

**Right Hand Turn Geometry
At
Urban Arterial Intersections in Edmonton:
Guidelines for Application of Different Geometric Treatments
For
Different Conditions**

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ABSTRACT

Right Hand Turn Geometry at Urban Arterial Intersections in Edmonton: Guidelines for Application of Different Geometric Treatments for Different Conditions

The City of Edmonton, like many municipalities in Canada, uses the Transportation Association of Canada's (TAC) Geometric Design Guide for Canadian Roads as the basis for its roadway design standards. Canadian municipalities, while using the TAC guide as a base, have typically developed their own specific geometric standards and typically rely on a single, one-size-fits-all, design standard for all their arterial intersections. The City of Edmonton's current standard for Arterial/Arterial intersections features right-hand turn geometry that includes a dedicated right-hand turning lane, a three-centered curve with 60m-35m-60m corner radii, a "pork-chop" island separating the right turning lane from the through lanes of the intersecting roadways and no taper on the receiving roadway. The City has, over the years, had concerns over the suitability of a single geometric standard for all situations at arterial intersections. In particular, the City appears to have experienced a higher rear-end collision rate than some other jurisdictions. There have also been concerns about the suitability of the current design standard for situations having high volumes of vulnerable users, or operating conditions that are significantly different from the characteristics implicit in the current design standard. For these reasons, the City commissioned Infrastructure Systems Limited (ISL) to review the current standard and to develop guidelines for use of several different right-hand turn geometric treatments that designers can choose from, to better fit the conditions expected at urban arterial intersections. The guidelines include several different geometric treatments to choose from, as well as criteria for their application. The guide was developed with input from a variety of technical sources as well as from professionals representing the transportation planning, roadway design, transit planning/operations and traffic operations disciplines within Edmonton's Transportation and Streets Department. The guidelines developed for Edmonton may be of interest to other communities who may wish to consider the proposition that the use of a single intersection design standard may not be the best approach.

1.0 BACKGROUND

The City of Edmonton, like many municipalities in Canada, uses the Transportation Association of Canada's (TAC) Geometric Design Guide for Canadian Roads as the basis for its roadway design standards. Canadian municipalities, while using the TAC guide as a base, have typically developed their own specific geometric standards and often rely on a single, one-size-fits-all, design standard for their arterial intersections. The City of Edmonton's current standard for Arterial/Arterial intersections features right-hand turn geometry that includes a dedicated right-hand turning lane, a three-centered curve with 60m-35m-60m corner radii, a "pork-chop" island separating the right turning lane from the through lanes of the intersecting roadways and no taper on the receiving roadway. The current design standard is applied at all arterial/arterial intersections, where possible, particularly in "green-field" situations where there are few, if any constraints.

Over the last ten to fifteen years, there has been increasing demand for and attention paid to the needs of pedestrians and other vulnerable users of Edmonton's transportation system. This evolution has arisen from greater public demand for pedestrian, bicycle-friendly and disabled-friendly transportation facilities. Likewise, the City of Edmonton has become more aggressive in its efforts to identify and address safety concerns through on going reviews of collision records, safety assessments, and safety audits.

In 2001 a study report entitled "Collision Analysis of Right Turning Roadways" was prepared for the **Centre for Transportation Engineering and Planning**. The study included a literature search, a national survey of Canadian practice, field observations, and a detailed review of collision records at arterial/arterial intersections in Edmonton, Strathcona County (east of Edmonton) and the Regional Municipality of Ottawa Carleton.

One of the few studies of turning roadway geometry was conducted by R.N. Aitken, et al, in Australia, in 1985/86. The study examined the designs of alternative left turn design geometry (equivalent to our right turns) and its influence on entry/exit tapers, driver vision and ease of entering cross-street traffic stream, accident records, and pedestrian accommodation. As a result of the study, the Road Construction Authority in Victoria, Australia, adopted a new tuning design standard that featured a high entry angle to improve visibility for turning vehicles, facilitate merging maneuvers into cross-street flow and improve the visibility of pedestrians crossing the turning stream.

