Code of Practice (Part 2)
Intersections

IUT

This document has been prepared by the Transportation Research and Injury Prevention Programme (TRIPP) for the Institute of Urban Transport (IUT), Ministry of Urban Development. The primary purpose of this document is to provide a code of practice for various Urban Road Components. It has been developed in five parts. This is part two of five, which elaborates various norms and standards for intersection design.

Institute of Urban Transport

Ministry of Urban Development

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The Road Intersections are the critical elements of the Road sections and the function of a designed intersection is to control conflicting and merging streams of traffic, to minimize the delay including pedestrian and bicycle traffic.

Intersection design influences the capacity of the corridor and the safe movement of conflicting directions. The pattern of the traffic movements at the intersection and the volume of traffic on each approach, during one peak period of the day determine the lane widths required including the auxiliary lanes, traffic control devices and channelization, wherever necessary. The arrangement of the islands and shape, length of the auxiliary lanes also differs based upon the type of intersection.

The general design principles of intersection design are the approach speeds[1], restriction on available land, sight distance available and the presence of the larger volume of all the road users in urban areas, although it is necessary for the users of these guidelines that there should be an application of the knowledge about the local conditions while interpreting and arriving at the solution in terms of design.

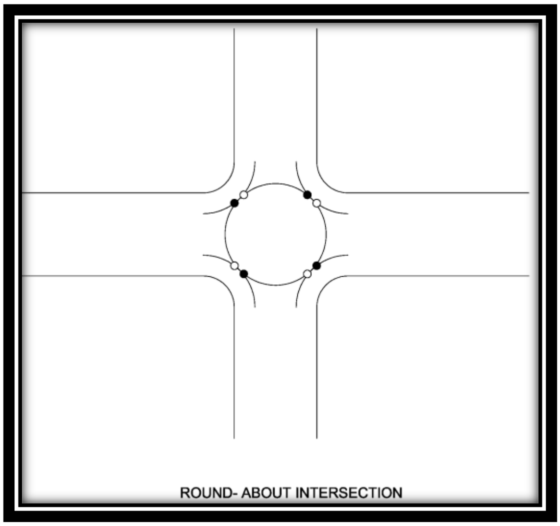


Figure 1-2 Road conflicts on roundabout

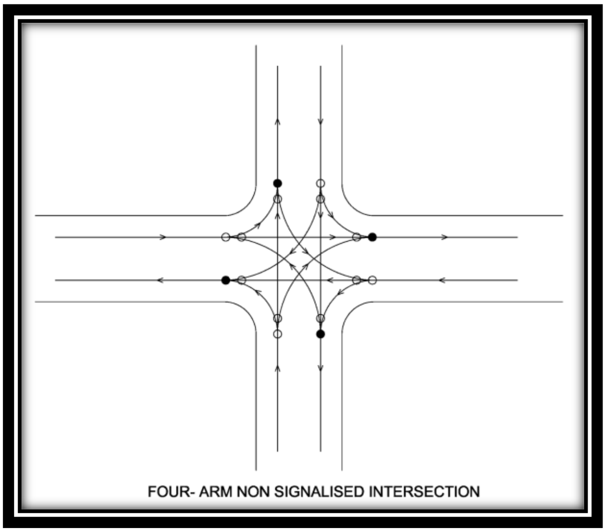


Figure 1-1 Road conflicts (Un signalized)

[1] A policy on Geometric of Design of Highways and streets, Chapter Collector Roads and Streets (Urban), page 479, AASHTO, 1994.

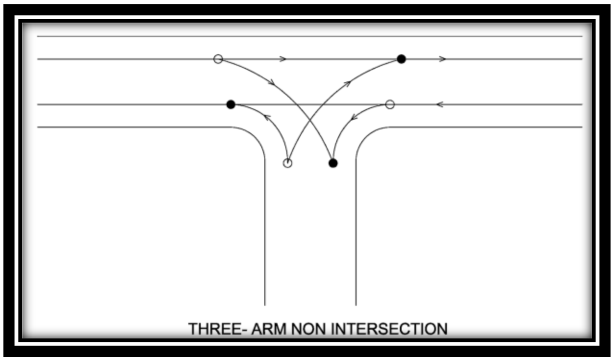


Figure 1-3 Road conflicts on un signalized Three Arm Junction

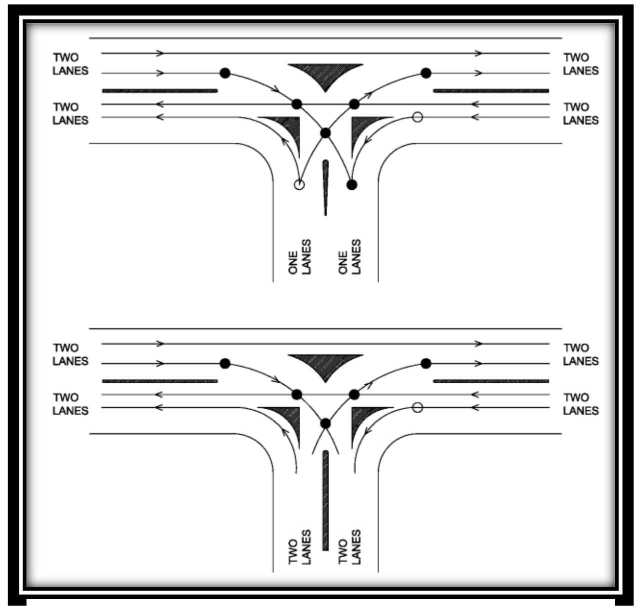


Figure 1-4 Channelization on three arm junction

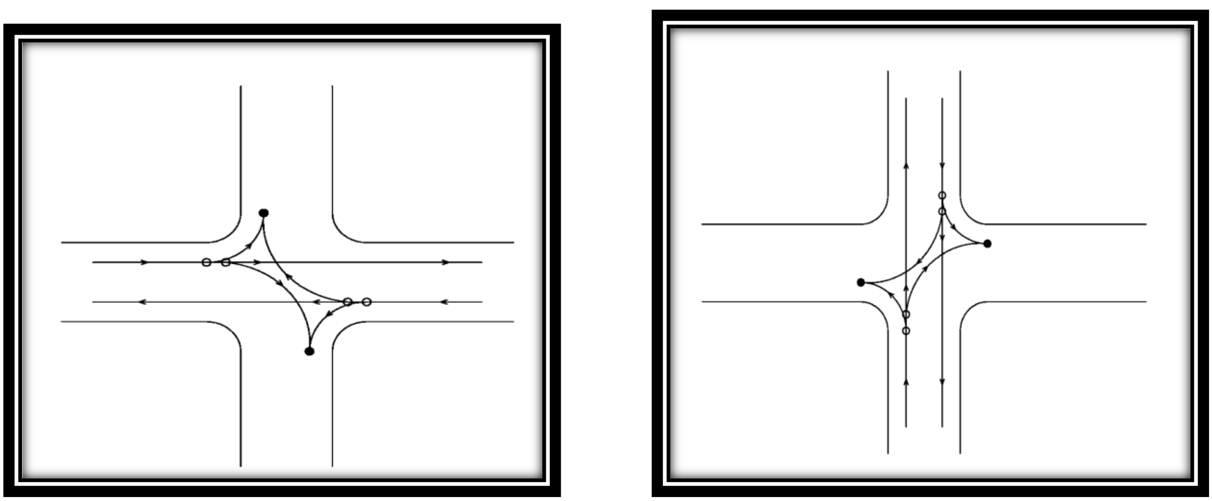


Figure 1-5 Road conflicts on signalized junctions

1.1. FUNCTION

The function of an intersection is to enable safe interchange between two directions or two modes.

The design of an intersection must be comprehensible to road users. This aim is best achieved with a well-organized situation with a minimum number of conflict points. The basic principle to limit the number of conflict points as much as possible can be at odds with other requirements; for example in relation to traffic flow. If additional lanes are built for this reason, the result can be that the traffic situation is no longer sufficiently comprehensible and 'aids' (such as traffic lights) are needed.

It is important that the speed of the various road users is minimized during interchanging. In collision with a car at low speed, the chance of survival is significantly greater than when the car is traveling at a higher speed.[2]

1.2. REQUIREMENTS OF A DESIGNED INTERSECTION

Intersections should have uniform design standards so that even a new comer in the area anticipates what to expect at the intersections. Some of the major design elements in which uniformity is required are design speeds, intersection curves, vehicle turning paths, super elevations, level shoulder width, speed change lane lengths, channelization types of curves and types of signs and markings.

Intersections must be designed to maintain the consistency and the continuity of the infrastructure dedicated to each road user and the cohesion should be maintained for which the design elements such as raised crossings , path markings and segregation by posts. All the intersection movements should be obvious to all road users.

1.3. SAFETY

The main objective of the intersection design is to reduce the number and severity of potential conflicts between cars, buses, trucks, bicycles and the pedestrians .[3]

[2] Highway Engineering. Martin Rogers , Blackwell publishing, 2003

[3] Guidelines for the Design of At Grade intersections in Rural and Urban Areas(special publication 41) ,Chapter 2, pare 2.2.1, page 06, Indian Road Congress, 1994

2. CLASSIFICATION OF INTERSECTION

Intersection functions to control conflicting and merging traffic(and to achieve this, intersections are designed on certain geometric parameters and are broadly classified into three main heads. Designers are often faced with tough choices of prioritizing the conflicting requirements of one mode over another. Here the key is to apply the most appropriate solution based on the type of junction as well site conditions/constraints. The three main types of junction solutions are:

1. Un signalized intersection,
2. Signalized Junctions
3. Roundabouts

Basic Design Principles

The ultimate aim is to provide all the road users with a road layout which minimizes confusion at the conflict points. The need for flexibility dictates the choice of the most suitable junction type. The selection process requires the economic, environmental and operational effects of each proposed option.

Different combinations of the intersection type is determined primarily by the number of intersecting legs, the topography, the character of the intersecting roads, the traffic volumes, patterns, and speeds, and the desired type of operation.

Types of intersection depending on the geometric forms are as follows

- ✓ *3- Leg Junction*
- ✓ *4- Leg Junction*
- ✓ *Multi-Leg Junction*

2.1. UN-SIGNALIZED

Locations, where secondary (access or distributor) or low volume roads intersect with primary or a higher volume corridor (arterial or distributor), may be treated as un-controlled or un-signalized junctions. These junctions may be three or four armed. Uncontrolled intersections can create dangerous situations for NMVs conflicting with crossing or turning motorized traffic. These conflicts can be classified as conflicts at primary or secondary roads.

2.1.1. PRIMARY ROAD CONFLICTS

At uncontrolled junctions with distributor roads all turns may be permitted, where vehicular traffic volume is considered low and enough safe gaps are available. At higher volume distributor roads, and on arterial roads where high volumes are combined with high speeds of motorized vehicles, restrictions on right turns for motorized vehicles should be enforced through a continuous median on the primary road. This discontinues or terminates the secondary streets at primary roads allowing only left turning movements at the resultant junction. However any restrictions on crossing NMV and pedestrian traffic across the primary roads would increase their journey time as well distances and adversely affect the directness of the route. At such locations where alternative safe crossings are more than 200m away 'NMV and pedestrian only' (no motorized vehicles allowed) crossings should be considered either as 'grade separated' or 'signalized at-grade', especially at locations where high crossing demand exists. On low volume distributor roads where all turns are permitted, NMVs may turn as vehicles by gap acceptance. Here speeds of 30km/hr or less should be achieved at the junction by introducing traffic calming devices on all conflicting streets, including the primary road.

2.1.2. SECONDARY ROAD CONFLICTS

NMVs moving along primary roads conflict with vehicular traffic while crossing secondary streets at uncontrolled junctions. Similar conflicts are also created at property entrances requiring vehicular access (such as residence and petrol stations). Adequate treatment along NMV path at junctions is required to resolve these conflicts and ensure safety and coherence for crossing bicyclists. Design requirements for such treatment include speed reduction for vehicles on secondary roads, design ensured continuation of NMV path/track and warning NMVs about expected vehicular conflicts. All of these requirements can be bundles in a single junction design known as the raised crossing design. Raising the motor vehicle lane or crossing by a set height achieves raised crossings. This is typically equivalent to the height of the footpath so that the design benefits pedestrians and others with special mobility needs (such as wheelchairs) to move across unhindered while crossing vehicles slow down (due to the steepness of the ramp access to the crossing as on a speed breaker) and are forced to yield to them. In this arrangement however cyclists need to be accommodated to ensure a similar quality and level of service as the pedestrian.

