Reducing head-on and run-off-road crashes: Unsealed shoulders can contribute to crashes; sealing the shoulders can reduce the risk.
- Allowing vehicles to stop on the side of the road in emergencies: Sealed shoulders provide a more appropriate space for vehicles to pull off the road in emergencies and have better clearance from live traffic.
- Structural support of the road pavement: This can provide essential support to the pavement area, which can increase the pavement life.
- Reducing the 'edge drop': Reducing the height difference between the road surface and shoulder, which can improve safety and driver comfort.
- Can provide additional areas for cyclists and pedestrians.

Cons

- Undesirable driver behaviour: In some cases, sealing shoulders can encourage motorists to use the shoulder as an additional lane, which can be unsafe.
- Sealed shoulders require maintenance and can be subject to wear and tear, increasing the possibility of additional maintenance.
- Environmental impact: Sealed shoulders may have a negative impact on the natural roadside environment, through the removal or relocation of vegetation to add room for the shoulders.

Types (material)

- Asphalt emulsion: This is a mixture of asphalt and water, creating a thin layer of sealant over the shoulder area. It is a cost-effective option with good durability and resistance to weathering.
- Chip seal: Application of a layer of small stones to the surface of the shoulder area, which is then sealed with an asphalt emulsion.
- Concrete: More expensive option; this is recommended for use in areas with heavy traffic or locations where durability is a concern.
- Gravel: Lower cost option but may require more regular maintenance due to its lack of durability.

Installation methods

Shoulder Sealing

Sealing the shoulder can help prevent moisture from entering the pavement laterally, especially protecting the outer wheel path of the adjacent lane. To improve pavement performance, it is recommended to seal the shoulder to a minimum width of 0.5 to 1 m. Sealing the full width of the shoulder is desirable as it provides the highest level of protection and enhances performance. However, additional factors, such as safety improvements, may require a larger portion of the shoulder to be sealed. Guidelines provided in Main Roads Western Australia's design standards and Austroads *Guide to Pavement Technology Part 5* offer direction on shoulder widths and treatment for pavement performance improvement (Queensland Department of Transport and Main Roads 2020).

There are other considerations associated with sealing shoulders, including effects on operating speeds along the road and adjoining sections, which should be addressed according to Main Roads design standards. The design and construction of the shoulder should also adhere to Main Roads design standards. The surfacing chosen for the shoulder should be appropriate for its intended users. Sealing the shoulder may necessitate adjustments to road safety barriers and road furniture, and can impact drainage, so these roadside infrastructures should be referred to for guidance (Austroads 2019a).

Installation considerations

- Road surface: This may involve removing the existing surface layer, repairing any existing cracks or potholes, and ensuring the pavement surface is free of debris.
- Drainage: Water pooling on the shoulder can lead to damage and deterioration.
- Traffic management: Traffic may require diversion, or controlled use of temporary traffic management onsite may be required.
- Selection of the material: The material selected should be appropriate for the specification of the road.
- Quality control: To ensure all works and processes performed are correct and meet the required specifications.
- Environment: Appropriate measures to minimise impacts such as dust and emissions from site works.

Cost

Medium

Inner regions:

- Approximately $42,000 per kilometre for sealed shoulders (0.5 m on either side) – Box out and top up, including installation
- Approximately $36,000 per kilometre for sealed shoulders (0.5 m on either side) – Tyne top up, including installation
- Approximately $52,000 per kilometre for sealed shoulders (1 m on either side) – Box out and top up, including installation
- Approximately $46,000 per kilometre for sealed shoulders (1 m on either side) – Tyne top up, including installation

Remote regions:

- Approximately $74,000 per kilometre for sealed shoulders (0.5 m on either side) – Box out and top up, including installation
- Approximately $29,000 per kilometre for sealed shoulders (0.5 m on either side) – Tyne top up, including installation
- Approximately $85,000 per kilometre for sealed shoulders (1 m on either side) – Box out and top up, including installation
- Approximately $37,000 per kilometre for sealed shoulders (1 m on either side) – Tyne top up, including installation

Life expectancy

5 to 10 years

2.2.10 Lane Widening

Lane Widening

Source: WALGA.
Description Lane widening increases the width of a traffic lane. This process aims to reduce the risk of head-on collisions by providing additional sealed width for vehicles to remain on their respective sides of the road, which also reduces the likelihood of vehicles crossing into the opposing traffic. Widening of a lane plays a significant role in road safety, particularly in locations where vehicles tend to use more of the travel lane such as on a curved horizontal alignment. Head-on collisions can occur when drivers inadvertently or deliberately 'cut the corner' on bends. Lane widening can provide a larger margin of safety in these areas.
Crash reduction factors 25% to 40% (iRAP 2022) Further details on crash reduction factors for lane widening can be found in the Main Road Western Australia's Treatment Resource Guide.
Potential locations • Sealed road: Yes • Unsealed road: No • Curves: Depending on the curve radius, lane width and design vehicle of the road. This is particularly important to the inside of curves to accommodate the rear wheel tracking of heavy vehicles when travelling through the curve. Also, lane widening can improve visibility. • Crests: If there is inadequate vertical sign distance, lane widening can improve visibility and provide drivers with a wider margin of safety. • High-risk locations: Considering the road function, crash history, alignment and roadside hazards, lane widening may improve the overall safety of the road.
Considerations In practice, rural roads may often be narrower than the recommended 3.5 m for lane widening. However, it is important to consider this standard as a guideline for new construction or when widening existing roads. When considering lane widening, several factors need to be considered, including passing locations, crests, curves, and soft shoulders. The appropriate lane width will vary depending on the location, with urban roads typically having lane widths of 2.75 m to 3.75 m and rural roads requiring lane widths of 3.5 m or wider. For low volumes of traffic with limited numbers of heavy vehicles, a minimum lane width of 3.1 m may be sufficient, while an optimum safe lane width for rural roads is 3.5 m. In addition to the above factors, lane widening plans should also consider the location of culverts, bridges and roadside infrastructures, and should ensure that taper lengths comply with the design speed of the road to ensure safe and smooth transitions.

Lane Widening

Warrants

The table below is sourced from Austroads *Guide to Road Design Part 3: Geometric Design* and provides guidance on minimum lane widths for rural roads based on traffic volumes.

Element	Design AADT				
	1–150	150–500	500–1000	1000–3000	> 3000
Traffic lanes[1]	3.7 (1 x 3.7)	6.2 (2 x 3.1)	6.2–7.0 (2 x 3.1/3.5)	7.0 (2 x 3.5)	7.0 (2 x 3.5)
Total shoulder	2.5	1.5	1.5	2.0	2.5
Minimum shoulder seal [2],[3],[4],[5],[6]	0	0.5	0.5	1.0	1.5
Total carriageway	8.7	9.2	9.2–10.0	11.0	12.0

1 *Traffic lane widths include centrelines but are exclusive of edge-lines.*
2 *Where significant numbers of cyclists use the roadway, consideration should be given to fully sealing the shoulders. Suggest use of a maximum size 10 mm seal within a 20 km radius of towns.*
3 *Wider shoulder seals may be appropriate depending on requirements for maintenance costs, soil and climatic conditions or to accommodate the tracked width requirements for Large Combination Vehicles.*
4 *Short lengths of wider shoulder seal or lay-bys to be provided at suitable locations to provide for discretionary stops.*
5 *Full width shoulder seals may be appropriate adjacent to safety barriers and on the high side of superelevation.*
6 *A minimum 7.0 m seal should be provided on designated heavy vehicle routes (or where the AADT contains more than 15% heavy vehicles).*

Source: Austroads (2021c).

