



# Supplement to Austroads Guide to Traffic Management

**Part 6: Intersections, Interchanges and Crossings (2013)**

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# 1. Introduction

## 1.1 General

All road agencies across Australia are working towards greater consistency between States/Territories in how road networks are managed. In order to achieve this, the Austroads Guide to Traffic Management (AGTM) and Australian Standards relating to traffic management have been adopted to assist in providing that level of consistency and harmonisation across all jurisdictions. This agreement means that these Austroads Guides and the Australian Standards are the primary technical references.

Austroads Guide to Traffic Management, Part 6: Intersections, Interchanges & Crossings (2013) is a nationally agreed guideline document and has been adopted by all jurisdictions, including VicRoads.

All jurisdictions will be developing their own supplement to clearly identify where its practices currently differ and to provide additional guidance to that contained within Austroads Guide to Traffic Management, Part 6: Intersections, Interchanges & Crossings (2013). This document is the VicRoads supplement and shall be read in conjunction with Austroads Guide to Traffic Management, Part 6: Intersections, Interchanges & Crossings (2013).

## 1.2 How to Use this Supplement

There are two key parts to this document:

- **Classification of Supplement Information:** this table classifies supplement information as a Departure, Additional Information or both. This information assists with identifying its hierarchy in relation to the Austroads Guide to Traffic Management, Part 6: Intersections, Interchanges & Crossings.
- **Details of Supplement Information:** this section provides the details of the supplement information.
  - **Departures:** where VicRoads practices differ from the guidance in the Austroads Guide to Traffic Management (AGTM). Where this occurs, these differences or 'Departures' will be highlighted in a box. The information inside the box **takes precedence** over the Austroads Guide to Traffic Management section. The Austroads Guide to Traffic Management, Part 6, section is not applicable in these instances.
  - **Additional Information:** all information not identified as a departure provides further guidance to the Austroads Guide to Traffic Management, Part 6: Intersections, Interchanges & Crossings and is read and applied **in conjunction** with the Austroads Guide to Traffic Management, Part 6: Intersections, Interchanges & Crossings, section.

Where a section does not appear in the body of this supplement, the Austroads Guide to Traffic Management, Part 6: Intersections, Interchanges & Crossings (2013) requirements are followed.

## 2. Classification of Supplement Information

The classification of each clause as a Departure, Additional Information or both is shown in the table below.

Section	Classification
2.2	Additional Information
2.3.2	Additional Information
2.3.3	Additional Information
2.3.4	Additional Information
3.2.2	Departure
3.3.5	Additional Information
4.5.9	Additional Information
5.1	Additional Information
5.3.2	Additional Information
5.7	Additional Information
6.2	Additional Information
6.3	Additional Information
6.5	Additional Information
6.7	Additional Information
6.8	Additional Information
6.10	Additional Information
8.2.1	Additional Information
8.2.3	Additional Information
Attachment A	Additional Information
Attachment B	Additional Information
Attachment C	Additional Information
Attachment D	Additional Information

Austrroads Guide to Traffic Management, Part 6 requirements are followed for sections not shown in this table.

### 3. Details of Supplement Information

## Section 2 – Selection of Intersection Type

### Section 2.2 – Types of Intersection

Every intersection in Victoria is to be controlled by either:

- The T-intersection Rule (Road Rule 73), or
- Give Way sign(s), Stop sign(s) or Give Way markings, or
- Roundabout signs, or
- Traffic signals (ie. 'Traffic lights' in the *Road Safety Road Rules 2009*)

### Section 2.3.2 – Selection Process

Guidance on the selection of traffic signals and roundabouts as the form of intersection control is given in Attachment A.

### Section 2.3.3 – Assessment of Intersection Control Options

Table 2.3 provides a broad guide to the suitability of the type of traffic control in relation to the functional classification of roads.

At intersections of primary/primary or primary/secondary arterial roads, where traffic volumes in particular during the peak periods are appropriately low enough, the selection of a '**roundabout**' treatment should be defined as a "most likely treatment" rather than "may be an appropriate treatment".

Importantly consideration should also be given to a **safe system approach** which may also influence the selection of a roundabout as an intersection control.

### Section 2.3.4 – Intersection Type Selection – Key Traffic Management Considerations

The following amendments are made to the guidelines for the selection of traffic signals in Table 2.4 *Key traffic management considerations in selection of intersection type*.

#### (1) Traffic Volume

Where the 85th percentile speed on the major road exceeds 80 km/h or in isolated communities of less than 10,000 populations, the minimum vehicular volumes may be lowered to 420 and 140 vehicles per hour respectively.

#### (2) Pedestrian Safety

Pedestrian operated signals may be provided where the following guidelines are met:

- For any hour on an average weekday:
  - The number of pedestrians (P) crossing within 20 m of the proposed site exceeds 100, **and**
  - The number of vehicles (V) which pedestrians have to cross exceeds 500 on an undivided road, or 1,000 where there is a median or pedestrian refuge, **or**
- A pedestrian crossing (zebra) would normally be justified but the operation of the crossing would interfere with the progression of vehicles to and/or from a nearby traffic signal installation **and** it would be practicable for the operation of Pedestrian Operated Signals at or near the proposed site to be coordinated with the nearby signals. **or**
- A pedestrian crossing (zebra) would normally be justified but would be hazardous for pedestrians due to conditions at the site (eg. disabled or elderly pedestrians, high vehicle approach speeds, high traffic volume, poor visibility, etc) **or**
- Where crash records indicate that two or more pedestrian casualty crashes have occurred in the last 3 years.

*NOTE: In determining pedestrian numbers, each older person, person with a disability and unaccompanied child of primary school age should count as two.*

Where the crossing is primarily intended for the use of school children, the device may be appropriate where for at least one hour of an average school day:

- The number of children (P) crossing the road within 20 m of the proposed site exceeds 50 per hour; **and**
- The number of vehicles (V) which children have to cross during that hour exceeds 500; **and**
- The product P x V exceeds:

- 25,000 for primary school children, or
- 34,000 for secondary school children.

Where the guidelines for a children's crossing are met but the road has a high traffic volume, pedestrian operated signals may be appropriate.

Pedestrian operated signals should not be installed on roads with a speed limit above 80 km/h. If necessary, the speed limit should be reduced to 80 km/h or less.

Pedestrian Operated Signals for school children are functionally the same as normal Pedestrian Operated Signals.

### (3) Crashes

To reduce crashes, signals may be considered if there is an average of **5** or more reported casualty crashes over **5** years which may be eliminated or reduced by traffic-control signals and the traffic volume is at least 80% of the volume guidelines given in (1) and (2).

Crashes which may be eliminated or reduced by the provision of traffic signals generally include only vehicle to vehicle right angle collisions, right turn against opposing flow and certain collisions involving pedestrians or cyclists (ie. Definition for Classifying Accidents - DCA - codes 110 to 119 inclusive and 100, 101,102).

Traffic signals should not be installed in 100 km/h speed zones.

### (4) Within Coordinated Signal Systems

Traffic signals may be occasionally justified at intersections within or near a coordinated traffic signal system where operation of the intersection without traffic signals causes significant interference to the progression of traffic to or from nearby traffic signals. Such signals will be appropriate only where it is possible for them to be coordinated with nearby signals.

### (5) Traffic Management Plans

Traffic signals may occasionally be justified as forming an essential part of an overall traffic management plan for an area to promote use of the road network in accordance with the objectives of the plan. However, caution needs to be exercised that through traffic problems are not created on the local road network in the area. Other factors which may need to be taken into consideration include bus routes and principal bicycle routes in the area.

## Section 3 – Unsignalised Intersections

### Section 3.2.2 – Stop Signs and Give Way Signs

#### DEPARTURE

In Figure 3.2, note 6, the observer's eye height should be taken as 1.10m. This value is considered consistent with Section 5.2.1, Austroads Guide to Road Design (AGRD), Part 3 and VicRoads supplement to the Austroads Guide to Road Design, Part C which are quite explicit about driver eye height being 1.10m. Therefore, VicRoads has adopted observer's eye height of 1.10m.

### Section 3.3.5 – Road Lighting

VicRoads policies and guidelines for road lighting are given in TCG006 – Guidelines for street lighting design.

## Section 4 – Roundabouts

### Section 4.5.9 – Lighting

VicRoads policies and guidelines for road lighting are given in TCG006 – Guidelines for street lighting design.

## Section 5 – Signalised Intersections

### Section 5.1 – Introduction

The primary aims of signal control are:

- to reduce traffic conflicts and delays

- to reduce crashes.

The optimum information transfer from the traffic signal control system to the road user occurs if the traffic light system, comprising signals, signs and linemarking can be easily seen and identified.

Traffic control signals are a Major Traffic Control Devices and are not delegated to councils.

The Road Rules covering traffic signals are given in Part 6 of the *Road Safety Road Rules 2009*.

### Section 5.3.2 – Table 5.2 – Medians

A number of intersections exist in Victoria where wide central medians are present, resulting in the storage of vehicles within the central median area while completing a right turn or U-turn. Confusion has arisen as to the responsibility of drivers at these intersections with regard to obeying traffic signals and/or line markings while located in the central median area. Line marking, signs and traffic signals should be arranged at these intersections so as to avoid confusion and clearly present the requirements to the driver.

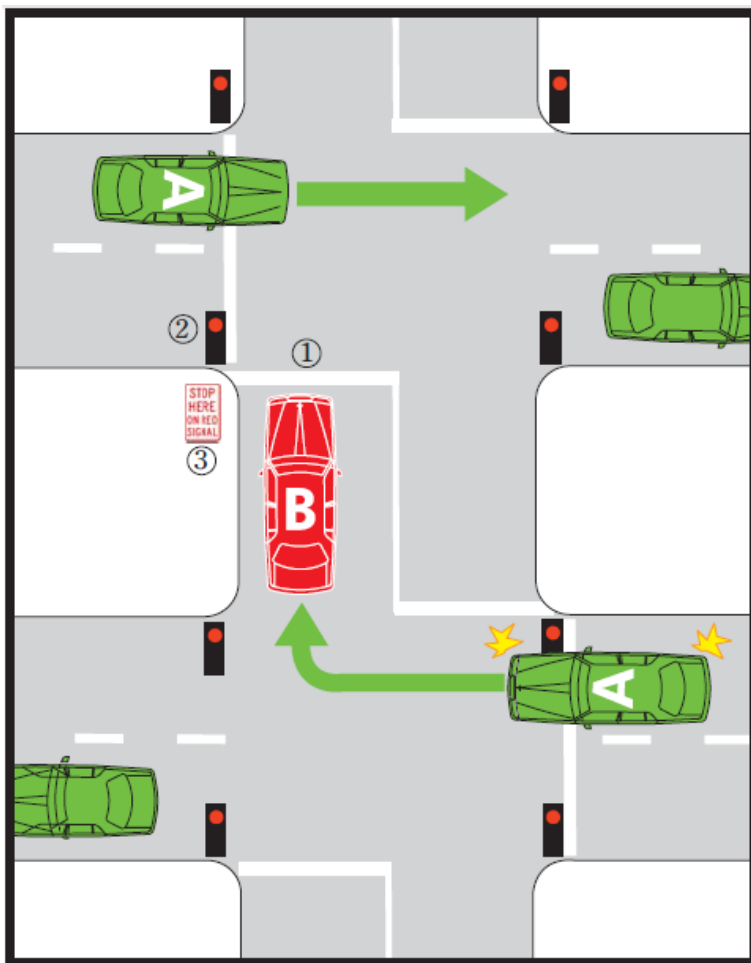
The following applies to intersections where vehicles completing a right turn or U-turn may be required to be stored within the central median area.

#### Drivers Required to Stop on Red Signal

Figure 1 shows the situation where drivers within the storage area in the central median are required to wait for a green light before proceeding.

The layout includes:

- a stop line
- traffic signal aspects facing the driver, adjacent to the stop line
- a “Stop Here on Red Signal” sign.



**Figure 1: Signalised intersection with wide median – Stop in median**

*Note: Indicated signage and signals are only for one direction of traffic flow.*

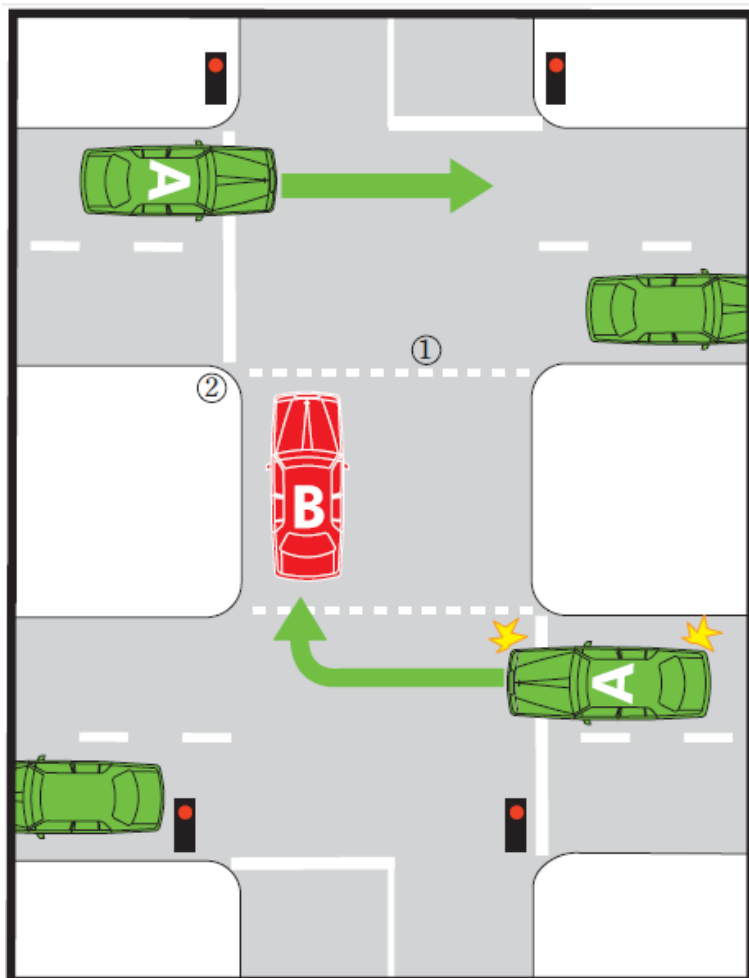


## Drivers Required to Give Way

Figure 2 shows the situation where drivers within the storage area in the central median may complete the right turn, (even though they face a red signal when departing the intersection), after giving way to any vehicles approaching on their left.

The layout includes:

- 'Statcon type' continuity line with 600 mm stripe and 600 mm gap, 150 mm wide for the full width of the median opening.
- Traffic signals may be installed adjacent to the storage in order to address a specific need at certain locations.



**Figure 2: Signalised intersection with wide median – Give Way in median**

Notes:

1. Even if traffic signals are installed at location (2), a "Stop Here on Red Signal" sign or "Stopline" at the signal shall not be installed if there is no requirement for right turning vehicles to stop within the median. Refer Road Safety Road Rules 58 (2).
2. Indicated traffic signals are only for one direction of traffic flow.

## Section 5.7 – Road Lighting

VicRoads policies and guidelines for road lighting are given in TCG006 – Guidelines for street lighting design.

## Section 6 – Interchanges

### Section 6.2 – Planning Considerations

#### 6.2.1 (a) Strategic Planning

Planning of freeways at a project level should always be preceded by strategic planning of the road network, to optimise the spacing of freeways and interchanges, and to provide estimates of traffic volumes for road design purposes.

The function of the existing road network may be altered by addition of a freeway. The planning should consider the present and future land development and the resulting demand for transport, and also must provide alternative routes for those road users and vehicles that are prohibited from using the freeway. It is important that the whole road network be integrated and appropriately interconnected through interchanges and intersections.

The justification for any interchange should be established from a comprehensive traffic study of the proposed road network, aiming to optimise traffic service and community interests.

The primary purpose of any interchange is to distribute conflicting traffic safely and effectively. The appropriate form of interchange is that which maintains the operational capacity under the predicted demand conditions.

#### 6.2.1 (b) Project Planning

The planning aspects of interchanges include:

- i. Choice of locations which have regard for travel demands, current and future operating conditions on the freeway, and geometric and other physical constraints.
- ii. Selecting the type of interchanges which will operate safely and also provide appropriate operating conditions for all traffic movements.
- iii. Reduction of accident potential by removal of conflict between major traffic movements.
- iv. Provision of high speed flows uninterrupted by access to private properties, parking, and cross traffic, where appropriate.
- v. Reduction of travel time and cost by selection of the minimum length route consistent with community and environmental values.
- vi. Restriction of access to the freeway to interchanges at selected locations.
- vii. Achievement of acceptable levels of service by provision of appropriate numbers of lanes and maintaining lane balance.
- viii. Retention of the use of the local road system by provision of grade separations across a freeway at selected locations.
- ix. Consideration of pedestrian needs on secondary roads connecting with a freeway.
- x. Consideration of the needs of cyclists along secondary roads which connect to the freeway, along those rural freeways where cyclists are permitted, and where a bicycle path passes through an interchange.
- xi. Provision of rest areas and Service Centres at appropriate intervals.
- xii. Consideration of environmental issues and preparing a landscape concept proposal;
- xiii. Consideration of political and legal requirements.

## 6.2.2 WARRANTS

### (a) Interchange Warrants

An interchange should be provided where:

- i. an economical analysis demonstrates that it is justified;
- ii. all forms of possible at-grade treatments are likely to be unsafe or would not meet objectives with respect to mobility of major traffic flows;
- iii. National Highways guidelines require an interchange;
- iv. a combination of at-grade intersection and interchanges would not be expected by motorists and hence could lead to unsafe situations.

**Table 1: Economic Warrants**

<b>Basic Interchange Warrant</b>	
<i>Expressway Volume (vpd)</i>	<i>Cross Road Volume (vpd)</i>
7500	3600
10000	3300
12500	3000
<b>Basic Overpass Warrant</b>	
<i>Expressway Volume (vpd)</i>	<i>Cross Road Volume (vpd)</i>
7500	1800
10000	1650
12500	1500
<i>Note:</i>	
(1) Assumed traffic growth rate was 3% p.a.	
(2) Target Benefit Ratio was 1.0	
(3) Assumed diamond interchange used	

An analysis of the economic justification of interchanges and overpasses for rural expressways with traffic in the range 7,500 to 12,500 AADT was carried out by van Every (1982) and summarised in **Table 1**.

These warrants are for guidance only, and an individual case, for example where accident rates are higher than average, may be justified by a specific economic analysis, or by the factors set out in 6.2.2(a) (ii), (iii) and (iv) above. Cost of accidents may justify grade separation where the sum of the crossing volumes is about 1000 v.p.d.

### (b) At-grade Intersection Treatments

Where a rural expressway is crossed by a local road with average daily traffic less than 50 vehicles per day (v.p.d), the cross road should be closed or relocated.

Roundabouts are generally not favoured as at-grade treatments on rural expressways, as they have a significant effect on the mobility of drivers using the major road. Where crossing traffic on a rural facility is greater than 50 v.p.d., the choice of treatment is usually either a staggered T intersection or a wide median treatment, see *AGRD Part 4A, Sections 4.11 and 4.13*.

Wide median treatments should be limited to:

- i. T intersections where the entering side road traffic is less than 1000 v.p.d.;
- ii. Cross intersections where the sum of the volumes entering from both side roads is less than 1000 v.p.d.;
- iii. Sites where the accident exposure (E) is less than 6000 v.p.d. expressed by:

$$E = 2\sqrt{(V_1 \times V_2)}$$

Where:

V1 is the sum of traffic volumes entering from the major route (v.p.d.), and

V2 is the sum of the traffic volumes entering from the minor legs

### **(c) Grade Separation Requirements**

It is desirable that the secondary roads carrying traffic across a freeway should continue without interruption or deviation. Grade separations should be of sufficient number and capacity to handle adequately not only the normal traffic, but the traffic diverted to the cross street from the other streets terminated by the freeway and traffic generated by connections to the freeway. Determination of the number and location of cross streets to be grade-separated requires extensive community consultation and a thorough analysis of traffic on the local network in addition to that on the freeway and interchanges.

Terminated and through streets may connect to frontage roads on either side of the freeway. Locations of intersections between frontage roads and major cross roads need to be chosen with care, as safety, operational or capacity problems arise if they are placed too close to freeway ramp terminal intersections.

### **(d) Right Of Way**

The process of acquiring right of way is complex and may take years. It is therefore preferable that the road reservation is defined fairly generously at the planning stage, especially at interchanges, so that small additional parcels of land are not required later. In complex interchanges carrying high volumes, some flexibility should be allowed for possible future change of interchange form when selecting boundaries.