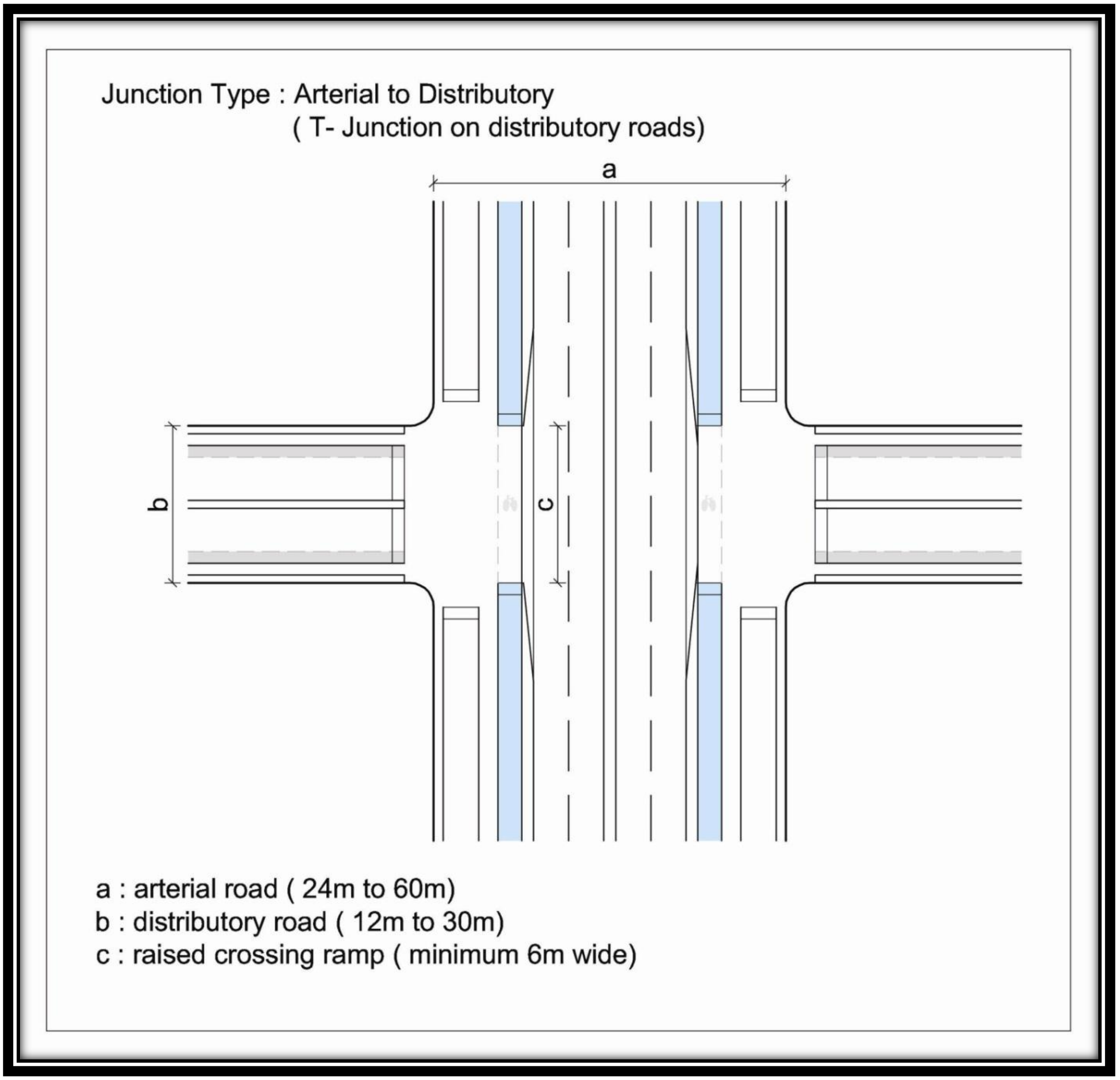


Figure 2-1 Arterial to Access – raised crossing on access roads

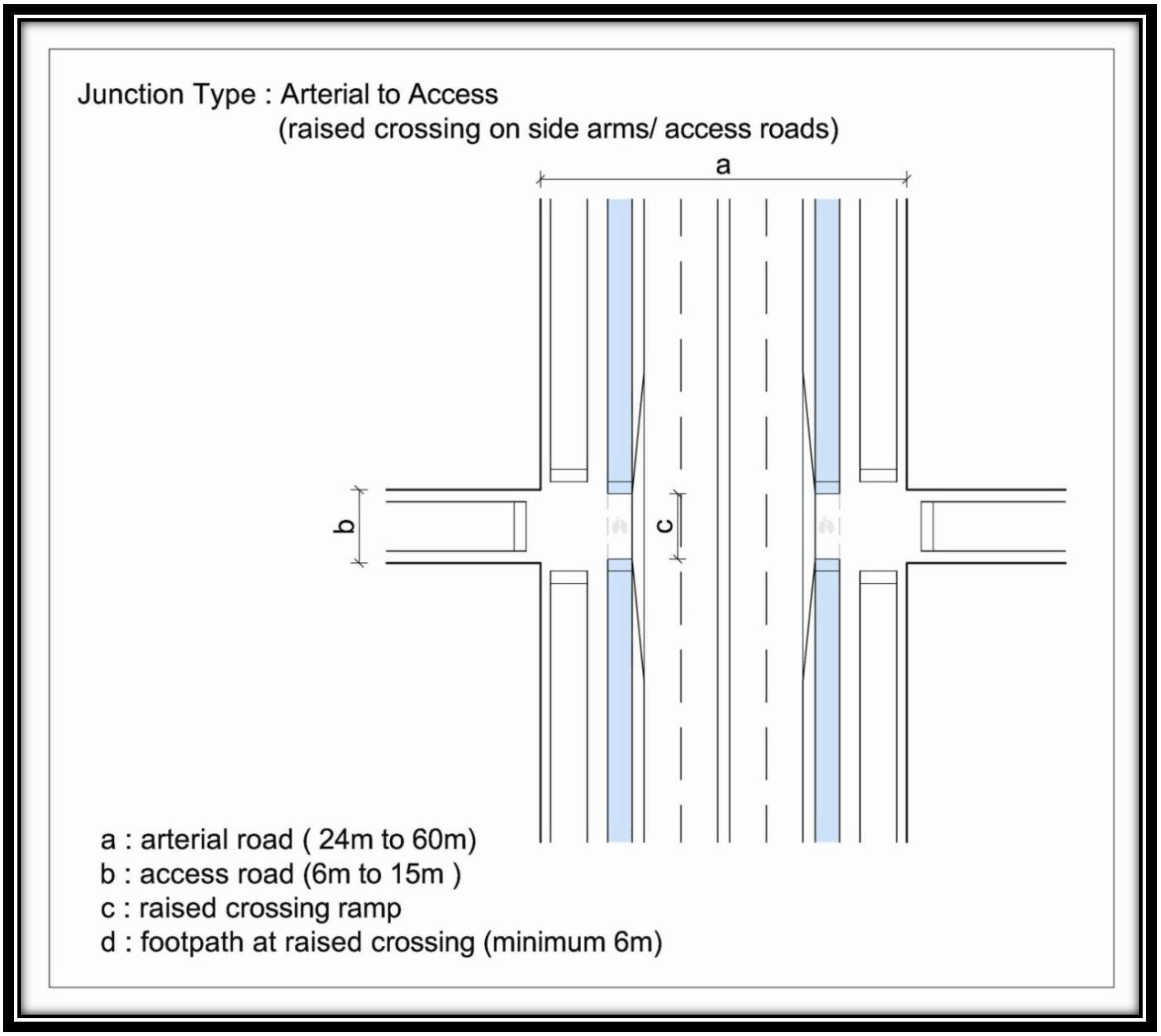


Figure 2-2 Arterial to Access – raised crossing on side arms

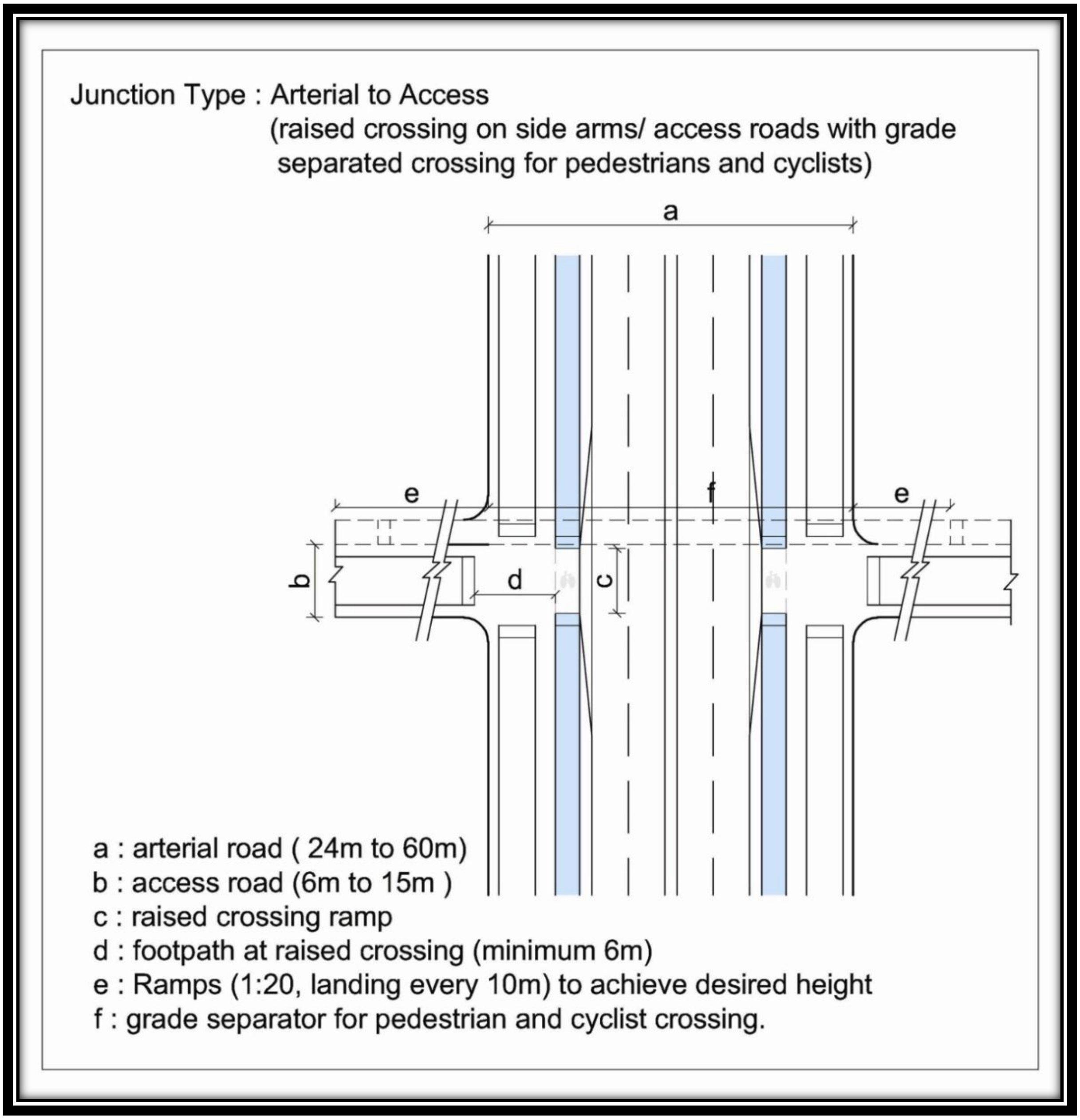


Figure 2-3 Arterial to Access – Raised Crossings on side arms with grade separated crossing for cyclists and pedestrians

1. **Common Raised Crossing** – Here the designer creates a common level for cycle track and footpath and vehicles access this through a single ramp on each side. Typically this is at the level of pedestrian path as pedestrian (especially those with special mobility needs) convenience is given a higher priority as they are considered the weakest and the most vulnerable link in the transportation chain. On arterial roads where separate cycle tracks exist, the cycle track level is raised to the level of the pedestrian path at the crossing using a 1:20 ramp. On distributor roads the bicycle lane continues along the primary road at the carriageway level and only the pedestrian path serves as a raised crossing.

2. **Split Raised Crossing** – On some arterial roads, where provision of a service road is not possible, direct property access would require to be provided. This would result in frequent vehicular access across the cycle track and footpath. Here the designer may choose to use 'split raised crossings' to avoid inconvenience to NMVs caused by frequent ramps/level changes at 'common raised crossings'. At split crossings, the pedestrian path and the NMV track continue at their respective (regular mid block) levels across the crossing. Vehicles cross each path using ramps. Hence the first ramp from the MV lane takes the motor vehicles to the level of cycle track, and another one takes it to the level of pedestrian path. These split ramps result in what is called a split raised crossing design.

3. **At common Raised Crossing** (locations along arterial roads where cycle tracks are used), the NMV path should be marked across the crossing, in placement markings, linking tracks on both sides as directly as possible.

4. **Priority Intersection** A priority intersection occurs between two roads, one termed the major road and the other the minor road. The major road is one assigned a permanent priority of traffic movement over that of the minor road. The minor road must give priority to the major road. The principle advantage of these type of intersections is that the traffic on the major road is not delayed. Visibility, particularly for traffic exiting the minor junction, is a crucial factor in the layout of priority intersection.

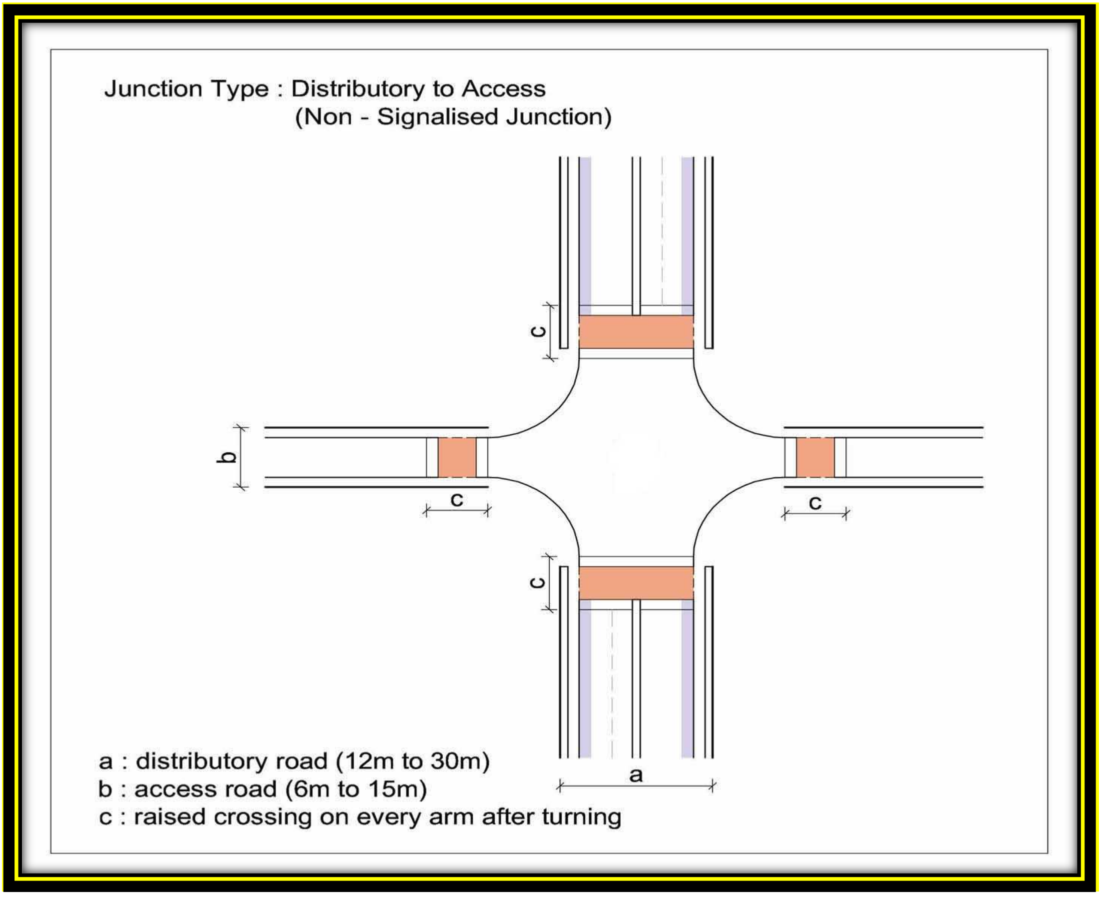


Figure 2-4 Non-Signalized Junction - Distributor to Access – raised crossings

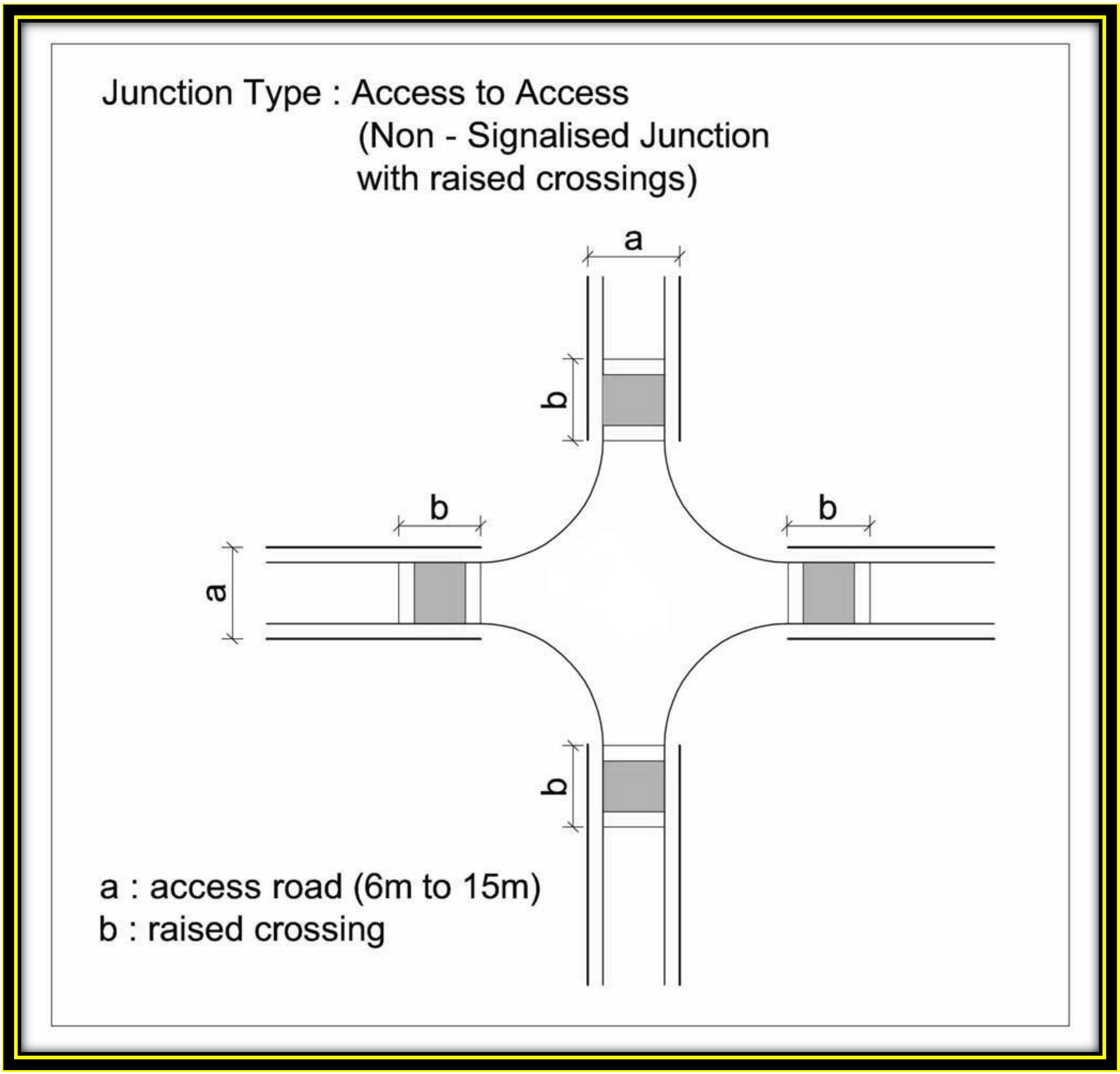


Figure 2-5 Non- Signalized junction - Access to Access- raised crossing

2.2. SIGNALIZED INTERSECTIONS

Signalized intersections are a less (sustainably) safe solution than roundabouts or grade separated intersections and must therefore be regarded as second best in terms of safety[4]. Since signalization is applied at junctions where higher motorized vehicle volumes require control by traffic lights, it is more likely that signal engineers will prioritize motorized traffic over bicyclists in the phasing plan. Here, selected geometric and signal phase design elements can be used to result in a signalized intersection, which significantly improves the crossing conditions for cyclists and pedestrians. The list of these elements available at a designer's disposal and the design process leading to their selection and use has been described in the following section.

Table 2-1 Criteria to provide a Signalized Intersection- Minimum Vehicular volume

Number of lanes for moving traffic on each approach		**Motor Vehicle per hour on major street (both direction)**	**Motor Vehicle per hour on minor street (one direction)**
Major Street (any type)	Minor Street (any type)		
1	1	650	200
2 or more	1	800	200
2 or more	2 or more	800	250
1	2 or more	650	250

4 CROW, Design Manual for Bicycle Traffic, Page 203, The Netherlands, June 2007

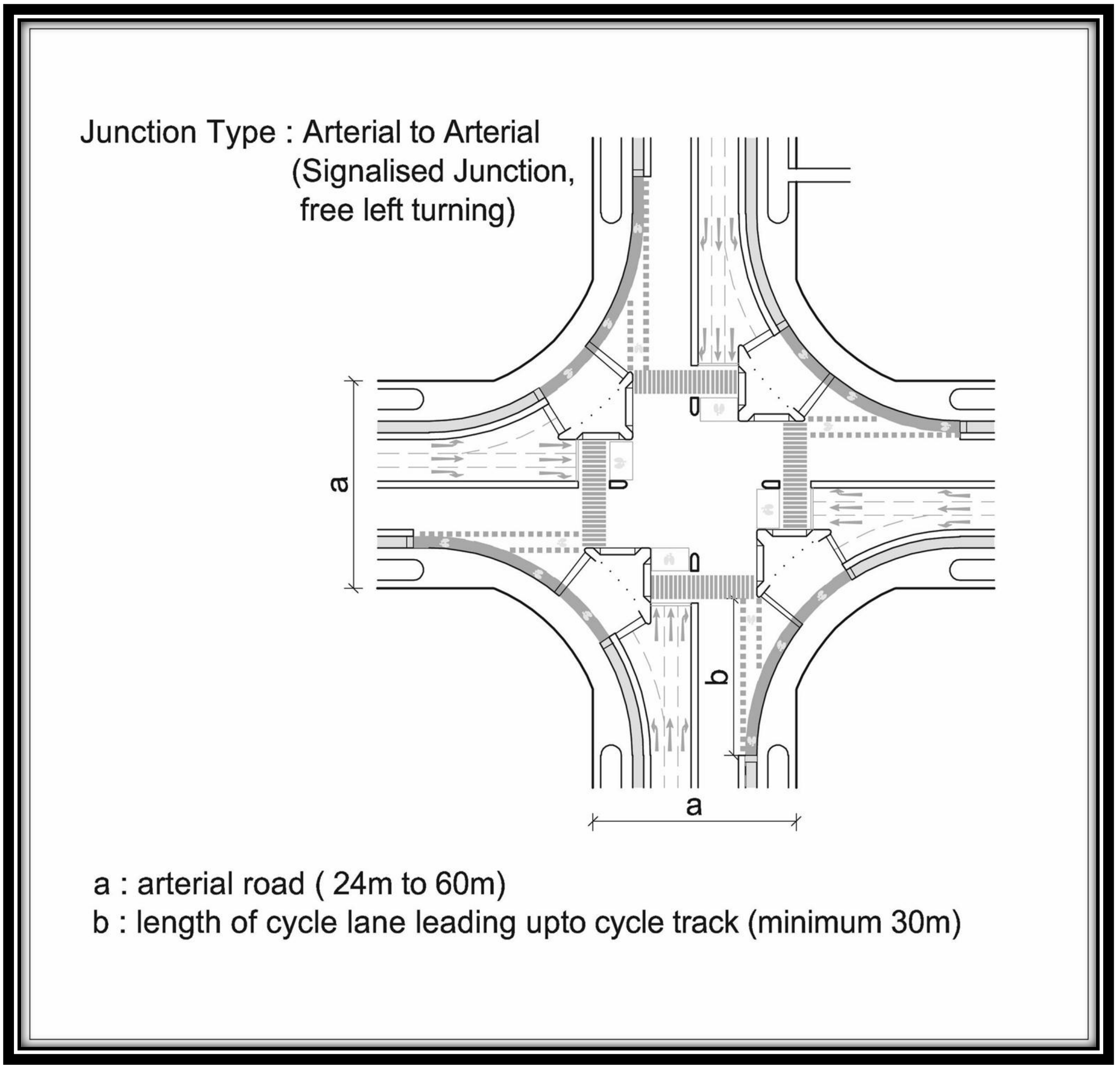


Figure 2-6 Arterial to Arterial –Signalized intersection (with pedestrians and cyclist facility)

Geometric and Signal Design Elements

As mentioned earlier, NMV crossing across a junction may be planned as along pedestrians or motorists or as an independent mode. Each method of crossing affects the intersection design and the use of geometric elements differently. What is important here is that the directness, safety and comfort of cyclists should not be compromised, by adapting a particular method and subsequent design based on the same. Since expected delays for cyclists at signalized intersections are already considerably longer than other junction solutions, a flexible approach to adapt a single or combination of crossing methods, in order to minimize the crossing delays should be adopted. This section elaborates on the use of a variety of bicycle friendly intersection design elements to minimize crossing delays for NMVs. A designer may use one of the following design tools for Signal and intersection geometry to be able to address NMV requirements without significantly compromising those of motor vehicles:

Table 2-2 Elements of Design and Criterion of use

Element	Criterion for Use
Signal Design	
Signal Cycle Design	Minimize delays to waiting cyclist and improve directness
Signal Pole Location and aspect design	Ensure safety of crossing cyclist
Geometric Design	
Segregation at or Near Intersection	Ensure safety and directness for cyclists
Bicycle Holding area (stacking spaces) or boxes	Ensure flow capacity and directness
Grade separated crossing for cyclists	Ensure Safety and directness for cyclists
Intersection Crossing Path	Ensure safety of cyclists

Out of these, bicycle holding area or boxes and signal phase design are inter related to the flow of bicyclists and motorized vehicles, and need to be looked at together. These have been discussed in a separate section after discussion on other design elements described here.

