Guide to Road Design Part 3: Geometric Design
Abstract
This Guide provides road designers and other practitioners with information about the geometric design of road alignments.

Design parameters include: road classification; design speeds; design vehicles; alignment controls; cross-section components, including travel lanes, shoulders and verges; and provisions for public transport and cyclists.

Speed parameters include: operating speed, desired speed and design speed; and their relationship with each other.

Horizontal and vertical alignments include development and application of: circular curves; superelevation; grades; vertical curves; procedures for the grading of a road alignment; and determination of sight distances across vertical curves.

Keywords
Geometric road design, operating speed, cross-section, traffic lanes, shoulders, verge, batters, roadside drainage, medians, bicycle lanes, HOV lanes, on-street parking, service roads, outer separators, footpaths, bus stops, sight distance, stopping sight distance, sight distance on horizontal curves, overtaking sight distance, maneouvre sight distance, intermediate sight distance, headlight sight distance, horizontal curve perception sight distance, horizontal alignment, vertical alignment, side friction factor, superelevation, adverse crossfall, grades, auxiliary lanes and bridge considerations, emergency landing strips.

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About Austroads
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Austroads’ purpose is to support our member organisations to deliver an improved Australasian road transport network. To succeed in this task, we undertake leading-edge road and transport research which underpins our input to policy development and published guidance on the design, construction and management of the road network and its associated infrastructure.

Austroads provides a collective approach that delivers value for money, encourages shared knowledge and drives consistency for road users.

Austroads is governed by a Board consisting of senior executive representatives from each of its eleven member organisations:
- Roads and Maritime Services New South Wales
- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department of Planning, Transport and Infrastructure South Australia
- Department of State Growth Tasmania
- Department of Transport Northern Territory
- Transport Canberra and City Services Directorate, Australian Capital Territory
- Australian Government Department of Infrastructure and Regional Development
- Australian Local Government Association
- New Zealand Transport Agency.

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This Guide is produced by Austroads as a general guide. Its application is discretionary. Road authorities may vary their practice according to local circumstances and policies. Austroads believes this publication to be correct at the time of printing and does not accept responsibility for any consequences arising from the use of information herein. Readers should rely on their own skill and judgement to apply information to particular issues.
This third edition contains minor editorial and technical changes throughout. Key new information and updates are:

- **Section 1.4**: Additional information and expansion on the design objectives.
- **Section 2.2**: Additional information on vulnerable road users, particularly motorcyclists (Section 2.2.4) and new information on emergency aircraft runway strips (Section 2.2.8).
- **Section 3.5**: Guidance for determining desired speed for rural roads and on steep grades (Section 3.5.1 – 3.5.4).
- **Section 4.2**: Additional guidance on crown line (Section 4.2.3) and rural road lane and shoulder widths (Section 4.2.6).
- **Section 4.3**: Additional guidance on shoulder widths and sealing (Section 4.3.3 – 4.3.4).
- **Section 4.4**: Additional guidance on verge slopes (Section 4.4.2) and rounding (Section 4.4.3).
- **Section 4.8**: Additional information on providing bicycle lanes (Section 4.8.4 – 4.8.12).
- **Section 7.7**: New guidance on a procedure for designing superelevation (Section 7.7.1) and development of superelevation on shoulders (Section 7.7.12).
- **Section 8.2**: New information outlining a procedure for checking critical vertical clearance points (Section 8.2.2).
- **Section 9.9**: Additional guidance on selecting a starting and terminating point of an auxiliary lane Section 9.9.1.

- **New Appendices**:
  - Appendix B: Emergency aircraft runway strips
  - Appendix E: Narrow median treatments with wire rope safety barrier
  - Appendix F: Guidance for wide centreline treatments
  - Appendix G: Flowcharts and table for determining stopping sight distance requirements for curves with barriers.
4.2.4 Traffic Lane Widths

Current Australian and New Zealand practice is to provide standard traffic lane widths of 3.5 m. Traffic lanes are measured to the face of the kerb or to the lane line for multi-lane roads, or roads with shoulders. Road agencies may also choose to provide an additional clearance to the face of the kerb to account for shy line effects, or for kerb profiles that have a wider channel (e.g. 450 mm) in areas of high rainfall. Refer to Figure 4.8 for the definition of the components of kerb and channel.