Detailed boundaries should allow space for features such as catch drains, noise attenuation mounds, stockpiles during construction, sedimentation basins, and ancillary works areas. Additional allowance for landscaping may be required at interchanges.

Minimum right of way clearances from batter points are set out in *AGRD Part 3, Section 4*. Further to *AGRD Part 3, Table 4.30*, the minimum clearance adopted between batters and right of way should be 10m during the planning phase of a project.

### **(e) Define planning goals**

The roles and functions of freeways within the road network need to be defined, together with the relative priorities of local political, social and environmental factors. It is preferable that controls, criteria and community expectations are written down, so that later design reviews can assess to what degree each interchange option satisfies the requirements.

Examples of planning objectives are set out in Section **6.2.1(b)** Planning Considerations above.

Should the objective be reservation of land in a planning scheme, boundaries should be set so as to allow flexibility for future interchange options.

### **(f) Traffic Network Predictions**

Proposed interchange locations should be shown on the road network prior to traffic assignment and predictions. The omission of an interchange would generally result in higher traffic volumes on arterial roads and greater circuitry of travel. However, too close spacing of interchanges can result in operational inefficiency in weaving areas and higher accident rates as more local trips are attracted to the freeway. For advice on interchange spacing, see *AGTM Part 6, Section 6.3.1* and *AGRD Part 4C, Section 2.4.2*.

Traffic predictions for urban networks should be carried out using computer modelling, but the results should be reviewed for practicality by comparing them to existing traffic patterns and assessing whether the results can be used to identify major turning movements and to determine the basic number of lanes for through carriageways and ramps.

### **(g) Obtain Site Details**

Reliable contoured mapping is required for an interchange layout, together with cadastral, planning scheme and major utility services information. Photogrammetric mapping may have to be supplemented by engineering survey where clearances are small or existing features are to be matched.

### **(h) Controls and Criteria**

The features which are to be regarded as controls on each design must be identified and further classified into mandatory and discretionary controls. Mandatory control must be met, whereas other controls may be allowed some degree of compromise.

Common criteria include the design principles listed in *AGTM Part 6, Section 6.3* and others such as:

- i. all movements to be provided at an interchange;
- ii. all access to and from the freeway to be on the left-hand side;
- iii. avoid use of reversed small radius curves;
- iv. avoid use of curves and loops with radii less than 55 metres.

Variations from the desirable criteria may be warranted in some circumstances such as:

- at major forks a right-hand diverge and merge might be appropriate, see **Section 6.5.2.(b)**;
- in rural areas with low traffic volumes, a cloverleaf may be considered appropriate although weaving is involved;
- rural cross roads which have very low volumes may be provided with at-grade intersections as an interim treatment, see **Section 6.2.2 (b)** for warrants.

#### **(i) Evaluate Options**

The interchange options should be compared against the selected controls and criteria, and the economic, environmental and operational factors set out in *AGTM Part 6, Section 6.5.5*. It is quite usual for some controls and criteria to be in conflict, and the most suitable interchange is that which achieves an optimal balance of the desired characteristics.

#### **(j) Design Review**

The planning concepts of an interchange should be reviewed before detailed design to determine whether the original controls are still relevant. Changes in land use, traffic patterns or design standards over time may necessitate corresponding changes in interchange design. In urban areas, community expectations about environmental issues such as noise and air pollution, conservation of vegetation and fauna habitats are becoming higher.

## **Section 6.3 Route Considerations**

### **6.3.1 Spacing of Interchanges**

#### **Urban freeways/motorways**

Weaving sections generate considerable turbulence in traffic flow, so interchange forms which eliminate weaving from the main carriageways are desirable. Any entry ramp located within about 3 km of a freeway to freeway interchange and aligned towards that interchange is likely to create weaving problems. Where provision of freeway access is unavoidable and the weaving volumes would be high, one solution to be considered is braiding of the entry and exit ramps .

Braiding in this sense refers to the grade separation between ramps intersecting at a low angle on one side of the freeway. By this means, weaving is avoided.

Good signing is essential for such interchanges to operate satisfactorily.

### **6.3.3 Route Continuity and Consistency**

#### **Separate Link**

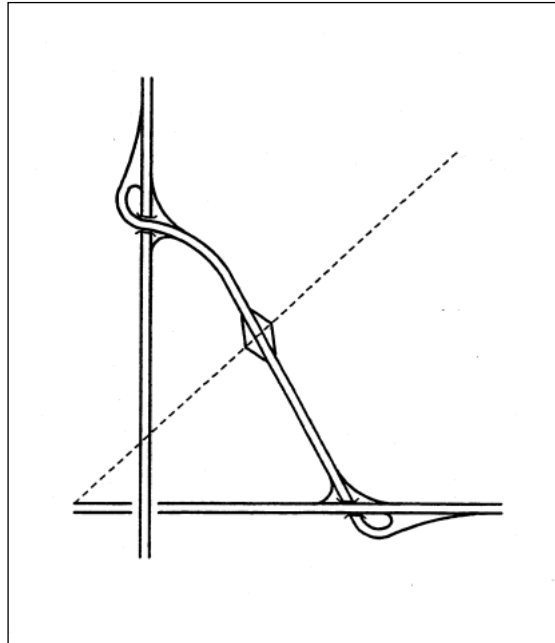
Access between freeways can be provided using a separate link as shown on **Figure 3**. Connections of this type can be useful in highly developed urban areas. The disadvantages are the additional travel distances, and possible driver disorientation.

## **Section 6.5 Interchange Forms**

### **6.5.2 System Interchanges**

#### **6.5.2 (a) Y Interchanges**

The simplest interchange form for a three-way junction is the Y interchange in which the angle of intersection is acute. The basic Y interchange does not cater for all movements, but is oriented to serve major traffic demand in one quadrant. The omitted movements must be provided elsewhere.



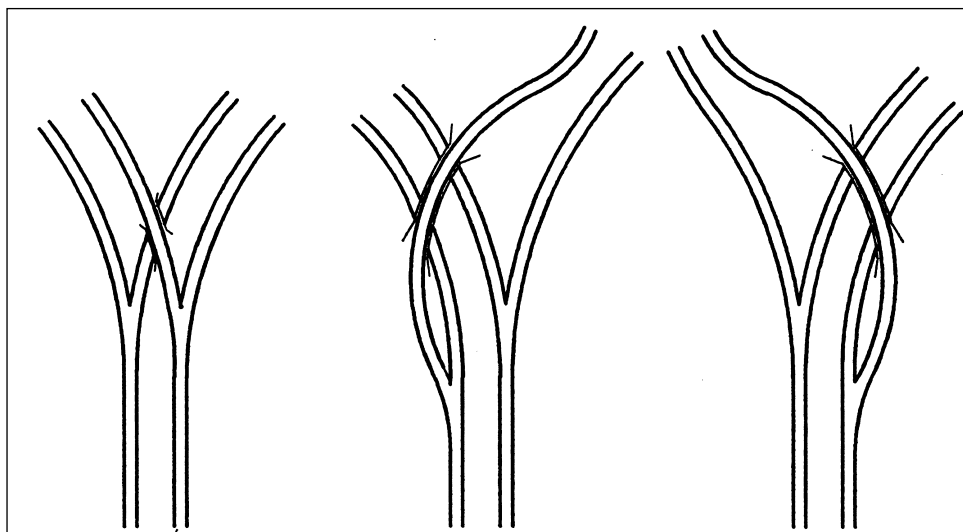
**Figure 3: Separate Link**

If future traffic patterns and demands are uncertain, it is prudent to reserve land for the ultimate provision of all movements.

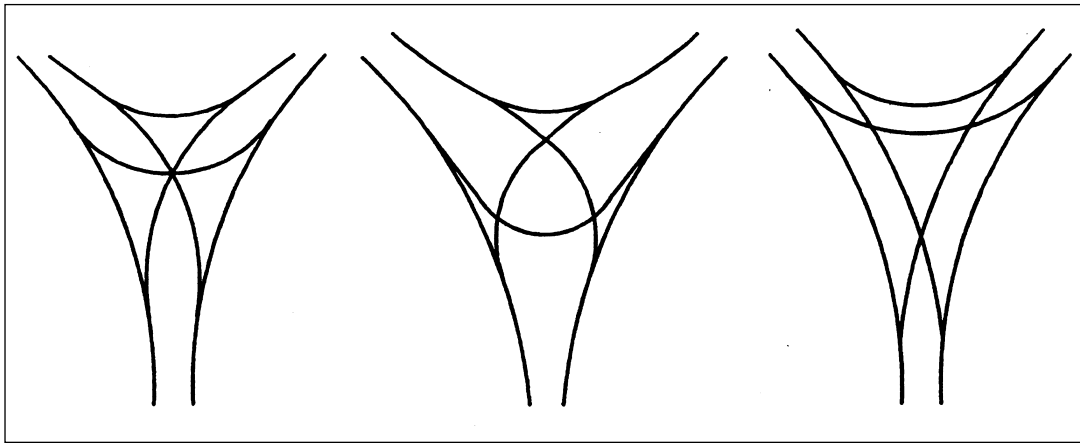
"Y" shaped interchanges which have no connection between the arms of the "Y" are shown on **Figure 4**.

The interchanges operate as "major forks", see also, *AGRD Part 4C, Section 11.2.3* and Section **6.5.2.(b)**. Where circumstances permit, access between the spread legs of these interchanges may be provided from a surface road which crosses the two arms.

"Y" interchanges with direct connections between the arms of the "Y" as shown on **Figure 5** are similar to the directional "T" layouts except that priority is given to the major legs of the Y, which are designed as freeway carriageways.



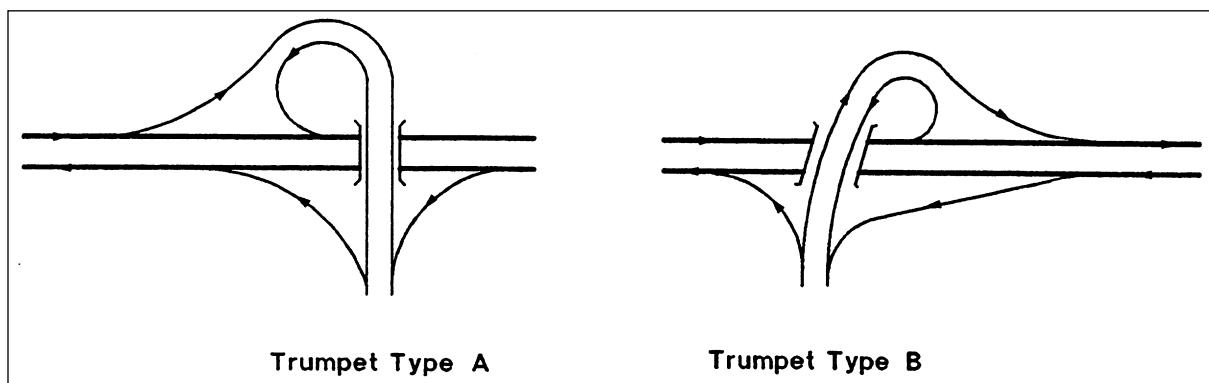
**Figures 4 : Simple Y Interchanges**



**Figures 5: Y Interchanges with Direct Connections to Arms**

In the examples shown, major forks and branch connections have been provided for the minor movements between the upper arms of the "Y", see *AGRD Part 4C, Sections 11.2.3 and 11.3.6* and *VicRoads Supplement*. These may be acceptable provided that right turns on the major fork are less than 30 per cent of the total traffic. In the case of the branch connection merges, it must be possible to provide exclusive lanes for the right-hand carriageway to avoid a right-hand merge. Refer to *AGTM Part 6, Section 6.6.7 and 6.6.8* for additional information regarding major forks and branch connections.

Another option is the Trumpet interchange, which may also be used for a T-interchange. The trumpet interchange is not favoured for freeway to freeway interchanges because a high speed carriageway ends in a low speed loop without passing through an obvious speed change area (discussed in Section 6.5.2(b)). Where used, the option of "Type A" or "Type B" trumpet interchange (see **Figure 6**) is chosen by assigning the loop to the lower turning volume. The "Type B" trumpet interchange is an appropriate application where the more direct alignment favours the major right turn and the loop provides for a volume less than 1000 v.p.h. Then the skewed crossing has a shorter travel distance and flatter turning radius for the heavier right-turning volume, and the turning angles for both right-turns are less.



**Figure 6 Trumpet Interchange**

### 6.5.2 (b) T Interchanges

The T interchange is the special case of a three-way junction where the legs intersect at or close to right angles. There are three basic options for directional T interchanges as shown on Figure 7 (a), (b) and (c).

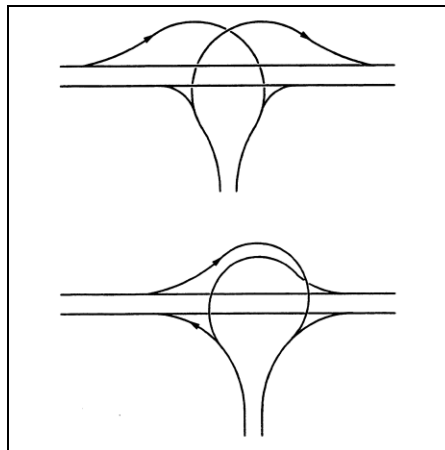
In three-level option shown on Figure 7(b) the connecting roadways cross over the centre of the interchange as with "the stack", see **Section 6.5.2 (c)**.

The layouts on **Figure 7 (b) and (c)** have outer ramp crossings. The location of the ramp intersection and the ramp grading are interdependent, and must satisfy the vertical clearance and maximum grade controls as well as providing a satisfactory horizontal alignment.

The feature of concern with all T interchanges is the design of the diverge in the carriageway at the end of the terminating freeway, called a major fork, see also *AGRD Part 4C, Section 11.2.3* and *VicRoads Supplement*. At major forks, the horizontal geometry of each carriageway should continue past the gore without any kinks or tapers, as shown on **Figure 7(d)**.

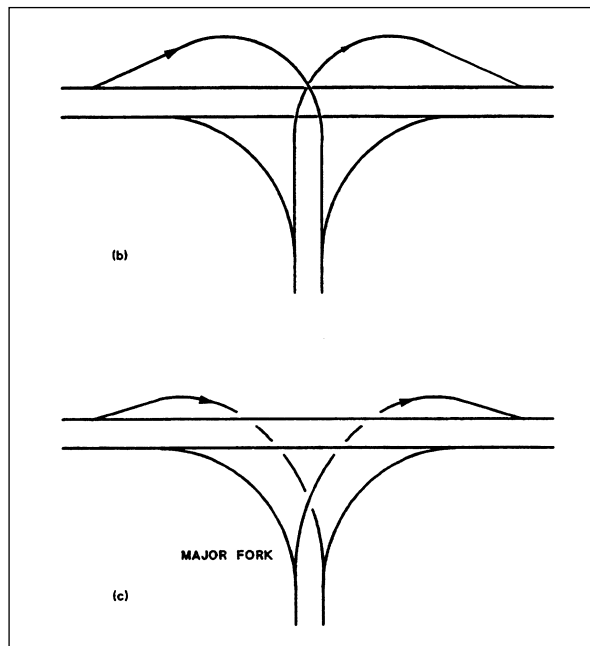
When traffic volumes on the right turn are more than 30 per cent of the total, the lanes should be arranged as shown on **Figure 7(d)**. Where right turn traffic is equal to, or less than 30 per cent of the total, the crossover ramp shown on **Figure 7(e)** may be considered. Refer to *AGTM Part 6, Section 6.6.7* for additional information regarding the alignment of major forks.

Where slow moving trucks delay other traffic at a major fork or where the distance available between a previous interchange and the major fork is insufficient for entering trucks to weave safely across the high speed freeway lane, a separate ramp as shown on **Figure 7(f)** may be justified.

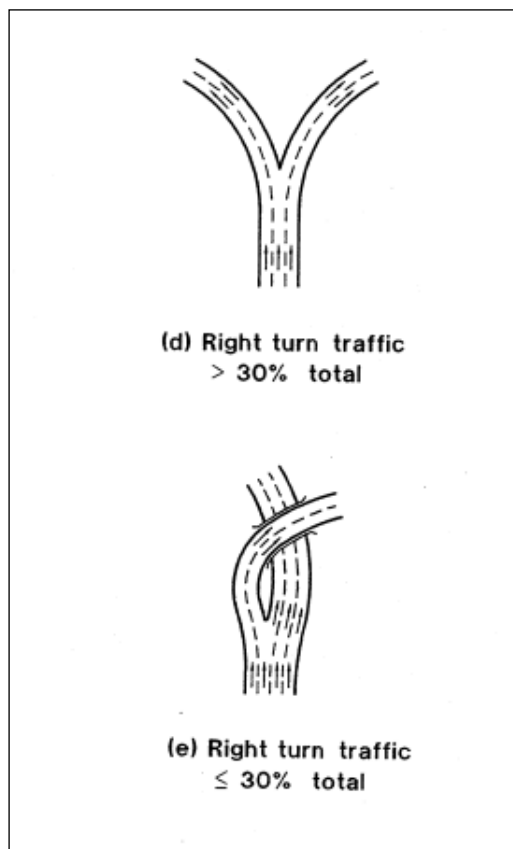


**Figures 7 (a): T Interchanges**

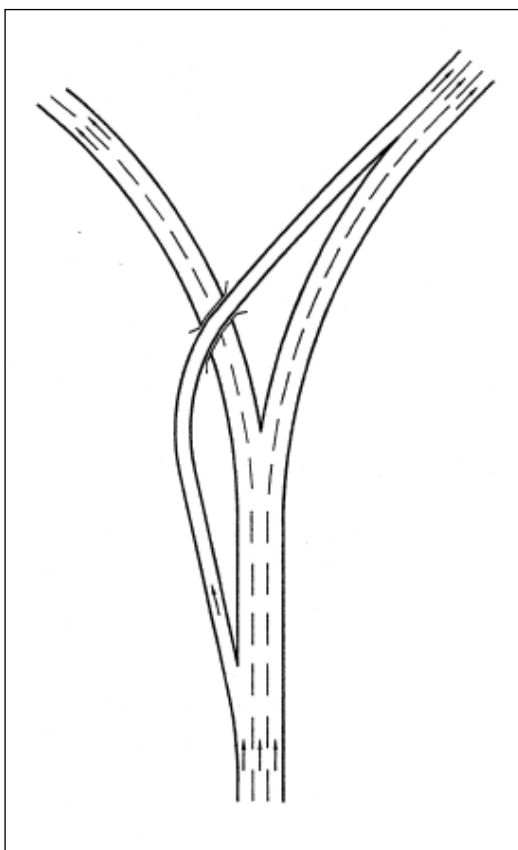




**Figures 7 (b) and (c): T Interchange Variants**



**Figure 7 (d) and (e): Major Fork Options**



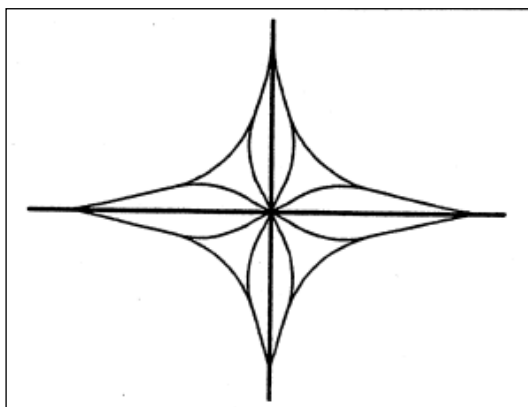
**Figure 7 (f): Truck Ramp at Major Fork**

### **6.5.2 (c) The Stack**

#### **The Basic Stack**

The Basic Stack is among the most effective four-leg freeway-to-freeway interchanges which provide direct connections for all movements. Other four leg freeway-to-freeway interchanges can be considered as variations to the basic stack. The name "stack" relates to the arrangement of the ramps, which are stacked in pairs at different levels at the centre of the interchange.

Because of the high cost of four leg interchanges, several options should be considered, as even minor adjustments may significantly affect the construction cost or traffic operation.



**Figure 8: The Basic Stack**

## Economic Factors

The cost of a stack depends on a number of factors including the ramp arrangement, the depth of cut and the curve radii used on the ramps.

(i) *Ramp arrangements*

The options available are shown in **Table 2**.

(ii) *Design Speed*

Although significant savings can be made by reducing ramp design speeds, safety is paramount, and the design speeds for ramp curves must correspond to the estimated operating speeds, see *AGRD Part 3, Section 3* and associated VicRoads supplement.