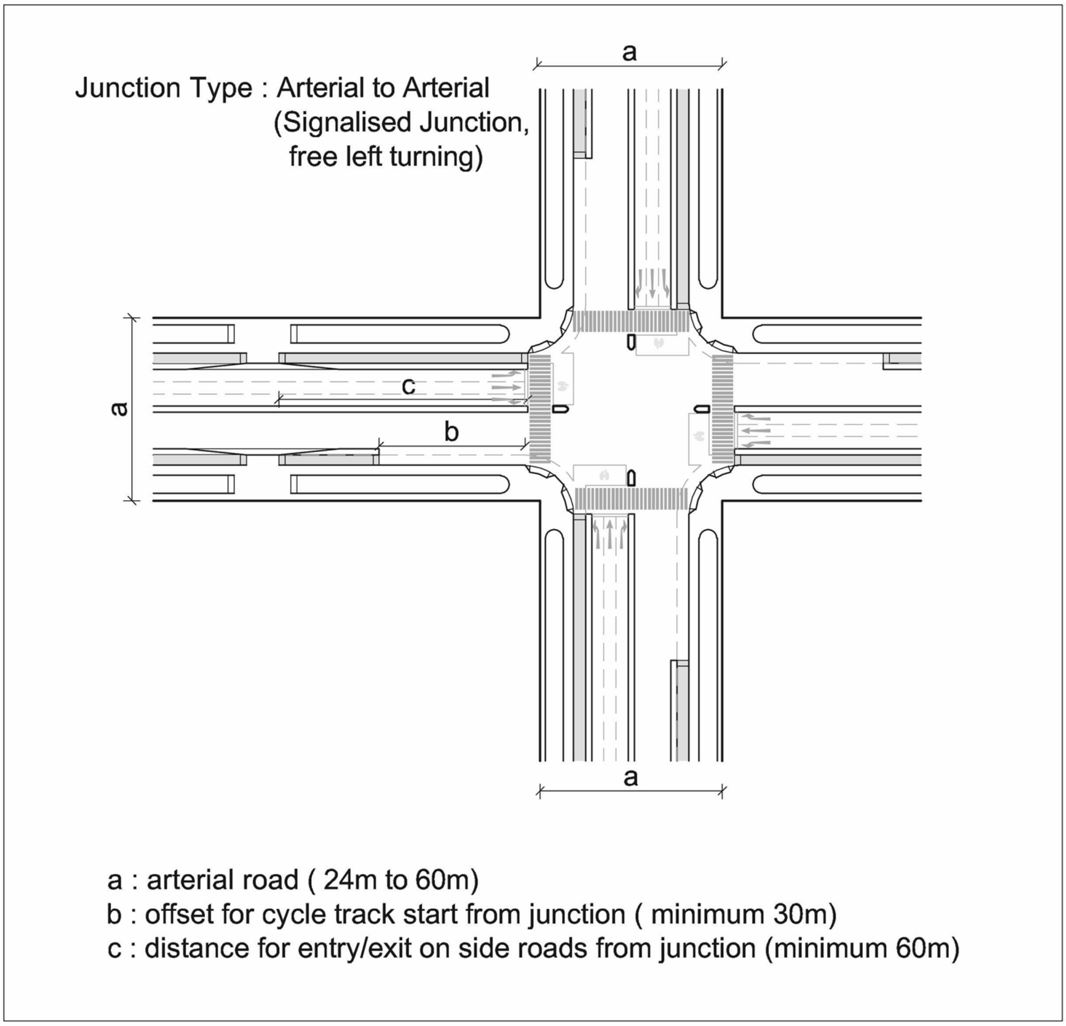


Figure 2-7 Signalized Intersection - Arterial to Distributor – with slip lanes

Segregated NMV tracks at or near the Intersection

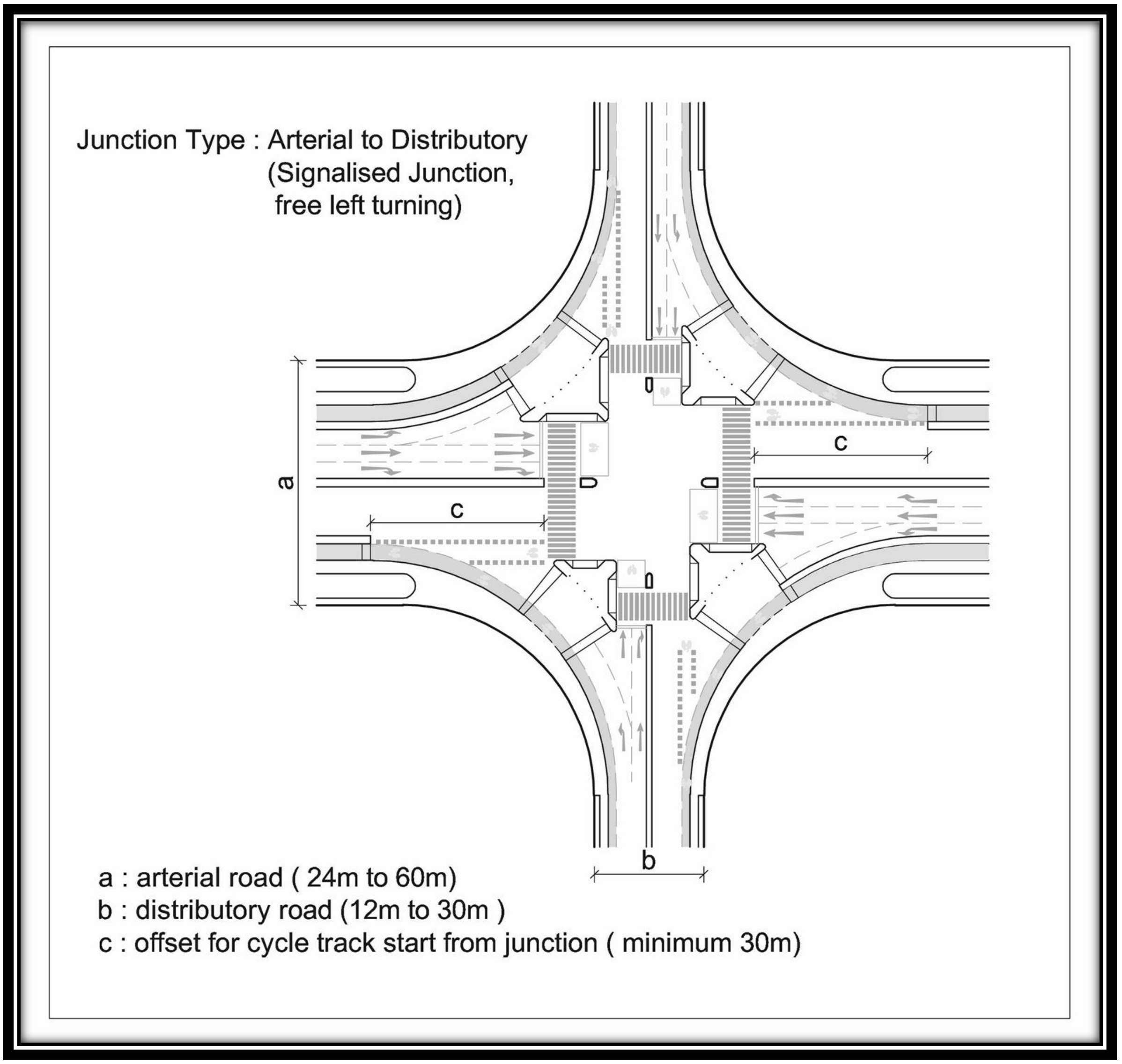


Figure 2-8 Signalized Intersection - Arterial to Distributor

For near side of the junction, the width of cycle track should be maintained as per requirements in the mid block for the approach to the intersection. For some intersections where significantly long motorized vehicle queues are expected, the cycle tracks or NMV path may require additional protection against encroachment by waiting motorists who might be tempted to encroach on the track to get to the top of the queue. Measures such as the use of additional barriers like Hedges, and avoiding provision of any raised crossings (which might serve as entrance to the track) for the expected length of the queue (or a bit longer) may be considered for such locations.

Segregated Left Turning Vehicular Lanes

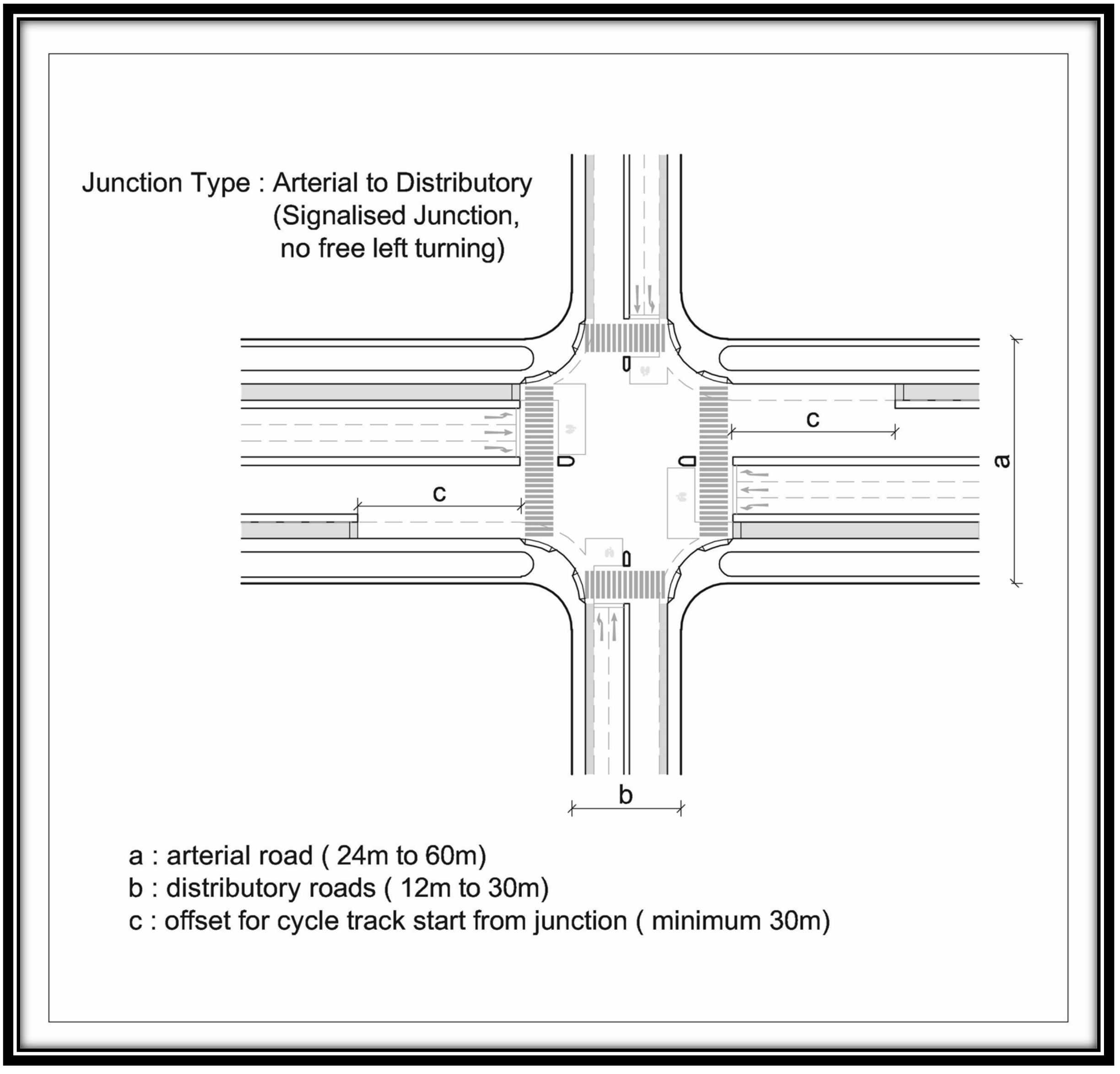


Figure 2-9 Signalized Intersection - Arterial to Distributor (No free left turning)

Segregated lanes for left-turning vehicles at an intersection is usually kept signal free in an attempt to reduce vehicular delays. This denies cyclists and pedestrians any safe time to cross the junction, and adds to their delays and risks. It is also known that in most cases signal free left turning lanes do not provide any significant benefit or relief to waiting motorists; on the contrary they cause friction and reduced flows for motorists merging after the junction. Keeping this in mind, one of the following designs for left turning vehicular lanes should be adopted in the order of priority:

Ignore segregated left turning lanes– Additional turning pocket for left turning vehicles may be provided on the near side of the junction but a segregated lane should be avoided. The left turning traffic moves as per regular signal along with straight moving traffic. Additional non-conflicting signal phases for left turn may also be included where the directness for cyclists is not compromised. Some of the key benefits and disadvantages associated with such left turning lane design at junctions are provided in table 2-3.

Table 2-3 Advantages and disadvantages associated with provision of non-segregated left turning lane at the junction

Advantages	Disadvantages
Left turning phase is not signal free allowing cyclists and pedestrians to make a safe crossing and turning at junction during designated phases	Such designs are generally accompanied by provision of an extra left turning lane or left turning pocket on the near side of the junction. This increase the crossing distance for pedestrians requiring longer pedestrian phase time.
Controlled left turns ensure that conflicts between straight and (left) turning vehicles can be avoided during specific phases ensuring higher efficiency and throughput during the straight phase.	Where very high left turning traffic is expected (higher than 30%), provision of a non-segregated and signalized left turn may contribute to some delays for vehicular traffic.
Non segregated left turning lanes reduce crossing delays for cyclists and pedestrians, as segregated left turns require staged and thus more number of crossings (separately across left turning lane and other traffic lanes) leading to accumulation of wait time at each crossing red light.	At junction where very high left turning traffic is expected, it may not be possible to separate left turning phase from straight phase on a traffic arm. Here cyclists arriving in the middle of the green phase may not be able to move with the motorized traffic for fear of conflicts with left turning vehicles
At junctions where left turning traffic percentage is expected to be significantly minor, a left turning pocket may allow introduction of left turning phase, independent of straight traffic on a traffic arm. This allows cyclists arriving in the middle of a vehicular green phase to safely move straight across the junction with motorized traffic.	

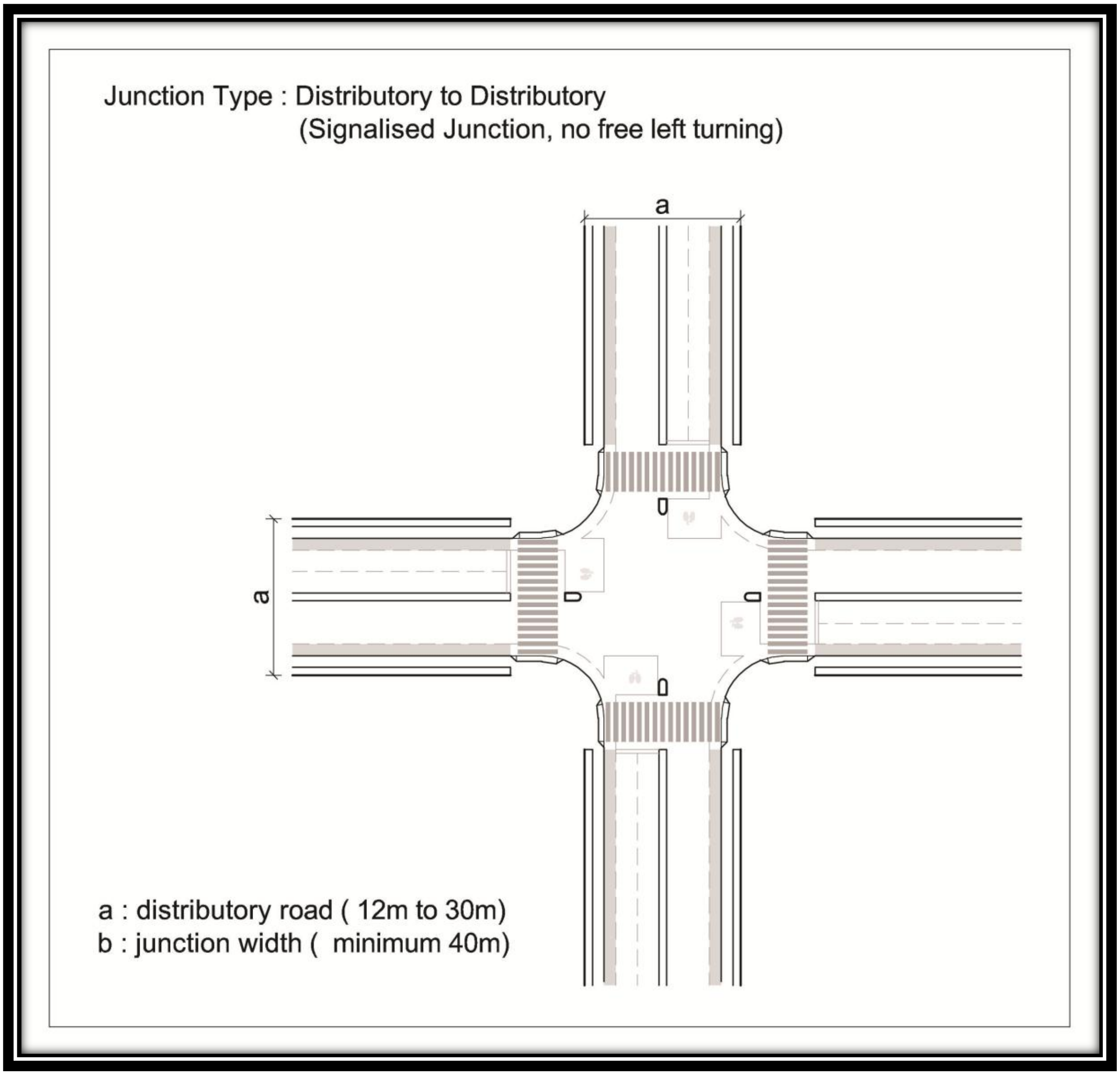


Figure 2-10 Signalized Junction - Distributor to Distributor

Bicycle Boxes or Stacking Spaces

Stacking spaces are required for waiting cyclists on the near side of junctions. Careful design of size, location, demarcation and access to these spaces contributes in ensuring directness, safety and comfort for cyclists and other NMV users.