Hierarchy

- Road safety audit risk control method: Reduce the risk.
- Safe System assessment framework: Supporting treatment.

Other supporting treatments

- Increase the curve radius: This involves modifying the design of a curve to make it more gradual.
- Centreline marking, guide posts and advanced warning signs: These treatments can improve road delineations with advance warning of upcoming hazards due to changes in road conditions.
- Safety barriers can be installed on the edge of a road to protect vehicles from colliding with roadside hazards or skidding off the roadway.
- Shoulder sealing: A sealed shoulder can provide additional space for drivers to manoeuvre and use the area in case of emergencies.

Pros

- Can help to improve the flow of traffic.
- Can help to reduce the risk of head-on, run-off-road and sideswipe crashes by providing more space for vehicles to manoeuvre.
- Can improve sight distance by increasing the distance between vehicles travelling in opposite directions.
- Opportunity to fix other road surface issues, such as cross fall and drainage.
- Beneficial for heavy vehicles, providing more space for manoeuvrability.
- Less need for frequent maintenance of the road shoulders, reducing the maintenance costs and prolonging the life of the road surface.

Cons

- Can be a costly treatment, depending on the extent of the work, and may require earthworks, removal of roadside vegetation and other associated infrastructure changes.
- Can lead to increased vehicle speeds.
- Risk of the lane being misused, which may lead to the widened lane being used as 2 lanes.
- Impact on the environment if this treatment involves removal of vegetation or habitat for wildlife.

Types (material)

- Spray seal.
- Asphalt is a commonly used material for lane widening due to its durability, flexibility and the ease of installation.
- Concrete is strong and durable and can withstand heavy traffic loads and adverse weathering conditions.
- In some cases, gravel may be used, particularly on rural roads or low-volume roads where the traffic loads are lighter.

Installation methods

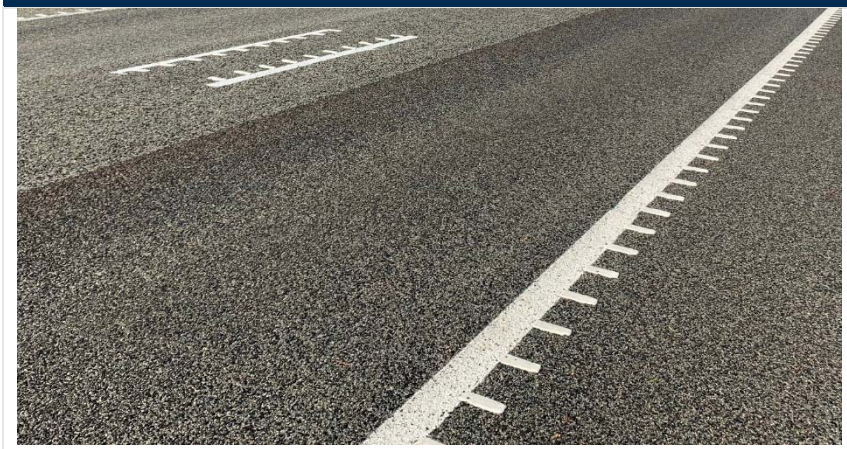
Full-depth pavement widening: This method involves removing the existing pavement entirely and constructing a wider pavement section from the subgrade up. Full-depth pavement widening is typically used when significant widening is required or when the existing pavement is in poor condition.

Partial depth pavement widening: In this method, only the top layer of the existing pavement is removed, and a new layer is added to widen the surface. Partial depth widening is suitable when the existing pavement structure is in good condition, and a moderate widening is needed.

Lane Widening
Installation considerations In order to fulfill the Technical Level of Service requirements, which include activities such as earthworks, services relocation, and installation of off-pavement assets, the scope typically focuses on a single lane width and the adjacent shoulder (Lyons et al. 2020). Road widening adjacent to trafficked lanes where levels are required to match the adjacent pavement levels (Austroads 2018).
Cost Medium to high ($100,000 - $500,000 per km)
Life expectancy 10 to 20 years

2.2.11 Audio-tactile Linemarking

Audio-tactile Line Marking



Source: Main Roads Western Australia website.

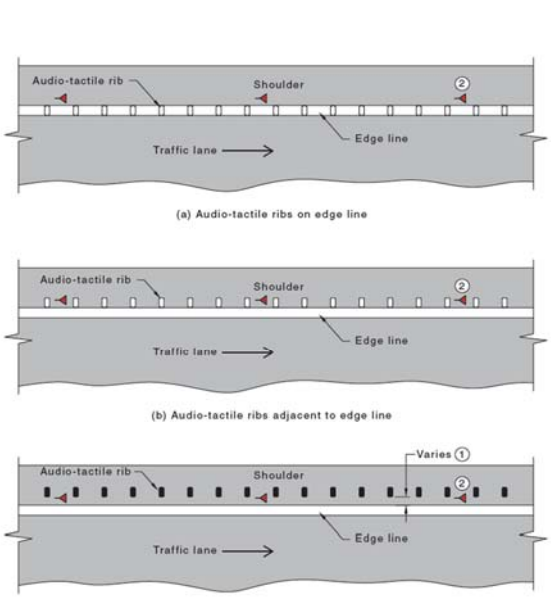


Figure 5.7 — Audio-tactile edge lines

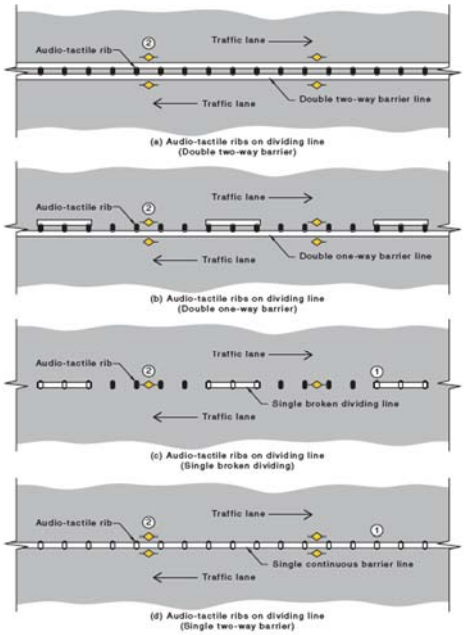


Figure 5.8 — Examples of audio-tactile dividing lines

Source: Australian Standards.