(iii) *Earthworks Balance*

Generally, construction costs decrease with cut depths relative to the cost of constructing from ground level upwards. Earthwork balance is required for maximum savings of up to 40 per cent, and this could require a cut approximately 10 metres deep. However, if pumped drainage is required, savings may not be realised.

(iv) *Angle between Freeways*

Costs increase with skew and become significant when the skew angle exceeds 15 to 20 degrees.

(v) *Structural Controls*

Significant savings in structure costs can be made by standardizing the spans on as many structures as possible. The example below shows typical pier locations for an S1 stack.

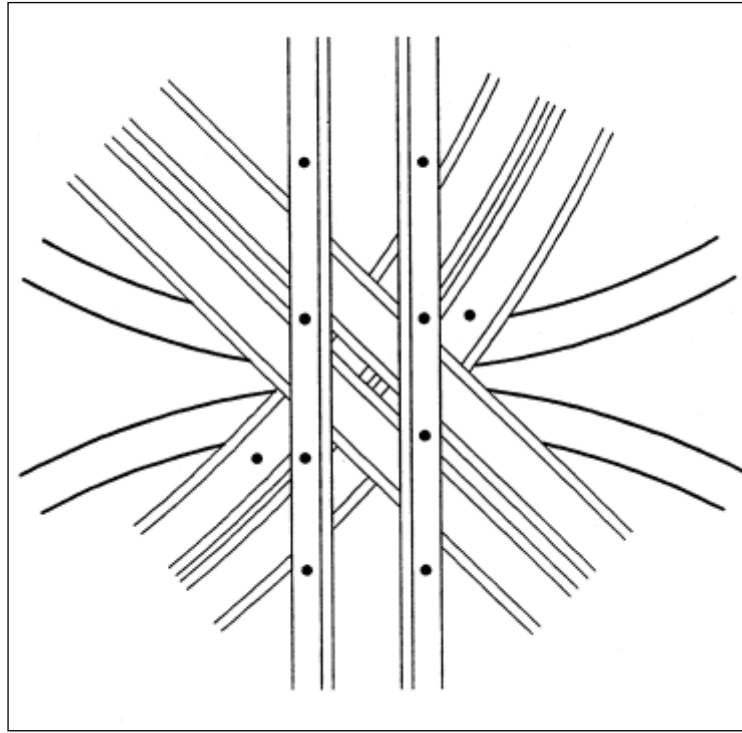
Note the spacing between the upper ramps which has been designed to enable the ramp to be supported on single piers. Note also the use of equal spans on the upper structure.

**Table 2: Ramp Arrangement Options for the Stack**

Roadway Level	Type of Stack					
	S1	S2	S3	S4	S5	S6
Highest	Ramp	Ramp	Ramp	Freeway	Freeway	Freeway
	Freeway	Ramp	Freeway	Ramp	Ramp	Freeway
	Freeway	Freeway	Ramp	Ramp	Freeway	Ramp
Lowest	Ramp	Freeway	Freeway	Freeway	Ramp	Ramp

**NOTES:**

- Stack S1 has ramps at upper and lower levels with the two freeway carriageways in between. For cuts in excess of 8 metres deep, interchange S1 is the cheapest with the cost of the other interchanges increasing in order from S1 to S6.
- or cuts less than 8 metres in areas with relatively low land values, interchange S2 can be cheaper than S1. The cost of the other stacks increase in the order shown. A disadvantage of S2 is the high rise and falls required for each ramp. For this reason S1 is considered to be preferable to S2.
- Stack S4 has the best ramp geometry overall with minimum rise and fall.
- Stack S5 does not appear to have any particular merit although S5 type interchanges have been constructed in the USA. The Hollywood Pasadena / Santa Anna Freeway interchange in Los Angeles is an example of this interchange. This layout should only be considered where local controls have a major influence on the ramp arrangement.
- Stack S6 would only be considered if both freeways were elevated on the approaches.



**Figure 9: Pier Positions for Upper Ramps in Stack Type S1**

(vi) *Interchange Height*

Where an interchange is mainly on filling, there is a loss of capacity with increasing ramp height arising from reduction of truck speeds. This effect can be significant when the proportion of trucks exceed 10 per cent and where there are high rises and falls on the ramps.

Options available to the designer include:

- lower the interchange;
- choose a different ramp arrangement with less rise and fall;
- permit trucks to use the left shoulder;
- provide an additional lane for trucks;
- adopt a different interchange layout with less rise and fall on the ramps.

**Variants of the Stack**

The Open Stack is a variant in which all the centrally located ramps are replaced by inner ramps, see **Figure 10(a)**. Variants of the Open Stack with the inner ramps moved out further from the centre are shown on **Figure 10(b) to 10(e)**. These layouts are usually not favoured because they require more land than other options.

Open stacks may be considered for use where:

- land is cheap, usually in rural areas, or
- the basic stack is considered to be unacceptably high because of noise or visual intrusion effects, and
- the slight savings in travel distance are considered to be worthwhile.

There are many other variants of the stack, replacing centrally located ramps with combinations of inner and outer ramps, as shown in **Figure 11**.

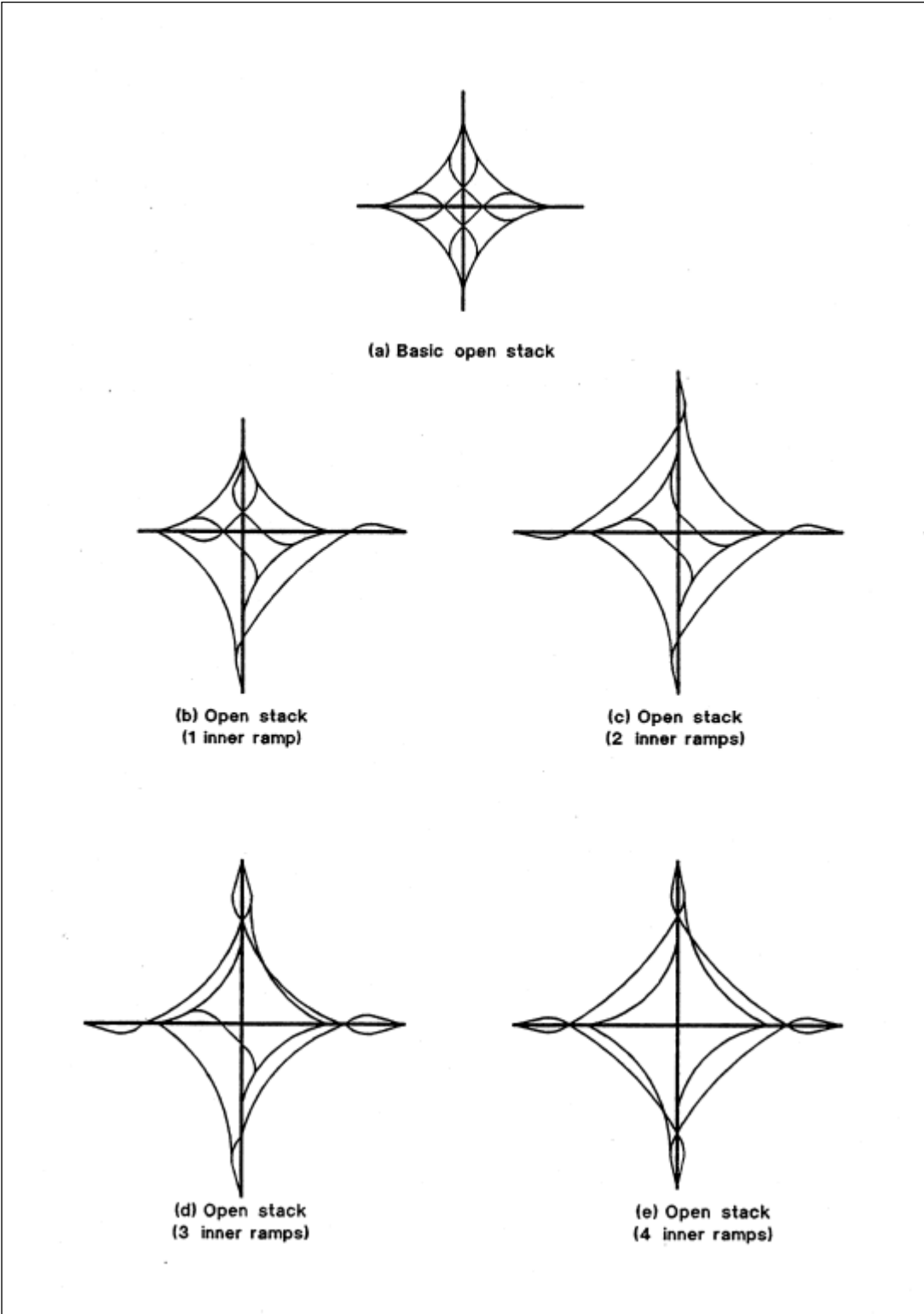
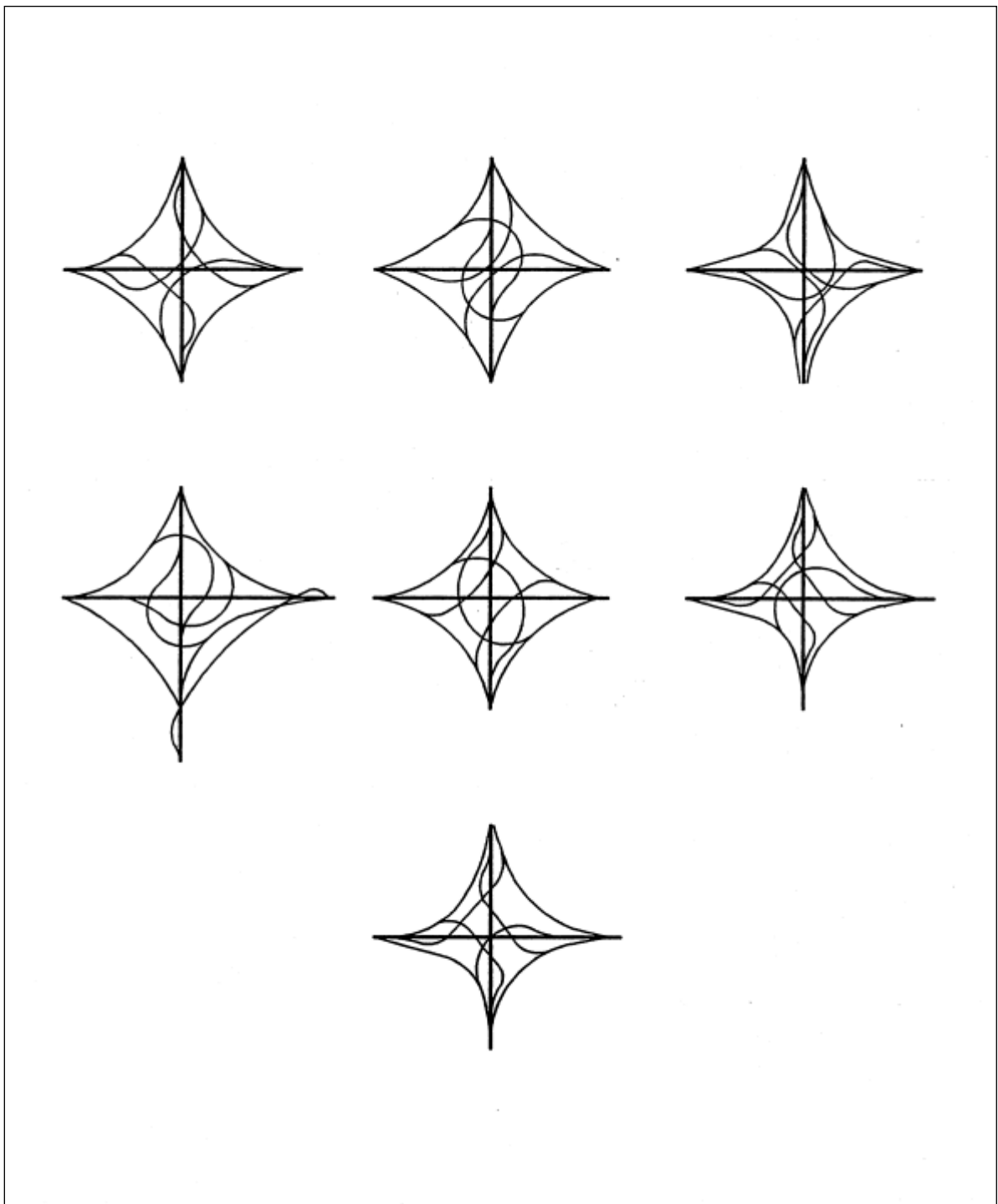


Figure 10(a) to (e): Open Stacks and Variants



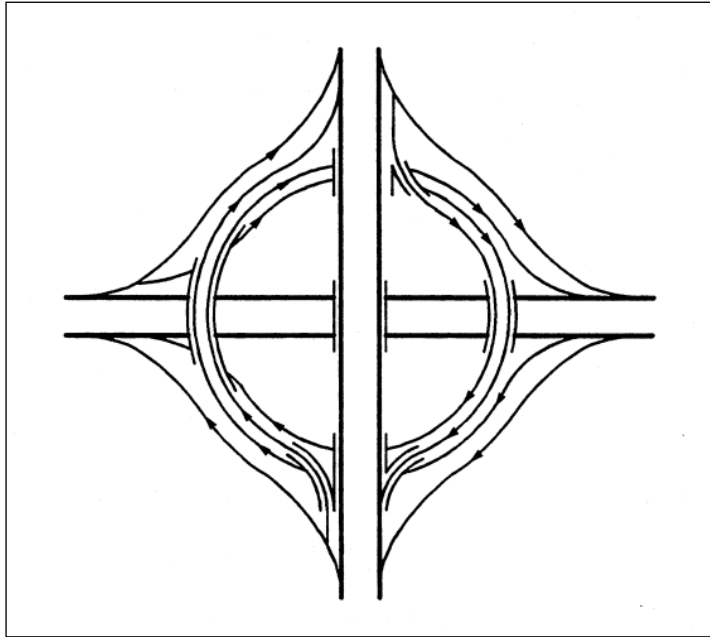
**Figure 11: Variants of Stack Interchanges**

The Turbine is a stack with outside turns as shown on **Figure 12**. Some variants of The Turbine include loops. The variants are shown in **Figure 13**.

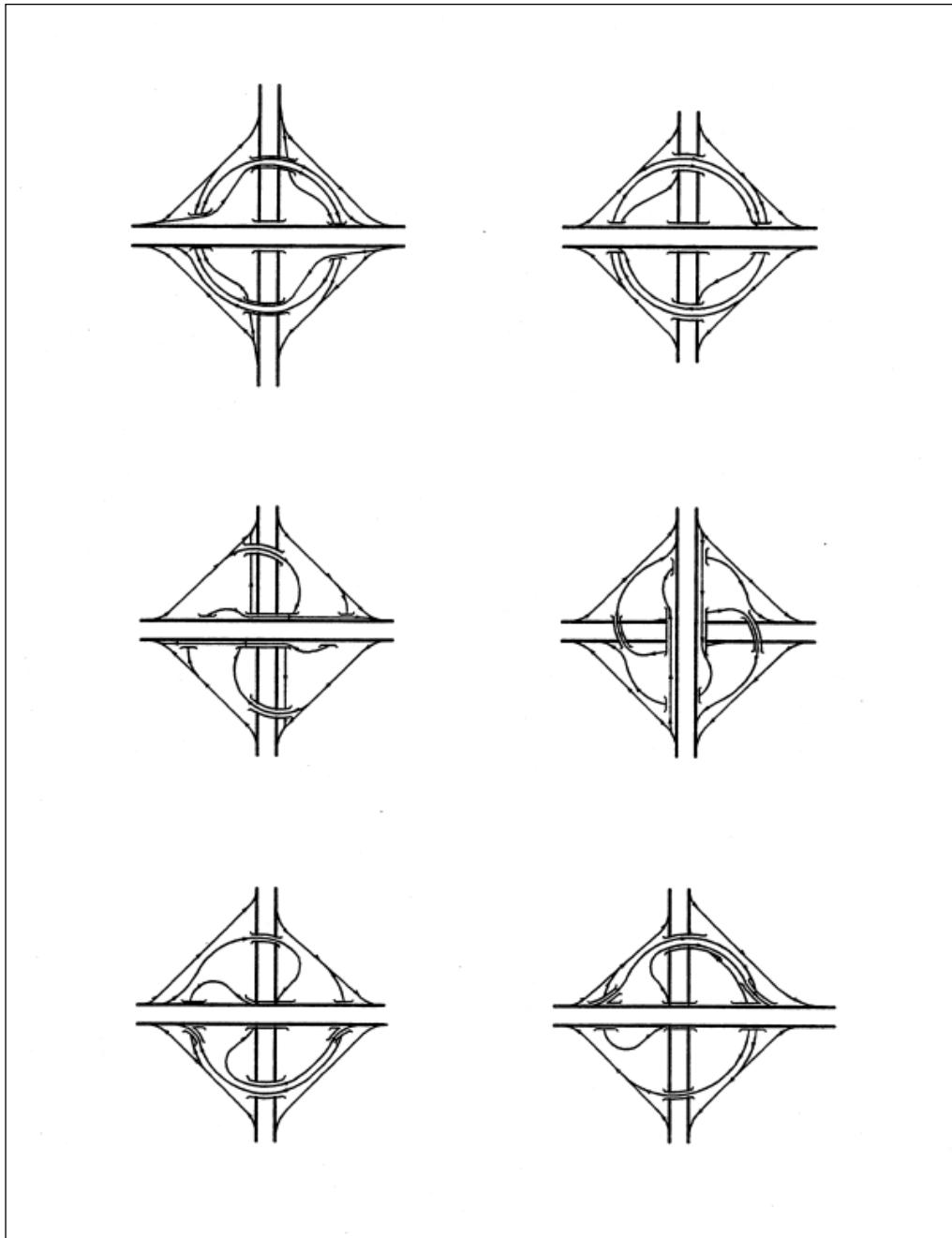
The Turbine could be considered for use where:

- the height of a stack is considered visually intrusive in urban areas;
- the use of simple single level structures is desirable, such as in areas with poor foundation conditions.

A disadvantage of The Turbine is the low radius curve either at the start or end of each turbine ramp.



**Figure 12: The Turbine Interchange**



**Figure 13: Variants of Turbine Interchanges**

### 6.5.2 (d) Interchanges with Loops

Loops are ramps which provide indirect right turn movements. They are usually circular. A single lane loop should only be considered for a quadrant with traffic volumes less than 900 pcu/h in the design year.

Loops have been incorporated into many interchanges overseas because they are cheaper than semi-direct turning roadways and require less land acquisition. However, accident rates are higher than comparable rates on turning roadways.

A number of interchanges in the USA which were originally constructed with loops have subsequently had turning roadways constructed to replace the loops in order to increase capacity.

A *cloverleaf interchange* may be considered at the intersection of two freeways in a rural environment where right-turns at-grade are to be avoided, demand for weaving is minimal, and the cost of right-of-way is relatively low. This interchange form has the safety disadvantage of low speed loops exiting from high speed lanes.



*Partial cloverleaf* designs may be used where land is not available in one or two quadrants, or where one or two movements in the interchange are large compared to the others and grade separation of the movement would provide superior operation. *Cloverleaf interchanges* with or without collector distributor roads are usually not economical for urban construction because of the large area required.

### The Cloverleaf

The Cloverleaf Interchange has a loop in each of the four quadrants. However, only the cloverleaf with two sets of collector distributor roads is suitable for use as a freeway to freeway interchange, see **Figure 14**. The topic of collector-distributor roads is covered in **Section 6.5.2.(e)**. The interchange is better suited to a semi-rural or rural area, due to the large area it occupies.

The disadvantages compared with direct or semi-direct interchanges are the extra travel distance required for right turning traffic, and the weaving manoeuvres generated between adjacent entry and exit noses.

Collector-distributor roads should be used in order to avoid:

- two closely spaced exits on the main carriageway,
- problems associated with signing for the second exit, and
- weaving on the main carriageway.

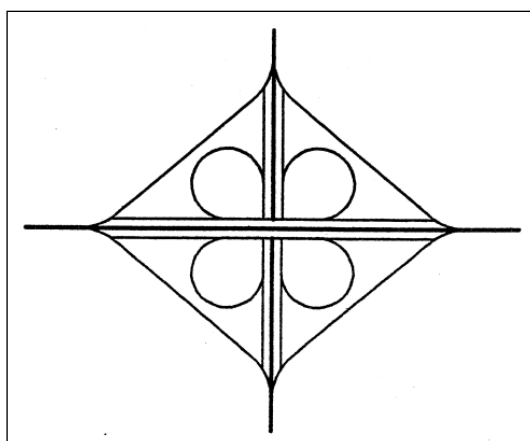
An analysis should be undertaken on weaving between the two adjoining loops, as at certain volumes interference increases rapidly and causes a reduction of through traffic speed.