Bicycle stacking spaces are required on at least two locations for each traffic arm (total eight locations for a four way junction) where segregated left turn vehicular lanes are not provided and at three locations for each traffic arm (total 12 for a four way junction) where segregated left turn lanes are provided. For non-segregated left turning lane arms, the bicycle boxes or stacking spaces are to be provided on the near side of the intersection, on the carriageway, after the stop line for vehicular traffic; as well at the junction corner (towards the left of the bicycle track/lane).

The intersection corner storage, outside the carriageway, should be designed to accommodate cyclists who arrive in the middle of the green vehicular phase for their arm, and thus cannot access the carriageway bicycle box. The space allocation for this area should ensure an adequate stacking space as per the expected volume of cyclists (based on peak cycle volume for the arm and the phase length in the signal cycle), outside the path of left turning NMVs. The cycle box ahead of the stop line on the carriageway should be designed to accommodate all waiting cyclists based on the expected peak bicycle volume and length of the duration of the red phase (for that arm) in the traffic signal.

Many traffic engineers believe bicycle boxes on the carriageway increase the size of an intersection, leading to limited inefficiencies in the motorized vehicle throughput. However it is clear that at all junctions, especially those on arterial roads, NMVs flexibility in crossing along with vehicles is required to reduce delays. This cannot be facilitated without providing stacking boxes ahead of vehicular queues.

A cycle box on the carriageway may be provided either ahead of or behind the zebra / pedestrian crossing. The pros and cons of each location have been discussed in table 2-4. For traffic arms with segregated left turns, the corner bicycle stacking zone (outside the carriageway) needs to be split on either side of the left turn lane. This creates an additional bicycle stacking area. The volume of cyclists that need to be accommodated on either side of the left turning lane is determined by the bicycle volume as well as signal the cycle and phase design.

Table 2-4 Advantages and disadvantages of locating bicycle boxes after the pedestrian crossing on the near side of the junction

Advantages	Disadvantages
Cycle boxes located after the pedestrian crossing provide up to a 7m gap between waiting cyclists and motorized vehicles. This allows cyclists a safe headway to enter the junction and clear the motorists' movement/turning path before they catch up.	Bicycle boxes provided ahead of the pedestrian path include conflicts between cyclists approaching the box and crossing pedestrians (during the red phase of a particular arm).

Clear demarcation of bicycle boxes or storage areas using pavement marking of holding area boundary, surface coloring, change of texture, bicycle text as well symbol etc., not only provide a legitimate and defined space for waiting NMVs, it limits the chances of motor vehicles encroaching on bicycle infrastructure and allows effective enforcement/prosecution. A variety of methods can be selected for demarcating the bicycle waiting area, the most commonly used being pavement marked (using thermoplastic paint) bicycle boxes in bold colored surface with a standard bicycle symbol .Whatever be the method used, a bolder demarcation has been known to increase effectiveness of use.

NMVs accessing bicycle boxes or stacking space should be provided with a clear, defined and barrier free path. This could be in the form of a raised crossing or table top across a segregated left turning lane or a gentle (1:12) ramp to the carriageway level, either from the bicycle track or from the holding area at junction corners (outside the carriageway). At locations, where the bicycle track does not open directly on to the cycle box, a surface colored and pavement marked bicycle lane should be provided as a direct connection between the two.

2.3. ROUNDABOUTS

Introduction

A Roundabout is a type of circular intersection with a specific design and traffic control features. Roundabouts can be designed to suit most site conditions, traffic volumes, speeds, and all road user requirements. This is one versatile solution, which combines the benefits of safety and efficiency in an attractive package. Safety is achieved by reduced speed (less than 40 km/hr) within the roundabout and efficiency by high directness in time and distance or minimal delays for all users.

Roundabouts, on higher traffic intensity junctions, requiring complex crossing decisions by cyclists would require segregated bicycle infrastructure along with safer crossing provisions for pedestrians, whereas lower intensity junctions may rely more on mixed conditions and traffic calming techniques.

Roundabouts are used to control merging and conflicting traffic flows at an intersection, by performing two main functions:

1. It defines the priority of the traffic streams entering the junction, so as to ensure that the traffic entering should not be a hindrance to the already existing traffic circulating in the roundabout.

2. It causes the diversion of traffic flow from its straight path, ensuring slow speeds of vehicles as they enter the junction.

2.3.1. DEFINITIONS

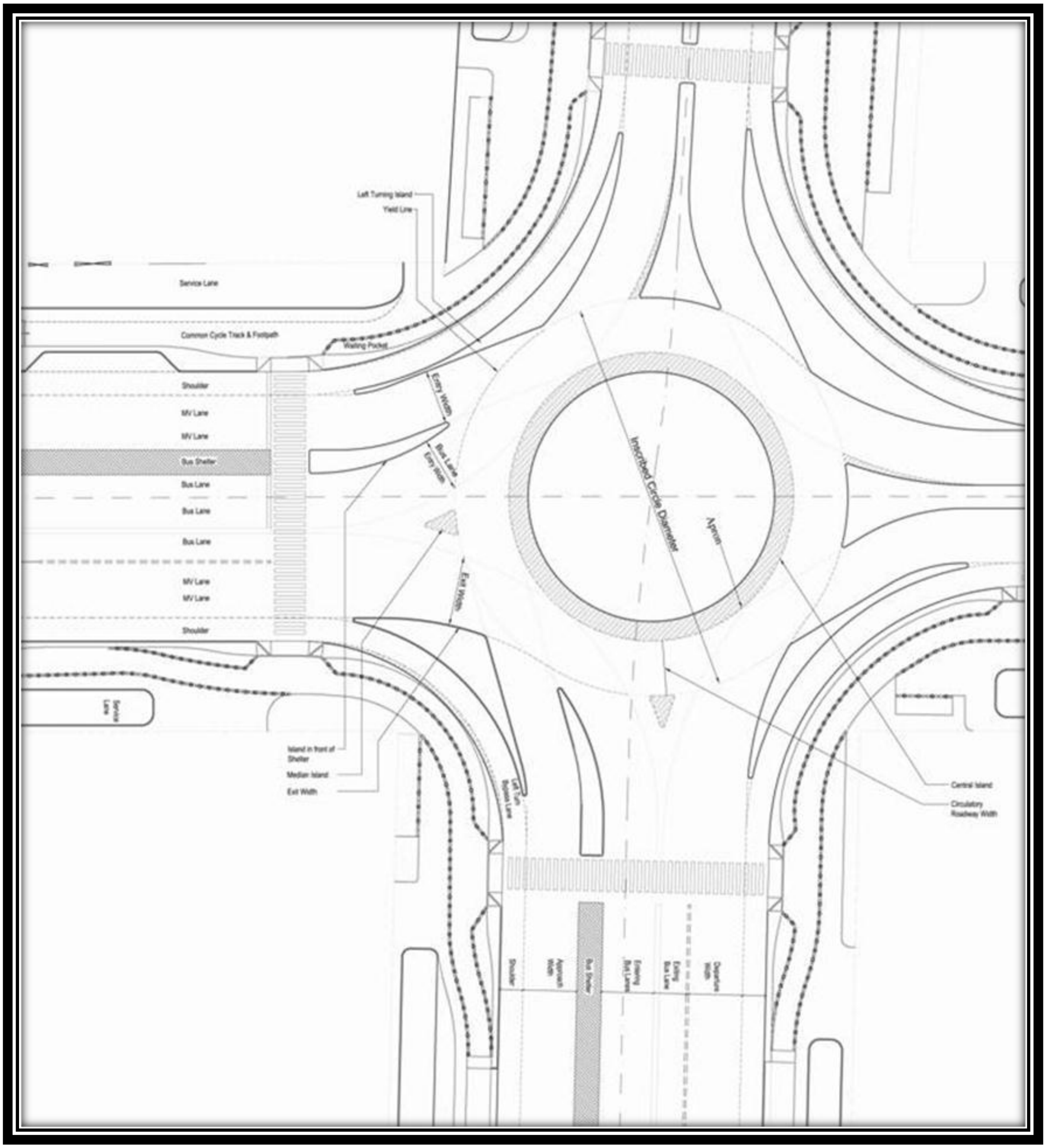


Figure 2-11 Terminology of Roundabout

Central Island [5]

- The central island is the raised area in the centre of a Roundabout, around which traffic circulates.

Splitter Island [6]

- A Splitter Island is the raised area or a painted area on an approach used to separate entering from exit traffic, deflect and slow entering traffic and provide storage space for pedestrians.

Apron [7]

- To accommodate the wheel tracking of large vehicles , on small size Roundabouts : an apron is the mountable portion of the central island adjacent to the circulatory Roadway

Circulatory Roadway[8]

- A curved path used by vehicles to travel around the central island**.**

Yield line

- A yield line is a pavement marking used to mark the point of entry from an approach into the circulatory roadway

Inscribed circle diameter

The inscribed circle diameter is the basic parameter used to define the size of the Roundabout. It is measured between the outer edges of the circulatory roadway.

Approach width

The width of the roadway used by approaching traffic upstream of any changes in width associated with roundabout. The approach width is typically no more than half of the total width opf roadway.

Departure width

The width of the road way used by departing traffic downstream of any changes in width associated with the roundabout. It is typically less than or equal to half of the total width of the roadway.

Exit width[9]

The width of the exit where it meets the inscribed circle' It is measured perpendicular to the right edge of the exit to the intersection point of the left edge line and the inscribed circle

Entry radius[10]

Minimum Radius of curvature of the outside curve

Entry Width:

---

[5] Roundabouts , an information Guide, US Department of Transportation, FHWA-RD-00-067

[6] Roundabouts , an information Guide, US Department of Transportation, FHWA-RD-00-067

[7] Roundabouts , an information Guide, US Department of Transportation, FHWA-RD-00-067

[8] Roundabouts , an information Guide, US Department of Transportation, FHWA-RD-00-067

[9] Highway Engineering. Martin Rogers , Blackwell publishing, 2003

[10] Highway Engineering. Martin Rogers , Blackwell publishing, 2003

It defines the width of the entry where it meets the inscribed circle. It is recommended that at least one lane in addition to the approach lane should be added.

2.3.1.1. SELECTION OF ROUNDABOUTS

Table 2-5 Selection of Roundabouts

	Arterial Roads	Sub Arterial Roads	Distributor Roads	Access Streets
Arterial Roads	1. Roundabouts (3,4 arm) 2. Signalized Crossings (3,4 arm) 3. Grade separated crossing for motor vehicles 4. Grade Separated Crossings for cyclists, along Arterial road (in case of 4 arm only)	1. Roundabouts (3,4 arm) 2. Signalized Crossings (3,4 arm) 3. Grade separated crossing for motor vehicles 4. Grade Separated Crossings for cyclists, along Arterial road (in case of 4 arm only)	1. Roundabouts (3,4 arm) 2. Signalized Crossings (3,4 arm) 3. Grade Separated Crossing for cyclists along Distributor road (4 arm only)	1. Traffic calmed crossing (3 arm only – access street opening on to an arterial road) 2. Grade Separated Crossing for cyclists along access road
Sub Arterial Roads	1. Roundabouts (3,4 arm) 2. Signalized Crossings (3,4 arm) 3. Grade separated crossing for motor vehicles 4. Grade Separated Crossings for cyclists, along Arterial road (in case of 4 arm only)	1. Roundabouts (3,4 arm) 2. Signalized Crossings (3,4 arm) 3. Grade separated crossing for motor vehicles 4. Grade Separated Crossings for cyclists, along Arterial road (in case of 4 arm only)	1. Roundabouts (3,4 arm) 2. Signalized Crossings (3,4 arm) 3. Grade Separated Crossing for cyclists along Distributor road (4 arm only)	1. Traffic calmed crossing (3 arm only – access street opening on to an arterial road) 2. Grade Separated Crossing for cyclists along access road
Distributor	1. Roundabouts	1. Roundabouts	1. Roundabouts	1. Roundabout

Roads	2. Signalized Crossings (3,4 arm) 3. Grade Separated Crossing for cyclists along Distributor road (4 arm only)	2. Signalized Crossings (3,4 arm) 3. Grade Separated Crossing for cyclists along Distributor road (4 arm only)	2. Signalized crossing	2. Unsignalized/ Traffic Calmed Crossing (3, 4 arm)
Access Streets	1. Traffic calmed crossing (3 arm only – access street opening on to an arterial road) 2. Grade Separated Crossing for cyclists along access road	1. Traffic calmed crossing (3 arm only – access street opening on to an arterial road) 2. Grade Separated Crossing for cyclists along access road	1. Roundabout (3, 4 arm) 2. Unsignalized/ Traffic Calmed Crossing (3, 4 arm)	1. Unsignalized/ Traffic Calmed Crossing (3, 4 arm) 2. Mini Roundabouts

In order to select a roundabout based on the Road categories, these are the recommended options for the four categories of urban Roads and their respective intersections.

Roundabouts on urban roads can be classified into four broad categories: as follows

1. Mini roundabouts
2. Urban compact roundabouts
3. Urban single lane Roundabouts
4. Urban double lane roundabouts

The following table[11] compares the fundamental elements of these four categories

[11] Roundabouts , an information Guide, US Department of Transportation, FHWA-RD-00-067

Table 2-6Roundabouts on Urban Roads Fundamental elements of

Design element	Mini	Urban compact	Urban single lane	Urban double lane
Recommended max entry design speed	25 km/h	25 km/h	35 km/h	40 km/h
Max no of entering lanes	1	1	1	2
Inscribed circle diameter	13m to 25m	25m to 30m	30m to 40m	45m to 55m

2.3.1.1.1. MINI ROUNDABOUTS

These Roundabouts are extremely useful in improving the existing urban junctions, and consist of a 1 way circulatory carriageway around a raised circular island less than 4 m in diameter, depending upon the width of the carriageway approaching the Roundabout.

It should be domed to the maximum height of 125 mm at the centre for a 4 m diameter island. The approach arm may or may not be flared. If in case sufficient vehicle deflection cannot be achieved, the speed of the traffic on the approach roads can be reduced using traffic calming techniques.

The following are some examples of Mini Roundabouts , where the central island diameter is , less than 4 m depending upon the width of the carriage way.

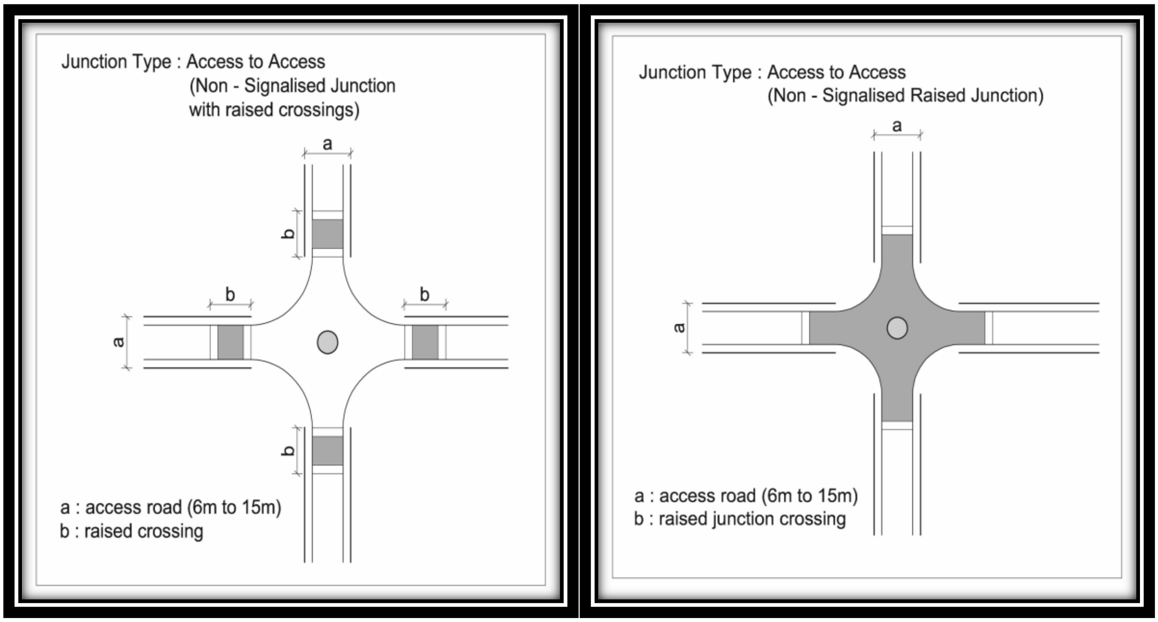


Figure 2-12 Mini Roundabouts (Access to Access)

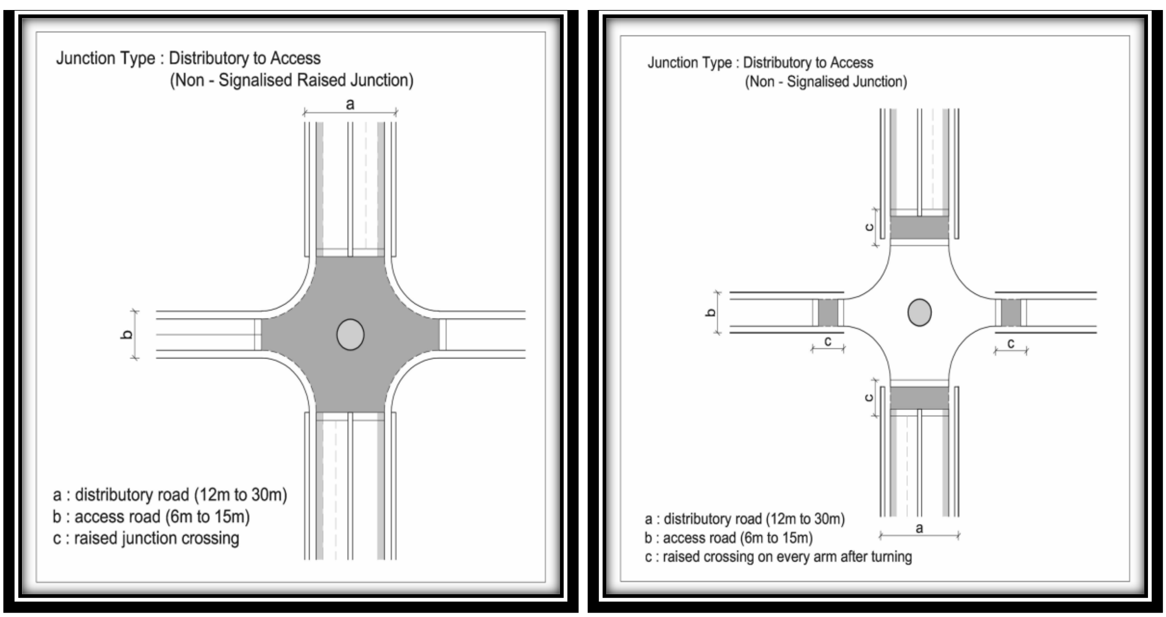


Figure 2-13 Mini Roundabouts (Distributory to Access)

2.3.1.1.2. URBAN COMPACT ROUNDABOUT

This Roundabout meets all the requirements of an effective roundabout, having the principle objective of enabling pedestrians to have safe and effective use of the intersection. The geometric design includes raised splitter islands and a non-mountable splitter island and an apron to accommodate large vehicles. Following figure is an example of urban compact Roundabout.