In late 2003, Infrastructure Systems Ltd. was retained by the City of Edmonton to examine the merits of alternative right turn design treatments and to develop guidelines for the application of different treatments for different situations. The process for developing these guidelines included review of different standards, input from a variety of professional perspectives from the City of Edmonton's Transportation and Streets Department, and input from a recognized and well respected member of the transportation engineering academic community.

2.0 CURRENT PRACTICE

2.1 Transportation Association of Canada (TAC)

The September 1999 edition of TAC's Geometric Design Guide For Canadian Roads, deals extensively with the topic of intersection channelization.

In Section 2.3.6.2, the Guide offers a list of thirteen "design heuristics" for consideration. As a preamble to these heuristics the Guide states:

"Due to the variations possible in intersection angle, design vehicles, traffic turning volumes, pedestrian movements and other physical conditions, channelization does not lend itself to standardization. However, design consistency within a municipality or region reduces driver confusion"

While all thirteen design heuristics are worthy of consideration, the authors wish to draw attention to two specific ones:

"5. The geometry of the channelization should encourage speeds consistent with safe operation of the intersection, with special attention to vehicle and pedestrian areas."

"7. Where the channelization provides for a merge condition, the angle of intersection of the two streams of traffic should be small. Where the channelization provides for a yield condition, the intersection angle at the yield should be at least 60° to ensure that the driver is not required to look back more than 120° to check the approaching traffic."

Figure 2.3.6.1 of the Guide, included as **Exhibit 1** in this paper, offers a graphical representation of Right Turn design treatments for different conditions. In fact, four different situations are represented:

- Stop condition
- Yield Condition
- Merge Condition
- Added Lane (Lane-away) Condition

2.2 City of Edmonton

The City of Edmonton, as with other municipalities, has developed its own standards for intersection design. **Exhibit 2** illustrates the City of Edmonton's arterial/arterial standard intersection design. Edmonton's right turn design geometry has the following characteristics:

- Dedicated parallel right turn lane

- Three-centred corner radius curve (60m-35m-60m)
- No departure taper
- Corner pork-chop island
- Traffic control at the departure end of the pork-chop is a “Yield”
- Nominal intersection angle at the “Yield” is 27°

It is noteworthy that the nominal intersection angle at the yield (27°) is considerably less than the TAC suggested 60° for a yield condition. This means that a driver must turn his/her head 153° in order to check approaching traffic. Again, this is a considerable deviation from the TAC suggested maximum of 120°.

Negotiating a right hand turn at arterial intersections is a complex task requiring significant driver concentration and attention to multiple factors including volume and speed of approaching vehicles, number and size of gaps, pedestrians, cyclists and downstream conditions, including traffic queues and stopped buses

2.3 Other Municipalities

While a rigorous review of the standards of other municipalities was not carried out, a cursory review has indicated that the standards of other municipalities may also deviate from TAC’s suggestion with respect to intersection angle for a yield condition.

The overview of standards, indicates that municipalities generally differ in the details of the corner geometry such as radii used, the provision or non-provision of departure tapers and the use of lane-away treatments.

It is noted that past research indicates that the presence of a taper at the departure end of the right turn geometry does not appreciably affect driver behavior, as drivers typically avoid using the taper and continue to behave as if it is a “yield” as opposed to a “merge” condition.

3.0 DESIGN ALTERNATIVES

In order to arrive at guidelines for application of different geometric treatments, ISL developed three alternative concepts that could be considered for application under different conditions.

The three alternatives are:

- Alternative 1: Existing City of Edmonton standard, or similar (Existing Design)
- Alternative 2: New standard modeled after Australian practice (“Aussie” Design)
- Alternative 3: New standard without “pork-chop” island (Simple Corner Design)

Following is a description of each alternative.