Description

Audio-tactile linemarking (ATLM) is a type of linemarking designed to provide an audio-tactile stimulus to drivers when they cross the edge or centreline of their travel lane. ATLM can be in the form of raised and transverse bars placed at short intervals or longitudinal linemarking with regularly spaced bars added.

ATLM is generally associated with edge lines or centreline and is primarily used in rural and remote areas to reduce fatigue-related and run-off-road crashes. It alerts drivers to hazards ahead by creating vibration and sound when a vehicle leaves the travel lane.

Crash reduction factors

Audio-tactile Line Marking
• 20% for ATLM edge line (Austroads 2020) • 15% for ATLM centre line (Austroads 2020) Further details on crash reduction factors for ATLM can be found in the Main Roads Western Australia Treatment Resource Guide.
Potential locations • Sealed road: Yes • Unsealed road: No ATLM can be installed on the shoulder side of the road, in the centre of the road or as a replacement or supplement to standard edge or dividing lines on road sections where required. These road sections may include high traffic volumes, a history of significant number of run-off-road crashes, poor visibility, frequent wet weathering condition or a history of night-time crashes.
Considerations • Commonly installed when sealing shoulders on rural roads. • The sound produced by ATLM may be difficult to hear in larger vehicles. • Noise may impact those living near the road. • It is recommended to install ATLM over a continuous length rather than at isolated locations. • The raised ribs used for ATLM may be white, matte black or matte grey in colour. White ribs should be retroreflective, matte black or matte grey ribs should not be retroreflective. • Minimum continuous length of ATLM should be 1 km. It is desired to place ATLM at least 500 m away from residential buildings if practicable, with a minimum of 200 m.
Warrants • Austroads (2020) notes the preferred cross-section width of a sealed roadway for the use of ATLM is 9.0 m comprising of two 3.5 m lanes and two 1.0 m sealed shoulders. However, the absolute minimum cross-section width is 7.0 m. • ATLM is typically installed on roads with a sealed shoulder width greater than 0.5 m and sufficient width for vehicle recovery. • Factors such as speed environment, road alignment, traffic volume and roadside environment should be considered before selecting ATLM treatment. • ATLM can be installed as part of a Blackspot project. • Mostly low-volume roads do not warrant ATLM installation.
Hierarchy • Road safety audit risk control method: Change road user behaviour. • Safe System assessment framework: Supporting treatment.
Other supporting treatments • Shoulder sealing: Help to prevent run-off-road crashes and provide a smoother transition for vehicles due to wider width of the pavement surface. • Raised retroreflective pavement markers (RRPMs): Particularly effective at night and in low-light conditions.
Pros • Reducing the occurrence of run-off-road crashes, collisions with roadside infrastructure elements and head-on crashes, particularly those attributed to fatigue and inattention. • Improved visibility of edge lines and centrelines during wet weather conditions, and potentially reduce maintenance costs of road shoulders.
Cons • May present a hazard to cyclists and motorcyclists. • Less noticeable for heavy vehicles. • Noise disturbance for adjoining land users. • Time consuming maintenance concerns. • Installation requires specialised equipment and workers. • May exacerbate pavement deterioration if pavement structure is already compromised.
Types (material) Thermoplastic: Heated and applied to the pavement surface using specialised equipment.

Audio-tactile Line Marking
Installation methods • Surface preparation: The pavement surface of the installation area must be clean and free of debris, oil and other contaminants. Existing linemarking should also be removed as part of the process. • Preheating: The thermoplastic rib is heated to a specific temperature. • Application: Once the thermoplastic is heated, spread evenly onto the pavement surface. Then, apply the rib and create the desired tactile pattern. • Cooling: Allow the thermoplastic rib to cool and harden. • Excess material and finishing: Trim and remove any excess material, inspect to ensure the treatment meets the associated standards and regulations.
Installation considerations • A minimum of 150 mm of sealed road outside longitudinal ATLM is required to avoid weakening of the road. • The recommended maximum offset from the linemarking is 200 mm. • ATLM should only be installed in conjunction with edge lines or centrelines. • ATLM should not be installed unless the structural integrity of the road surface and base is in sound condition. • If substantial portions of the road (greater than 25%) are likely to require resurfacing within 3 years of installation, ATLM should not be installed.
Cost Low (approximately $7,000 per kilometre for installation of centreline and edge line)
Life expectancy 5 years

2.2.12 Road Safety Barriers

Road Safety Barriers

Source: WALGA.

Description

Road safety barriers can be installed along the side of a road and in the median. The structure of the barrier may be either rigid, semi-rigid or flexible, depending on the specific hazard it is intended to address. Some barriers are designed to absorb the impact of a crash, while others are designed to deflect the vehicle away from the hazard.

In addition to providing protection for motorists from roadside hazards, road safety barriers can also help prevent head-on and run-off-road crashes.

When selecting a road safety barrier, it is important to consider factors such as the speed and volume of traffic, the type of hazard being protected against and the available space for installation. Proper installation and maintenance of the barriers are important to ensure the functionality and condition of the barrier structure over time.

Crash reduction factors

40% to 60% (iRAP 2022)

Further details on crash reduction factors for road safety barriers can be found in the Main Roads Western Australia Treatment Resource Guide.

Potential locations

- Sealed road: Yes
- Unsealed road: Yes

The need for road safety barriers to protect motorists from various hazards will depend on a variety of factors, including the type and severity of the hazard, vehicle speed, volume of traffic and the available space for installation. However, in general, road safety barriers should be considered in areas where there is a high risk of vehicles leaving the road and colliding with a hazard that cannot be removed or relocated.

Considerations

Consider the types of vehicles that will be using the road. For example, heavy vehicles may not be effectively contained by a normal roadside safety barrier. However, a barrier designed for heavy vehicles may pose a greater risk to car occupants in the event of a collision.

Also consider the length of the barrier required, the specific needs of motorcyclists and the potential for impalement in interlocking design barriers. It is important to install road safety barriers in continuous lengths and not in isolated sections in order to ensure the greatest level of protection for road users.

The choice of rigid, semi-rigid or flexible barriers will depend on factors such as the available space and the hazards being protected. While flexible barriers may be the best option for minimising injuries to vehicle occupants, they may pose a greater risk to motorcyclists. Semi-rigid barriers may be a better option in locations where the available space is limited, while rigid barriers should only be used when there is no room for deflection.

Road Safety Barriers

Warrants

- Austroads *Guide to Road Design Part 6: Roadside Design Safety and Barriers* provides an assessment methodology to determine the need for road safety barriers (Austroads 2022b).
- Installation of road safety barriers follows Main Roads Western Australia, Austroads *Guide to Road Design Part 6: Roadside Design Safety and Barriers* and Australian Standards.
- Road safety barriers are chosen for capital renewal projects based on improved safety standards.
- Selection is guided by internal and external road safety audits of substandard curves.

Hierarchy

- Road safety audit risk control method: Reduce the risk.
- Safe System assessment framework: Primary treatment.