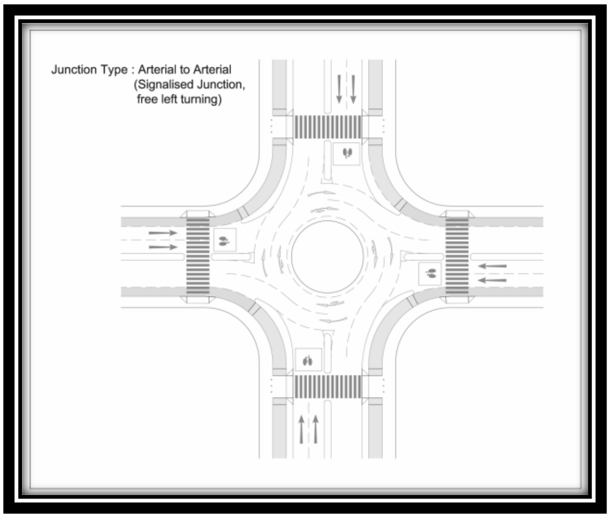


Figure 2-15 Arterial to Arterial Junction (Signalized)

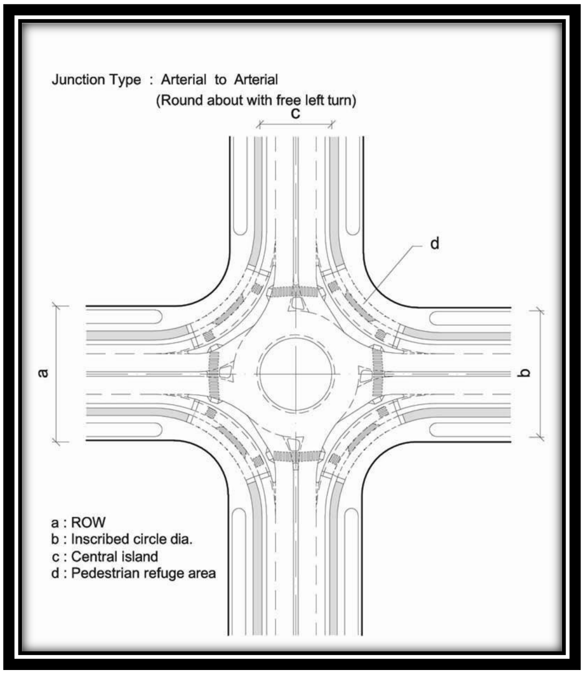


Figure 2-14 Arterial to Arterial Junction

2.3.1.1.3. URBAN SINGLE LANE

These are of higher capacities as compared to the urban compact Roundabouts. Also these have large inscribed circle diameter as well as more tangential entries and exits. The geometric design includes raised splitter islands and a non-mountable splitter island and an apron to accommodate large vehicles.

2.3.1.1.4. URBAN DOUBLE LANE ROUNDABOUT

Urban double lane roundabouts are the ones with at least one entry with two lanes. These require wider circulatory roadways. Urban double lane roundabouts are provided in areas having high pedestrian and cycle user volume. The geometric design includes raised splitter islands and a non-mountable splitter island and no trunk apron and a proper horizontal deflection.

2.3.1.2. CAPACITY OF ROUNDABOUTS

The Geometric elements of Roundabout affect the rate of entry flow. The most important geometric element is the width of the entry and circulatory roadways, or the number of lanes at the entry and on the roundabout. Wider circulatory roadways allows vehicles to travel along side, or follow, each other in tighter bunches and so provide longer gaps between bunches of vehicles. The flare length also affects the capacity. The inscribed circle diameter and the entry angle have minor effects on the capacity.[12]

The capacity depends mainly on the capacities of the individual entry arm. The parameter is defined as entry capacity and depends on the geometric features such as entry width, approach half width, entry angle and flare length.

The predictive equation of entry capacity (Q_e) is given below[13]

Q_e = entry capacity into circulatory area (vehicles per hour)

$= k (F - f_c Q_c)$

Where

Q_c = Flow in circulatory area in conflict with entry (vehicles per hour)

$k = 1 - 0.00347(o - 30) - 0.978 [(1/r) - 0.05]$

$F = 303X_2$

$f_c = 0.21tD(1 + 0.2 X_2)$

$tD = 1 + 0.5/(1+M)$

$M = \exp [(D - 60)/10]$

$X_2 = v + (e-v)/(1+2S)$

$S = 1.6(e-v)/l'$

And

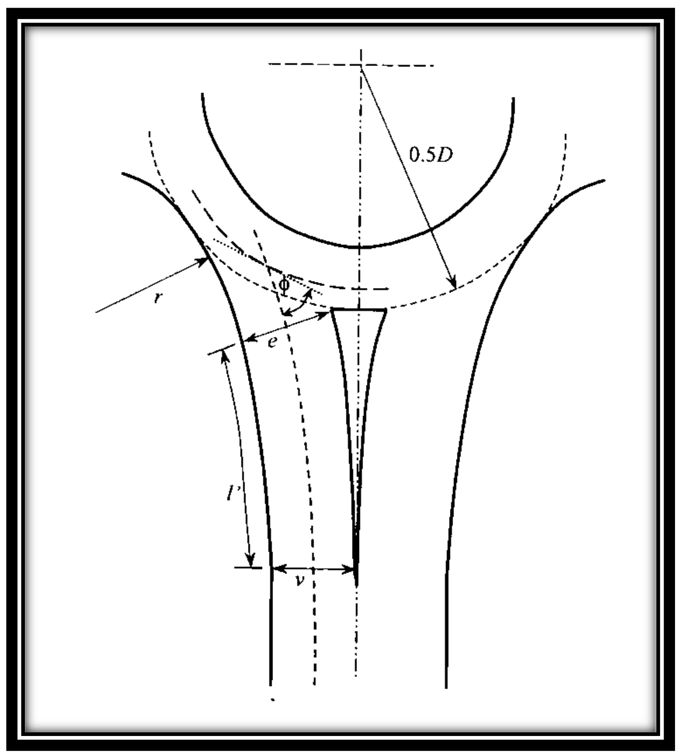


Figure 2-16 Predictive equation of entry capacity

[12] Roundabouts , an information Guide, US Department of Transportation, FHWA-RD-00-067

[13] Highway Engineering. Martin Rogers , Blackwell publishing, 2003

e = entry width (meters) – measure from a point near to the curbside

v = approach half width – measured along a normal fro a point in the approach stream from any entry flare

l' = average effective flare length

S = Sharpness of flare – indicates the rate at which extra width is developed within the entry flare

D = inscribed circle diameter

o = entry angle – measures the conflict angle between entering and circulating traffic.

r = entry radius – indicates the radius of curvature of the near side curb line on the entry

For the Urban single lane and double lane Roundabouts except the grade separated junctions , where in this case F term is multiplied by 1.1 and the f_c term by 1.4 i.e. :

$Q_{E(\text{ grade separate})=}$ k [1.1F – 1.4($f_c Q_c$)]

2.3.1.3. GEOMETRIC DESIGN

2.3.1.3.1. DESIGN PRINCIPLES

- Safety is the most important principle in roundabout design. Roundabouts limit vehicular speeds by virtue of design and are hence effective even in peak or late hours when traffic signals are not followed.
- To ensure safety is not achieved at the cost of efficiency, principles of modern roundabout must be followed. They are:
- *Entering vehicles give way to exiting vehicles by design*
- This is achieved by ensuring that the speed of entering vehicles is reduced by design
- Vehicles exit at a relatively higher speed.
- *Limiting vehicular speeds inside roundabouts.*
- This is achieved by providing an adequate turning radius for vehicles. Low turning radii ensure reduced speeds in the roundabout. Appropriate turning radius can be achieved with the aid of the central island diameter, the circulatory roadway width, the entry turning radius and the entry width.
- *Integrating safe crossing infrastructure for pedestrians and cyclists.*
- Roundabouts permit near continuous vehicular movement due to which special attention must be paid to the requirements of pedestrians, cyclists and other NMV users at all arms of the junction.

- A variety of measures exists for the same and must be chosen on the basis of requirement, governed by vehicular and pedestrian traffic.

Design Speed

A well designed roundabout reduces the relative speed between the conflicting traffic streams by requiring vehicles to negotiate the roundabout along the curve path.

Recommended maximum entry design speeds of roundabouts are as follows [14]

Table 2-7 Recommended maximum entry design speeds of roundabouts

	Mini	Urban compact	Urban single lane	Urban double lane
Recommended max entry design speed	25 km/h	25 km/h	35 km/h	40 km/h

Inscribed Circle

- Intersecting centre lines of crossing roads provide the centre of the roundabout.
- The general principle is that the approach roads should be radial to the roundabout. Suitable modification in alignment is required in cases where the centre lines of the approach roads do not intersect
- The diameter of the inscribed circle is the sum of the diameter of the central island and twice the width of the circulatory roadway width..
- In case of single lane roundabouts, the diameter must be large enough to accommodate the design vehicle and achieve the desired deflection.
- In case of double lane roundabouts, the factors that govern the diameter of the inscribed circle are the need to achieve deflection and the need to fit entries and exits around the circumference.
- However, it should be at least as much as the carriageway.

[14] Roundabouts , an information Guide, US Department of Transportation, FHWA-RD-00-067

Following are the recommended inscribed circle diameter ranges [15]

Table 2-8 recommended inscribed circle diameter ranges

Category	Inscribed Circle diameter range
Mini	13-25m
Urban Compact	25-30m
Urban Single lane	30-40m
Urban Double Lane	45-55m

Assumption: 90 degree angles between entries and 4 arm junctions

Single lane Roundabout [16]		
Inscribed Circle Diameter (m)	approximate radius(m) Left turn path radii	Maximum radius(m) entry path radii
30	11	54
35	13	61
40	16	69
45	19	73
Double lane Roundabout [17]		
Inscribed Circle Diameter (m)	approximate radius(m) Left turn path radii	Maximum radius(m) entry path radii
45	15	65
50	17	69
55	20	78
60	23	83
65	25	88
70	28	93

[15] Roundabouts , an information Guide, US Department of Transportation, FHWA-RD-00-067

[16] Roundabouts , an information Guide, US Department of Transportation, FHWA-RD-00-067

[17] Roundabouts , an information Guide, US Department of Transportation, FHWA-RD-00-067

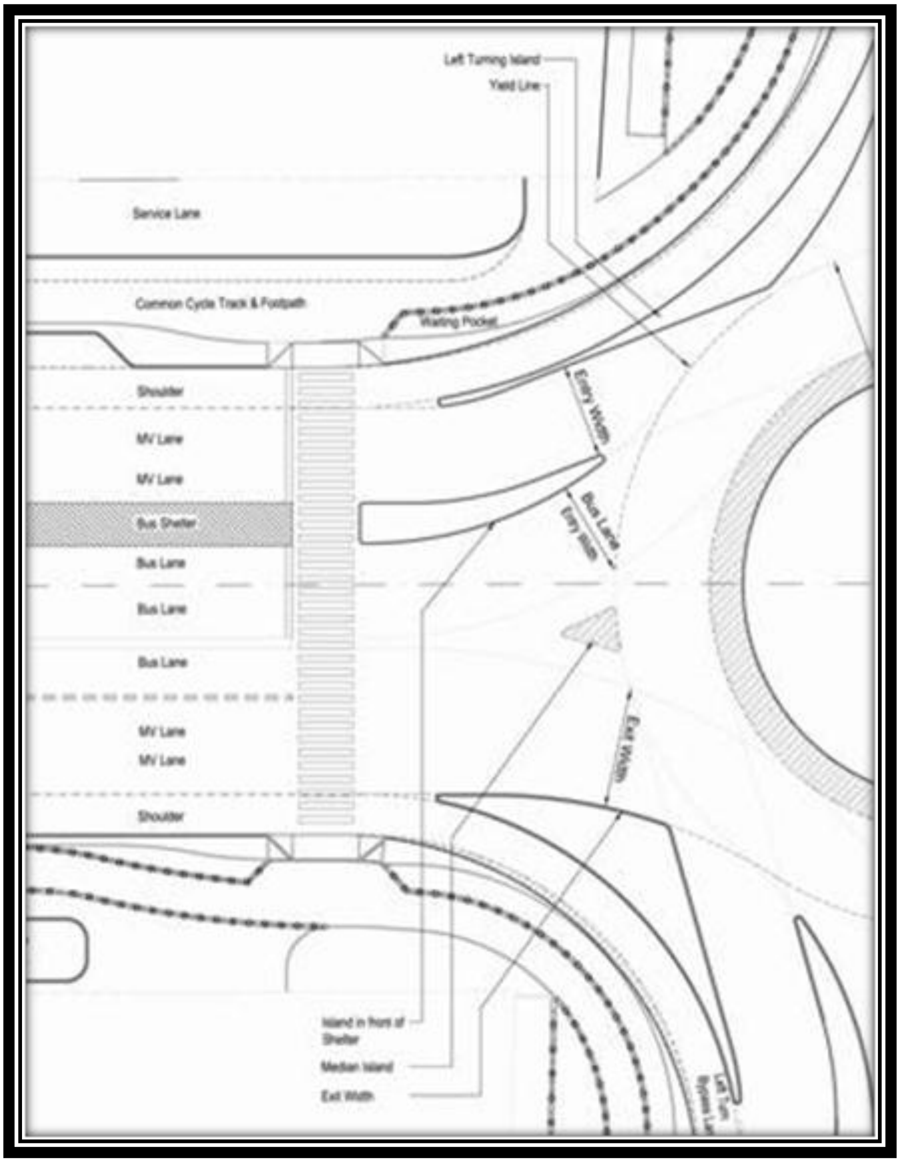


Figure 2-17 Various elements of a intersection

Central Island:

- The central island is the raised, non-traversable part of roundabout, generally
- Landscaped for aesthetic reasons and for enhanced driver recognition.
- It may include a traversable apron (1-4m wide) for the benefit of trucks and

- semi-trailers
- The apron must be of a different material as a warning and should have a slope
- 3-4% away from the central island.
- The outer edge of the apron must be at least 30mm high to discourage other vehicles from traversing on it.
- The diameter of the central island depends on the inscribed circle diameter and the required roadway width. The fastest vehicle path is determined once the ICD and roadway width are obtained. If the fastest path exceeds the design speed, the central island diameter may need to be increased suitably.
- In case the ROW restricts the diameter of the central island, the width of the apron should be considered to be a part of the same.

Circulatory Roadway Width:

- It is determined from the carriageway width of the approach roads and by the number of approaching lanes.
- Single lane roundabouts are preferred incase of low vehicular densities and one approach road. In single lane roundabouts, the circulatory roadway should just accommodate the design vehicle.
- In case of two or three approach roads, double lane roundabouts should be used.
- Incase of three or more approach roads, two lane roundabouts must be provided with an additional left turning lane.
- At double-lane roundabouts, the circulatory roadway width is usually not governed by the design vehicle. The width required for one, two, or three vehicles, depending on the number of lanes at the widest entry, to travel simultaneously through the roundabout should be used to establish the circulatory roadway width.
- The circulatory roadway width should always be at least as wide as the maximum entry width (up to 120 percent of the maximum entry width) and should remain constant throughout the roundabout.
- Table below provides minimum recommended circulatory roadway widths for two lane roundabouts where semi-trailer traffic is relatively infrequent.

Table 2-9 Minimum recommended circulatory roadway widths for two lane roundabouts

Inscribed Circle Diameter	Minimum Circulatory Lane Width*	Central Island Diameter
45 m (150 ft)	9.8 m (32 ft)	25.4 m (86 ft)
50 m (165 ft)	9.3 m (31 ft)	31.4 m (103 ft)
55 m (180 ft)	9.1 m (30 ft)	36.8 m (120 ft)
60 m (200 ft)	9.1 m (30 ft)	41.8 m (140 ft)
65 m (215 ft)	8.7 m (29 ft)	47.6 m (157 ft)

70 m (230 ft)	8.7 m (29 ft)	52.6 m (172 ft)

Source: Roundabouts: An Information Guide, U.S. Department of Transportation, Federal Highway Administration, Publication No.FHWA-RD-00-067

Entry Width:

- The entry width in a roundabout is measured from the point where the yield line intersects the left edge of the traveled way to the right edge of the traveled way.
- The widths of entry are dictated by the needs of the entering traffic stream. The entry width must be at least as wide as the widest entry and must maintain a constant width there on.
- The entry radius should be at least as much as the radius of the central island.
- The entrance to a roundabout is flared to facilitate the deflection that occurs in the vehicular path.
- The flaring provided depends upon the capacity of the roundabout and the deflection in the vehicular path.
- The entry to the roundabout is steep to reduce vehicular speeds.
- The minimum flaring required for a comfortable entry to the roundabout is of 1 m. Since flaring of the entry would result in higher speeds of entry, the same is restricted to a maximum of 3.1m or a full lane width.
- Generally, flare lengths should be at least 25 m in rural and 40m in urban roundabouts. Incase of limitations due to ROW, lesser flare lengths may be provided which would influence the capacity of the roundabout.