3.1 Alternative 1 – Existing Design

As described in section 2.2 and depicted in **Exhibit 2**, the existing City of Edmonton standard has the following characteristics

- Dedicated parallel right turn lane
- Three-centred corner curve
- No departure taper
- Corner pork-chop island
- Traffic control at the departure end of the pork-chop is a “Yield”
- Nominal intersection angle at the Yield is significantly less than 60°

3.2 Alternative 2 – “Aussie” Design

A new right turn design concept, based on Australian practice was developed as depicted in **Exhibit 3**. This concept has the following characteristics:

- Dedicated parallel right turn lane
- Two-centred corner curve, with **controlling radius in the 15-20m range**
- No departure taper
- Corner pork-chop island
- Traffic control at the departure end of the pork-chop is a “Yield”
- Nominal intersection angle at the Yield is **greater** than 60°

The main objectives of this design concept are:

- To reduce driver workload by reducing the angle that drivers must turn their heads to check approaching traffic

- To improve the visibility of pedestrians by reducing the viewing angle for drivers having to slow down for approaching pedestrians
- To reduce the turning speed to make it more consistent with a “yield” condition that may require a vehicle to come to full stop

3.3 Alternative 3 – Simple Corner Design

A new arterial intersection design concept was developed that features simple corner geometry, without a pork-chop island as depicted in Exhibit 4. The main features of this alternative are:

- Dedicated parallel right turn lane
- Simple or two-centred corner radius with **controlling radius in the 12-15 m range**
- No departure taper
- No corner pork-chop island
- Traffic control at the intersection is a “**Stop**”

The main objectives of this design concept are:

- To reduce driver workload by eliminating the pork-chop island and all the associated factors that drivers must pay attention to
- To improve the visibility of pedestrians/vulnerable users and reduce points of possible conflict with pedestrians
- To reduce the turning speed and the variability associated with driver behaviours at a “yield”.

4.0 EVALUATION OF ALTERNATIVES

In order to assess the merits of several different design concepts, ISL and City of Edmonton staff, representing the Transportation and Streets Department, convened a workshop in the Fall of 2003. City participants in the workshop represented the following disciplines:

- Roadway Functional and Detailed Design
- Traffic Operations
- Transit Planning/Operations
- Community Transportation Planning
- Development Review

In addition to City participants and ISL staff, the workshop included Dr. John Morrall of the Canadian Highways Institute Ltd., who served as an outside expert and advisor to the project team.

4.1 Design Objectives

The project team, including workshop participant, identified the following design objectives (in no particular order of preference) for the design alternatives under consideration, some of these objectives were explicitly as identified as “sacred cows”:

- Accommodate transit
- Accommodate emergency vehicles, fire trucks
- Move turning traffic out of through traffic stream
- Maximize capacity
- Facilitate merging of through and turning traffic
- Reduce vehicle-pedestrian conflicts
- Provide appropriate pedestrian refuge
- Accommodate design vehicles
- Accommodate bicycles
- Ensure consistency for similar situations
- Recognize uniqueness of each intersection
- Reduce driver workload
- Consider maintenance issues
- Consider “human factors”
- Provide safety “equity”

4.2 Evaluation Criteria

In order to evaluate the design concept alternatives, the following criteria were selected and used:

- Traffic Volumes; both cross-street and right turn volumes were considered
- Pedestrian/Bicycle Volumes
- Right Turning Truck Volumes
- Safety; pedestrian visibility, sightlines, driver workload, and approach speed
- Downstream Conditions; downstream access driveways, bus stops, transit service frequency, operating speed of receiving roadway
- Capacity

4.3 Evaluation of Design Alternatives

The three design alternatives under consideration were evaluated against the above noted evaluation criteria. A rating scale of 1 to 10 was used with 1 being the worst possible score and 10 being the best possible score. For each evaluation criterion, the alternatives were assigned a score between 1 and 10. The scoring was performed by the Fall 2003 workshop participants. The evaluation of the three design alternatives are depicted in Tables 1, 2 and 3 respectively.