Figure 4.8: Kerb and channel components

The provision of standard lane widths of 3.5 m allows for large vehicles to pass or overtake, without either vehicle having to move sideways towards the outer edge of the lane. Research has shown that there is no evidence (Elvik et al. 2009) that supports the assumption that road safety is increased with wider traffic lanes. It was also reported that most freight-efficient vehicles could travel comfortably along roads that have a useable lane width of 3.5 m, although vehicles such as the rigid-plus-three and the A-triple require 3.7 m wide lanes (Prem et al. 1999) due to the tracking capability from the multi-combination trailers. Where the operation of Type 2 (triple) road trains (or even larger vehicles) is anticipated, designers should consider the use of wider traffic lanes.

Some road agencies also provide for the movement of larger vehicles, e.g. mobile cranes or low loaders transporting large earthmoving machinery up to 3.5 m wide without requiring a permit or pilot vehicle on specific sections of their road network. On these routes, designers should be cognisant of the movement of these larger vehicles when considering traffic lane widths less than 3.5 m wide.

Traffic lane widths may also need to be widened on curves to accommodate the extra tracking width required by trucks (refer to Section 7.9). Horizontal curve radii larger than 300 m should be used to avoid lane widening (Table 7.13). The use of lanes wider than 4.6 m as a result of lane widening is not favoured because of the possibility of two cars travelling side-by-side within the lane. If greater width is required for truck tracking, an edge line should be placed at 3.5 m and full pavement depth widening should be provided for the remainder of the width.

Narrower lanes (down to 3.3 m – Austroads 2009b) may be considered where any of the following apply:

- The road reserve or existing development form stringent controls preventing wider lanes.
- The road is in a low speed environment.
- There is little or no truck traffic.
- The alignment and safety records are satisfactory in the case of a reconstructed arterial.
4.2.5 Urban Road Widths

Adoption of standard traffic lane widths of 3.5 m is desirable in urban areas, for the reasons given above. However, where site constraints preclude the use of the desirable standard width, consideration may be given to reducing the traffic lane width to 3.3 m, subject to the approval of the relevant road agency. While it is desirable to maintain consistent lane widths along a road, there may be a need to reduce lane widths at intersections to accommodate additional turn lanes. Lane widths at intersections are detailed in the Guide to Road Design Part 4: Intersections and Crossings: General (Austroads 2009b). Table 4.3 provides guidance for traffic lane widths on urban arterial roads and Table 4.4 provides traffic lane widths and shoulder widths for urban freeways.

Lane widths to be adopted in residential, commercial and industrial areas are typically determined by the local municipality. Given the varying nature of these developments in terms of scale and traffic mix, designers should seek guidance regarding the choice of traffic lane width from the relevant municipal road agency.

Table 4.3: Urban arterial road widths

<table>
<thead>
<tr>
<th>Element</th>
<th>Lane width (m)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>General traffic lane</td>
<td>3.5</td>
<td>General traffic lane widths to be used for all roads</td>
</tr>
<tr>
<td></td>
<td>3.0–3.4</td>
<td>For use on low speed roads with low truck volumes</td>
</tr>
<tr>
<td>Service road lane</td>
<td>3.4–5.5</td>
<td>Range of lane widths on service roads (refer to Section 4.11)</td>
</tr>
<tr>
<td>Wide kerbside lane</td>
<td>4.2</td>
<td>Locations where there are high truck volumes (additional width provided for trucks)</td>
</tr>
<tr>
<td></td>
<td>4.2–4.5</td>
<td>Locations where motorists and cyclists use the same lane (refer Section 4.11)</td>
</tr>
<tr>
<td>HOV lane</td>
<td>3.5–4.5</td>
<td>Bus lane (refer Section 4.9.2)</td>
</tr>
<tr>
<td></td>
<td>3.3</td>
<td>Tram/light rail vehicle lane (refer Section 4.9.3)</td>
</tr>
<tr>
<td>Minimum width between kerb and channel (to provide for passing of broken down vehicles)</td>
<td>5.0(1)–6.5(2)</td>
<td>Width of a single lane suitable for use in a left turn slip lane, or two lane, two way divided road with a raised median</td>
</tr>
<tr>
<td></td>
<td>2 × 4.0 (8.0)</td>
<td>Width of two lanes that provide for two lines of traffic to (slowly) pass a broken down vehicle.</td>
</tr>
</tbody>
</table>

1 Generally, a minimum width of 5.0 m should be provided. However, at the discretion of the road agency a lesser width may be considered on urban roads where the site is constrained and traffic using the facility is comprised of cars and small commercial vehicles, or where the length of treatment is short (e.g. channelised left-turn roadway).