Two lane loops would require widening of the grade separation structure by two lanes, larger radii and greater separation of the terminals of adjacent ramps. Usually two lane loops are not economical on account of construction cost, land acquisition, and additional travel distance. Therefore, two lane loops are rare.

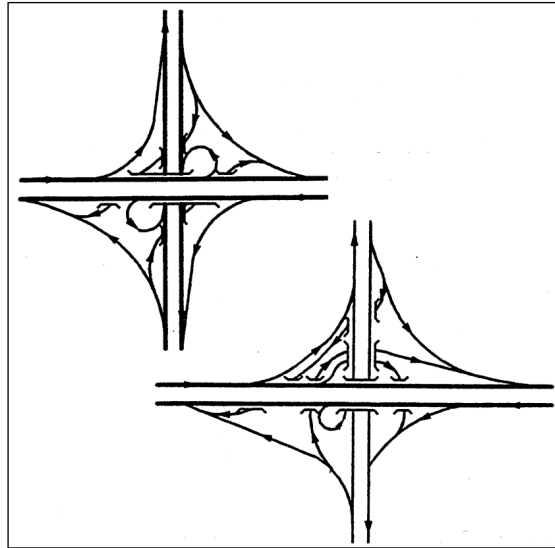
Economic evaluations comparing loops with directional ramps should take into account the additional costs of the collector distributor roads required.

### Other Interchanges with Loops

Semi-directional interchanges with loops but no weaving are shown on **Figure 15**. Spread of through lanes is not required for these schemes. However, four or more structures are required. Single exits and entrances on the left enhance operational characteristics of these layouts.



**Figure 14: Cloverleaf with Two Sets of CD Roads**



**Figure 15: Other Interchanges with Loops**

#### **6.5.2 (e) Collector Distributor Roads**

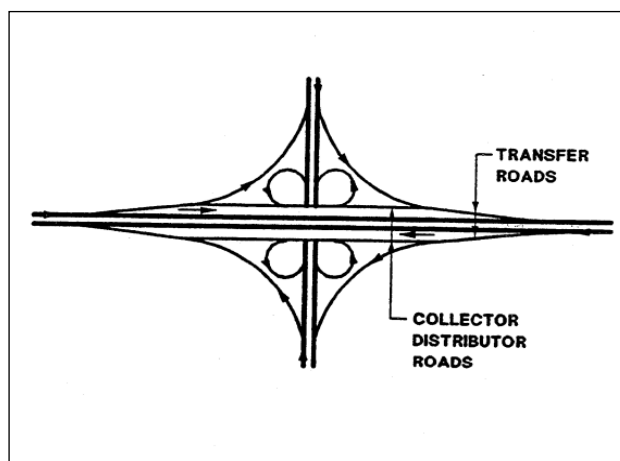
The purpose of a collector-distributor road is to accommodate weaving clear of the through carriageway, and to provide adequate capacity while minimising the number of entry and exit points, see **Figure 16**. Collector-distributor roads are one-way roads which traverse a single interchange, or pass through two interchanges, or which pass continuously through several interchanges rather like a continuous frontage road except that access to abutting property is prohibited. In addition to removing weaving from the through carriageways, collector-distributor roads allow single entrances and exits to be developed, allow exits from the through carriageway to occur in advance of the structure, and allow a uniform pattern of exits to be maintained.

The minimum number of lanes on a collector distributor road is two. Continuous collector-distributor roads should be integrated into the basic lane design, and capacity analysis and basic lane determination should be performed for the overall system rather than for the separate carriageways. The operating speed of collector distributor roads is usually slower than the main carriageway because of the interference caused by weaving.

The shoulders on a collector distributor road should at least equal the widths of those on the adjacent main carriageway, and in weaving sections it is desirable to have a 3-metre right shoulder so that trapped or broken-down vehicles do not disrupt traffic flow.

The collector-distributor road should be separated from the main carriageway by the required minimum width of clear zone, or by a safety barrier.

Operational problems will occur if collector-distributor roads are not properly signed, and those servicing more than one interchange will require special consideration.



**Figure 16: Collector Distributor Roads**

## Transfer Roads

Connections between the main carriageways and collector distributor roads are called transfer roads, which may be either onyese or two lanes. The principle of lane balance applies to design of transfer roads at both ends. The left-hand shoulder of the transfer road should be equal in width with that on the main carriageway. The terminals of the transfer roads should be designed as entry or exit ramps, see *AGRD Part 4C, Sections 11.2 and 11.3*.

## 6.5.3 Service Interchanges

### General

(In this section, “secondary” describes any road of lesser classification than a freeway. In many cases this will be an arterial road, but in rural areas it is common for interchanges to be placed at intervals on roads which serve local and municipal traffic circulation.)

Freeway to secondary road interchange types usually include a stop condition on the turning movements associated with the secondary road. Capacity of the interchange is restricted by the conflicting traffic movements on the secondary road, and can be improved by provision of additional lanes at the ramp terminal and on the secondary road approaches.

An interchange desirably should provide for all traffic movements because operational problems may result if any movements cannot be performed. Generally, where an exit or entry movement is provided, the reverse movement should be provided as well. Exceptions may only occur in inner city areas, perhaps in conjunction with a one-way street system.

Common criteria include the design principles listed in *AGTM Part 6, Section 6.3, Section 6.2.2 (h)* and others such as:

- i. use single lane exits where traffic volumes permit because they are simpler for drivers to comprehend and therefore easier to sign;
- ii. avoid use of at grade intersections along freeway main carriageways, see **Section 6.2.2, Warrants**.

### Buttonhook Ramps

Unusual configurations where ramp connections are made to roads remote from the secondary road over the freeway, such as so-called “buttonhook” ramps, should be avoided, as they confuse many drivers.

#### 6.5.4 Characteristics of Service Interchange Types

##### Figure 6.7 (AGTM, Part 6): Conventional Diamond Interchange

Reasons for the preference given to diamond interchanges include:

- i. they are readily recognised from the freeway, and consistently present the simple driving tasks of exiting from the left, decelerating on the ramp, and turning at the terminal;
- ii. diamond type ramps are about 30 per cent safer than loop ramps;
- iii. the right of way requirements are lower than Parclo's A and B;
- iv. all exits precede the bridge, a desirable operational feature;
- v. ramp terminals can be signalised when warranted;
- vi. where other roads intersect near the ramp terminal, a roundabout may be an appropriate ramp terminal treatment.

##### Figure 6.11 (AGTM, Part 6): Split Diamond Consideration

Performance is improved if the split diamonds are placed on pairs of one way roads as shown on **Figure 13a**. One advantage is that storage on the structure for right turning vehicles is not required.

##### Figure 6.13 (AGTM, Part 6): Grade Separated Roundabout

Traffic volumes of 30,000 to 35,000 pcu's/day can be handled on the roundabout although delays to lower volume movements occur if the traffic movements are not balanced. In this circumstance, performance can be improved by signalising the entries to the roundabout.

As an ultimate development, the cross road can be grade separated over the roundabout to create a three level roundabout interchange, see **Figure 15a**.

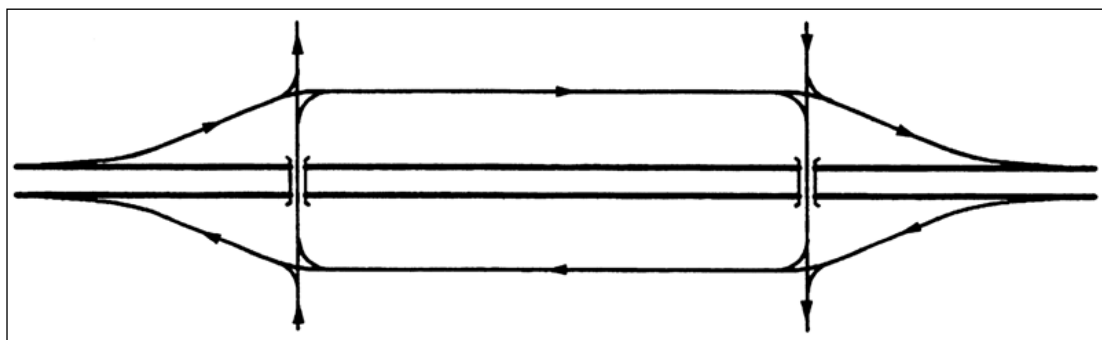
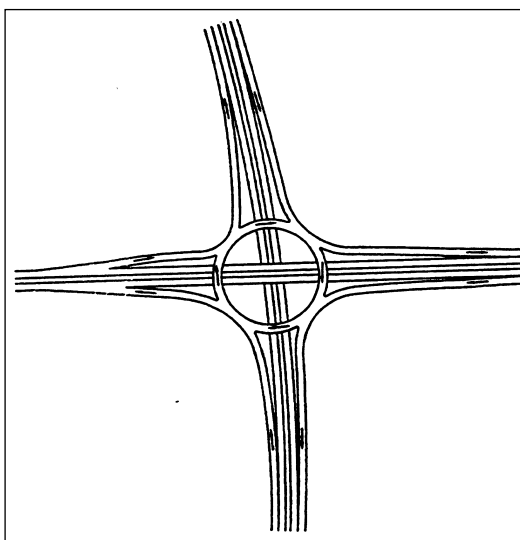


Figure 13a: Alternate Split Diamond Interchange



**Figure 15a: Three Level Roundabout**

***Figure 6.14 (AGTM, Part 6): Single Point Urban Diamond (Fast Diamond)***

The minor (secondary) road grade should be less than 2%.

Single point urban diamonds cost 50% to 100% more to construct than conventional diamonds, due mainly to the structures. In the secondary-road-over case, complex shaped structures are required. Wider structures are often required so that the bridge railing is offset sufficiently to meet sight distance requirements.

## Section 6.7 Basic Lane Numbers and Lane Balance

### 6.7.1 Basic Lane Numbers

Localised volume decreases are ignored, while increases on short sections may be accommodated by auxiliary lanes.

An increase in the basic number of lanes **is required** where traffic builds up sufficiently to warrant an extra lane in each direction over a substantial length of the route.

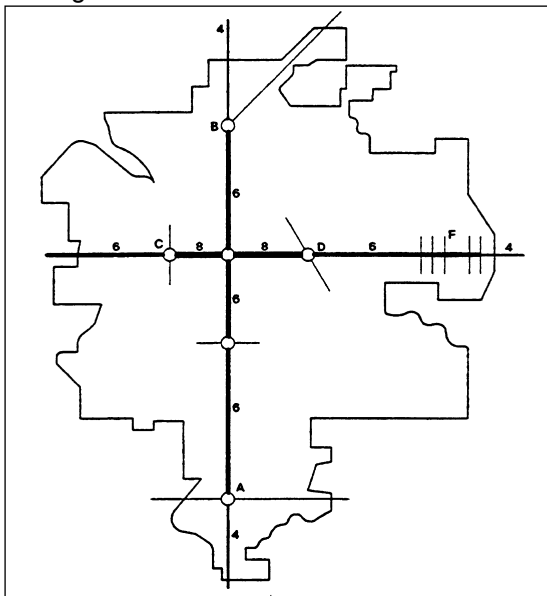


Figure 16: Basic Number of Lanes

## Section 6.8 Traffic Considerations

### 6.8.2 Traffic Data Requirements

Estimation of traffic volumes may be based on either:

- i. transport planning studies in urban areas involving the estimation of future network volumes using computer modelling techniques, together with a detailed assessment of localised influences; or
- ii. in rural areas, estimated volume based on growth trends within corridors.

In urban areas capacity is normally important, and designs are based on predicted peak hour volumes for the design year. However, the traffic demand on a new freeway may result in it operating at capacity a relatively short time after opening. In this situation the design should aim to provide reasonable capacity, but more importantly to achieve a balanced level of service throughout the freeway.

### 6.8.4 Level of Service

Refer to *AGTM Part 3: Traffic Studies and Analysis* for Level of Service definitions and methods of analysis. The most critical points for analysis are usually just upstream of a diverge or just downstream of a ramp merge. Traffic using the interchange elements should be able to operate at a satisfactory level of service without reducing the design level of service on the freeway.

Calculations should be carried out in accordance with the *Highway Capacity Manual* (Transportation Research Board 2000).

Target levels of service in the design year will be influenced by economic and political criteria, and the designer should aim to achieve the highest practicable levels. Suggested guidelines are set out in Table 3. The appropriate measure for signalised ramp terminals is degree of saturation rather than level of service. Closely spaced ramp terminals where signals will be required should be designed as complex signalised intersections. Four phase systems with phase overlap are more efficient than three phase systems. The target sum of the critical ratios of flow to saturation flow in the design year should not exceed 0.9.

Road Type	Environment and Terrain			
	Rural Level	Rural Rolling	Rural Mountainous	Urban and Suburban
Freeway	B	B	C	C
Arterial	B	B	C	C
Collector	C	C	D	D
Local	D	D	D	D

**Table 3: Target Levels of Service in Design Year**

### Section 6.10 – Signing, Marking and Lighting

VicRoads policies and guidelines for road lighting are given in TCG006 – Guidelines for street lighting design.

## Section 8 – Pedestrian and cyclist crossings of roads

### Section 8.2.1 – General Considerations for All Road Users

#### *Additional Information to Table 8.1 Benefits of treatments – general crossing facilities.*

##### a) Pedestrian Refuges

Pedestrian refuges are kerbed islands near the centre of a road. They are perhaps the best treatment that can be provided to help pedestrians get across undivided roads with moderate to heavy traffic, because they simplify the task of crossing the road: a gap in only one direction of traffic needs to be found at any one time. Refuge islands need to be adequately delineated; edge lines on the approaches to a refuge island should be continued past the sides of the island, without any gap in the line (eg. at the pedestrian position) to guide drivers past the island. Road lighting should be provided in accordance with AS 1158.3.1 and AS 1158.4.

APPROPRIATE LOCATIONS	INAPPROPRIATE LOCATIONS
<ul style="list-style-type: none"> <li>• Where adequate room is available for traffic to pass (consider parking bans to achieve this).</li> <li>• Where there are high numbers of pedestrians.</li> <li>• Where it overcomes a sight distance restriction in one direction for pedestrians.</li> <li>• On safe routes to school.</li> <li>• Over an extended length of road in conjunction with a painted median.</li> <li>• At tram stops on undivided roads, for 'wrong side' loading, in conjunction with pedestrian signals and road widening to retain number of traffic lanes.</li> <li>• In conjunction with a median turning lane.</li> </ul>	<ul style="list-style-type: none"> <li>• On a traffic route where it reduces the number of traffic lanes (consider realigning the kerbs to maintain number of lanes)</li> <li>• Where a heavy right turn volume occurs and a right turn lane cannot be provided if the refuge island is provided.</li> <li>• Where they are not expected by drivers or can't be lit or delineated adequately.</li> </ul>
ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none"> <li>• Allow pedestrians to cross in two stages and find a gap in only one direction of traffic at a time.</li> <li>• Can be low cost.</li> <li>• Available for use by pedestrians at all times.</li> <li>• Provide some physical separation from traffic for pedestrians.</li> <li>• May reduce vehicle speeds.</li> <li>• Low maintenance compared to pedestrian operated signals.</li> </ul>	<ul style="list-style-type: none"> <li>• If used with a pedestrian crossing, may lead to confusion about right of way near the island.</li> <li>• May reduce on-street parking.</li> <li>• Road width reduction may squeeze cyclists.</li> <li>• May require road widening.</li> </ul>

##### b) Medians

Typical pedestrian behaviour is to use a direct route between two points, even at increased risk. Medians help reduce the risk. Medians should be kerbed or 'raised' (except on freeways, where kerbs increase the severity of any crash). On traffic routes, semi-mountable kerbing should be used. Where a kerbed median cannot be provided in an urban area, a painted median will usually require refuge islands at intervals, to create adequate separation of traffic and refuge space for pedestrians.



APPROPRIATE LOCATIONS	INAPPROPRIATE LOCATIONS
<ul style="list-style-type: none"> <li>On a traffic route, where adequate room is available to maintain the number of traffic lanes (consider parking bans to achieve this).</li> <li>Where there are high numbers of pedestrians.</li> <li>Where there is a history or likelihood of head-on crashes.</li> <li>Where tram tracks are being reconstructed and the road is wide enough for traffic lanes plus a median.</li> </ul>	<ul style="list-style-type: none"> <li>On a traffic route where it reduces the number of traffic lanes.</li> <li>Where a heavy right turn volume occurs and a right turn lane cannot be provided if the median is provided (redesign and leave gap in median for a length of right turn lane).</li> </ul>
ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none"> <li>Allow pedestrians to cross in two stages and find a gap in only one direction of traffic at a time.</li> <li>Reduces the frequency of head-on collisions.</li> <li>Controls turning movements.</li> </ul>	<ul style="list-style-type: none"> <li>Road width reduction may squeeze cyclists.</li> </ul>



**Example of a Kerbed Median**



**Example of a Painted Median**

### c) Kerb Extensions

Kerb extensions benefit pedestrians by reducing the pavement width they need to cross, and by making pedestrians more visible to approaching motorists. Figure 4 shows a typical treatment.

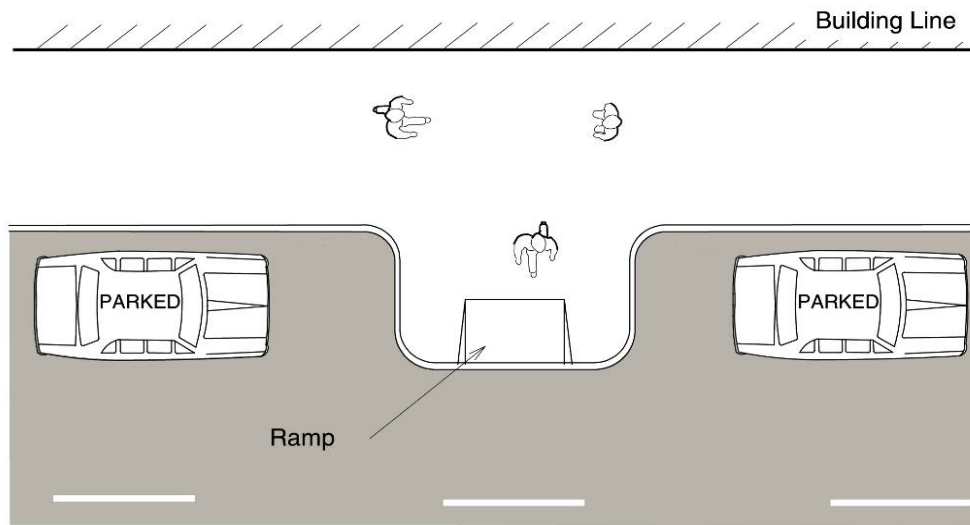


Figure 4 Typical Kerb Extension

4. APPROPRIATE LOCATIONS	INAPPROPRIATE LOCATIONS
<ul style="list-style-type: none"> <li>On traffic routes where the number of traffic lanes is maintained or the number of traffic lanes has been determined through an area-wide assessment, possibly including parallel routes and cross routes.</li> <li>In local shopping centres.</li> <li>At school crossings.</li> <li>On the 'downstream' side of a side road.</li> </ul>	<ul style="list-style-type: none"> <li>Where the left edge of the road is needed for moving traffic (part time or full time).</li> <li>Where they are not expected by drivers or can't be lit or delineated adequately.</li> <li>Where traffic needs to shift left to turn left (e.g. to avoid rear end collisions).</li> <li>Adjacent to bus stops or loading zones where it will impede ingress or egress (consider reshaping it or shifting the parking restrictions).</li> </ul>
5. ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none"> <li>View between pedestrian and approaching traffic is improved (on a straight or a curve).</li> <li>The width of road to walk across is reduced.</li> </ul>	<ul style="list-style-type: none"> <li>Unless installed in conjunction with a refuge island or median, pedestrians must still select a gap in both directions of traffic at once.</li> <li>May reduce on-street parking</li> <li>Prevents the parking lane from being used as a traffic lane.</li> </ul>

### d) Pedestrian Fencing

Pedestrian fencing may be useful in controlling pedestrian access to the roadway however, should be seen as a 'last resort' option for managing pedestrian crossings.