It is clear from the evaluation of the three different design alternatives, that the workshop participants see a place for different right turn design treatments, depending on conditions. It is also clear that the City's existing right turn design standard is rated poorly under some conditions, but is deemed to be quite appropriate in other situations

On the basis of the evaluation of the alternatives, the following broad conclusions can be reached:

Alternative 1 – Existing Design Standard

The existing standard, or a variation thereof, is deemed to be appropriate under the following conditions:

- Low pedestrian volumes crossing right turning traffic
- Moderate to high turning volumes
- Moderate to high proportion of right turning trucks and/or buses
- High operating speed and / or high level of service on receiving roadway
- No downstream bus stop in close proximity to intersection, or infrequent bus service
- No downstream access driveways in close proximity to intersection, or low use driveway

Alternative 2 – “Aussie” Design

This design concept is deemed to be appropriate under the following conditions:

- Moderately high turning and cross-street traffic volumes
- Low to moderate pedestrian volumes crossing right turning vehicles
- Low to moderate amounts of turning truck and bus traffic
- Moderate to high operating speeds and level of service on receiving roadway
- No downstream bus stop in close proximity to intersection, or infrequent bus service
- No downstream access driveways in close proximity to intersection, or low use access driveway

Alternative 3 – Simple Corner Design

This design treatment is deemed to be most appropriate under the following conditions:

- Low to moderate turning and cross-street traffic volumes
- Moderate to high pedestrian volumes crossing right turning vehicles
- Low amounts of right turning truck and bus traffic
- Low to moderate operating speeds and level of service on receiving roadway
- Bus stop in close proximity to intersection, or frequent bus service
- Downstream access driveways in close proximity to intersection, or high use driveway

Table 1
Evaluation of Existing Right Turn Design

CRITERION			
TRAFFIC VOLUMES		High	Medium
Cross Street and/or Rt. Turn Volume		<i>7</i>	<i>5</i>
PEDESTRIAN VOLUMES		High	Medium
High Right Turn Volume		<i>2</i>	<i>3</i>
Med Right Turn Volume		<i>2</i>	<i>3</i>
Low Right Turn Volume		<i>2</i>	<i>2</i>
TRUCK VOLUMES		High (~10%)	Med (~5%)
Right Turning Truck Volumes		<i>8</i>	<i>7</i>
SAFETY			
Visibility of Peds to Rt Turn Vehicles		<i>2</i>	
Visibility of Cross-street traffic		<i>3</i>	
Driver Workload		<i>3</i>	
Approach speed vs. Driver Behaviour		<i>3</i>	
DOWNSTREAM CONDITIONS			
Driveway Accesses to Development		<i>2</i>	
Far-Side Bus Stop		<i>2</i>	
High Operating Speed on Receiving Road		<i>7</i>	
CAPACITY		<i>Inconclusive Rating</i>	

Rating Scale: 10 = Best; 1=Worst

Table 2
Evaluation of “Aussie” Right Turn Design

CRITERION			
TRAFFIC VOLUMES		High	Medium
Cross Street and/or Rt. Turn Volume		5	6
PEDESTRIAN VOLUMES		High	Medium
High Right Turn Volume			6
Med Right Turn Volume			5
Low Right Turn Volume			3
TRUCK VOLUMES		High (~10%)	Med (~5%)
Right Turning Truck Volumes		3	5
SAFETY			
Visibility of Peds to Rt Turn Vehicles		7	
Visibility of Cross-street traffic		6.5	
Driver Workload		6	
Approach speed vs. Driver Behaviour		6	
DOWNSTREAM CONDITIONS			
Driveway Accesses to Development		<i>Not Rated</i>	
Far-Side Bus Stop		<i>Not Rated</i>	
High Operating Speed on Receiving Road		<i>Not Rated</i>	
CAPACITY		<i>Inconclusive Rating</i>	

Rating Scale: 10 = Best; 1=Worst

Table 3
Evaluation of Simple Right Turn Corner Design

CRITERION			
TRAFFIC VOLUMES		High	Medium
Cross Street and/or Rt. Turn Volume		3	5
			8
PEDESTRIAN VOLUMES		High	Medium
High Right Turn Volume		7	7
Med Right Turn Volume		7	7
Low Right Turn Volume		7	8
TRUCK VOLUMES		High (~10%)	Med (~5%)
Right Turning Truck Volumes		2	4
			6
SAFETY			
Visibility of Peds to Rt Turn Vehicles		8	
Visibility of Cross-street traffic		8	
Driver Workload		8	
Approach speed vs. Driver Behaviour		8	
DOWNSTREAM CONDITIONS			
Driveway Accesses to Development		<i>Not Rated</i>	
Far-Side Bus Stop		<i>Not Rated</i>	
High Operating Speed on Receiving Road		<i>Not Rated</i>	
CAPACITY		<i>Inconclusive Rating</i>	