Following table provides the minimum recommender circulatory roadway width for two lane roundabout:[18]

Table 2-10 minimum recommender circulatory roadway width for two lane roundabout

Inscribed Circle diameter	Minimum circulatory lane width	central island diameter
45m	9.8m	25.4m
50m	9.3m	31.4m
55m	9.1m	36.8m
60m	9.1m	41.8m
65m	8.7m	47.m
70m	8.7m	52.6m

[18] AASHTO, Table III-20

Exit Curves

- Exit curves are designed to permit speeds greater than at the entry or the circulatory pathway. This feature counters congestion in the roundabout.
- The exit curve is tangential to the MV edge and inscribed circle after the junction.
- It is designed to be curvilinear tangential to the outside edge of the circulatory roadway. The projection of the inside edge of the same is curvilinear tangential to the central island.
- At single lane roundabouts, exits should be designed for speeds less than 40kmph to ensure pedestrian safety. The exit radii should be at least 15m. However, at locations with high pedestrian activity and in the absence of semi-trailer traffic, the exit radius can be as low as 10-12m.
- At double lane roundabouts, slower exit speeds are preferred to ensure pedestrian safety. Exit speeds are lesser due to insufficient accelerating distance, though higher than the entry speeds.

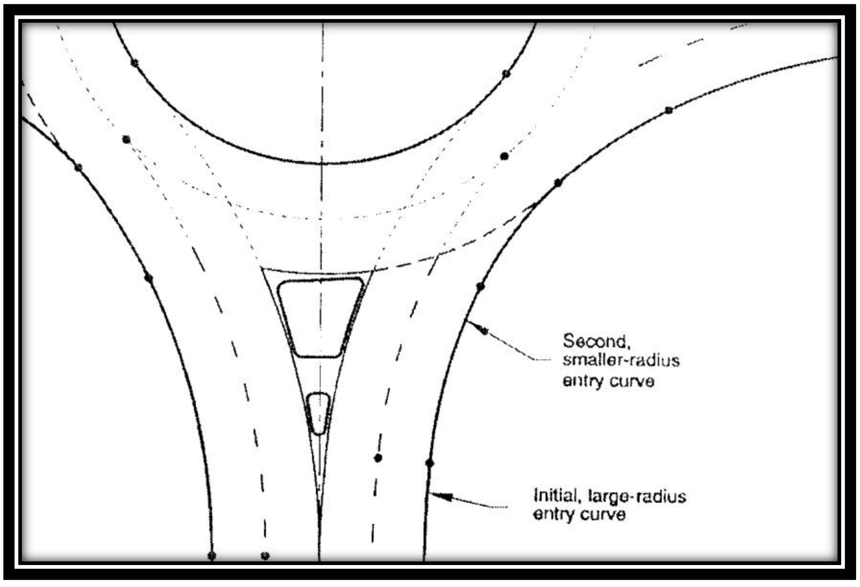


Figure 2-18 Initial-large radius and Second -small radius entry curve

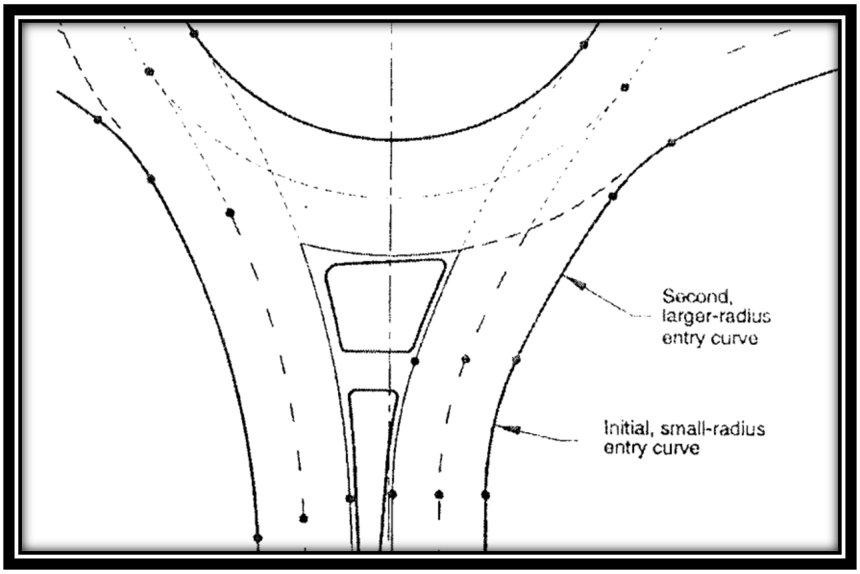


Figure 2-19 Figure 2 18 Initial-small radius and Second -large radius entry curve

NMV/ Pedestrian crossings

- The pedestrian crossing must be located at least 7.5m away from the yield line to avoid turning vehicles. They must also maintain a distance of 5-15m from the inscribed circle for the same purpose.
- These can be classified as

At grade signalized

At grade with raised crossing

Pelican

Grade separated

- At grade signalized raised crossings should be incorporated for enhanced safety of cyclists, other NMV users and pedestrians.
- In case of the at grade crossings, the free left turn ramp must be at least 3m away from the pedestrian crossing ramp. A standing space of at least 1.8m should be provided before the pedestrian crossing.
- A refuge of width 1.8m (min) must be obtained from the aligning of the unpaved and demarcated with the help of bollards.
- Grade separated crossings are used incase of fast moving traffic and high pedestrian and NMV usage. They may be provided at major signalized intersections, roundabouts and other un-signalized locations where crossing of only bicyclists and pedestrians is to be allowed and at grade crossing is considered unsafe and inefficient.

- They maybe elevated (overpass) or depressed (underpass) as per need.
- They avoid interruption to vehicular traffic and reduce the risk of off peak hour accidents and discourage possible misuse of turning restrictions, by more flexible motorized modes such as two wheelers.
- Crossings also act as traffic calming devices in roundabouts. They enforce slower speeds on vehicles due to the change in levels.

Cycle Track and Footpaths:

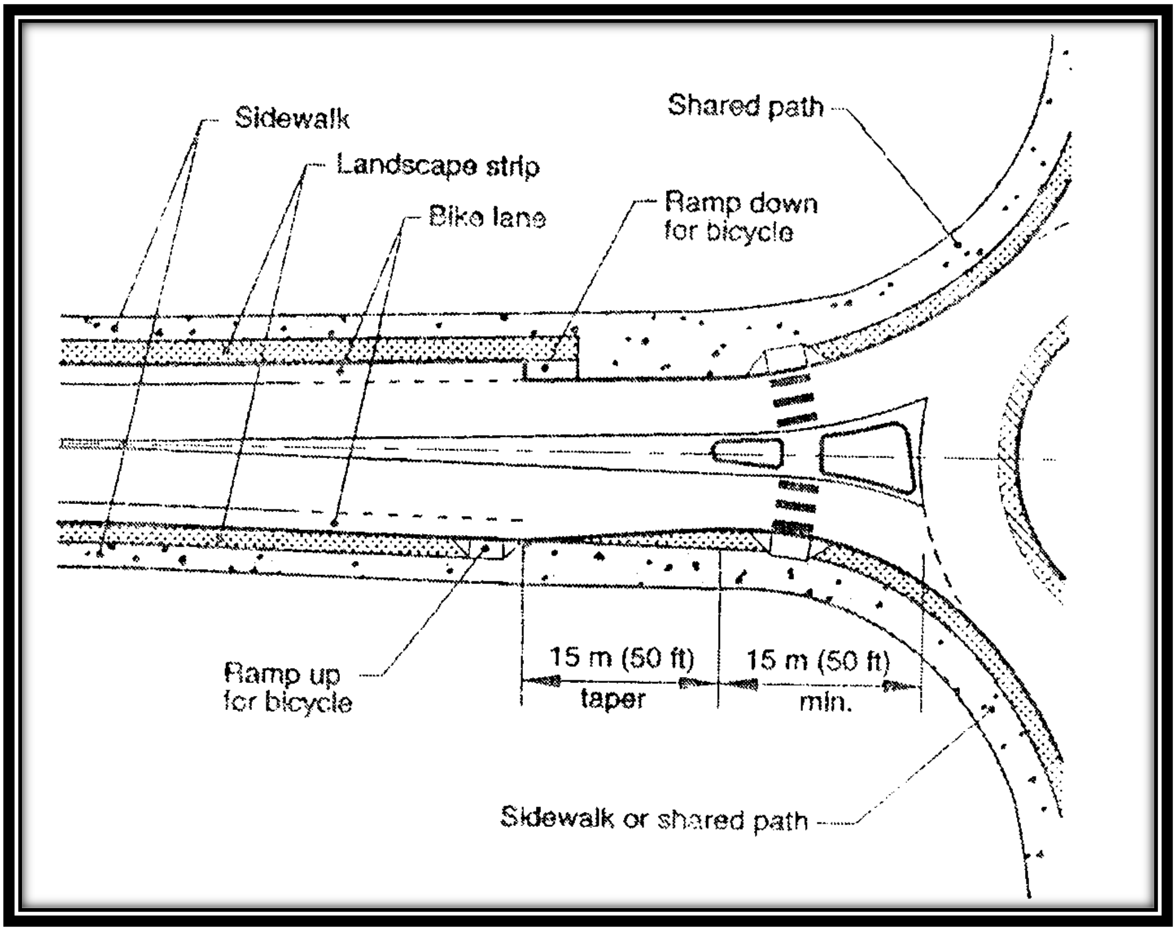


Figure 2-20 Cycle tracks and Footpaths

- Cycle Tracks and footpaths are provided at the periphery of the roundabout.
- At crossings, infrastructure for cyclists may differ based on the type of roundabout.
- At single –lane roundabouts, the cyclists move with the other traffic. At crossings, however, pavement markings should be provided for the benefit of cyclists.
- In case of double-lane roundabouts, painted cycle lanes should be provided along the carriageway and raised crossings at the traffic arms.
- At double-lane roundabouts with left turning lanes, segregated cycle track along the periphery and grade separated access to inner circle should be incorporated for the convenience and safety of cyclists.
- Footpaths are segregated along the roundabout and raised crossings or grade separated treatments may be provided at crossings.

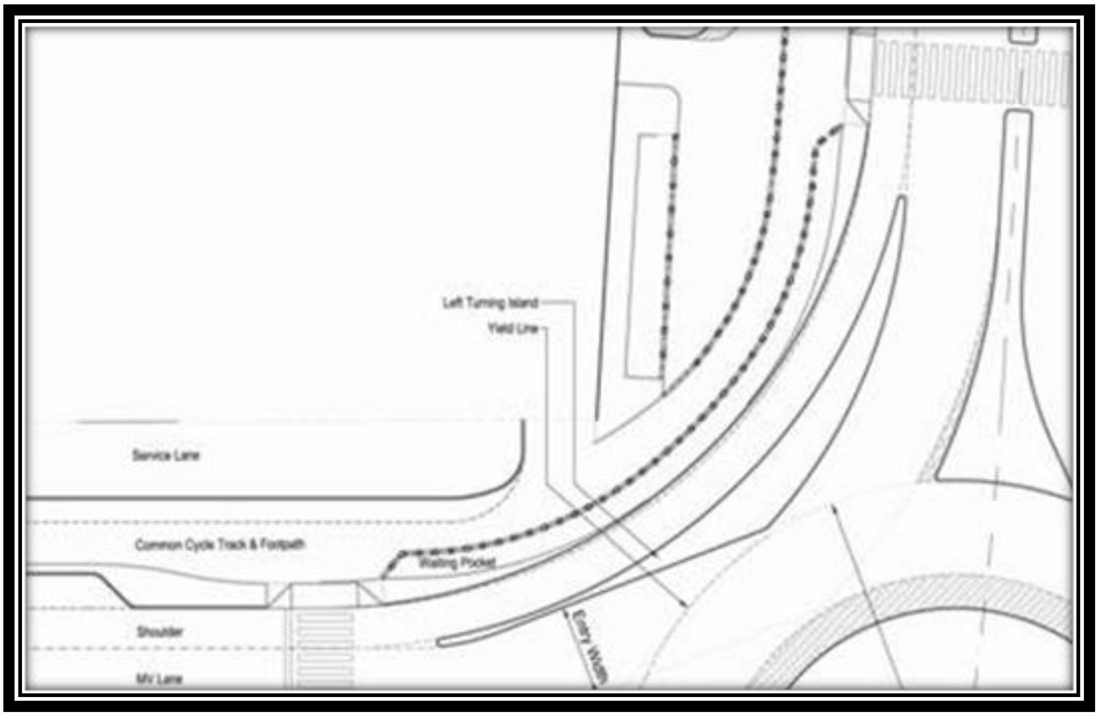


Figure 2-21 Service lane, Cycle Track and other elements of left turning

Green Belts or Landscaped Areas

These spaces can be landscaped for aesthetic purposes. They may also contain light poles and other service lines.

Care must be taken to see that their height does not exceed 90cm to maintain visual continuity.

2.3.1.4. DESIGN PROCESS

There are two methods with which the geometric alignment of a roundabout can be designed: Each method has been explained in detail in the Annexure after this section. The methods are:

METHOD 1 – Tangential Method.

METHOD 2 – Lane widening at Splitter Island at circulatory roadway side.