Other supporting treatments

- Improving roadside infrastructure, such as removing obstacles.
- Reducing speed limits can help to decrease the severity of crashes and the risk of injury.
- Proper linemarking and signing for delineation can help to alert drivers to the changes in the road environment.
- Guide signs and guide posts, to be installed on road safety barriers.

Pros

- Can contain and redirect a vehicle away from a roadside obstacle.
- Can further reduce the severity of a crash by absorbing some of the vehicle's kinetic energy.
- Able to reduce the incidence of single vehicle run-off-road crashes and other types of crashes involving errant vehicles.

Cons

- Can pose a risk to motorcyclists in the event of a crash. Wire ropes or posts can cause serious injury or even fatalities to motorcyclists.
- Can obscure other safety treatments such as traffic signs with low longitudinal clearance depending on the placement.
- If located very close to the roadside, can increase the risk of collisions by reducing the available recovery area for drivers who may have lost control of the vehicles.
- May redirect the vehicle back into the live traffic lane.
- Regular maintenance is required to remain effectiveness, increasing cost and time.

Types (material)

Road safety barriers are typically made of materials that are strong and durable, such as steel and concrete.

Flexible barriers: Designed to transfer the kinetic energy of a collision into the lateral deflection of the barrier. Wire rope barrier is the most common type, consisting of a series of wire ropes supported by frangible posts that break away upon impact.

Semi-rigid barriers: Designed to deform in the event of a vehicle impact and guide the vehicle in the direction of the traffic flow. Steel guardrail is the most common type and can come in different shapes such as W-beam, Thrie-beam or modified Thrie-beam.

Rigid barriers: Constructed of reinforced concrete and negligible deflection when impacted. Rigid barriers are the most durable and permanent type of barrier and are used in locations where there is no space for deflection. Examples of rigid barriers include New Jersey, F-type, Vertical Face, Single Sloped or High Containment.

Installation methods

Refer to Main Roads Western Australia *Specification 603 Safety and Traffic Barrier Systems* for details on products/materials, fabrication and installation.

Installation considerations

- The installation of road safety barriers requires adequate space along the roadside or median to ensure effectiveness. The layout of the road, presence of roadside obstacles and space availability can affect the type of barrier that can be installed.
- Ground conditions, such as soil type and stability, can affect the installation process and effectiveness.
- The type of barrier selected should be appropriate for the specific environmental conditions and able to withstand weathering over time.
- To maximise the safety benefits for road users, it is important that road safety barriers do not interfere with the visibility of other safety measures and cause confusion for road users.

Cost

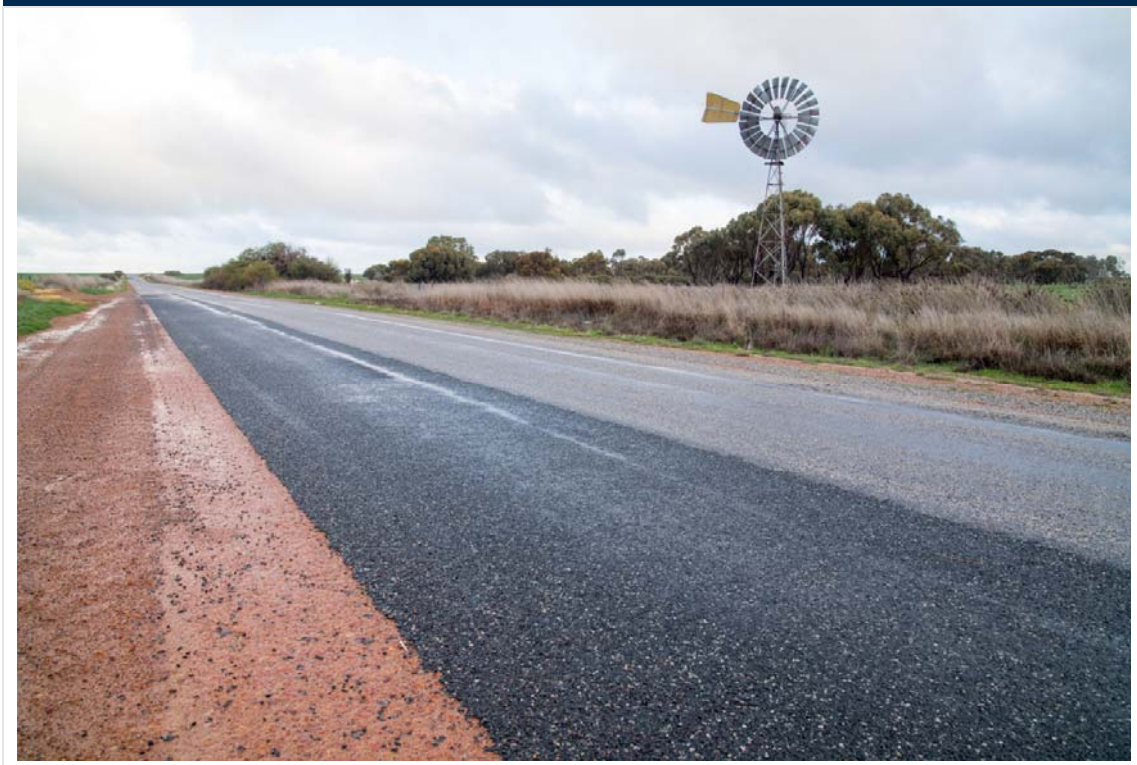
Medium (varies based on treatment type)

Life expectancy

10 years

2.2.13 Improving Skid Resistance (Reseal, High Friction Surfacing)

Skid Resistance



Source: WALGA.

Description

Skid resistance treatments are designed to improve the frictional properties of a pavement surface, thus reducing the risk of skidding. The choice of the skid resistance treatment will depend on a range of factors, including the type of pavement, traffic volume and speed, and local weather conditions.

Skid resistance treatments are typically applied to existing pavements as a cost-effective means of improving road safety. However, it is important to note that these treatments are not a substitute for regular pavement maintenance, which is critical for ensuring that the pavement surface remains in good condition and retains its skid resistance properties over time.

By enhancing the frictional properties of the pavement, skid resistance treatments can help to prevent and reduce the severity of injuries in the event of a crash.

Crash reduction factors

In wet conditions: 25% to 40% (iRAP 2022)

Potential locations

- Sealed road: Yes
- Unsealed road: No
- Can be used to improve the frictional properties of the pavement on curves.
- Areas to help prevent vehicles from sliding or losing control, such as pavements on steep grades.
- Areas where braking commonly occurs, such as at intersections.
- Locations where there is a history of a specific type of crashes, such as rear-end crashes and wet weather crashes.