Rating Scale: 10 = Best; 1=Worst

5.0 GUIDELINES FOR APPLICATION OF RIGHT TURN DESIGN TREATMENTS

On the basis of the evaluation of three alternative right turn design concepts, a tentative set of guidelines have been developed for selection of appropriate right turning geometry at arterial intersections in Edmonton. The guidelines are subject to further review and fine-tuning, but they point to a rational and informed way to choose between several possible design treatments. Use of these guidelines is expected to result in geometric selections that are better suited to specific situations which may vary from intersection to intersection.

In addition to the criteria used in the evaluation of geometric alternatives discussed in section 4, the guidelines include two additional criteria: land use and truck route designation of the roadways under consideration.

The land use criterion has been added as it is seen as a proxy for a number of other factors. In green-field situations, where volumes of vehicles, trucks, buses and pedestrians may not be known, land use or proposed land use can be a good proxy that can be used to predict the kinds of conditions that are likely to materialize at an intersection. For example, if an elementary school is slated for construction near an arterial intersection, it is reasonable and prudent to assume that significant pedestrian activity can be expected at that location. Conversely, if an intersection is located within a predominantly industrial area, it may be reasonable to expect higher levels of trucks traffic through the intersection, thereby influencing the choice of right turning geometry.

The truck route designation has been added, again, to assist the designers in situations where other information may not be readily available.

Table 4 provides the suggested guidelines for the selection of tight turn geometry at arterial intersections.

6.0 CONCLUSIONS

It is clear from the evaluation of the different geometric design alternatives, that there is a place for applying different right turn design treatments, depending on conditions. It is also clear that the City of Edmonton's existing right turn design standard is not well suited for all conditions, and there are clearly other design "standards" that should be applied in some circumstances.

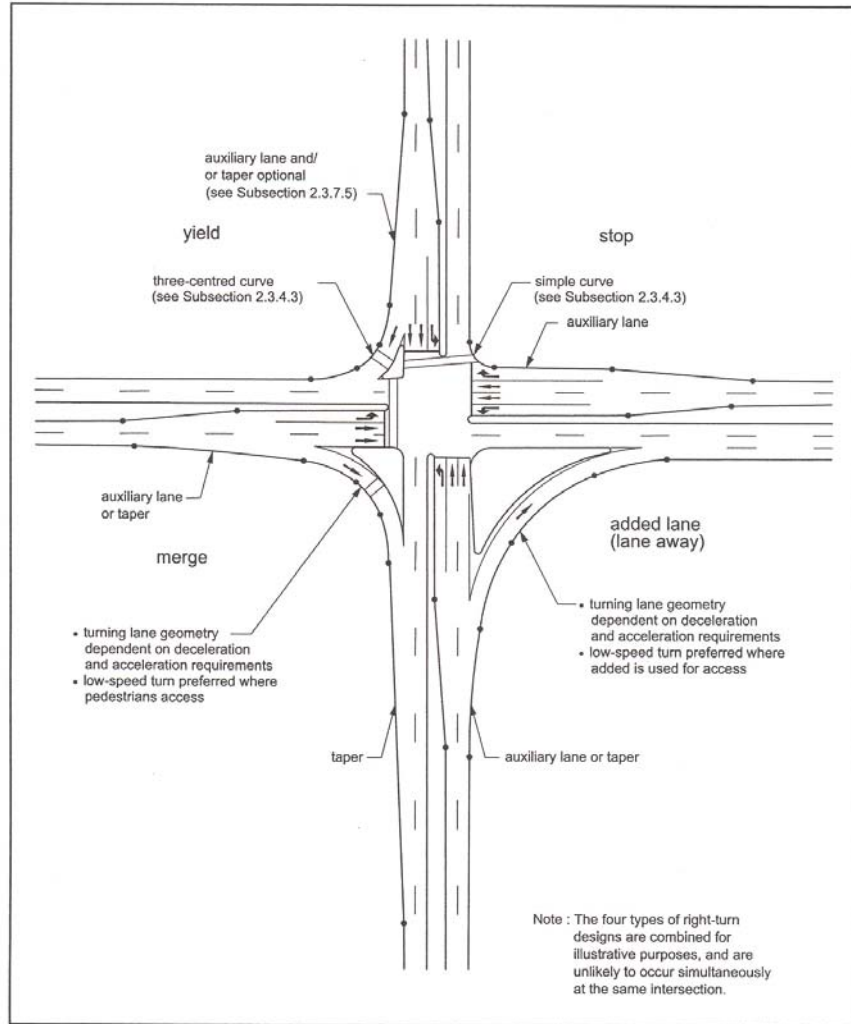
A tentative set of guidelines have been developed to assist designers in selecting right turn design geometry that is best suited to prevailing or expected conditions at any given intersection. The work carried out for Edmonton, may have broader implications in that other municipalities may be faced with similar issues. The City of Edmonton has as yet not accepted or formally adopted the guidelines presented in this paper.