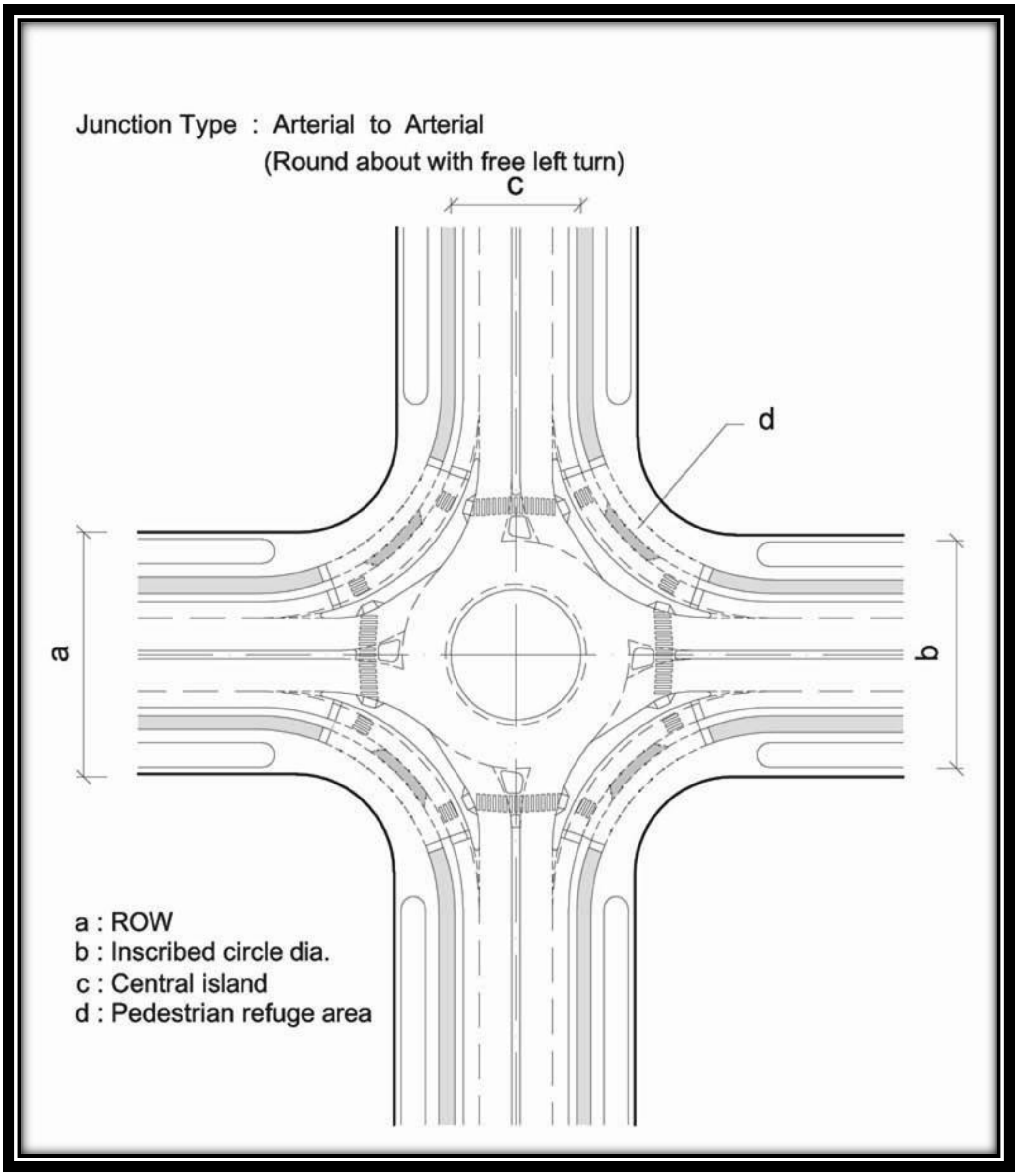


Figure 2-22 Roundabout with free left turn– Arterial to Arterial – METHOD 1

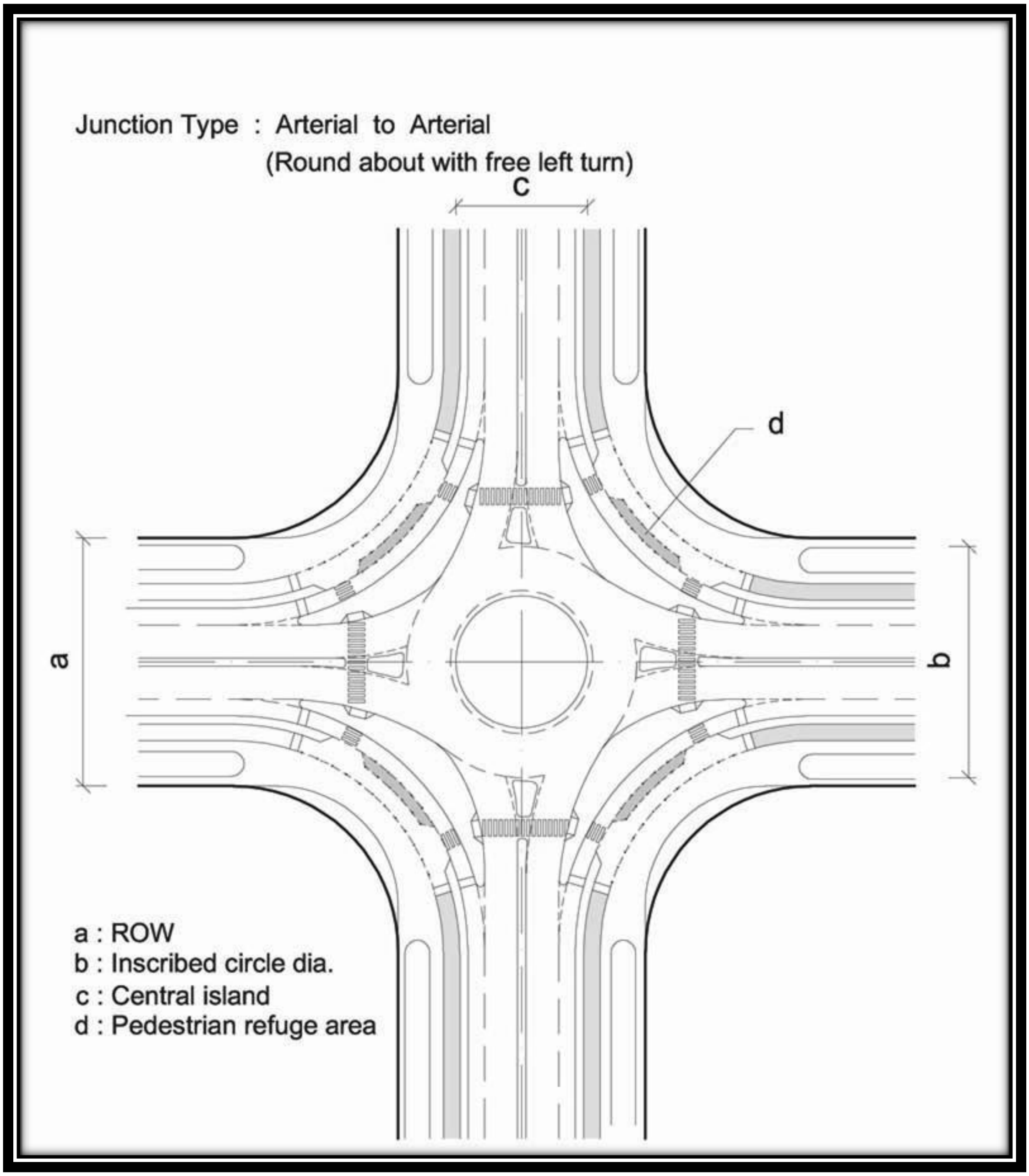


Figure 2-23 Roundabout with free left turn– Arterial to Arterial – METHOD 2

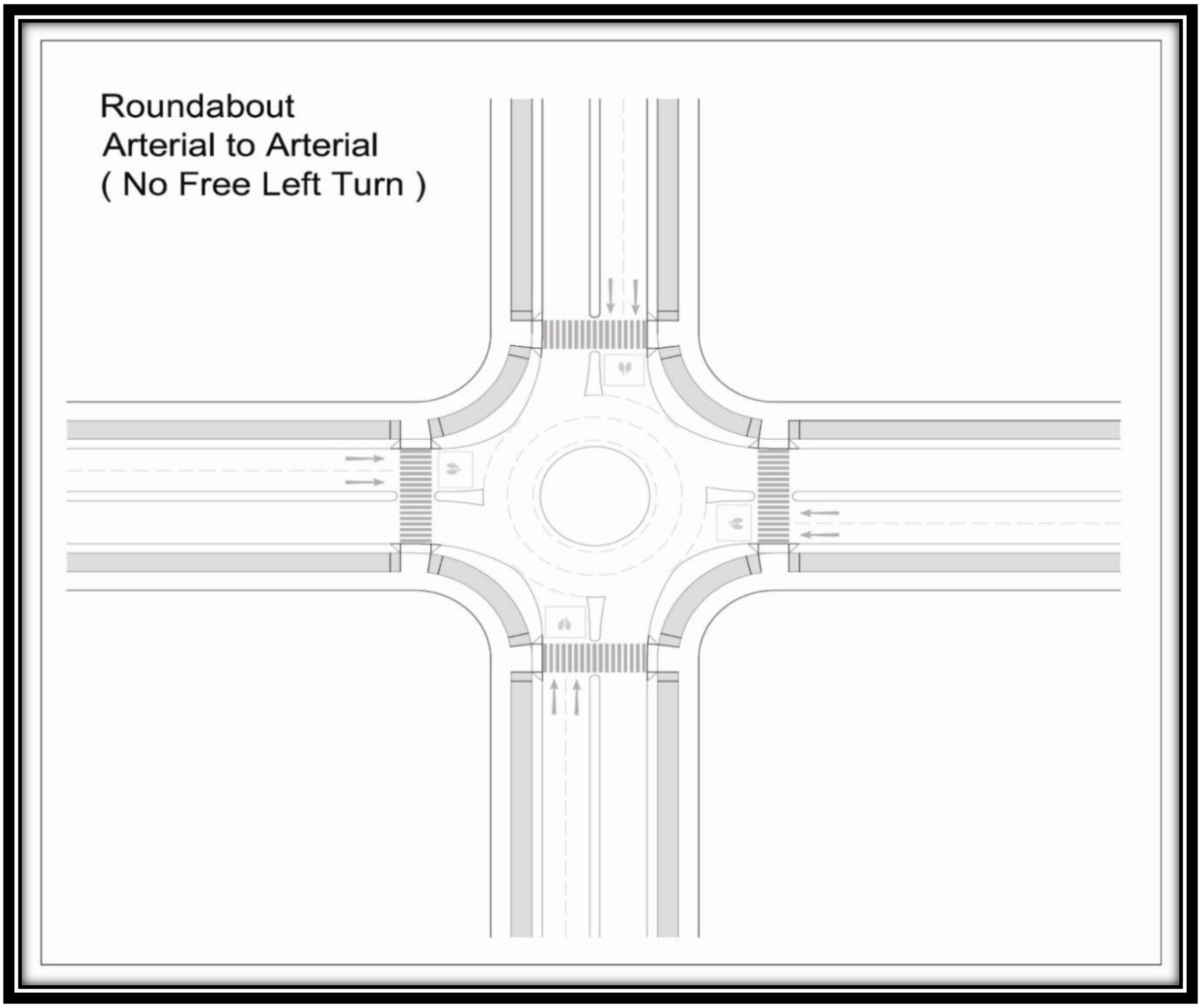


Figure 2-24 Roundabout – Arterial to Arterial (no free left turn)

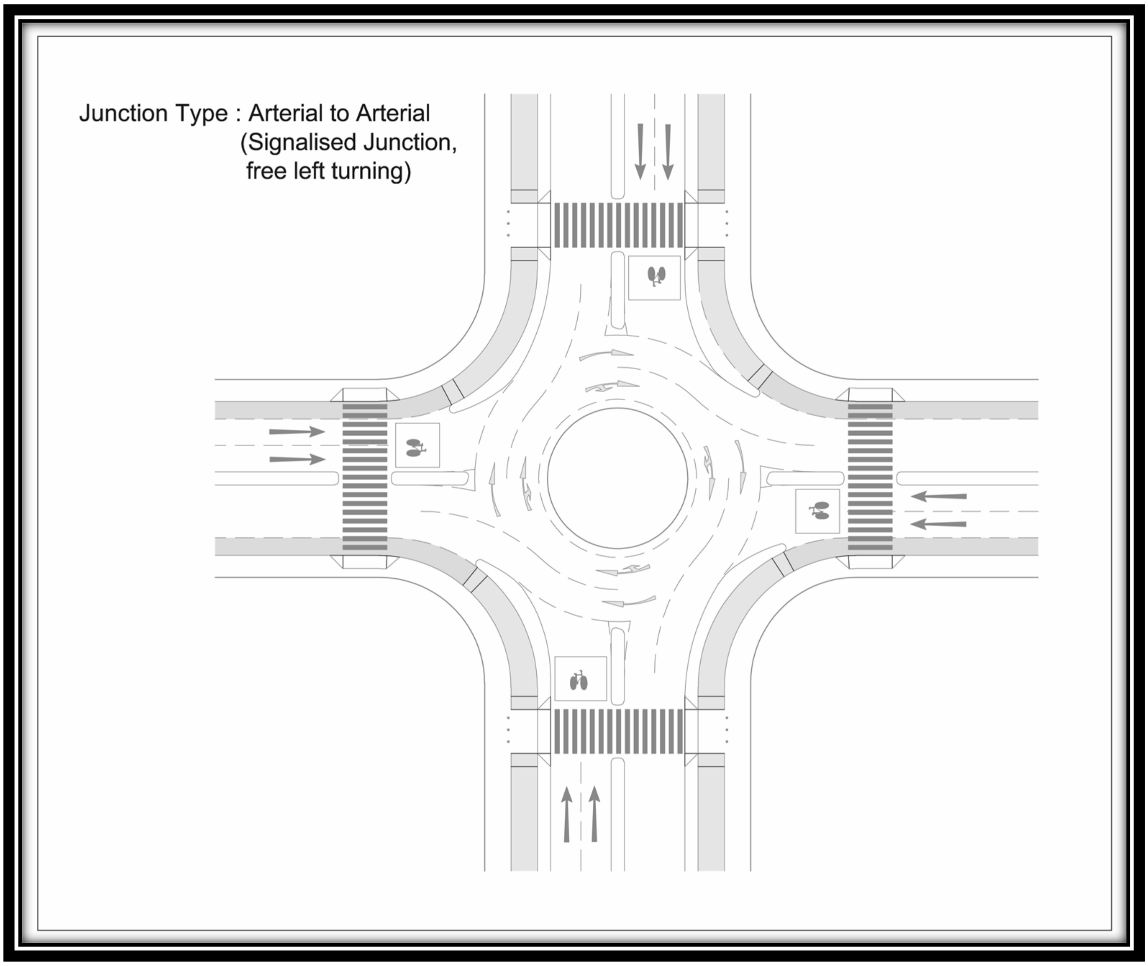


Figure 2-25 Roundabout – Arterial to Distributory

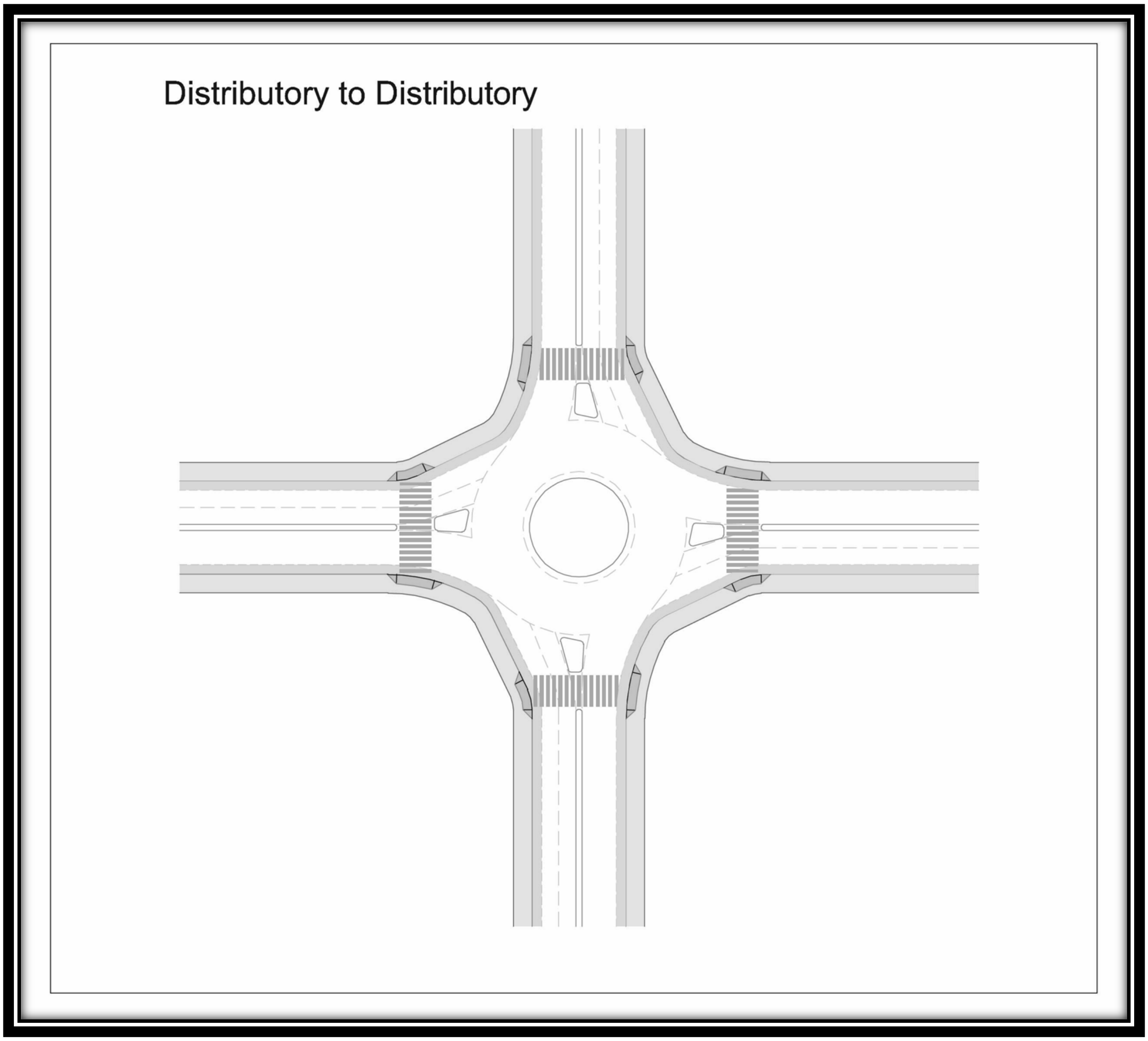


Figure 2-26 Roundabout – Distributory to Distributory

Road types based on four main functions, viz., Arterial, Sub Arterial Distributor and Access. Intersections created within and between each road type presents varying challenges to directness, safety, comfort and attractiveness of cycle/NMV infrastructure.

Table 3-1 Intersection designing based on the various road types

	Arterial Roads	Sub-Arterial Roads	Distributor Roads	Access Streets
Arterial Roads	1. Roundabouts (3,4 arm) 2. Signalized Crossings (3,4 arm) 3. Grade separated crossing for motor vehicles 4. Grade Separated Crossings for cyclists, along Arterial road (in case of 4 arm only)	1. Roundabouts (3,4 arm) 2. Signalized Crossings (3,4 arm) 3. Grade separated crossing for motor vehicles 4. Grade Separated Crossings for cyclists, along Arterial road (in case of 4 arm only)	1. Roundabouts (3,4 arm) 2. Signalized Crossings (3,4 arm) 3. Grade Separated Crossing for cyclists along Distributor road (4 arm only)	1. Traffic calmed crossing (3 arm only – access street opening on to an arterial road) 2. Grade Separated Crossing for cyclists along access road
Sub Arterial Roads	1. Roundabouts (3,4 arm) 2. Signalized Crossings (3,4 arm) 3. Grade separated crossing for motor vehicles 4. Grade Separated Crossings for cyclists, along Arterial road (in case of 4 arm only)	1. Roundabouts (3,4 arm) 2. Signalized Crossings (3,4 arm) 3. Grade separated crossing for motor vehicles 4. Grade Separated Crossings for cyclists, along Arterial road (in case of 4 arm only)	1. Roundabouts (3,4 arm) 2. Signalized Crossings (3,4 arm) 3. Grade Separated Crossing for cyclists along Distributor road (4 arm only)	1. Traffic calmed crossing (3 arm only – access street opening on to an arterial road) 2. Grade Separated Crossing for cyclists along access road
Distributor Roads	1. Roundabouts 2. Signalized Crossings (3,4 arm) 3. Grade Separated Crossing for cyclists along	1. Roundabouts 2. Signalized Crossings (3,4 arm) 3. Grade Separated Crossing for cyclists along Distributor road (4 arm only)	1. Roundabouts 2. Signalized crossing	1. Roundabout 2. Unsignalized/ Traffic Calmed Crossing (3, 4 arm)

	Distributor road (4 arm only)			
Access Streets	1. Traffic calmed crossing (3 arm only – access street opening on to an arterial road) 2. Grade Separated Crossing for cyclists along access road	1. Traffic calmed crossing (3 arm only – access street opening on to an arterial road) 2. Grade Separated Crossing for cyclists along access road	1. Roundabout (3, 4 arm) 2. Unsignalized/ Traffic Calmed Crossing (3, 4 arm)	1. Unsignalized/ Traffic Calmed Crossing (3, 4 arm) 2. Mini Roundabouts

Arterial Road – Arterial Road Intersection

At arterial road intersections, two high speed and high volume roads intersect. This not only adds to the risk of crossing vehicles and cyclists but also makes crossing complex and less comprehensible. Here traffic needs to be warned, calmed and ordered into no or least conflicting movements. The two most common and low investment solutions that may be applied on such high potential risk intersections are roundabouts and signalized intersections Roundabouts are preferred to intersections as they provide higher safety and capacity than the intersections[19]. However they may require more space for implementation at junctions in which situation a signalization of the intersection becomes desirable.

Table 3-2 Roundabouts and Intersections - Pros and Cons

Roundabout	Intersection
Pros	
• Reduces the number of conflicts to eight as against 32 in un-signalized intersections. • Ensures safety through speed reduction by design. This is particularly useful at late night hours when speeds are high and compliance of signals and traffic rules is low. • Minimal or no delays for all road users	Signalized intersections can handle high traffic volumes. This can be achieved by accommodating wider carriageway with more number of lanes.

19 Thomas Jefferson Planning District Commission, Report 29H250, Why Modern Roundabouts Rather than Signals, May 2003

including cyclists.	
Cons	
Roundabouts are not very effective for more than two circulatory lanes. They have capacity limitations and may not be able to handle a very high volume of traffic.	• Four times the number of conflicts than the roundabout. • Safety is ensured by eliminating conflicts through signalization – high dependence on enforcement. • Higher delays for all road users including cyclists.

A designer may also consider grade separated crossing facilities for NMVs and pedestrians based on his judgment of the complexity and risks involved in at-grade crossings. Since the option for introduction of grade-separated infrastructure is based on the comfort, safety and convenience of pedestrians and cyclists, they need to be designed to address all requirements of both captive and potential cyclists. In some situations, this approach may require provision of both, at grade and grade separated crossing facilities to address differing requirement for various NMV users.

Grade separation of intersecting motorized vehicle carriageway is a high cost intersection design solution, which may be suitable for use on highways or expressways. Such solutions are not desirable within the built up areas or urban limits due to their adverse impact on accidents, pollution, etc. However grade separation of NMV and pedestrian traffic across high-speed high volume motorized vehicle carriageway may often be advisable to ensure safety of cyclists and pedestrians.

Table 3-3 Grade Separated NMV Crossing & At Grade NMV Crossing - Pros and Cons

Grade Separated NMV Crossing	**At Grade NMV Crossing**
Pros	
• Safety of cyclists is ensured through physical separation from high-speed vehicular traffic. • Reduces motorized vehicular delays (especially at mid block and not so much at intersections) by eliminating a signal phase or the entire cycle.	• Convenient to use by cyclists. Requires less energy than negotiating level differences. • Inexpensive solution can be repeated at regular intervals within the built up areas or urban limits.
Cons	
• Grade separated solutions are capital	• Safety of cyclists can only be ensured through

intensive and thus cannot be repeated at close/regular intervals. • Grade separated crossing infrastructure for cyclists is very inconvenient to use because of higher energy requirements to negotiate steep ramps. This is particularly true for overbridges.	proper enforcement of signalization at the crossing. • May increase motorized vehicle delays, especially at mid block locations where a signal is added.