Considerations

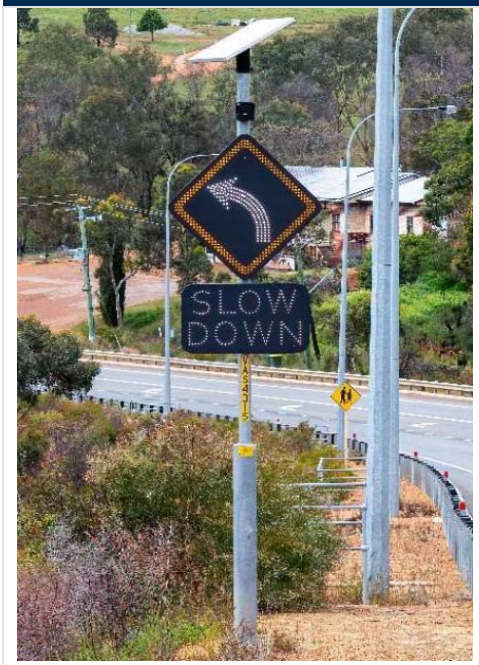
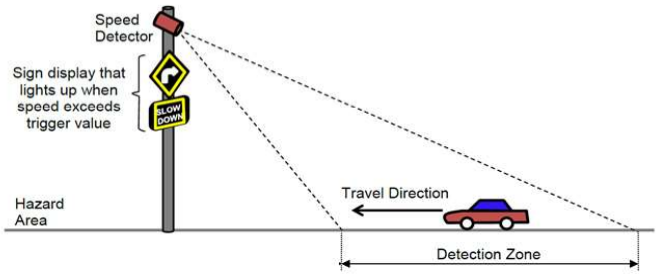
- Before applying any skid resistance treatments, it is important to assess the condition of the existing pavement. This includes measuring skid resistance levels and checking for signs of rutting or potholes. If the pavement is severely degraded, it may not be suitable for the treatment and may require complete reconstruction before any skid resistance treatment is applied.
- The type of pavement can also affect the effectiveness of skid resistance treatments. Different pavement materials, such as asphalt and concrete, may require different types of treatments to achieve the desired level of skid resistance.
- High traffic volume roads may require more durable treatments to ensure that the pavement remains safe and effective over time.
- Weather conditions can affect the performance of skid resistance treatments. For example, treatments that are designed to prevent aquaplaning may be more suitable in areas with high rainfall or wet weather conditions.

Warrants

Surface treatment for skid resistance may be selected based on a high-speed condition survey, which can identify the need for improved skid resistance.

Skid Resistance
Hierarchy • Road safety audit risk control method: Reduce the risk. • Safe System assessment framework: Supporting treatment.
Other supporting treatments 'Slippery' warning signs are used to alert drivers to sections of pavement where the skid resistance level has been reduced to an unexpectedly low level. These signs are typically installed in areas where skidding is more likely to occur, such as on curves, steep grades or areas prone to wet weather conditions.
Pros • Help to reduce the risk of skidding and prevent both rear-end and run-off-road crashes. • Reducing the amount of wear and tear to the pavement caused by skidding and other factors. This helps to lessen the need for pavement repairs or replacement. • Help to reduce the amount of moisture that penetrates the pavement, reducing the risk of cracking and other forms of damage. This extends the life of the pavement surface.
Cons Regular monitoring is required to ensure that the skid resistance treatments remain effective over time, particularly on roads with large volume of heavy vehicle traffic, which can cause more wear and tear on the pavement surface. Regular monitoring can be time consuming and costly and may require specialised equipment and expertise.
Types (material) Consists of a layer of durable, anti-abrasion and polish resistant aggregate over a thermosetting polymer resin binder that locks the aggregate in place to restore or enhance friction and skid resistance.
Installation methods • Re-texturing involves the mechanical working of the existing pavement surface to improve its frictional characteristics. This may include methods such as diamond grooving, shot-blasting, bush hammering or high velocity water blasting. These methods typically involve the removal of a thin layer of the existing surface material to create a new textured surface that provides an improved skid resistance level. • Resurfacing involves the application of a new layer of material over the existing pavement surface to improve its texture and skid resistance. This may include relatively low-cost thin surfacing treatments, which not only improve the surface texture and resistance skidding but can also seal the existing pavement surface against water penetration and arrest disintegration. Resurfacing methods may include applications of chip seals, slurry seals or micro surfacing.
Installation considerations • Proper surface preparation is essential to ensure adhesion between the treatment material and the existing pavement. • The surface must be free of debris. • Installation should be done in dry weather conditions. • Allow sufficient curing time before opening the treated road to traffic.
Cost Low to medium (varies based on treatment type)
Life expectancy 10 years

2.2.14 Vehicle Activated Signs

Vehicle Activated Sign	
	 *Figure 9: Illustrative VAS installation* (Figure adapted from NSW Roads and Maritime Services Specification No. TSI-SP-066)
Source: Main Roads Western Australia website.	Source: Main Roads Western Australia website.

Description

Vehicle activated signs (VAS) are designed to alert motorists to potential hazards on the road. VAS are triggered by the speed of the vehicle and are typically installed in locations with a history of speeding problems or speed-related crashes.

VAS operates by using sensors to detect the speed of approaching vehicles. When a vehicle exceeds a predetermined speed threshold, the sign is activated and displays a warning message to the approaching driver. The warning message is typically a speed limit, an approved warning sign or a message to slow down, and is related to the hazard ahead.

The aim of a VAS is to encourage motorists to reduce their speed before they encounter a potential hazard such a sharp turn. VAS is an effective way to improve road safety in areas where static speed and warning signs have not been effective in reducing speed or altering driver behaviour.

In addition, speed indication devices are basically a form of vehicle activated sign. This treatment has been included in this section because it is primarily utilised to encourage higher levels of compliance, consequently minimising the necessity for enforcement.

Radar or similar technology is deployed to measure the speed of an approaching vehicle, and the measured speed is then displayed (Austroads 2016c).

Crash reduction factors

- VAS for curves: 40% (Austroads 2019)
- VAS for intersections: 70% (Austroads 2019)
- The installation of speed indication devices resulted in an average speed reduction of 13% and a 10% reduction in the 85th percentile speed across different speed zones and road hierarchies, ranging from 40 to 70 km/h (Burke 2015).

Potential locations

- Sealed road: Yes
- Unsealed road: Yes
- Short sections of a road with an adverse alignment, such as a sharp curve or steep grade.
- Sites where static warning signs have been ineffective.
- Signalised intersections on the outskirts of a city or town where motorists are failing to adjust from the high-speed rural environment to the urban environment can benefit from VAS, encouraging drivers to slow down and adjust to the new environment.
- Unsignalised intersections with high crash history.
- Speed indication devices aim to promote safety through increasing driver awareness of their travelling speed and to achieve better adherence to the speed limit in locations with identified or suspected speed issues.

Considerations

One of the first steps in developing a VAS program is to identify and prioritise corridors with the highest risk. This can be done by analysing crash data and identifying the locations where crashes are most likely to occur. Countermeasures such as VAS can be applied to reduce the risk of crashes once these locations have been identified.

To ensure VAS are applied consistently and effectively, it is also important to develop safety plans. These plans should outline the specific treatments to be applied at each location, including the use of VAS, and provide guidance on how it should be implemented.