In the event of a collision, pedestrian fences must not present an additional hazard. Particular consideration should be given to ensuring there are no horizontal rails that can separate from the rest of the fence

structure during a collision and form a spearing hazard; and that the sections of fencing are separable in the event of a collision to reduce the likelihood of roll-over.

The design of any pedestrian fencing must not restrict driver visibility at critical locations - either to pedestrians or to other vehicles, e.g. at intersections and driveways.



**Example of pedestrian fencing**

APPROPRIATE LOCATIONS	INAPPROPRIATE LOCATIONS
<ul style="list-style-type: none"> <li>• Near pedestrian crossings to guide pedestrians to the crossing.</li> <li>• Outside hotels to keep patrons off the roadway.</li> <li>• At bus stops, especially school bus stops, to keep patrons off the roadway.</li> <li>• Near intersections, to prevent jay-walking.</li> <li>• At locations where parking is (or needs to be) banned but illegal quick stop parking occurs.</li> <li>• Opposite school gates.</li> </ul>	<ul style="list-style-type: none"> <li>• Where the fence and/or the posts may obstruct sight lines between road users (design the fence so this does not occur).</li> <li>• Where pedestrians are unlikely to agree to being diverted and will seek to go around the wrong way (Select another type of treatment).</li> <li>• Where the hazard is no less for pedestrians at the end of the fence.</li> <li>• Where kerbside parking is permitted.</li> </ul>
ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none"> <li>• Redirects pedestrians to a safer crossing point.</li> <li>• Effective in stopping illegal parking.</li> </ul>	<ul style="list-style-type: none"> <li>• May get hit by errant vehicles.</li> </ul>

**e) Improved Street Lighting**

Improved street lighting should be considered at high pedestrian usage areas such as at bus and tram stops, where pedestrian safety is a potential concern. As the use of a shopping centre changes, such as with more late night shopping or increased restaurant activity, the suitability of street lighting should be reviewed and upgraded if necessary.

**Additional Information to Table 8.2 Benefits of treatments – time separated (traffic controlled) facilities**

**f) Pedestrian (Zebra) Crossings**

A pedestrian crossing is defined in Rule 81 of the *Road Safety Road Rules 2009* as an area of a road—

- “(a) at a place with white stripes on the road surface that—
  - (i) run lengthwise along the road; and
  - (ii) are of approximately the same length; and
  - (iii) are approximately parallel to each other; and
  - (iv) are in a row that extends completely, or partly, across the road; and
- (b) with or without either or both of the following—
  - (i) a pedestrian crossing sign;
  - (ii) alternating flashing twin yellow lights.”

‘Pedestrian crossing sign’ means a sign similar to that illustrated in Road Rule 81.



(Sign R3-1)

A pedestrian crossing sign is a Major Traffic Control Device and its installation or removal is not delegated to Council.

**g) Pedestrian (Zebra) Crossings at left turn slip lane**

Zebra crossings should be installed on slip lanes if there is a potential danger to pedestrians and it is an appropriate treatment for the volume of pedestrians and vehicles present. Additional factors, apart from pedestrian and vehicle volumes which may lead to the installation of a pedestrian facility include 85 percentile speeds of vehicles using the slip lane, sight distance to pedestrians on the left hand footpath, the width of the slip lane, the number of heavy vehicles or the presence of pedestrians with special needs. Examples of best practice include:

- Low volumes of pedestrians and vehicles with little likelihood of conflict between them and good sight distance - treatment unlikely to be required;
- Low volumes of pedestrians and vehicles but poor sight distance to the left hand kerb line of the slip lane or pedestrians with special needs or high vehicle speeds and/or high numbers of heavy vehicles leading to the potential for conflict- installation of zebra crossing;
- Routinely used by pedestrians and significant vehicle numbers leading to the potential for conflict- installation of zebra crossings;
- Higher pedestrian numbers which are conflicting with vehicles and where the installation of a zebra crossing will lead to significant vehicle delays - installation of fully signalised pedestrian crossing.

**h) Pedestrian Crossings with Flashing Lights**

The installation of a pedestrian crossing with flashing lights may be appropriate where, for any one hour of an average weekday, the following apply:

- The number of pedestrians crossing within 20 m of the proposed site exceeds 60 persons per hour, and
- The number of vehicles per hour which pedestrians have to cross in one bound exceeds 500.

*NOTE: In determining the pedestrian numbers, each older person, person with a disability and unaccompanied child of primary school age should count as two.*

Pedestrian crossings with flashing lights are best used where traffic speeds are lower (due to congestion, traffic management devices or restricted carriageway widths). A typical situation would be in a shopping

street or commercial area. Drivers are more aware of pedestrians in these situations and with lower speeds drivers will be more inclined to give way to pedestrians. At locations where the above guidelines are met but traffic speeds are higher, pedestrian operated signals should be considered.

Pedestrian crossings give pedestrians priority over vehicles. Delays to both pedestrians and vehicles may be minimised compared with pedestrian operated signals, although vehicle delays can increase considerably when pedestrian flows become very high.

Road Rule 172 of *Road Safety Road Rules 2009*, establishes a 'No Stopping' area of 20 m on the approach side and 10 m on the departure side of a pedestrian crossing. These distances are measured from the nearest part of the pedestrian crossing. However, parking may be permitted within these statutory No Stopping distances by use of permissive parking signs. This should only be done if the parking is indented.

#### **i) Pedestrian Crossings Without Flashing Lights**

A pedestrian crossing without flashing lights is a legal pedestrian crossing under Road Rule 81. However, these devices should generally be used under the circumstances outlined below.

Pedestrian crossings without flashing lights are Major Traffic Control Devices, requiring VicRoads approval for their installation, removal or alteration.

It is acceptable to install pedestrian crossings without flashing lights across left turn slip lanes at signalised intersections where pedestrian demands are high and pedestrian safety is not achieved due to poor sight distance. Consideration should be given to erect advance pedestrian crossing ahead warning signs on the approaches to the crossing.

Acceptable Locations:

- Collector and local roads on which traffic speeds are low.
- Left-turn slip lanes at signalised intersections where VicRoads Regions consider them to be necessary.
- Car parks.
- Other off-road situations, eg. caravan parks, reserves.
- Service roads where pedestrian operated signals or intersection signals operate on the main carriageway.

Unacceptable Locations:

- Across arterial roads
- Left turn slip lanes at unsignalised intersections (unless considered necessary for pedestrian safety).
- Where there is poor visibility on the approach to the proposed site of the crossing, or where conspicuity of the device may be less than optimal.

General Guidelines:

- Pedestrian volumes of 20 or more per hour.
- Vehicle volumes of 200 or more per hour for the same hour.
- Speed limit of 50 km/h or less.
- Vehicle speeds of 60 km/h (85th percentile) or less.

*NOTE: In determining pedestrian numbers, each older person, person with a disability and unaccompanied child of primary school age should count as two.*

#### **j) Children's Crossings**

The provision of a children's crossing may be considered at locations where during any hour on a normal school day, 20 or more children cross the road within 20 m of the proposed crossing location and the vehicle flow during the same hour exceeds 50 vehicles per hour.

The above figures should be used for a Council installing a children's crossing under the delegation by VicRoads. If the above figures are not met and the Council wishes to install a children's crossing, the proposal should be submitted to the VicRoads Regional Director and consent sought to the Major Traffic Control Device.

A children's crossing should not be installed for the sole use of kindergarten children unless the children will be escorted by an adult when using the crossing.

These crossings should not be installed where the speed limit during operation is above 60 km/h.

Following approval for the installation of a children's crossing, it is the responsibility of Council in accordance with the Code of Practice 'Operational Responsibility for Public Roads' to arrange for the installation of the crossing on municipal and arterial roads in accordance with standards provided by VicRoads, and to provide the standard "Children Crossing" flags (sign R3-3).



**Example of Children's Crossing**

### **Additional Information to Table 8.3 Benefits of treatments – grade separated facilities**

#### **k) Grade Separation**

Grade separated pedestrian facilities, (achieved through pedestrian bridges, overpasses or subways) provide the highest level of safety for pedestrians crossing roads. However, in practice, pedestrians often do not use these devices due to the additional walking time and distance required to negotiate the access ramps.

The cost of the facility requires a careful benefit/cost assessment in order to provide best use of resources by comparing with alternative lower cost pedestrian treatments. Grade separated crossings are best used where topography minimises the length of ramps required.

To give equal access for all users, it is generally necessary to use ramps and not stairs to access the overpass. The design of ramps must comply with AS 1428:2010 Design for Access & Mobility.

Grade separation of a pedestrian crossing may be justified if each of the following conditions are met for at least one hour of a normal weekday.

Where the proportion of pedestrians under 12 years of age and over 60 years of age is 40% or less.

- undivided road  $V > 850$ ;  $P > 250$ ; and  $PV > 250,000$ , or
- divided road  $V > 1,500$ ;  $P > 250$ ; and  $PV > 400,000$

Where the proportion of pedestrians under 12 years of age or over 60 years of age is greater than 40%.

- undivided road  $V > 750$ ;  $P > 200$ ; and  $PV > 180,000$ , or
- divided road  $V > 1,100$ ;  $P > 200$ ; and  $PV > 280,000$

V is the volume of vehicular traffic (2 way) in vehicles/hour.

P is the volume of pedestrian traffic in pedestrians/hour.

### **Additional Information for Table 8.4 Benefits of treatments – integrated facilities**

#### **l) Shared Zones**

Further information on Shared Zones is found in:

- Austroads Guide to Traffic Management, Part 8 – Local Area Traffic Management, section 7.5.7
- VicRoads Supplement to Austroads Guide to Traffic Management, Part 8

- Austroads Guide to Traffic Management, Part 7 – Activity Centres, Commentary 3

### Section 8.2.3 – Crossings at Signalised Facilities

#### a) Connection to SCATS

Connection to SCATS (Sydney Coordinated Adaptive Traffic System) provides monitoring of the pedestrian operated signals and the facility to link the site to nearby signalised intersections if necessary. All pedestrian operated signals on arterial roads in metropolitan Melbourne must be connected to SCATS. All rural pedestrian operated signals on arterial roads should be connected to SCATS where practical. Pedestrian operated signals on municipal roads may be connected to SCATS at the discretion of the municipality.

#### b) Puffin Crossings

Puffin (**P**edestrian **U**ser **F**riendly **I**ntelligent) crossing facilities are similar in appearance to pedestrian operated signals and utilise the same hardware. They also include additional overhead detectors to detect the presence of pedestrians on the crossing. The guidelines for the installation of pedestrian operated signal crossings also apply to the installation of Puffin crossings.

Puffin crossings offer the following advantages:

- the clearance phase is shortened when the crossing detectors sense that a pedestrian has crossed quickly, reducing delays to vehicles,
- the clearance phase is lengthened when the crossing detectors sense pedestrians still on the crossing towards the end of the normal clearance time. This is an advantage for slower pedestrians.

In general, all new mid-block pedestrian operated signals should be installed as puffin crossings.

Puffin crossings may be used for a crosswalk at an intersection in the following circumstances:

- turns across the crosswalk are either fully controlled, in a slip lane or banned, (the detectors cannot distinguish between vehicles and pedestrians);
- there is adequate separation between the pedestrian crosswalk and the parallel vehicle path to avoid false detections of vehicles.

At a trial site, the traffic volume of a two lane fully controlled left turn movement increased 3-4% with the clearance time (3 second variation permitted) controlled by crossing detectors.

Puffin crossings are Major Traffic Control Devices and as such new installations, or conversions to Puffin crossings, require VicRoads approval. Regional Directors are authorised to approve the conversion to Puffin operation.

In order to ensure correct installation and operation, signal layout plans should clearly identify the proposed Puffin operation.



**Example of Puffin Crossing**

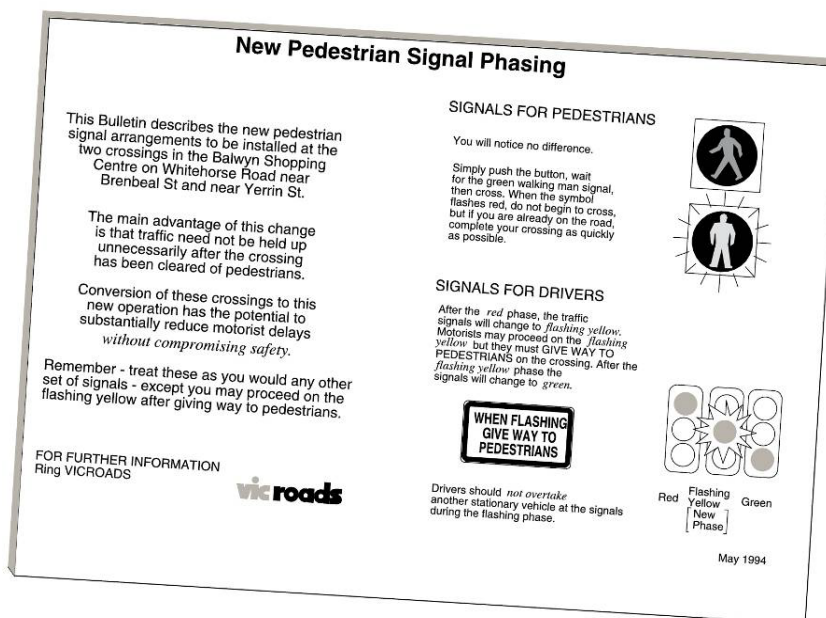
### c) Pelican Crossings

Pelican (**PE**destrian **L**ight **CON**trol) crossing facilities are similar in appearance to pedestrian operated signals and utilise the same hardware. Pelican crossings offer an advantage over normal pedestrian operated signal (POS) crossings by introducing an early start opportunity for vehicles to proceed if pedestrians have cleared the crossing. This early start facility is a flashing yellow phase for motorists, and it permits drivers to enter the crossing provided they give way to any pedestrians still on the crossing. Rule 65 of *Road Safety Road Rules 2009* covers this matter.

The conversion of a set of pedestrian operated signals to operate in the Pelican crossing mode requires VicRoads approval. If the crossing is in a 60 km/h speed zone (or less), authority to approve the conversion is delegated to the Regional Director. If the crossing is in a speed zone greater than 60 km/h the approval of the Manager, Road and Traffic Standards is required.

In order to ensure correct operation, the signal layout plans should clearly identify the proposed Pelican operation in the phasing diagram.

It is recommended that a black on white sign reading "WHEN FLASHING GIVE WAY TO PEDESTRIANS" (R3-V101) be placed at all new Pelican crossings to face drivers. It is also necessary to make the public aware of the changes to the crossing. A copy of a typical letterbox leaflet is shown in Figure 5 below. This is important during the initial months of operation, particularly when the Pelican is the first in an area.



**Figure 5 Example of Leaflet for Pelican Crossing**

For pelican crossings with children's crossing supervisors, the supervisor should be made aware of the pelican operation of the crossing. The supervisor should follow the instructions in VicRoads instructions for Children's Crossing Supervisors for pedestrian operated traffic control signals.

Generally, Puffin operation is preferred over Pelican operation. In any case, Pelican operation should **not** be implemented:

- where the speed limit is 70 km/h or above. The preferred option in these locations is to retain the POS facility.
- at pedestrian operated signals where primary school aged children comprise more than half of the daily pedestrian flow. The preferred option in these situations is to retain the POS facility.
- where there is known daily usage by numbers of disabled or elderly people who require additional clearance time in order to cross the road safely. The preferred option in these situations is to convert to a Puffin crossing.





**Example of Pelican crossing**

## Attachment A – Roundabouts and Traffic Signals – Guidelines for the Selection of Intersection Control

This Appendix presents guidelines for the use of roundabouts and traffic signals for intersection control on arterial roads and includes discussion of issues related to assessment of safety and operational performance, geometric controls and user impacts.

### A1 Introduction

#### A1.1. Overview

Intersections play a significant role in the operation of the road network. Where two or more roads meet or cross, the intersection controls the amount of traffic able to use the intersecting roads and together with the capacity of the road links themselves, provides a significant contributing factor in determining the capacity of the road network as a whole. Generally, in urban areas, the intersection capacity controls the capacity of the road network.

The crossing and turning movements at intersections need to be appropriately managed to ensure that safety and operational efficiency are optimised. Generally, appropriate intersection control depends on traffic and site needs that may rely on the T-intersection road rule, regulatory signs (Stop or Give Way), roundabouts, traffic signals or grade separations. These forms of control may also be provided with appropriate layout design and channelisation to control vehicle movements and points of conflict.

At major arterial road intersections with medium and high volumes, where grade separation cannot be justified, traffic would generally be controlled by either traffic signals or roundabouts.

#### A1.2. Background

Over recent years there has been a growing interest in the selection of roundabouts for intersection control. There has also been some concern about when roundabouts or traffic signal control may be appropriate and the relative performance of these forms of control.

There are various approaches across VicRoads for undertaking analysis or in formulating recommendations for intersection control. These may be based upon perceptions about the advantages and disadvantages of various intersection controls that may or may not be substantiated by objective data. This can lead to conclusions lacking sound technical analysis, design or argument.

In some cases the provision of roundabouts has proved contentious due to the following concerns that may arise in subsequent years:

- Increasing delays due to traffic growth.
- Limitation of treatment life.
- Delays due to unbalanced flows.
- Perceived safety problems for pedestrians.
- Perceived safety problems for cyclists.
- Perceived operational problems for heavy vehicles.
- Inability to prioritise traffic movement (eg for public transport)

Every effort should be made to ensure that there is an understanding of relevant performance factors and that appropriate analyses are carried out as part of the assessment. This will assist in the choice of the appropriate form of control for the intersection that will lead to the best overall operational and safety outcomes for the community.

A preference by the municipal Council, community or a stakeholder group is also a consideration when arriving at a decision relating to the choice of a roundabout or signals.

In some cases the community has a clear preference for roundabouts as they generally:

- Keep the traffic moving with minimal delay.
- Are more aesthetically pleasing than traffic signals.

In other more developed or congested areas the community has indicated a preference for intersections controlled by traffic signals. A preference for traffic signals can be because they:

- Allow all traffic movements to get a turn in a signal cycle. This results in a form of control that is more predictable to use, often reducing stress on the user.
- Give pedestrians specific priority.
- Allow specific priority to public transport vehicles.
- Allow the use of longer delays for particular movements to discourage these specific movements.

### **A1.3. Purpose of this Report**

This report provides an assessment of intersection control using roundabouts and traffic signals including the following aspects:

- Safety performance.
- Operational performance.
- Reliability and accuracy of currently available analytical tools for intersection performance.
- Guidelines for the selection of an appropriate intersection form of control and traffic control in various situations.

The report is intended to relate to arterial roads with roundabout and traffic signal intersections. Although some of the principles may also be relevant to local road intersections, this is not the intended focus of the report.

The report is intended to provide information and additional guidance in relation to design and choice of form of control involving roundabouts and traffic signals.

## **A2 Safety Performance of Roundabouts and Traffic Signals**

### **A2.1. Overview**

Typical crash rates for similar types of intersections can provide a basis for assessing safety performance in the following ways:

- A comparison of performance for intersections of differing types or traffic control.
- A benchmark against which a specific intersection can be compared.

### **A2.2. Crash Frequencies**

A VicRoads study dated March 2004<sup>1</sup>, provides averaged safety performance data for arterial road intersections controlled by roundabouts and traffic signals. These average rates are generally used to compare a specific intersection with the network wide average appropriate to the road environment.

These safety performance rates are summarised in Table A2.1.

**Table A2.1: Summary of Casualty Crash Rates**

Arterial Road / Arterial Road Intersections	Mean Casualty Crash Frequency <sup>1</sup> (Crashes / Intersection / Year)	
	Traffic Signals	Roundabouts
Inner Melbourne <sup>2</sup>	2.11	1.08 <sup>4</sup>
Outer Melbourne <sup>3</sup>	2.00	1.01
Country Victoria (rural cities and towns)	0.95	0.47

**Notes:**

1. Based on accident data for the period 2000 to 2002 for urban locations and 1998 to 2002 for nonurban locations.
2. Municipalities of Melbourne, Yarra, Port Phillip, Stonnington, Boroondara, Glen Eira, Bayside, Hobsons Bay, Maribyrnong, Moonee Valley, Brimbank, Moreland, Darebin, Banyule, Whitehorse, Monash and Kingston.
3. Municipalities of Cardinia, Casey, Frankston, Dandenong, Hume, Knox, Manningham, Maroondah, Melton, Mornington Peninsula, Nillumbik, Whittlesea, Wyndham and Yarra Ranges.
4. Low sample size – 37 sites.

<sup>1</sup> Crash Rates by Road Profile, Final Report, VicRoads, March 2004.