2 Depending on the classification of the road, the design vehicle to be accommodated and space available at the site, the road agency may consider the provision of a width up to 6.5 m. However, where this width is likely to result in operational issues (e.g. two lines of cars in a left-turn roadway that is intended to operate as a single lane) measures should be undertaken to delineate the expected path for cars and other small vehicles.

[see Commentary 6]
Table 4.4: Urban freeway widths

<table>
<thead>
<tr>
<th>Element</th>
<th>Lane width (m)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic lane(^{(1)})</td>
<td>3.5</td>
<td>General traffic lane width</td>
</tr>
<tr>
<td>Lane width on interchange ramps</td>
<td>3.5–4.5</td>
<td>Range of lane widths on interchange ramps, (refer to the Guide to Road Design Part 4C (Austroads 2015e))</td>
</tr>
<tr>
<td>Left shoulder(^{(2)}) (sealed for the full width)</td>
<td>2.0–3.0(^{(3)})</td>
<td>Range of left shoulder widths</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>Minimum shoulder width adjacent to a safety barrier</td>
</tr>
<tr>
<td>Median shoulder(^{(2)}) (sealed for the full width)</td>
<td>1.0–3.0(^{(3)})</td>
<td>Range of shoulder widths</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>Minimum shoulder width adjacent to a safety barrier</td>
</tr>
</tbody>
</table>

1 Traffic lane widths include lane lines but are exclusive of edge lines.
2 Shoulder widths may be locally narrowed where there are overpass bridge piers or similar large constraint. Designers should maintain at least minimum clearances/offsets from traffic lanes to barriers where locally narrowing shoulders.
3 A 3.0 m shoulder enables a truck to stop clear of the traffic lane.

Note: Where the wearing course is placed on the traffic lane, but not the shoulders (e.g. open graded asphalt), this should extend for the full width of shoulders on the high side of superelevation. The wearing course should extend a minimum of 0.3 m beyond the edge line to minimise the risk associated with the edge drop-off.

4.2.6 Rural Road Widths

The desirable lane width on rural roads is 3.5 m. This width allows large vehicles to pass or overtake without either vehicle having to move sideways towards the outer edge of the lane. The lane width and the road surface condition have a substantial influence on the safety and comfort of users of the roadway. In rural applications the additional costs that will be incurred in providing wider lanes will be partially offset by the reduction in long-term shoulder maintenance costs. Narrow lanes result in a greater number of wheel concentrations in the vicinity of the pavement edge and will also force vehicles to travel laterally closer to one another than would normally happen at the design speed. Drivers tend to reduce their travel speed, or shift closer to the lane/road centre (or both) when there is a perception that a fixed hazardous object is too close to the nearside or offside of the vehicle. When there is a perceived fixed hazard, there is a movement by the vehicle towards the opposite lane line.

Single carriageways

On many roads in Australia, traffic volumes are less than 150 vehicles per day. Some of these are arterial roads passing through sparsely settled flat country where the terrain leads to a high operating speed. Where traffic volumes are less than 150 vehicles per day and, particularly, where terrain is open, single lane carriageways may be used. The traffic lane width adopted on such roads should be at least 3.7 m (refer Table 4.5). A width of less than 3.7 m can result in excessive shoulder wear. A width greater than 4.5 m but less than 6.0 m may lead to two vehicles trying to pass with each remaining on the seal. This potentially increases head-on accidents. The width of 3.5 m ensures that one or both vehicles must have the outer wheels on the shoulders while passing. On two lane sealed roads, the total width of seal should desirably be not less than 7.2 m to allow adequate width for passing.
Table 4.5: Single carriageway rural road widths (m)

<table>
<thead>
<tr>
<th>Element</th>
<th>Design AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1–150</td>
</tr>
<tr>
<td>Traffic lanes (1)</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>(1 x 3.7)</td>
</tr>
<tr>
<td>Total shoulder</td>
<td>2.5</td>
</tr>
<tr>
<td>Minimum shoulder seal (2),(3),(4),(5),(6)</td>
<td>0</td>
</tr>
<tr>
<td>Total carriageway</td>
<td>8.7</td>
</tr>
</tbody>
</table>

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).