Vehicle Activated Sign

Warrants

Appendix 1: Warrants and Site Assessment Items for Installation

Sites must comply with all warrants and have a crash history that has or is likely to result in KSI crash types which VAS would address. Sites must also meet one of the criteria in the following table: except where indicated and for where there is likely to be a significant change of traffic profile which is likely to significantly increase crash risk.

Table 1: Warrants for Installation

Hazard Identification and Understanding Warrants			
Criteria	**Required Value**	**Comment**	**Criteria Met? (Yes / No)**
KSI Crashes	A record of KSI crashes at the site*		
KSI Metric	High or medium high*		
Black Spot Funding	Site meets the criteria for State or Australian Government Black Spot funding*		
Road Safety Audit/ Inspection or other documentary evidence	A credible risk of KSI crashes*		
		Passed warrant screening (yes / no)?	
*			

Where the above criteria are not met but there is going to be a significant change of traffic profile which is likely to significantly increase crash types addressed by VAS, then the site can also be considered to meet the warrants.

The below criteria must be considered through the detailed site assessment. These criteria are advisory and should be considered as one part of a broader assessment process. An overall recommendation must be made through consideration of each assessment item.

Table 2: Site Assessment Items

Site Assessment (Complete only if Hazard Identification warrants are met)		
Assessment Item	**Detail**	**Finding (Supportive / Not Supportive)**
All pavement marking and signage up to standard		
All additional static pavement marking, and sign enhancements undertaken		
Engineering solutions (considered/planned)		
Complexity: Number of lanes		
Sight distance		
Comprehension: Interference with Traffic Control Devices		
Effectiveness: Oversaturation		
Effectiveness: Overuse		
Overall recommendation (suitable/not suitable):		

Source: Main Roads Western Australia (2022a).

Hierarchy

- Road safety audit risk control method: Change road user behaviour.
- Safe System assessment framework: Supporting treatment.

Other supporting treatments

- Duplication with static sign.

Pros

- Effective at controlling speeds on horizontal curves, where the risk of run-off-road crashes is high.
- Alert drivers to potential hazards such as sharp curves, intersections or other change in road condition.
- May be able to collect vehicle data for monitoring purposes (depending on the set-up of the device).

Cons

- Prone to vandalism.
- Power supply for VAS can be problematic.

Types (material)

- Aluminium: Lightweight and durable material, often used for the frame of the sign.
- LED lights: Used to provide the visual warning to drivers and are arranged in a matrix pattern to form the symbol.
- Solar panels: VAS may be powered by solar panels.
- Batteries: In addition to solar power source, VAS may also use batteries to provide power to the LED lights and sensors.
- Reflective materials: The sign is covered in reflective materials to improve visibility in low light conditions.

Vehicle Activated Sign
Installation methods The installation methods for VAS can vary depending on the specific design and purpose of the sign, and the location in which it will be installed. However, some common installation methods for VAS include: • mounting the VAS directly onto the ground using a concrete foundation or other type of base • a design that makes them portable so they can be moved to different locations as needed. These may be mounted on trailers or other mobile platforms.
Installation considerations • Should be installed in a location where the VAS will be most effective at improving road safety and will be easily visible to drivers. • The height and orientation of the VAS should be carefully considered. • Reliable power source. E.g. solar panels may be appropriate in areas with abundant sunlight, while battery-powered VAS may be more appropriate in areas with limited sunlight. • Proper wiring and installation of VAS is important to ensure that the sign is safe and effective.
Cost Medium to high Range: $8,000 to $8,500 per sign including installation.
Life expectancy 10 years

2.2.15 Intersection Warning Signs

Intersection Warning Signs
 Source: ARRB Group.
 Source: AS 1742.2: 2022
Description Intersection warning signs inform motorists that they are approaching an intersection. These signs are usually placed in advance of the intersection to provide drivers ample time to adjust their driving behaviour and prepare for the upcoming intersection. Intersection warning signs are important because intersections are a common location for crashes to happen. The risk of crashes can be reduced by providing motorists with advance warnings of an upcoming intersection.
Crash reduction factors 10% to 30% (Main Roads Western Australia 2021)
Potential locations • Sealed road: Yes • Unsealed road: Yes Intersection signage should be implemented in areas where the alignment of the road changes, such as on curved sections or where there is a change in the grade of the road. Only implement the warning signs in locations where they can effectively mitigate the underlying crash risk. For example, intersection warning signs should be provided in advance of intersections where the sight distance along the main road to a vehicle from a side road is less than the required stopping sight distance for the corresponding travel speed on the main road.

Intersection Warning Signs

Considerations

- Type and size of the signage: Signs should be large enough and positioned effectively to be visible to drivers and convey the message clearly.
- Engineering changes should be considered first to achieve the required sight distance rather than relying on implementation of warning signs.
- Intersection warning signs should not draw attention away from regulatory signage such as Give Way or Stop signs. The placement of the warning signs should be carefully considered to ensure they do not interfere with other traffic control measures.

Warrants

- Intersection warning signs should be provided on the major road where sight distance along the major road to a vehicle about to enter from the minor road is less than the required stopping sight distance for the corresponding operating speed. Further, intersection warning signs should be considered on the minor road where appropriate approach sight distance is not provided. Unusual intersection layouts may also require intersection warning signs.
- Intersection warning signs are chosen based on different factors, including road safety audits, community requests, and adherence to standards like AS 1742 series and Austroads Guide to Road Design.
- These signs may be installed as part of bigger maintenance or improvement projects or to enhance intersections with blackspot funding.

Hierarchy

- Road safety audit risk control method: Change road user behaviour.
- Safe System assessment framework: Supporting treatment.

Other supporting treatments

- Flattening batters: This involves adjusting the slope or gradient of the road approaching to the intersection. This can improve sight distance and reduce the likelihood of crashes caused by lack of sight distance.
- Improving sight distance: Remove obstructions and trim vegetation.

Pros

- Inform motorists of the upcoming changes in road conditions, such as an approaching intersection, allowing them to adjust their driving behaviour accordingly to navigate through the intersection safely.
- Cost-effective treatment to improve safety on the road.
- Able to alert drivers to hazardous or potentially hazardous conditions that may not appear apparent due to road geometry or environmental conditions.

Cons

- Regular maintenance is required to ensure that signs remain visible and effective, which can be costly and time consuming.
- Warning signs do not eliminate the hazard itself, and poorly maintained or installed signs can add to the risk of crashes.
- Overuse of warning signs can be confusing for drivers and reduce their effectiveness due to inconsistency.
- Warning signs are prone to vandalism.

Types (material)

Typically made of reflective sheeting and aluminium substrate that is shaped into the appropriate intersection warning sign configuration. It provides a durable and long-lasting material for the sign that can withstand adverse weathering conditions.

Installation methods

Typically involves mounting the sign on a post or pole, which is buried in a hole that is dug into the ground. For additional stability, the hole is then backfilled with concrete which helps to prevent the post from leaning or falling over. Once the post or pole is anchored into the ground, the sign is then attached to the post or pole using bolts or other fasteners, which are tightened securely.