The summary data generally indicates that the averaged casualty crash rate at roundabouts is about half the rate of signalised intersections. This applies for all road environments.

### **A2.3. Crash Rates – Exposure Relative to Traffic Volumes**

When crash frequencies are related to traffic volumes using the intersection, they provide a measure related to exposure and traffic use.

Recent data is not currently available however VicRoads research based on data for the period 1992 to 1994<sup>2</sup> provides averaged safety performance rates for arterial road intersections controlled by roundabouts and traffic signals. These exposure rates are summarised in Table A2.2.

**Table 2.2: Summary of Casualty Crash Exposure Rates**

Arterial Road Intersections - Melbourne Urban Area	Mean Casualty Crash Frequency <sup>1</sup> (Crashes / Intersection / Year / 10 <sup>7</sup> entering vehicles)	
	Traffic Signals	Roundabouts
Primary/Primary Arterial Roads	1.41	1.12
Primary/Secondary Arterial Roads	1.73	1.40
Secondary/Secondary Arterial Roads	1.68	1.26

**Notes:**

1. Based on accident data for the period 1992 to 1994. Data shown is the averaged values for divided and undivided roads without trams.

The summary data generally indicates that the averaged casualty crash rate at roundabouts is in the order of 20 to 25% less than the rate for signalised intersections. This applies for all road environments. These exposure rate differences are less than the rates related to frequency only. As the data is about 10 years old a further study to determine current rates is desirable.

### **A2.4. Pedestrian Safety at Roundabouts**

A Review of Pedestrian Safety at Roundabouts<sup>3</sup> was carried out by VicRoads in 1997. The review considered available investigations and literature from Australia and overseas as well as an evaluation of data for roundabouts constructed on arterial roads in the Melbourne metropolitan area over the period 1987–1994.

The review concluded that there is not a demonstrated safety problem for pedestrians at roundabouts. The Melbourne data indicated that there is an average of 0.02 pedestrian crashes per roundabout per year at roundabouts. The findings also indicated that the severity of crashes involving pedestrians is lower than for other forms of control at intersections, with 2% of crashes resulting in a fatality and two thirds of crashes being the lower severity 'other injury' type crashes.

Although available information indicates that roundabouts are relatively safe for pedestrians, there appears to be a perception that they are unsafe. This is sometimes because of confusion between perceptions of safety and level of service. It may also be because pedestrians can have difficulty using roundabouts. Section A4.4 discusses various design features that should be considered in relation to pedestrians and roundabout use.

### **A2.5. Why are Roundabouts Safer?**

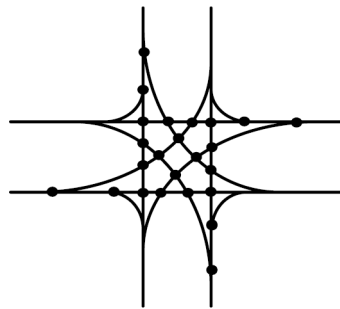
When designed correctly the roundabout is probably the safest type of intersection. The following features generally contribute to the high standard of safety of roundabouts:

- Low operating speed. Slow moving traffic means low energy / low severity crashes and can also enable a driver to avoid a collision. Traffic at a roundabout is initially slowed down by the curved approach and the provision of the splitter island. The splitter island also provides advanced notice of the intersection. The location of the central island then physically deflects the traffic through the intersection and controls the speed of traffic.

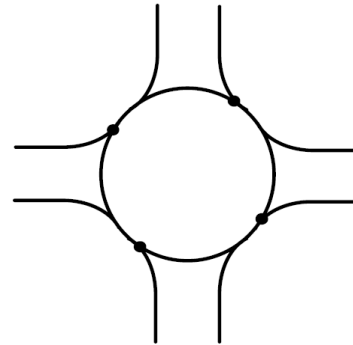
<sup>2</sup> Accident Analysis by Road Profile Study, Operational Report, VicRoads, January 1996.

<sup>3</sup> Review of Pedestrian Safety at Roundabouts, Charmaine Tumber, Road Environment Safety, Road Safety Department, VicRoads, April 1997.

- The low relative speed at possible collision points. The roundabout layout limits the types of crashes and angle of impact. This results in low severity crashes in the event of a collision because traffic is moving in the same general direction at a low relative angle ie. significantly reducing the incidence of headon or right angle crashes.
- Fewer conflict points. A conflict point occurs where two travel paths merge or cross. Roundabout layouts satisfy safe intersection design principles in relation to conflict points as they:
  - Minimize the number of conflict points. Roundabouts minimise conflict points as demonstrated in the following diagrams.



24 Conflict points



4 Conflict Points

Traffic signal phasing separates major conflicting movements in time, so this reduces some conflict situations. However, this is less effective in preventing crashes than physically restricting vehicle conflicts. At signals, crashes may also occur at controlled conflict situations when a vehicle travels through a red light.

- Minimize and separate the areas of conflict. A large area of conflict can occur where wide roads or offset crossroads intersect or when roads intersect at an acute angle. Roundabout layouts minimise conflict areas and have simple channelised approaches to separate points of conflict.
- The decision making for drivers is relatively simple. Drivers only look for traffic on the right, making it easier to judge an entry into the intersection

### A3 Capacity Performance of Signals and Roundabouts

#### A3.1. Accuracy of Current Analytical Tools

The computer software SIDRA INTERSECTION<sup>4</sup> is the primary tool used for capacity and operating performance analysis of traffic signals, roundabouts and other non signalised intersections. Although early manual analysis methods based on ARRB Research reports or Austroads guides are available, the SIDRA INTERSECTION software has refined these methods and theory over the years and is the usual tool used for performance analysis. While the roundabout analysis method used in SIDRA INTERSECTION was originally based on the Austroads Roundabout Guide, significant enhancements have been introduced in various versions of SIDRA.

Case studies relating to the validation of the SIDRA modelling are referred to in the SIDRA INTERSECTION User Guide. For signalised intersections, one case study<sup>5</sup> indicates that performance measures for actuated signals were found to be highly accurate based on the results of real life surveys. In a roundabout case study<sup>6</sup>, the analyses showed that the roundabout operated in excess of expectations in spite of increased levels of demand.

#### A3.2. Reliability of Capacity Analyses

The modelling of intersection capacity needs to consider a number of parameters including traffic volumes for the various movements, number of lanes and lane configuration, type of control, signal phasing, etc.

<sup>4</sup> The SIDRA INTERSECTION software is available from Akcelik and Associates Pty Ltd.

<sup>5</sup> Ferntree Gully Rd / Scoresby Rd Intersection, Akcelik R., Chung E. and Besley M. (1997).

<sup>6</sup> Fitzsimons Lane / Porter St Roundabout, O'Brien A., Akcelik R., Williamson D., and Pantas T. (1997).

The studies referred to in Section A3.1 and other anecdotal experience indicate that generally there can be confidence in the capacity analysis tools available. However, the results obtained from analysis may be questionable due to the following factors:

- Severely congested intersections may result in inconsistent performance outputs. In some situations the SIDRA INTERSECTION program may also indicate uncertainty due to the analysis having 'unsettled results.'
- The traffic volumes used in a capacity analysis are often the 'weak link' in the overall process of determining performance. This may be due to:
  - Using existing traffic counts where demand is much higher than the volumes able to clear the intersection. In this case existing throughput is counted rather than the volumes actually needing to use the intersection;
  - Adopting existing traffic volumes rather than future volumes based on an assessment of traffic growth. The determination of realistic design volumes is one of the keys to accurate modelling of intersection performance. This is discussed further in Section A4.6.
- Knowledge of the person undertaking the analysis relating to geometric intersection layout and parameters affecting capacity. The capacity analysis is closely related to the geometry of an intersection, the number of lanes, need for exclusive lanes and, if a signalised intersection, the type of signal phasing to be provided. Knowledge of these factors is essential to the effective use of the capacity analysis computer software.
- Knowledge and expertise relating to the use of the SIDRA INTERSECTION software. Although the SIDRA software is relatively user friendly, there are a number of variables to be entered and default values may need to be adjusted to accurately calibrate the program. Training and knowledge in the use of SIDRA is essential.

The actual performance of an intersection some years after construction may also lead to certain conclusions relating to the adequacy of the initial analysis or the form of control choice. For example, with traffic signals, the signal timings are only effective as long as the traffic patterns that were used to generate the initial signal timings or lane configurations remain reasonably similar. Over time traffic patterns change, so initial signal timings, phasing, linking plans or lane allocations should be reviewed to ensure effective operation. Similarly, traffic patterns may change at a roundabout and a review of exclusive lane allocation or need for change (additional lanes or metering signals) may be required. Ideally, flexibility should be built into an initial design, particularly in a developing area, to accommodate future changes.

Section A4.6 provides further discussion relating to capacity analysis of intersections and alternative forms of control involving roundabouts and traffic signals.

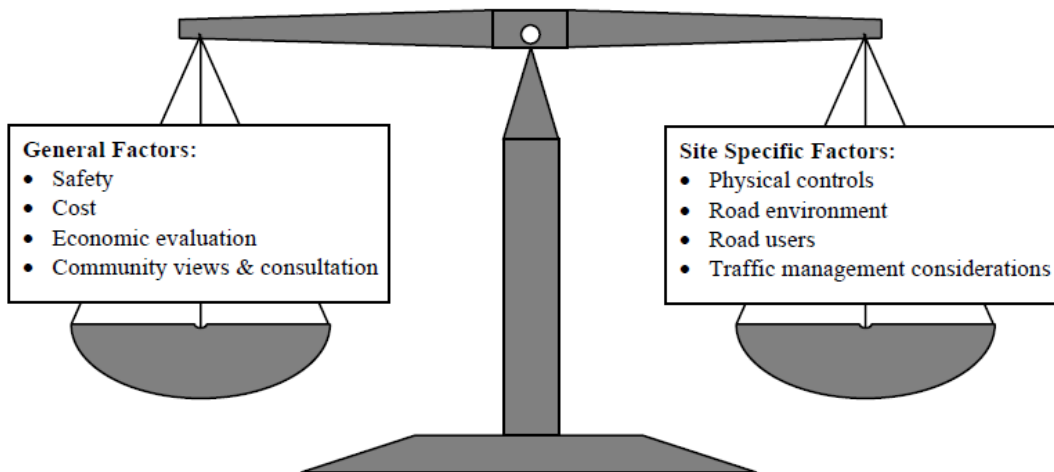
## **A4 Factors Affecting the Choice of Form of Control for Roundabout or Traffic Signal Intersections**

### **A4.1. Balancing the Factors to be Considered**

Traffic signals or roundabouts are generally considered for major arterial road intersections with significant traffic flows where Stop signs, Give Way signs or other forms of channelisation would be unsatisfactory.

The objective when choosing a form of control for an intersection should be a cost effective control that balances the safety, traffic flow and amenity needs of both motorised and non-motorised road users.

The choice of type of control of either a roundabout or traffic signal is influenced by consideration and 'balancing' of important drivers in the overall decision process. These may be either general factors relating to higher level objectives and viability or site specific requirements related to engineering and traffic operational details of the location involved. The factors to be considered are shown in Figure A4.1.



**Figure A4.1 – Balancing Factors in Choice of Form of Control**

The following Sections provide information relating to balancing these various factors. These are also summarised in Section A4.7.

**A4.2. General Factors:**

**A4.2.1. Safety**

The safety of an intersection needs to be a key input when selecting a treatment or type of intersection control.

The research summary provided in Section A2 indicates that roundabouts are generally safer when compared with signalised intersections. Therefore, where signals are chosen at a site, it is generally accepted that there needs to be a balance between safety and other important factors at the site. To maximise safety on the road network, a roundabout would generally be the preferred option unless other factors make a roundabout option inappropriate.

**A4.2.2. Cost**

The cost of a control proposal may include:

- Land acquisition.
- Relocation of utilities.
- Construction cost.

The cost may also be influenced by the degree to which a proposal is to be compatible with staging of longer term works.

Recurrent costs may also need to be considered, particularly in relation to an economic evaluation. A form of control involving traffic signals would generally have higher recurrent costs than a roundabout. The costs include maintenance, linking and operation of the signals.

**A4.2.3. Economic Evaluation**

The economic evaluation relating to a decision on control options under consideration needs to quantify and compare the anticipated benefits for each option (positive and negative) and costs discounted over the life of the control. The factors to be considered generally include:

Benefits	Costs
<ul style="list-style-type: none"> <li>• Safety performance - anticipated crashes that may occur or be saved.</li> <li>• Capacity performance – delay costs based on calculated delays relative to alternative options.</li> </ul>	<ul style="list-style-type: none"> <li>• Construction cost.</li> <li>• Recurrent costs – maintenance / operation.</li> </ul>

The project life in the economic evaluation needs to consider a realistic timeframe relating to nature of works before the control may need to be replaced or upgraded. For example, common practice for assessment of 'accident black-spot' projects is to adopt a standard project life of 10 years for signal projects and 20 years for projects involving roadworks, eg roundabouts. While the objective of the program is to address current crash problems, invariably the longer term capacity needs are not evaluated.

The project life can be an important issue in relation to capacity, particularly in a developing area where there is the potential for high traffic growth. Where forms of control are designed as a staging of medium or longer term works, a 20 year project life may be appropriate. However, if a control is not compatible with upgrading to accommodate traffic increases, a shorter project life is appropriate.

The travel time costs relating to operation would usually be based on calculated delays obtained from SIDRA capacity analyses using design volumes for the peak periods. However, also considering the operation for control options during off peak operation provides a more precise assessment of 'whole of day' community benefits or disadvantages. The off peak operational periods during the day are particularly relevant for business and freight.

#### *A4.2.4. Community Views and Consultation*

The views of the municipal Council relating to community needs and preferences are key inputs of the decision making process. Inputs in relation to freight and public transport needs are also important. In some situations the views of the community or stakeholder groups (eg. a chamber of commerce or adjacent users) may also be desirable.

### **A4.3. Physical Controls**

#### *A4.3.1. Space Available*

The Right of Way (ROW) width, size of intersection splays as well as the availability and/or cost of land acquisition are key considerations when choosing which form of control to adopt. The space needs to accommodate:

- The required number of traffic lanes to ensure appropriate capacity.
- The turning paths for design vehicles at an appropriate radius.
- The clearances to the ROW boundary for footway or verge areas.

For example, to accommodate a design semi-trailer turning right at the minimum outside radius of 12.5 metres, the diameter of the roundabout central island would need to be 10 metres for a single lane roundabout (inscribed circle diameter of 25.2 metres plus ROW clearance), and 24 metres for a two lane roundabout (inscribed circle diameter of 44.6 metres plus ROW clearance).

When planning new areas for future development, the ROW widths and splays can enable flexibility for future control options.

#### *A4.3.2. Site Topography*

The topography at a site can influence a designer's ability to achieve appropriate standards for sight distance, grades and crossfalls within the intersection. It may also have an impact on the cost of construction. Ideally, roundabouts should be sited on relatively level ground or in sag vertical curves rather than near crests, so that road users have good visibility and can adjust their driving behaviour to reflect the layout.

#### *A4.3.3. Access to Adjacent Properties*

In some locations the nature of access to adjacent properties may need to be considered where major points of access and turning movements to private property occur at or close to the intersection.

### **A4.4. Road Environment**

#### *A4.4.1. Rural, Outer Urban and Inner Urban Areas*

- In rural areas traffic signals would generally be inappropriate due to the nature of the road environment and the approach speeds of traffic. Roundabouts should be considered where a T intersection, staggered T intersection, or wide median control would be unsatisfactory due to the relative traffic volumes involved. However, roundabouts in rural, high speed environments must be visible and incorporate appropriate geometric characteristics (deflection of approaches, central island size, long splitter islands etc), signs and pavement markings to ensure safe operation.



- In rural towns and cities with short peak periods, roundabouts would generally be appropriate and operate with minimal delays. Roundabouts also facilitate U-turning movements where traffic circulation in a shopping or town centre is a consideration. At cross or T intersections where the major flow of traffic turns right or left (eg. in country towns where the highway turns through 90o angle) a roundabout will generally provide a safe and efficient form of control to manage the turning traffic. Traffic signals (or separate nearby pedestrian crossings or pedestrian signals) need to be considered in areas with high pedestrian numbers.
- In outer urban and fringe areas either traffic signals or roundabouts may be appropriate, subject to other considerations described in this section. However, roundabouts would generally provide safety advantages and lower delays in off peak periods.
- For inner urban areas roundabouts may be appropriate at isolated sites where space and other factors are appropriate. However, traffic signals are often the preferred form of control due to pedestrian or signal linking needs.

#### *A4.4.2. Speed of Approaching Traffic*

In high speed traffic environments, such as in rural or urban fringe areas, roundabouts generally operate safely and provide physical control of speed when designed with appropriate alignment and channelisation.

If traffic signals are used in high speed areas, reduction of traffic speeds with an 80 km/h speed limit or higher is generally required. The use of advanced warning devices may also need to be considered. However, these measures generally have limited success in controlling speeds without regular enforcement.

In these environments, it is generally preferable to keep the traffic moving with roundabout forms of control, rather than using traffic signals.

#### *A4.4.3. Adjacent Land Use*

Traffic signals or roundabouts may operate satisfactorily in a range of environments. However, the nature of the adjacent land use may influence a decision.

In a rural town, roundabouts at each end of the shopping area can be advantageous in slowing traffic entering the area and in providing U-turn opportunities for motorists circulating to and from kerbside parking.

In an industrial area where a median may restrict vehicle movements into adjacent properties, a roundabout of appropriate size may also facilitate circulation and U-turning of trucks.

### **A4.5. Road Users**

#### *A4.5.1. Needs related to Pedestrians*

Pedestrians are unprotected road users and therefore are generally at greater risk than road users in motor vehicles. Pedestrian needs on the road relate to mobility and safety and this is of particular concern in relation to children, the elderly and people with disabilities.

In high traffic volume locations, pedestrians generally prefer to use traffic signals as these provide priority with a pedestrian signal phase and separation from through traffic flows. Pedestrian crashes at signalised intersections generally involve turning traffic failing to give way, pedestrians crossing against the red light or vehicles driving through the red light.

While crash data at roundabouts generally indicates that there is not a particular safety problem for pedestrians (refer Section A2.4), there is a general dislike for roundabouts by pedestrians and a perceived safety risk as they may be difficult to cross. Pedestrian concerns at roundabouts generally relate to:

- No specific priority for pedestrians compared to signals where 'Walk' phases are provided.
- Drivers looking right towards circulating or entering traffic, rather than watching for pedestrians. Pedestrians crossing from the left may be more vulnerable in this situation.
- Lack of gaps in the traffic flow, particularly at congested roundabouts and moving queues of traffic, rather than the queue of vehicles coming to a complete stop.
- Roundabouts with two or three lane approaches presenting greater crossing difficulties for pedestrians compared with single lane roundabouts, even with the provision of splitter islands which can act as staging points.

Where a roundabout is being considered in an environment with pedestrians, consideration should be given to incorporating the following design features, as appropriate and in accordance with design guidelines:

- Pedestrian signals across the approaches - to provide for children, elderly persons or pedestrians with disabilities.
- Pedestrian (zebra) crossings (with or without flashing lights) or pedestrian signals across approaches – where a significant number of other pedestrians are expected (e.g. near a shopping centre or school).
- A lower design speed than usual, generally 40 km/h maximum (usual maximum is 50 km/h), to slow vehicles entering and travelling through the roundabout. This will improve the ability of pedestrians to cross and also assist in reducing the severity of injury in the event of a pedestrian crash. This lower design speed is achieved with physical horizontal deflection of vehicle paths prior to the pedestrian crossing points using an appropriate left hand curve radius and a splitter island or shaping of the median. The size of the central island and the adverse crossfall of the circulating roadway also assist in controlling vehicle speeds. Tighter geometry to achieve low exit speeds, rather than the usual practice of facilitating the exiting of vehicles, will also improve safety for pedestrians crossing the roundabout departures.
- Ensuring good visibility so that pedestrians can see traffic and be seen by drivers and motorcyclists.
- Ensuring the roundabout has adequate vehicular capacity. With minimal congestion, the resultant gaps in traffic flow can facilitate pedestrians crossing the vehicle flows on approaches and departures (Note: pedestrian needs are usually considered in traffic signal capacity analysis but rarely considered in relation to roundabouts).
- Pedestrian crossing points set back approximately 6 metres or 12 metres (one or two car lengths) from the holding line to separate the points where pedestrians and circulating vehicles cross a driver's path. At this location a pedestrian is not crossing in front of vehicles about to enter or leave the circulating roadway and is more likely to be seen by a motorist in the queue. Balance must be made here as vehicles exiting the roundabout will be accelerating as they pass this point and drivers coming out of the roundabout may not see pedestrians using the crossing.
- Splitter islands on each leg of the roundabout being of sufficient size to provide staging points for pedestrians (including wheelchairs, bicycles, prams etc.). This enables pedestrians to cross one direction of traffic flow at a time and also minimises the width of roadway to be crossed.
- Where a signalised pedestrian crossing is provided across an approach, the crossing points across each section of roadway should be staggered at the median or splitter island to minimise 'walk' times and delays to traffic. The stagger also increases the distance for queuing on the departure before traffic interferes with the circulating flow in the roundabout.
- Consideration of fencing or landscaping to discourage inappropriate pedestrian movements and to direct pedestrians to the formal crossing points.