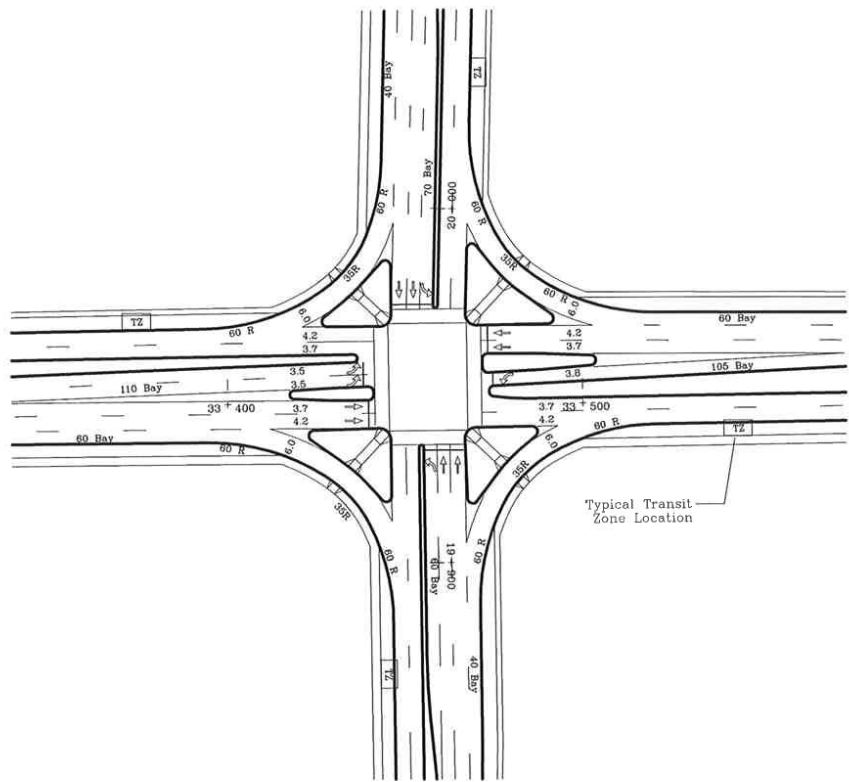
Table 4: Guidelines for Selection of Right Turn Geometric Treatments at Arterial Intersections

Criteria	Existing Design Standard	"Aussie" Design	Simple Corner Design
Peak Hour Traffic Volumes			
V _c = Cross-street Volume in Curb Lane			
V _r = Right Turning Volume	>= 150 vph	75-150 vph	< 75 vph
V _t = V _c +V _r	<= 500 vph	500-700 vph	> 700 vph
Peak Hour Right Turning Truck and Bus Volumes			
V _{tb} = Right Turning Truck and Bus Volumes	>= 25 vph	10-25 vph	< 10vph
PK Hr Pedestrian Volume Crossing Turning Traffic			
	<= 20 peds/hr. (LOW)	20-40peds/hr.(MED)	> 40 peds/hr. (HIGH)
Downstream Conditions			
Proximity of Downstream Access Driveways	> 60m	40-60m	<40m
Bus Stop/Bus Service Frequency	< 12 buses/hr	12-24 buses/hr	> 24 Buses/hr
Land Use Mix within 400m			
Low/Medium Density Residential	x	x	x
High Density Residential		x	x
Schools, College, University		x	x
Seniors Housing		x	x
Retail Commercial		x	x
Highway Commercial	x		
Industrial	x		
Truck Route Designation			
Arterial Truck Route	Yes	Yes	No
Arterial Non-Truck Route	No	Yes	Yes