The installation process must adhere to AS 1742 to ensure the sign is properly positioned and visible to drivers approaching the curve.

Installation considerations

When determining the placement of the signs, it is important to consider their positioning and visibility. Generally, an intersection warning sign should be placed on the left side of the carriageway and is positioned without restricting lateral clearance or sight distance. However, duplication of the sign may also be erected on the right side of the carriageway if deemed necessary.

Cost

Low (approximately $350 per sign, including installation)

Life expectancy

5 years

2.2.16 Flag Lighting (Solar Powered)

Flag Lighting
 Source: WALGA.
Description Flag lighting involves using illuminated streetlights to mark the presence of an intersection in remote or rural areas. This type of lighting is particularly useful at night or in low-light conditions when visibility may be poor, and drivers may not be able to see the intersection until they are almost at it. Placing flag lighting at the intersection will allow motorists to see the illuminated streetlight from a distance, giving them a clear indication of the presence of the intersection and allowing them to adjust their travelling speed accordingly. Flag lighting can also be helpful in alerting drivers to potential hazards not only at intersection, but also areas of steep inclines, dips, narrow roads or other obstacles. By illuminating these hazards, drivers can take the necessary precautions to navigate them safely.
Crash reduction factors 10% (Main Roads Western Australia 2021)
Potential locations • Sealed road: Yes • Unsealed road: Yes Isolated rural intersections with no street lightings, especially intersections that are difficult to see due to sharp bends or crests.
Considerations • Typically funded by the developer and rarely retrofitted elsewhere.
Warrants • Crash history. • Entry/exit by slow moving vehicles or vehicles longer than 19 m. • Road alignment. • Pedestrian activity.
Hierarchy • Road safety audit risk control method: Change road user behaviour. • Safe System assessment framework: Supporting treatment.
Other supporting treatments • Warning signs, vehicle activated signs and pavement markings can help to alert motorist to the presence of an intersection and provide guidance or warning through the intersection. • Vegetation maintenance, such as trimming trees can help to improve visibility at the intersection.

Flag Lighting
Pros • Improve visibility for drivers, particularly at night or in low light conditions. • Improve visibility for bicyclists and pedestrians, allowing safe passage through or across an intersection.
Cons • May be less effective in adverse weather conditions, which could reduce visibility for drivers. • While flag lighting may require less maintenance than normal street lighting, it still requires some maintenance, such as bulb replacement or any damage repairs.
Types (material) • Solar-powered flag lighting: This type of flag lighting uses solar panels to power the lights and is ideal for use in areas where there is no access to power sources. • Wired flag lighting: This type of flag lighting is connected to a power source via wiring and is often used in areas where power sources are readily available. This option is typically the most reliable for effectiveness and is the brightest option,, but it can be more expensive for installation and maintenance. • Battery powered flag lighting: This type of flag lighting is powered by batteries and is typically used in areas where solar power is not feasible. Battery powered flag lighting can be a good option for temporary installations.
Installation methods Solar flag lighting utilises solar panels to generate electricity during the day, which is stored in batteries. Solar-powered flag lights are advantageous as they do not require external power sources or wiring. When installing flag lighting, it is important to consider factors such as the height and location of the flagpole and local regulations regarding lighting installations, and the desired lighting effect. Note that outside of built-up areas, flag lighting is the responsibility of the Local Government Authority.
Installation considerations When installing flag lighting at isolated rural intersections, it is important to consider factors such as the location of the intersection, the terrain and other environment conditions such as if the location is prone to regular adverse weather conditions.
Cost Low to medium (average: $12,000 per light, including installation)
Life expectancy 20 years

3 Case Studies

This section summarises various case studies related to the implementation of low-cost safety treatments on rural local government roads in WA. Each section discusses the success and effectiveness of these treatments, including any challenges faced during implementation. Refer to **Error! Reference source not found.** for more information on the Local Government engagement.

3.1 Audio-tactile Linemarking

Local Government (LG): City of Albany		
Road	Lower Denmark Road	
Treatment type	Audio-tactile linemarking	
Start Straight Line Kilometres (SLK) and End SLK	0-36.7	
Road classification	Regional Distributor	
Traffic volume	2,000 vehicles per day	
Speed limit	60–90 km/h	
Installation year	2022	
What was the driver behind the installation of the treatment?	Regional Road Safety Program funding	
What were the safety benefits after the treatment was installed? Has it reduced crashes? Any anecdotal safety outcomes?	Too soon to say	
Were there any challenges during the implementation of this treatment?	Preparing shoulders and widening to get best safety results	
Other comments	Nil	

LG: Shire of Esperance	
Road	Fisheries Road
Treatment type	Audio-tactile linemarking
Start SLK and End SLK	61.0 - 115.9
Road classification	Regional Distributor
Traffic volume	100–500 vehicles per day
Speed limit	110 km/h
Installation year	2022
What was the driver behind the installation of the treatment?	• High-speed road environment • Restricted Access Vehicle (RAV) route • Road alignment
What were the safety benefits after the treatment was installed? Has it reduced crashes? Any anecdotal safety outcomes?	No head-on crashes or run-off-road crashes have been reported since the installation. Increased visibility and road alignment during dark. Better delineation at night especially in wet weather
Were there any challenges during the implementation of this treatment?	Traffic management on high-volume roads. Availability of contractors and mobilising to regional areas.
Other Comments	Nil

3.2 Road Safety Barriers

LG: City of Esperance	
Road	Fisheries Road
Treatment type	Road safety barriers
Start SLK and End SLK	14.00 – 14.37
Road classification	Regional Distributor
Traffic volume	1,500–2,000 vehicles per day
Speed limit	110 km/h
Installation year	2022
What was the driver behind the installation of the treatment?	• To create a RAV route. • To offer a protection system to substandard road width along the bridge section. • To offer protection on horizontal curved alignment segment in case a driver loses control. • To lower the crash severity of out-of-control vehicles.
What were the safety benefits after the treatment was installed? Has it reduced crashes? Any anecdotal safety outcomes?	Allows drivers to identify the roadside safety hazard. No run-off crash or out-of-control crashes have been reported since installation.
Were there any challenges during the implementation of this treatment?	Road safety barrier installation experience and knowledge becoming scarce. Logistic issues for some barrier parts such as custom bends which come from eastern states. Fluctuation of material prices.
Other comments	Nil

3.3 Guide Signs (Chevron Alignment Markers)

LG: City of Albany		
Road	Frenchman Bay Road	
Treatment type	Guide signs i.e chevron/curve alignment markers (CAMs)	
Start SLK and End SLK	7.29 – 7.49	
Road classification	Regional Distributor	
Traffic volume	2,000 vehicles per day	
Speed limit	70–80 km/h	
Installation year	2010	
What was the driver behind the installation of the treatment?	Community feedback	
What were the safety benefits after the treatment was installed? Has it reduced crashes? Any anecdotal safety outcomes?	Unknown.	
Were there any challenges during the implementation of this treatment?	Nil	
Other comments	Cheaper option than lighting in rural area.	