#### *A4.5.2. Needs related to Bicycles*

Cyclists are unprotected road users at greater risk than motorised road users. Therefore designs need to minimise risks to safety by providing separate road space, particularly because of the high speed differential between bicycles and other vehicles.

At traffic signals a cyclist's mobility needs relate primarily to sharing road space.

At roundabouts, cyclists' concerns relate more to safety and operation such as:

- Motor vehicles travelling too fast.
- Motor vehicle drivers entering the roundabout not giving way to cyclists in the circulating roadway.
- Motor vehicles cutting across lane lines.
- Cyclists needing to cross the path of exiting vehicles, particularly at multilane roundabouts.

In an area with significant bicycle usage (particularly children or recreational cyclists), preference may need to be given to traffic signal forms of control with specific provisions such as bicycle lanes, advanced stop lines and storage areas.

At roundabouts, commuter or experienced cyclists would generally prefer to use the roadway and ride through a roundabout with the traffic. However, an option to leave the road and use an off-road shared path may be desirable, particularly for inexperienced cyclists and children.

Crash data<sup>7</sup> generally indicates that there is a safety problem for cyclists at roundabouts. However, further research relating to cyclists and roundabouts is desirable, particularly in relation to single-lane/multilane roundabouts, differing intersection environments (inner / outer urban) and traffic volumes (vehicles / bicycles).

A Monash University Traffic Engineering and Management publication<sup>8</sup> provides information relating to the designing of roundabouts for pedestrians and cyclists, as well as information relating to more 'cycle friendly' roundabouts that are found in continental countries where cycling is more prevalent. These design principles generally include 'tighter' geometry.

Where bicycles are expected to use a site where a roundabout is the preferred form of control, specific provisions may need to be considered such as:

- Low design speed (generally 30 to 40 km/h) to slow vehicles entering and travelling through the roundabout. This will enable cyclists to mix with other traffic and take control of the lane. This may also need to include a low exit speed incorporating tighter geometry than the usual practice of enabling vehicles to exit easily
- Avoiding squeeze points for cyclists on the approach and through the roundabout. If a bicycle lane is provided on the approach it should be continued to the holding line. The provision of a separate channelised entry into the roundabout on the left of the general traffic lane is not recommended, as the separation of entering bicycles may not be obvious to motorists.
- The provision of a separate bicycle lane within the circulating roadway is desirable at large single lane and multilane roundabouts<sup>9</sup>.
- Provision for cyclists to move off the carriageway to use shared paths around the outside of the roundabout, particularly at locations used by children or recreational cyclists. The crossings of the splitter islands should be wide enough to shelter a bicycle, be flush with the road pavement and be set back 6 metres, or preferably 12 metres (one or two car lengths), from the holding line. Pedestrian signals or a pedestrian crossing (with or without flashing lights) could also be considered (refer Section A4.5.1).

#### *A4.5.3. Needs of Large Vehicles*

In rural and semi rural environments, some drivers of large vehicles dislike slowing down for a roundabout. In instances where the freight industry has indicated concerns after roundabouts have been installed at an intersection, the context of comments has generally been related to the previous intersection layout where traffic on the major road had right-of way and there was no need to slow down. However, the roundabouts at these locations had generally been installed for safety reasons or to enable vehicles to enter the major road from the intersecting arterial. Traffic signals in these locations would require traffic to slow and/or stop and this may have greater impact on freight movements. Generally, in these rural or semi rural environments, it is preferable to keep the traffic moving with roundabout controls, rather than using traffic signals.

In regard to either signal or roundabout forms of control, it is essential to provide appropriate space for the swept path of large vehicles such as semi-trailers and buses (refer to Section A4.3 above).

### **A4.6. Traffic Management**

#### *A4.6.1. Route or Area Strategies*

The consideration of route strategies when selecting a form of intersection control includes consideration of the form of control at adjacent intersections. Eg:

- Traffic signals would be appropriate where adjacent intersections are controlled by traffic signals and the spacing of intersections would enable effective signal linking. Roundabouts in this traffic environment would interfere with the platoons created by adjacent traffic signals.
- Roundabouts are more appropriate at relatively isolated locations or where the adjacent sites have roundabout control.

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<sup>7</sup> Refer Austroads Guide to Traffic Engineering Practice, Part 14 - Bicycles – Section 5.2.2

<sup>8</sup> *Performance and Design of Roundabouts*, Chapter 6.4, Gary Veith, Traffic Engineering and Management, Institute of Transport Studies, Monash University, 2003.

<sup>9</sup> Refer VicRoads Cycle Notes No. 15 'Providing for Cyclists at Roundabouts'

#### *A4.6.2. Road Hierarchy, Local Access and Amenity*

Area strategies relating to the use of municipal roads may also need to be considered. The functional road classification of the intersecting roads needs to be considered when determining the appropriateness of a form of control. This could be an issue where control of traffic into a local area is important for amenity reasons. This may occur where a municipal road intersects with an arterial road intersection and 'rat running' could occur. In these situations traffic signals would give greater control of traffic movements, in the same way traffic signals enable priority to be given to particular routes/turns which warrant priority movements.

#### *A4.6.3. Traffic Volumes*

In choosing a form of control for an intersection, operational analyses require an understanding of traffic volumes that are to use the intersection during anticipated periods of peak flow.

The first step is to determine design traffic volumes that would be applicable for the morning peak, evening peak or high flow periods such as events, recreational periods, holidays etc. The determination of design volumes may be based on:

- An existing turning movement traffic count. This may then be factored up using a growth rate appropriate to the site.
- Traffic studies considering a range of issues, including traffic growth that may result from development in the area or along a growth corridor.
- Network modelling that estimates future traffic flows. These may be based on various scenarios relating to land use development or road network improvements.

#### *A4.6.4. Capacity Analysis*

The capacity of a form of control to operate satisfactorily is dependent on the traffic volumes during periods of peak flow, including the volumes of turning traffic and the distribution of traffic on the various approach legs at the intersection. Therefore, it is important to determine appropriate design volumes as outlined above.

Analyses are best undertaken using SIDRA which provides various output measures relating to operational performance for a proposed intersection layout.

The key output measures generally used for evaluating or comparing performance of individual lanes, approaches or the intersection as a whole are:

- Degree of saturation (ratio of arrival volume/capacity). The desirable maximum is 0.85 with values in the range up to 0.95 leading to increasing congestion and reducing spare capacity. Values over 0.95 are undesirable and result in high levels of congestion and delay.
- Average delays (veh-h/h and sec/veh).
- In some situations, the length of queues. This is of particular importance in assessing requirements for the length of auxiliary through lanes or storage in turn lanes. The 95% queue length is generally adopted as the minimum storage for turn lanes however longer lane lengths may be required for deceleration of vehicles.

A sensitivity analysis to consider the implications of higher volumes may need to be considered where there is uncertainty regarding design volumes or future traffic growth.

The calibration of SIDRA for the capacity analysis may be desirable when modelling congested intersections or comparing improvement options with an existing situation. The most critical 'default' values and parameters that can be modified when calibrating SIDRA are:

- Lane saturation flows.
- Gap acceptance parameters.
- Phase and cycle times if signals are in a linked system.
- Lane utilisation factor, where applicable.

A roundabout operating within design volumes will manage peak traffic flows in a self regulating manner and provide acceptable delays under usual roundabout priority control. Even with relatively high traffic flows on each approach, traffic is generally broken up to create gaps in the circulating flow for entering traffic.

For multilane roundabouts, the provision of exclusive lanes for turning traffic is generally unnecessary unless a turning movement requires more than one lane. The shared lanes then provide more flexibility for off peak periods or times when flows vary from the design volumes used.

However, roundabouts are sensitive to unbalanced flows where the entering traffic from a dominant leg prevents traffic from another approach from entering the roundabout (generally the adjacent approach to the left of the dominant flow). This deficiency can usually be addressed by the provision of part time metering signals that regulate the dominant flow and provide gaps in the circulating traffic. Metering signals are activated by queue loops in the approach that is being delayed. Further information relating to signals at roundabouts is in Section A5.

Roundabouts generally provide significant advantages over traffic signals in minimising delays during off peak periods. An economic evaluation may be based on calculated delays for the peak periods, but may also consider the operation during off peak operation. A 'whole of day' analysis provides a more precise assessment of benefits / disadvantages. Lower off peak delay during the day is particularly beneficial for business travel and freight.

At traffic signals, the number and layout of lanes and phasing are determined to suit peak demands. The phase times and operation for the varying periods through the day are then managed by the vehicle actuated controller and signal linking settings.

#### ***A4.6.5. Project Life***

Consideration of the project life can influence a decision on the form of control, particularly where significant future traffic growth may be expected. Consideration of the form of control compatibility with other future works is also an important input in the decision process. For example a single lane roundabout constructed as an initial form of control may be a staging of a 2 or 3 lane roundabout in the longer term. Alternatively, a roundabout may be chosen as an appropriate form of control to address current problems, even though traffic signals may be envisaged in the long term.

The project life needs to be consistent with adopted design traffic volumes and capacity analyses, as well as the value used for the economic evaluation.

#### ***A4.6.6. Public Transport - Trams or Buses***

Traffic signals enable specific priority to be given to trams or buses through an intersection. Signals may also facilitate the clearing of queues at an intersection that may be obstructing the movement of a tram or bus.

Trams moving through a roundabout have priority under the road rules. Although historically, roundabouts have been provided on tram routes, generally, traffic signals would be the preferred form of control.

In relation to buses, roundabouts would generally provide lower delays during off peak periods and may also provide lower delays during the peak periods, subject to available capacity. Traffic signals would provide greater control where bus priority or exclusive bus lanes are to be provided.

#### ***A4.6.7. Public Transport – near Railway Level Crossings***

The control of traffic movements adjacent to a railway level crossing can be a significant matter that affects the choice of the form of control to be adopted. Traffic queues extending across a railway level crossing are able to be controlled more effectively with traffic signals. These controls would generally include a 'track clearance' signal phase and 'train' phase within the cycle.

A roundabout could be considered near a railway level crossing where traffic volumes are low or where capacity analyses confirm that queues will not extend across the tracks.

#### ***A4.7. Summary of Site Specific Factors and Form of Control Choice***

A summary of the various factors outlined in Sections A4.3 to A4.6 is provided in Table A4.1.

**Table 4.1 – Summary of Site Specific Factors and Form of Control Choice.**

Site Specific Factors	Signals	Roundabout
<b>Physical Controls</b> <ul style="list-style-type: none"> <li>• Space available</li> <li>• Site topography</li> <li>• Access to adjacent properties</li> </ul>	<p>M – subject to design</p> <p>M – subject to design</p> <p>M – subject to design</p>	<p>M – subject to design</p> <p>M – subject to design</p> <p>M – subject to design</p>
<b>Road Environment</b> <ul style="list-style-type: none"> <li>• Rural area</li> <li>• Outer urban or fringe areas</li> <li>• Inner urban area</li> <li>• High speed approaching traffic</li> </ul>	<p>U</p> <p>M</p> <p>L</p> <p>U – May consider with 80 km/h speed limit &amp; warning signs / flashing lights</p>	<p>L</p> <p>L</p> <p>M</p> <p>L - with design features to control approach speed</p>
<b>Road Users</b> <ul style="list-style-type: none"> <li>• Pedestrian needs <ul style="list-style-type: none"> <li>○ Children, the elderly and the disabled.</li> <li>○ Significant number of other pedestrians</li> </ul> </li> <li>• Bicyclists needs <ul style="list-style-type: none"> <li>○ Significant number of children or recreational cyclists</li> <li>○ Significant number of other cyclists</li> </ul> </li> <li>• Needs of large vehicles</li> </ul>	<p>L</p> <p>M</p> <p>L</p> <p>M</p> <p>M</p>	<p>U – unless pedestrian signals provided</p> <p>M - consider pedestrian facilities, low design speed and spare capacity</p> <p>U – unless off-road facility and pedestrian signals provided</p> <p>M – with low speed design</p> <p>M</p>
<b>Traffic Management</b> <ul style="list-style-type: none"> <li>• Route or area strategies <ul style="list-style-type: none"> <li>○ Adjacent to linked signals</li> <li>○ Isolated locations</li> <li>○ Adjacent sites controlled with roundabouts</li> <li>○ Control of traffic through a local area</li> </ul> </li> <li>• Traffic volumes and capacity <ul style="list-style-type: none"> <li>○ Balanced flows</li> <li>○ Unbalanced flows</li> <li>○ Significant turning volumes</li> <li>○ Minimising off-peak delays</li> </ul> </li> <li>• Public transport <ul style="list-style-type: none"> <li>○ Trams</li> <li>○ Buses</li> <li>○ Adjacent to a railway level crossing</li> </ul> </li> </ul>	<p>L</p> <p>M</p> <p>M</p> <p>L</p> <p>M</p> <p>M</p> <p>M - with adequate turn lane capacity</p> <p>U</p> <p>L</p> <p>L</p> <p>L</p> <p>L</p>	<p>U</p> <p>L</p> <p>L</p> <p>U</p> <p>M</p> <p>M - with metering signals</p> <p>L</p> <p>L</p> <p>U</p> <p>L</p> <p>U</p>

**Legend:**

**L - Likely to be an appropriate form of control**

**M - May be an appropriate form of control**

**U - Unlikely to be an appropriate form of control**

**A4.8. Summary Information for Project Approval**

The consideration and balancing of the site specific items, as well as appropriate analyses and evaluation, are essential parts of determining an appropriate form of control for an intersection.

A table summarising appropriate information for a project approval decision is provided in Section A6 in the form of a proforma.

## A5 Traffic Signals at Roundabouts

The combination of traffic signals with roundabouts is not the main focus of this report. However, the following comments are provided in relation to the operation of traffic signals in conjunction with roundabouts.

### A5.1. Metering Signals

Roundabout performance is sensitive to unbalanced traffic flows. This may occur where the entering traffic from a dominant leg prevents traffic from the adjacent or another affected approach to the left of the dominant flow from entering the roundabout. This situation results in excessive queues and delays in the affected approach.

The dominant traffic flow at a roundabout may be either:

- A high uninterrupted traffic flow.
- A low but consistent flow from a minor approach that takes priority over a major flow.

This deficiency can usually be addressed by the provision of part time metering signals that regulate the dominant flow and provide gaps in the circulating traffic. This enables the traffic from the affected approach to enter the roundabout. The metering signals are activated by queue loops in the affected approach that is being delayed. Metering signals provide the following benefits:

- Management of the peak flows to provide appropriate priority for a major movement.
- Provide better balance of queues and delays between approaches.
- They can extend the life of a roundabout rather than require its replacement.

Metering signals are generally considered as a 'short term fix' stage when problems develop due to changing traffic flows over time. However, at some locations they could be considered as part of a new roundabout control to proactively manage the traffic. This form of control may avoid the need for installation of intersection traffic signals and retain safety and operational benefits at times of lower flow at the roundabout.

Metering signals use 2 aspect (yellow/red) lanterns set back on the approach to control the traffic. When traffic is released it enters the roundabout under usual 'give way' priority conditions in a self regulating manner.

The provision of metering signals can also be beneficial for pedestrians, as the metering system can be combined with pedestrian signals to provide a pedestrian facility across a leg (or legs) of a roundabout. In these installations the signals would also stop traffic leaving the roundabout, so queuing of traffic may extend back into the circulating roadway. As the crossing distances and times are usually relatively short, this queuing is generally not a significant operational problem, depending on the frequency of operation. Subject to the pedestrian 'desire line,' at some sites it may be possible to locate the crossing further back from the circulating roadway so that storage on the roundabout exit is maximised.

### A5.2. Signalised Roundabouts in the UK

More extensive signalling of roundabouts is used in the United Kingdom<sup>10</sup> to improve capacity and address delays at roundabouts with increasing traffic flows.

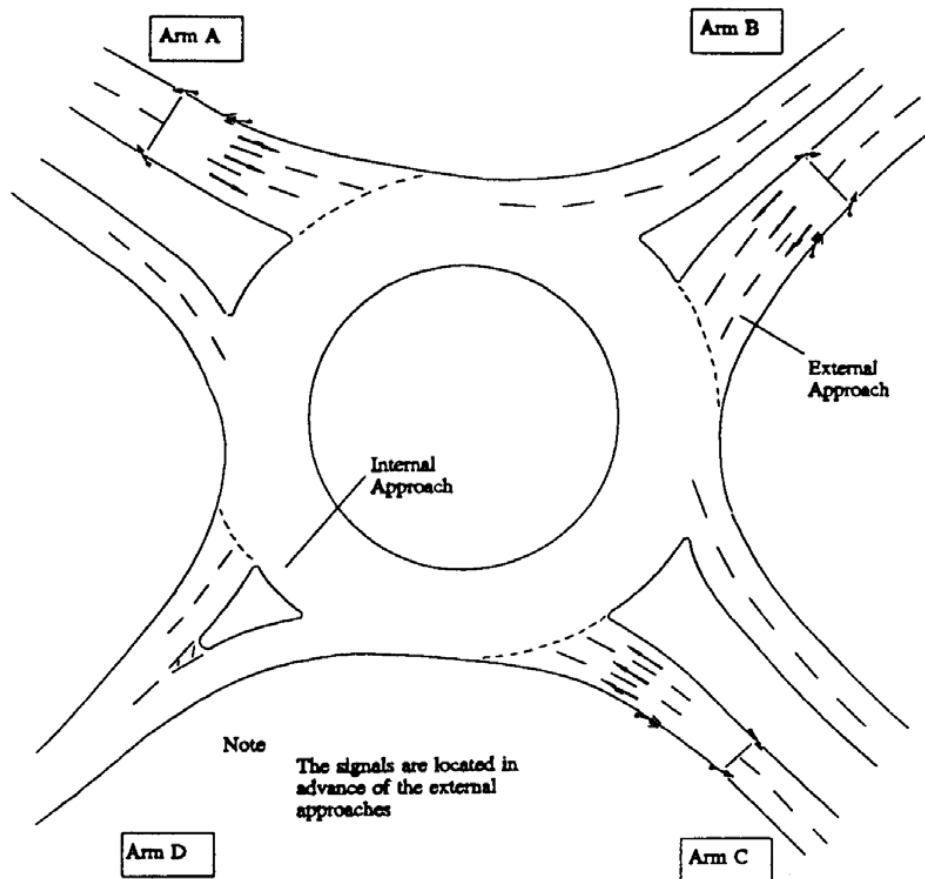
Signalised roundabouts in the UK generally have one of the following types of signal control:

**1. Indirect Signal Control** – where the signals are situated on a roundabout approach some distance away from the roundabout entry so that the roundabout continues to operate under normal roundabout priority control. Where this control is provided it may include one or more roundabout entries (refer to Figure A5.1).

This form of operation is similar to the metering signals described in Section A5.1 that operate at several locations in Victoria.

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<sup>10</sup> Design Manual for Roads and Bridges (DMRB), Volume 6 Section 2 – Chapter 6 Signalised Roundabouts.