Divided carriageways

Divided roads are provided where traffic volumes are high and it is necessary to provide motorists with a satisfactory level of service or where a section of road has an unacceptable number of crashes, particularly head-on crashes.

Austroads (2010c) showed that casualty crash rates were 1.6 times higher on undivided rural roads than on divided rural roads. Although there are many other differences between the two road types besides the presence of a median the finding shows that lack of a separation between opposing traffic is a significant risk contributing factor. The finding also showed that severity of crashes on undivided roads was generally higher. This was most likely due to the occurrence of high speed head-on crashes on undivided roads which are very rare on divided roads.

Table 4.6 shows traffic lane and shoulder widths on rural roads with divided carriageways, including rural freeways. Each of the two carriageways should have at least two traffic lanes so that overtaking is possible. With each carriageway, the left shoulder should be at least 2 m wide, but preferably wider to accommodate a broken-down vehicle.

Where the shoulder is less than 2 m, opportunity should be taken to provide wider standing areas at regular intervals, by flattening fill slopes on low formations or by widening shoulders at the transition from cut to fill. It is desirable that the widening be sufficient to allow traffic to pass a stopped vehicle without having to change position in the lane. As a minimum, the widening should be sufficient to allow traffic to pass a stopped vehicle by changing position in the lane without encroaching into the adjoining lane. Although few rural roads in Australia carry traffic volumes sufficient to require more than four lanes, in designing a rural road it is common to assume that wider carriageways may be required at some future time and to reserve the land required.
Table 4.6: Divided carriageway rural road widths

<table>
<thead>
<tr>
<th>Element</th>
<th>Design AADT</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 20 000</td>
<td>&gt; 20 000</td>
<td></td>
</tr>
<tr>
<td>Traffic lanes(^{(1)})</td>
<td>3.5</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Shoulder Left</td>
<td>2.5</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Shoulder Median</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Shoulder seal(^{(2, 3)})</td>
<td>1.5</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Shoulder Median</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

1 Traffic lane widths include lane lines but are exclusive of edge lines.
2 Wider shoulder seals may be appropriate depending on requirements for cyclists, maintenance costs, and soil and climatic conditions.
3 Full width shoulder seals are appropriate beside road safety barriers and on the high side of superelevation.

4.3 Shoulders

4.3.1 Function

Road shoulders are provided to carry out two functions; structural and traffic. The structural function of the shoulder is to provide lateral support to the road pavement layers.

The traffic functions of the shoulder are:

- an initial recovery area for any errant vehicle
- a refuge for stopped vehicles on a firm surface at a safe distance from traffic lanes
- a trafficable area for emergency use
- space for cyclists
- clearance to lateral obstructions
- provision of additional width for tracking of large vehicles (Section 7.9).

4.3.2 Width

Shoulder width is measured from the outer edge of the traffic lane to the edge of usable carriageway and excludes any berm, verge, rounding or extra width provided to accommodate guideposts and guard fencing. Wide shoulders have the following advantages:

- Space is available for a stationary vehicle to stand clear of the traffic lanes; a vehicle standing partly on a shoulder and partly on a traffic lane may be a hazard.
- Space is available on which vehicles may deviate to avoid colliding with other vehicles and on which a driver may regain control of an errant vehicle.
- The resulting wider formations increase driver comfort and the quality of service of the road.
- They contribute to improved sight distance across the inside of horizontal curves.

Table 4.4 to Table 4.7 list shoulder width values for both urban and rural roads based on AADT volumes or functional classification. These widths allow a vehicle to stop, or a maintenance vehicle to operate, with only partial or no obstruction of the traffic lanes. Provided volumes are not high or sight distances are sufficiently long, partial obstruction of the traffic lane will not present an undue hazard to traffic.