Figure 2.3.6.1 Typical Right-Turn Designs

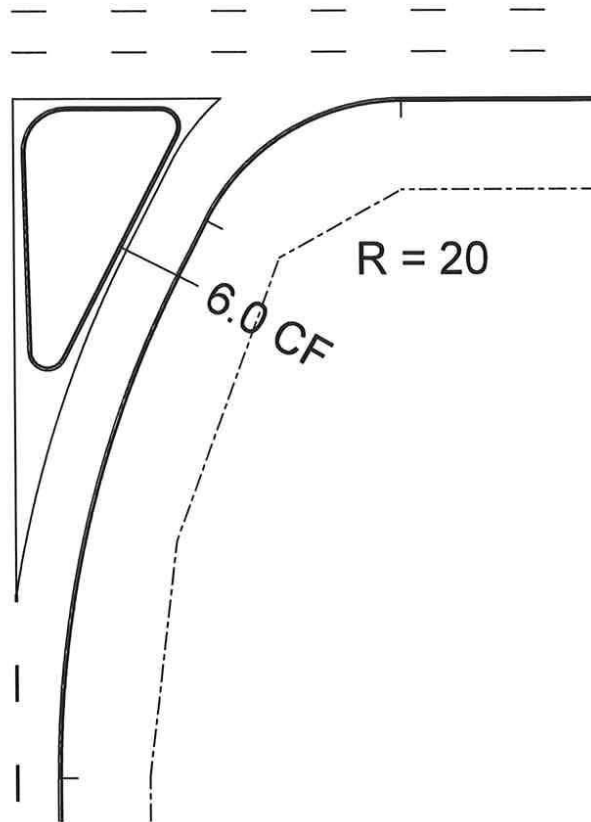




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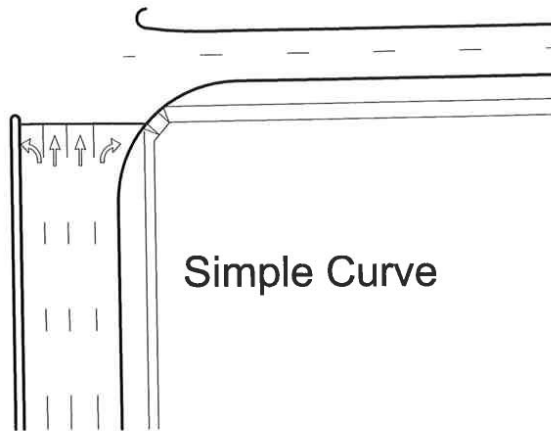
**EXISTING
DESIGN STANDARD**

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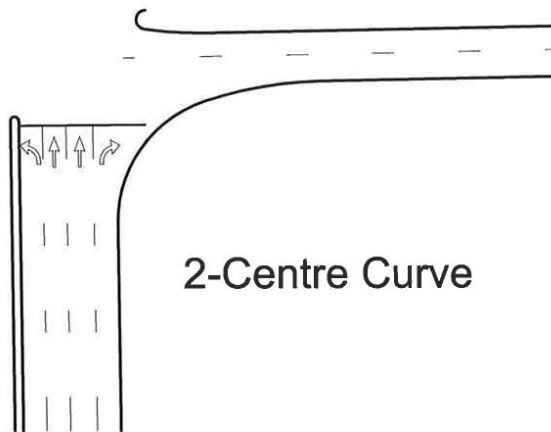


"AUSSIE" DESIGN

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Simple Curve



2-Centre Curve

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**SIMPLE
CORNER DESIGN**

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6.0 REFERENCES

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