**Figure A5.1 – Indirect Signal Control in the UK**

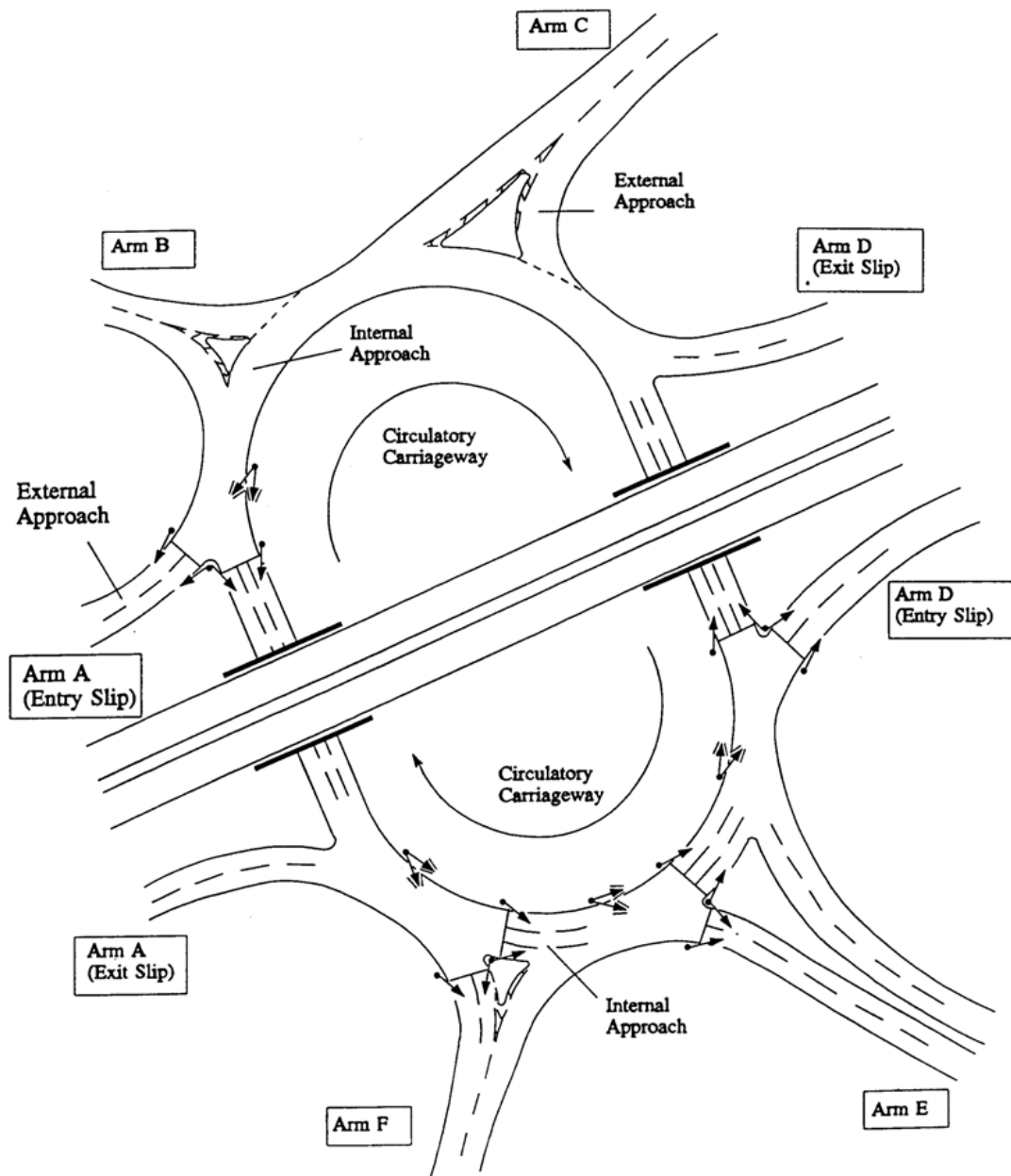
(Source: *Design Manual for Roads and Bridges (DMRB), Volume 6 Section 2 – Chapter 6 Signalised Roundabouts*)

**2. Direct Signal Control** – where signal control is provided at the junction of a roundabout entry with the circulating roadway (refer to Figure A5.2). Where this control is provided it may include:

- All entries to the roundabout (fully controlled).
- Only some of the roundabout approaches (partially controlled).

Direct signal control is more suited to large roundabouts where storage space is available for traffic to stop within the circulating roadway between the departure and entry legs of the roundabout. Where direct signal control is provided this may need to be accompanied with widening of approaches and/or the circulating roadway approaches at the signals to increase capacity or storage.





**Figure A5.2 – Direct Signal Control in the UK**

(Source: *Design Manual for Roads and Bridges (DMRB), Volume 6 Section 2 – Chapter 6 Signalised Roundabouts*)

The direct signal control phasing sequence is able to operate to minimise lost time (generally anti-clockwise phasing). Phasing at a four-leg roundabout could allow opposite external approaches to run concurrently which would allow the through and left turning vehicles to depart the roundabout without stopping within the circulating roadway. The right turning vehicles would need to stop at the circulating roadway approach to the signals. This operation would provide similar safety benefits to fully controlled right turn movements at a conventional signalised intersection.

### **A5.3. Future of Signal Control at Roundabouts in Victoria**

Either form of signal control retains the safety benefits of roundabouts as traffic speeds are relatively slow. Each form of signal control could also operate under either:

1. Full-time control – where signals are permanently operating.
2. Part-time control – where the signals are switched on or off at set times (generally peak periods) or under certain traffic conditions by queue detectors.

#### *A5.3.1. Metering Signals (Indirect Control)*

This form of signal control has a proven effectiveness at a number of sites in Victoria. However, currently there is limited ability to analyse sites to determine capacity and operational benefits. Further improvement of current capacity analysis tools and methodologies needs to be undertaken.

#### *A5.3.2. Direct Signal Control*

It is considered that direct signal control warrants further investigation and assessment to determine its potential to improve the operation of roundabouts in Victoria. This form of control may be a solution to addressing delays at congested sites where indirect signal control may not be appropriate. However, it may only be feasible to provide direct signal control at large roundabouts.

If direct signal control is able to provide the benefits achieved in the UK, this may avoid significant costs to replace roundabouts with signals and also retain the operational benefits of roundabouts at off peak periods. The safety of roundabout operation at all times of operation will also be safer than conventional signalised intersections.

## A6 Intersection Control Options Checklist

This table provides summary information to ensure critical issues are considered in making the recommendation. This is relevant to control options for arterial road intersections e.g. options for either traffic signals or a roundabout.

The table would generally be applicable to an intersection upgrading proposal or for intersection controls being part of a widening or duplication proposal. Where further detail is provided in the accompanying report, cross referencing should be provided.

Project / Site:				File Ref:			
Municipality:				Region:			
Item	Option 1 – Indicate Form of Control			Option 2 – Indicate Form of Control			Comment / Report Reference
<b>Road Environment</b>							
• Rural or inner/outer urban, adjacent land use, speed environment etc.							
• Space, topography, design issues etc.							
<b>Road User Needs (if applicable)</b>							
• Pedestrians							
• Bicycles							
• Trucks							
• Public transport							
<b>Traffic Management Considerations</b>							
• Route strategies – eg signal linking							
• Road hierarchy, local access etc.							
• Basis of design volumes / design year							
<b>Intersection Operational Performance</b>	<b>AM Peak</b>	<b>Off Peak</b>	<b>PM Peak</b>	<b>AM Peak</b>	<b>Off Peak</b>	<b>PM Peak</b>	
• Degree of saturation							
• Delay (veh-h/h)							
• Queues							
<b>Analysis of Safety Performance</b>							
• Casualty crashes saved / year							
<b>Economic Evaluation</b>							
• Estimated cost (90% confidence)							
• Economic value of crashes saved							
• Economic value of operational delays							
• BCR							
<b>Consultation</b>							
• Community / Council comments							

## **Attachment B – Externally Funded Traffic Signal Installation**

Externally funded works can be either installations or signal remodels to suit a change in the road layout. A council narrowing a road requiring the relocation of a signal pedestal is an example.

The Region has the responsibility for ensuring that agreements are transacted between VicRoads and the relevant council or developer regarding the signals works and a commitment from the council or developer to pay full costs incurred by VicRoads. An advance payment of full estimated cost of installation, design and maintenance (for ten years) where applicable is required before works will proceed.

When other authorities carry out works it is preferable to inform these authorities that they must recover their own costs.

The total maintenance cost over 10 years includes the cost of power and is calculated for:

- intersections with SCATS
- intersections without SCATS
- pedestrian operated signals with SCATS
- pedestrian operated signals without SCATS
- pedestrian (zebra) crossings.

## Attachment C: Additional Interchange Types, Elements and Consideration

### C1 Trumpet Interchanges

#### Trumpet Type A

The Trumpet caters for all movements at a three-leg intersection. Care must be taken with signing on the secondary road, because right turns and left turns to the freeway both exit to the left.

When viewing the Trumpet Type A in the direction of freeway traffic, the loop appears before the bridge, see **Figure 6**.

The main hazard with the Type A layout is that approach speeds on the secondary road exceed the safe speed on the loop, and the loop is obscured from view by the bridge parapet. For these reasons, this layout should not be used unless:

- i. traffic volumes in the quadrant served by the loop are low, and
- ii. loop approach speeds can be controlled.

#### Trumpet Type B

In the Trumpet Type B, when viewed from the direction of through traffic the loop appears on the far side of the structure, see **Figure 6**.

Generous radii should be used for the right turn ramp from the secondary road to the freeway in order to prevent truck instability.

Where the exit nose from the freeway to the loop would lie in the shadow of the structure, drivers may have difficulty in identifying the exit; preferably, the exit nose should be moved in advance of the structure.

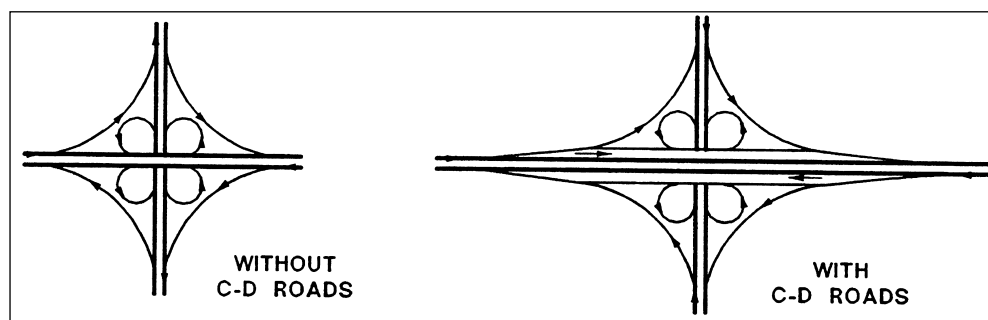
### C2 Cloverleaf Interchanges

Cloverleaf interchanges can be used either as freeway to freeway interchanges, see The Cloverleaf in Section 6.5.2(d), or as surface road interchanges. As they are more expensive than conventional diamonds, cloverleaves would only be considered for use for connections between major arterials and freeways.

The principal deficiency of the layout is the limited capacity within the weaving sections between the loops. As a guide, cloverleaves without collector distributor roads have weaving capacities of only 500 to 1000 veh/h. The lower value applies when traffic volumes between a loop pair are unbalanced. Cloverleaves with collector distributor roads have greater weaving capacities which should be determined by analysis, with expected values between 1000 and 1500 veh/h, see **Figure C1**.

Factors to be considered with cloverleaf interchanges include:

- the capacity of the weaving section between loops depends on the distance between the noses. This can be maximised by using either loops with radii greater than the 55 metres minimum specified in “Exit Loop Ramps” and “Entry Loop Ramps” in *AGRD Part 4C, Section 8.3.4* and *VicRoads Supplement*, or using elongated loops. Loops for cloverleaf interchanges should have radii in the order of 60 metres to 80 metres. At some locations elongated loops may be required although these are not favoured because of their increased accident rates.



**Figure C1: Cloverleaf Interchanges- Freeway to Arterial**

- the larger the loop radius, the larger the area of the interchange and the longer is the travel distance. However, typical cloverleafs require areas comparable to other types of freeway to freeway interchanges.
- generous sight distance must be provided to exit ramp noses on downhill loops. This can only be achieved when the approach road is either relatively flat or on a sag vertical curve.
- collector distributor roads should be used, and should be provided with full width shoulders on both sides of the carriageway adjacent to the weaving area as a refuge for trapped or disabled vehicles.

### **C3 Parclo Interchanges**

#### *General*

The partial cloverleaf interchange, or Parclo, has loops usually in two quadrants and at-grade junctions where the ramps meet the secondary road. The determination of which quadrant is to be without ramps is usually dependent on availability of right of way, or the predominant turning movements to be handled. This type of interchange may be adopted where design controls such as industrial development or protected environmental features in one or more quadrants preclude use of a diamond interchange. It can be used to great advantage for grade separating major turning movements. When evaluating interchange options, one factor is that accident rates are higher on loop ramps than on diamond ramps, .

Parclo interchanges can be used to increase the effective weaving length between closely spaced interchanges. However, the Parclo's will generally not permit passage of abnormally high loads due to bridge clearance restrictions except in the case of A4 and B4 type interchanges which have similar ramps to diamonds, see Figures 6.16 and 6.18 shown in *AGTM Part 6, Table 6.1* .

Guidelines for Parclo Interchanges include:

- the ramp arrangement should enable major turning movements to be made by left-turn exits and entrances;
- where the through traffic volume is significantly greater than on the secondary road, preference should be given to an arrangement placing the left-turns, either exit or entry, on the freeway, even although it results in a direct right turn from the secondary road.

Other factors to be taken into account when considering the use of a Parclo include:

- clear advance direction signs are essential, as drivers on the secondary road may be confused by the need to turn in the opposite direction to their intended direction of travel;
- an auxiliary acceleration lane will be required beyond the entry nose, as truck speeds at the end of loop entry ramps will be less than the acceptable minimum merge speed;
- wherever a loop is proposed in order to increase weaving distances between closely spaced interchanges, a weaving analysis is required to ensure that truck numbers and speeds will not create a bottleneck within the weaving section;
- loops shall not be designed entirely with spirals, that is, without any circular curve;
- loops with compound curves or straights have higher accident rates than circular loops.

In determining whether the freeway goes under or over at a Parclo interchange, it is desirable that traffic slowing (uphill) approaching the minor road and accelerating (downhill) approaching the freeway.

When viewing a Parclo A interchange in the direction of freeway traffic, the loop appears before the bridge. In the Parclo B, the loop

## Attachment D: Procedure for Traffic Signal Installation

### D1 Specifying Site Works For Traffic Signal Plans

Remodel notes on signal layout plans need to be clear to avoid any misrepresentation by signal installation contractors. The 'Remodel/Installation Notes' have been standardised and shall follow the format below.

Installation/remodel notes

#### A. SIGNAL CONTRACTOR

##### NEW SITE

1. Install new hardware as shown.
2. Install meter box or switch box at point of supply.  
(See "general notes" for further notes required).

##### TOTAL REMODELS

1. Install new hardware as shown.
2. Install/replace meter box or switch box at point of supply.
3. Remove all existing above-ground hardware.
4. Remove all existing P.O.S, pedestrian crossing, school crossing, hardware on ..... approach.  
(See "general notes" for further notes required).

##### PARTIAL REMODELS

1. PEDESTAL .....
  - Relocate existing 2A, B, JUP, MA from .....
  - Install new 2A, B, JUP, MA .....
  - Install new lanterns as shown.
  - Install new ..... lanterns.
  - Remove .....lanterns.
  - Replace ..... lantern with ..... lantern.
  - Relocate ..... lanterns from redundant pedestals.
2. Pedestal ..... Etc. (Repeat above applicable notes for all pedestals altered)
3. Remove ..... (List all items)
4. Install/replace meter box at point of supply.
5. A. Install 32 mm conduit, ..... conduit pits, new controller base and ..... detector pits as shown, or  
B. Install 32 mm conduit to telephone pit as shown.
6. Install ..... detector pits on ..... approach, 50 mm conduit to conduit pit and ..... feeder cables.  
(See general notes for further notes required).

##### GENERAL NOTES

1. Install parking sign poles and faces at .....
2. Remove parking sign poles and/or faces at .....
3. Relocate parking sign faces from ..... to .....

4. Install 10 pair communication cables as shown/from controller to fire station, ambulance, Tram Operator communication room.
5. Install audio tactile pedestrian detectors (constant or variable).
6. Reuse audio tactile pedestrian detectors (constant or variable).
7. Additional cabling (approximately .....m) to be placed in pit near pedestal ..... to provide for relocation of pedestals due to future road widening.
8. Contractor to seal verandah roof / ceiling at pedestal
9. Cap pedestal ..... under verandah and fit junction box.
10. Install road signs where shown and remove redundant signs.
11. Provide for advance tram detection, see note
12. Relocate photo-violation camera and flash unit as shown.
13. Install 63 mm Public Lighting conduit as shown.
14. Install additional detector pit on ... (location)... for telephone (Telstra) connection.

#### **B. COUNCIL**

1. Construct roadworks as shown.
2. Install ..... pram crossings as shown.
3. Reinstate kerb at ..... pram crossings as shown.
4. Arrange for transfer/installation of public lighting and/or the removal of any redundant poles or equipment. See notes
5. Trim/remove trees as shown.
6. Construct pedestrian footpath as shown.
7. Install temporary kerbing as shown.
8. Install parking sign poles and/or faces at .....
9. Remove parking sign poles and faces at .....
10. Relocate parking sign faces from ..... to .....
11. A Linemark as shown and remove any redundant markings, or.  
B Repaint linemarking.
12. Install R.R.P.M.'s and R.P.M.'S as shown and remove any redundant markers.
13. Install road signs where shown and remove redundant signs.

#### **C. VicRoads REGION**

1. Construct roadworks as shown.
2. Install ..... Pram crossings.
3. Reinstate kerb at ..... Pram crossings as shown.
4. Linemark as shown above and remove any redundant markings.
5. Install R.R.P.M.'S and R.P.M.'S as shown and remove any redundant markers.
6. Arrange for transfer/installation of public lighting to new joint use poles and the removal of any redundant poles or equipment. See notes
7. Install road signs where shown and remove redundant signs.
8. Install detector loops as shown.
9. Install new controller, or replace existing controller.
10. Linemark as shown and remove any redundant markings.



11. Terminate communication cable as shown from controller to fire station, ambulance, met rail.
12. Program controller or reprogram controller for modified phasing.

#### **D. TRAM OPERATOR**

1. Install overhead detector cable on approaches.
2. Install safety zones as shown.
3. Relocate P.T.C. Poles as shown.
4. Relocate/remove /install tram stops/shelters as shown.

#### **OTHER NOTES WHICH MAY BE REQUIRED ON THE PLAN**

A. The following notes, as appropriate, are to be placed in the notes section.

1. Advance tram detection on:-
    - (i) North approach - pit to base of P.T.C pole .....(.....M), detector cable overhead at M pole
    - (ii) South approach - pit to base of P.T.C pole .....(.....M), detector cable overhead to M pole

Or

    - (i) North approach - use tram loop .....(.... M), at the intersection of .....(Drg no ).
    - (ii) South approach - use tram loop .....(.... M), at the intersection of .....(Drg no ).

Or

    - (iii) Tram loop ..... to be used for transfer of demand to the intersection, POS at ..... (Drg no ).
  2. Audio tactile pedestrian detectors installed.
  3. Base information from ..... Plan no ..... and VicRoads site inspection.
  4. Public lighting notes,
    - (i) Pedestal .....to be ..... M JUP, JUMA, mounting height .....M, outreach M, with lights.
    - (ii) Pole on corner of ..... to be .....M JUP, mounting height ..... M, with lights.
    - (iii) Tram Operator pole no ..... to be JUP, mounting height .....M, outreach .....M, with ..... lights.
  5. Show speed zone.
- B. The following notes are to be placed near phasing diagrams.
1. Tram priority phases not shown.
  2. For full phasing details refer to phase selection drg no. .... (Traffic Operations).
- C. The following note to be placed under plan number.
1. Supersedes plan no..... Date

## **Display of signs on plans**

Signs and their standard identification numbering should be shown on the signal layout plan.

For information regarding typical signing layout for various intersection types refer to the Traffic Engineering Manual Volume 2.

If a sign is existing it will be shown for example as (E) and proposed signs are indicated on a sign schedule.

## **D2 Summary of Signal Design Procedure**

1. Obtain Base Plan (from files, Councils and/or Site survey).
2. Obtain
  - turning movement count for AM/PM peaks,
  - crash data,
  - information on any roadwork modifications.
3. Place signal hardware/roadwork changes on plan based on standard signal design.
4. Locate controller in position where it is "safe" and easily connected to telephone and power supply.
5. Arrange for a design or re-assessment of public lighting and include any public lighting on the plan.
6. Check plan for all features/hardware.
7. Send copies of the preliminary plan and form for comment to relevant stakeholders.
8. Collate comments and include on plan if appropriate.
9. Send copies of the plan to the following for agreement:
  - Council(s)
  - Operators of Private Company where a bus or tram route is affected.
10. Arrange installation.
11. Complete "as built" plan.

## **VicRoads Standard Drawings for Traffic Signal Components**

VicRoads Standard Drawings for traffic signal components can be found on VicRoads website [www.vicroads.vic.gov.au](http://www.vicroads.vic.gov.au).

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