LG: Shire of Dardanup	
Road	Venn Road
Treatment type	Guide signs i.e. chevron/curve alignment markers (CAMS)
Start SLK and End SLK	0.42 to 0.52 (curve)
Road classification	Access
Traffic volume	75 vehicles per day
Speed limit	110 km/h (default)
Installation year	2021–22

LG: Shire of Dardanup	
What was the driver behind the installation of the treatment?	Determined by site safety review.
What were the safety benefits after the treatment was installed? Has it reduced crashes? Any anecdotal safety outcomes?	No anecdotal feedback received.
Were there any challenges during the implementation of this treatment?	Easy to install
Other comments	Nil

LG: Shire of Dardanup	
Road	Waterloo Road
Treatment type	Guide signs i.e chevron/curve alignment markers (CAMS)
Start SLK and End SLK	0.57 - 1.10 (Curve 1) 2.50 - 2.96 (Curve 2)
Road classification	Regional Distributor
Traffic volume	1,000 vehicles per day
Speed limit	100 km/h
Installation year	2016–17
What was the driver behind the installation of the treatment?	Main Roads Western Australia safety review following fatality on road.
What were the safety benefits after the treatment was installed? Has it reduced crashes? Any anecdotal safety outcomes?	No anecdotal feedback received. Latest crash data: 2017–2021. Three crashes on the curves, property damage only (PDO).
Were there any challenges during the implementation of this treatment?	Easy to install
Other comments	Nil

LG: Shire of Dardanup	
Road	Collie Road
Treatment type	Guide signs i.e chevron/curve alignment markers (CAMS)
Start SLK and End SLK	4.14 (Curve)
Road classification	Access
Traffic volume	110 vehicles per day
Speed limit	110 km/h (default)
Installation year	2021–22
What was the driver behind the installation of the treatment?	Determined by site safety review.
What were the safety benefits after the treatment was installed? Has it reduced crashes? Any anecdotal safety outcomes?	No anecdotal feedback received. Latest crash data: 2017–2021. Zero crashes.
Were there any challenges during the implementation of this treatment?	Easy to install.
Other Comments	Nil

3.4 Speed Limit Review and Zoning

LG: Shire of Esperance	
Road	Collier Road
Treatment type	Speed limit review and zoning
Start SLK and End SLK	• 0 to 1.24 – 60 km/h • 1.24 to 2.68 – 80 km/h • 2.68 to 3.54 – 60 km/h
Road classification	Local Distributor
Traffic volume	100–500 vehicles per day
Speed limit	60–80 km/h
Installation year	2022
What was the driver behind the installation of the treatment?	• Curved road alignment. • School bus stop locations and their restricted sight distances for the oncoming traffic.
What were the safety benefits after the treatment was installed? Has it reduced crashes? Any anecdotal safety outcomes?	No crashes have been reported in Collier Road for the last 5 years.
Were there any challenges during the implementation of this treatment?	Process and time taken from the regulatory body was lengthy.
Other comments	Nil

3.5 Surface Corrections

LG: Shire of Cunderdin	
Road	Meckering – Goomalling Road
Treatment type	Full reconstruction with new 14/7 mm seal (14 mm aggregate size for bottom layer and 7 mm top layer)
Start SLK and End SLK	0.00 - 6.50
Road classification	Regional Distributor
Traffic volume	Less than 300 vehicles per day.
Speed limit	110 km/h (default)
Installation year	2022–23
What was the driver behind the installation of the treatment?	Wheatbelt Secondary Freight Network route
What were the safety benefits after the treatment was installed? Has it reduced crashes? Any anecdotal safety outcomes?	Should help the flow of large trucks.
Were there any challenges during the implementation of this treatment?	Nil
Other comments	Nil

3.6 Flag Lighting

LG: Shire of Dardanup	
Road	Moore Road
Treatment type	Flag lighting
Start SLK and End SLK	0.09 to 3.33 (Flag lighting along straight section near industrial enterprises). Flag lighting at 3 intersections and upgraded lighting at roundabout.
Road classification	Local Distributor
Traffic volume	700 vehicles per day
Speed limit	80 km/h
Installation year	2017–18

LG: Shire of Dardanup	
What was the driver behind the installation of the treatment?	State Black Spot Project due to head-on, overtaking crashes. 5 crashes 2008–2013, 1 casualty.
What were the safety benefits after the treatment was installed? Has it reduced crashes? Any anecdotal safety outcomes?	No anecdotal outcomes. Latest crash data: 2017–2021. Three crashes in total: • Two night-time crashes with kangaroos (one fatality) – at intersections where lighting was improved. • One rear-end crash – daylight conditions.
Were there any challenges during the implementation of this treatment?	Can be issues with operation.
Other comments	Nil

3.7 Improving Skid Resistance

LG: Shire of Esperance	
Road	Fisheries Road
Treatment type	Surface treatment for skid resistance
Start SLK and End SLK	24.75 to 32.50
Road classification	Regional Distributor
Traffic volume	1,500–2,000 vehicles per day
Speed limit	80 km/h
Installation year	2017–18
What was the driver behind the installation of the treatment?	• During the pavement condition assessment, worn and polished road surface aggregate on the wheel path on loaded side. • High volume of daily heavy vehicle traffic during harvesting period.
What were the safety benefits after the treatment was installed? Has it reduced crashes? Any anecdotal safety outcomes?	• Road safety was improved where a lot of crashes were imminent, especially in wet weather. • It helped to prevent rear-end and run-off-road crashes.
Were there any challenges during the implementation of this treatment?	Nil.
Other comments	• Resurfacing addressed other road surface defects such as rutting and ravelling. • Life of the pavement/ surface is extended significantly.

3.8 Lessons Learnt

Many of the treatments which formed the case studies were installed recently, however, anecdotal evidence showed positive safety benefits for the majority of treatments reviewed. Where available, before and/or after crash statistics have been collated and recorded in the case studies. Further monitoring of these case studies may be required to fully understand the impacts that these treatments are having on potential crash reduction.

Consultation with the local governments provided an array of useful information in the implementation of these treatments. For example, real world costs have been incorporated into the factsheets, as well as the drivers behind a local government installing a particular treatment where there may not be specific warrants available for guidance.

4 Recommended Applications

Practitioners and local government will best be able to apply this Guideline by noting the following:

- The Guideline provides the practical user friendly information and is best used alongside the technical report when further detailed information is required.
- The implementation of low-cost road safety treatments on local government road networks supports a reduction in the risk of crashes and fatalities, these benefits can be leveraged to fund works.
- Initiatives with community engagement and education in road safety help to create values in road safety and encourage road users to adopt safer road behaviours will maximise the benefit of the treatments.
- The Guideline is published with the best knowledge available but changes in local road contexts and the availability of new materials and technologies are expected. Updates to this Guideline are anticipated to maintain the currency of the information.

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