Arterial Road - Distributor Road Intersections

Two main types of junctions occur between arterial and distributor roads:

- Crossings with limited turning movement - Left turn movement is only allowed between arterial and distributor roads (where median on arterial road restricts right turning vehicular movement).
- Intersections where all turns permitted - on a 4 arm or a 3 arm junction

At crossings, traffic calming on distributor roads should be used to slow down the traffic entering or leaving such roads at the intersection. This may be achieved through the use of raised crossings or speed tables at the intersection. Vehicular speed reduction for turning vehicles would ensure safety of crossing bicyclists (along the arterial road), and would also ensure the cyclists and pedestrian right of way. Restrictions on turning vehicles at such intersections should not be extended to pedestrians and NMVs as it would adversely affect the directness and coherence of bicycle infrastructure. Here crossing facilities for NMVs and pedestrians could be provided at grade with a two phase pedestrian and/or bicycle signal; or grade separated (along distributor roads) with a gentle ramp and minimal grade difference for bicyclists.

At intersections, a roundabout or a signalized junction may be introduced to resolve conflicts between NMVs and motorized vehicles. It has been mentioned earlier that roundabouts are preferred for reasons of safety and efficiency, and this solution is more likely to be considered suitable here; both traffic intensity and space restrictions are unlikely to be a constraint. However, the decision should to be based on designers understanding of the site and other conditions. Intersection solutions may be combined with grade separated crossing for pedestrians and cyclists (along the distributor road), though such measures and proposals will need to be weighed against user requirements of directness, coherence, comfort, safety and attractiveness (for both captive and potential users) for its suitability.

Arterial Road – Access Street Intersections

In an urban design and planning parlance, a scenario, which creates a junction between, an Arterial and an Access Street should be non-existent; as a very low speed and mixed use access road should never open directly onto a high speed and high volume arterial road. However In the current context of the Indian Sub-continent, similar junctions are a common occurrence in the built environment. The most common condition is on service roads (which is an access road), which are an integrated component of an arterial road.

Designers should ensure that such junctions are always treated as a crossing with restricted right turns and never as an intersection with all turns permitted. Here a raised crossing should be provided to slow turning vehicles, to make them aware of crossing cyclists and pedestrians to warn them of changed road as well traffic conditions ahead. At locations where it is felt that a direct link across the arterial road would add to the directness and coherence of the bicycle network, a grade separated provision for bicyclists and pedestrians should be provided, without compromising their requirements of comfort and safety.

Distributor Road – Distributor Road Intersections

Distributor roads carry low intensity (speed and volume) traffic. The junctions between these roads are more likely to be an intersection than a crossing with restricted right turns. These intersections can be treated conveniently with a one or two lane modern roundabout design. Bicyclist conflicts can be resolved by segregating bicycle traffic into a peripheral path at the roundabout, along with raised crossings on the traffic arms.

Distributor Road – Access Street Intersections

Access roads are very low speed and low volume roads. Their junction with distributor roads can be easily treated as an intersection. The safety of crossing cyclists at such intersections can be introduced through the introduction of a one to two lane roundabout with a segregated bicycle path on the periphery. Alternately the intersection may be traffic calmed and treated as an un-signalized junction if the volume of intersecting traffic is considered low for the location. In such condition bicyclists can cross along with other traffic, at grade, and their safety is ensured through reduced speeds of motorized traffic.

Access Street – Access Street Intersections

Two intersecting access streets can be treated as minor un-signalized intersections **.**due to the expected low speed and low volume vehicular traffic at the location. These intersections may simply be traffic calmed to maintain 15-20km/hr speeds across the junction area. Here bicyclists and pedestrians should be safe to cross in all directions at grade.

4. ANNEXURE

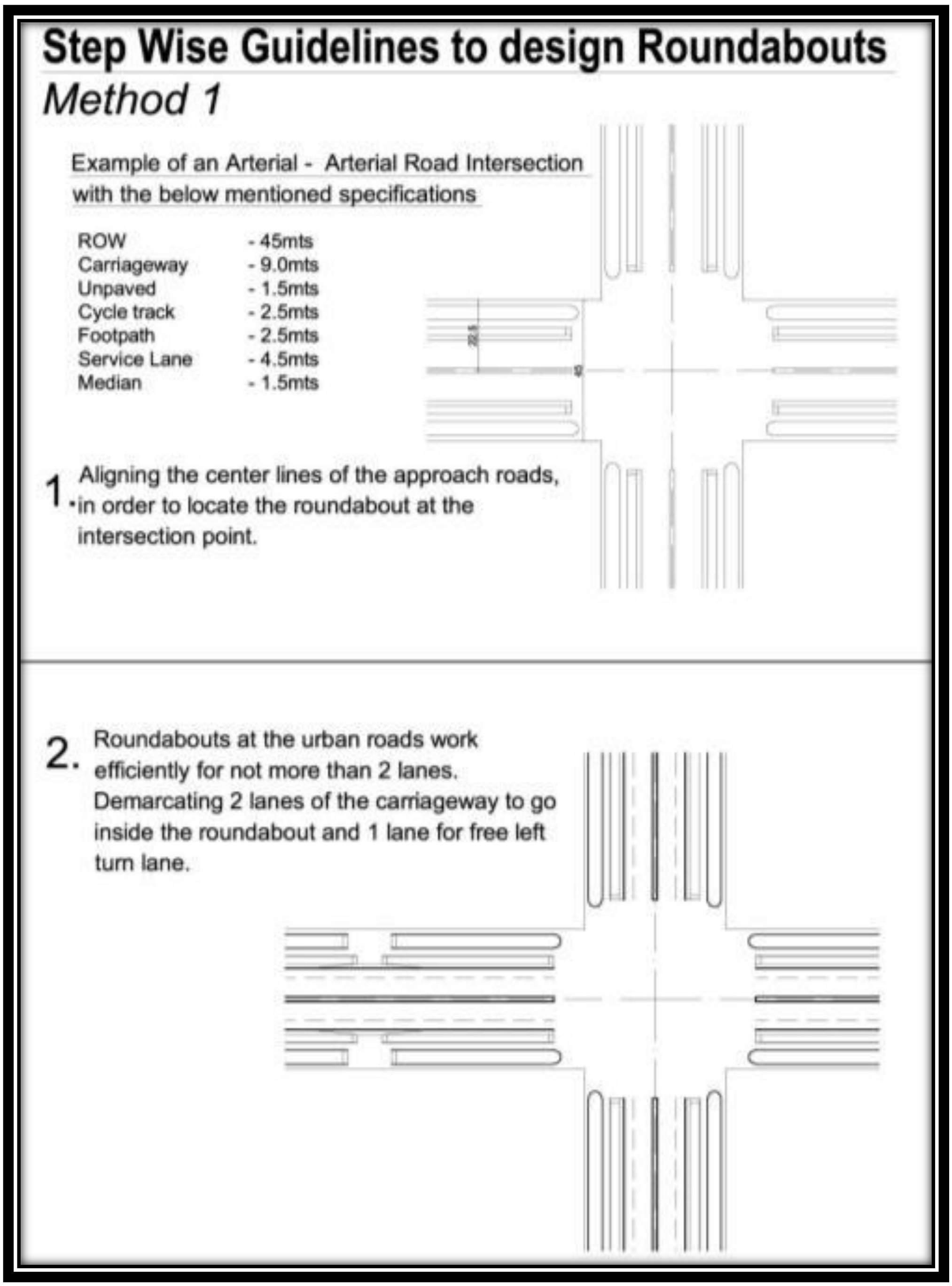
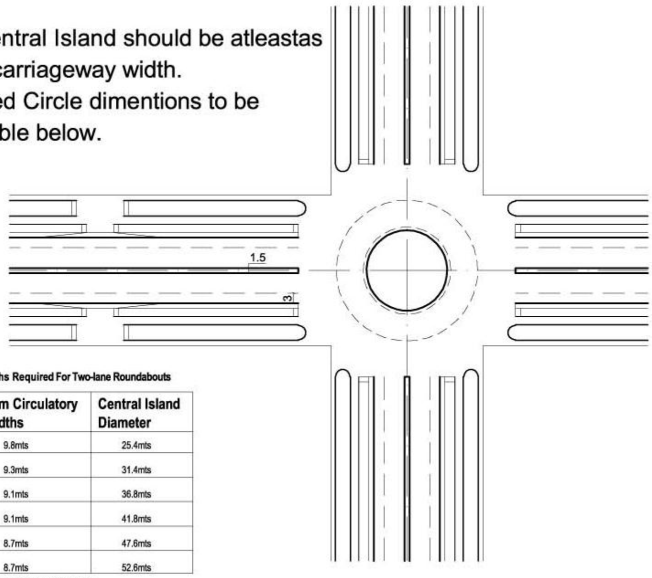


Figure 4-1 Tangential Method of Roundabout Designing (Step 1 & 2)

Method 1

3. Diameter of the Central Island should be atleastas much as the total carriageway width.
Apron and Inscribed Circle dimentions to be refered from the table below.



Minimum Circulatory Lane widths Required For Two-lane Roundabouts

Inscribed Circle Diameter	Minimum Circulatory lane Widths	Central Island Diameter
45mts	9.8mts	25.4mts
50mts	9.3mts	31.4mts
55mts	9.1mts	36.8mts
60mts	9.1mts	41.8mts
65mts	8.7mts	47.6mts
70mts	8.7mts	52.6mts

Reference: From Geometric design

4. For introducing Entry Radius 10-15mts before the Yeild Line, to have a Flare Length of 20-30mts.

Entry radius to be as much as the central island radius atleast.

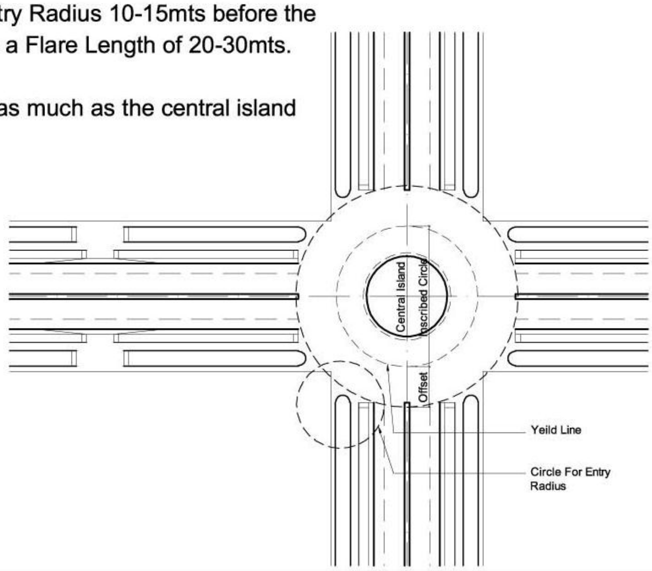


Figure 4-2 Tangential Method of Roundabout Designing (Step 3 & 4)

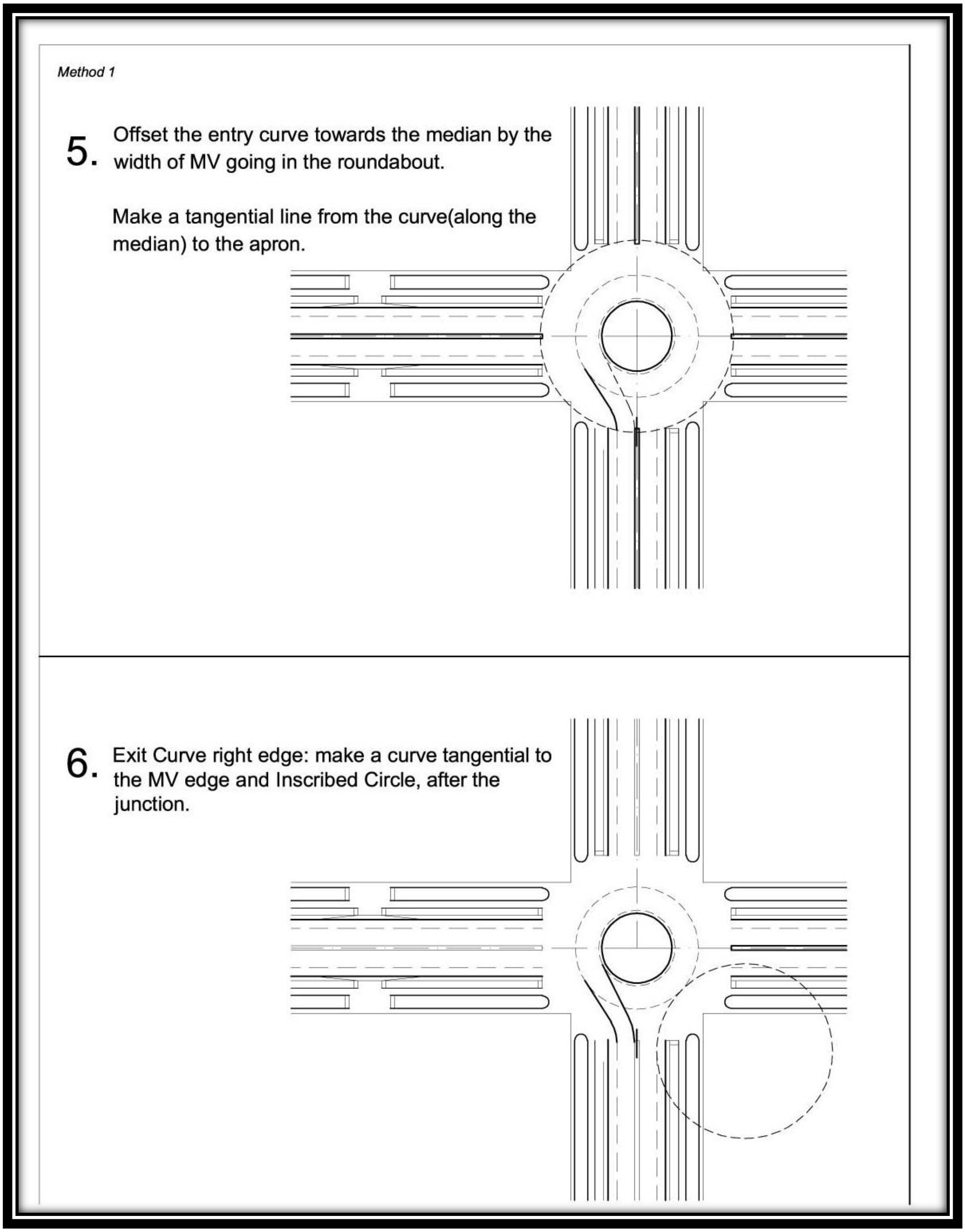


Figure 4-3 Tangential Method of Roundabout Designing (Step 5 & 6)

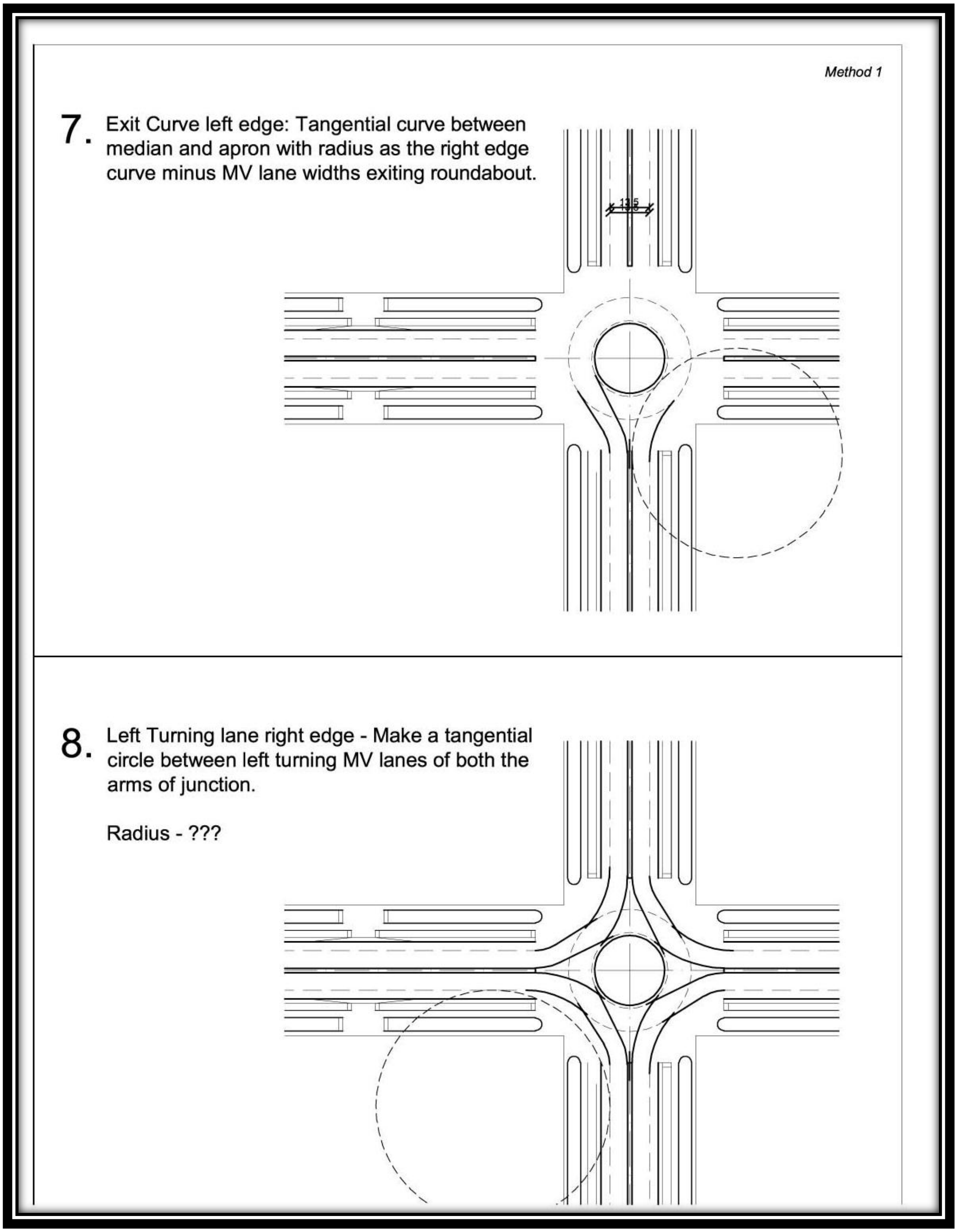


Figure 4-4 Tangential Method of Roundabout Designing (Step 7 & 8)

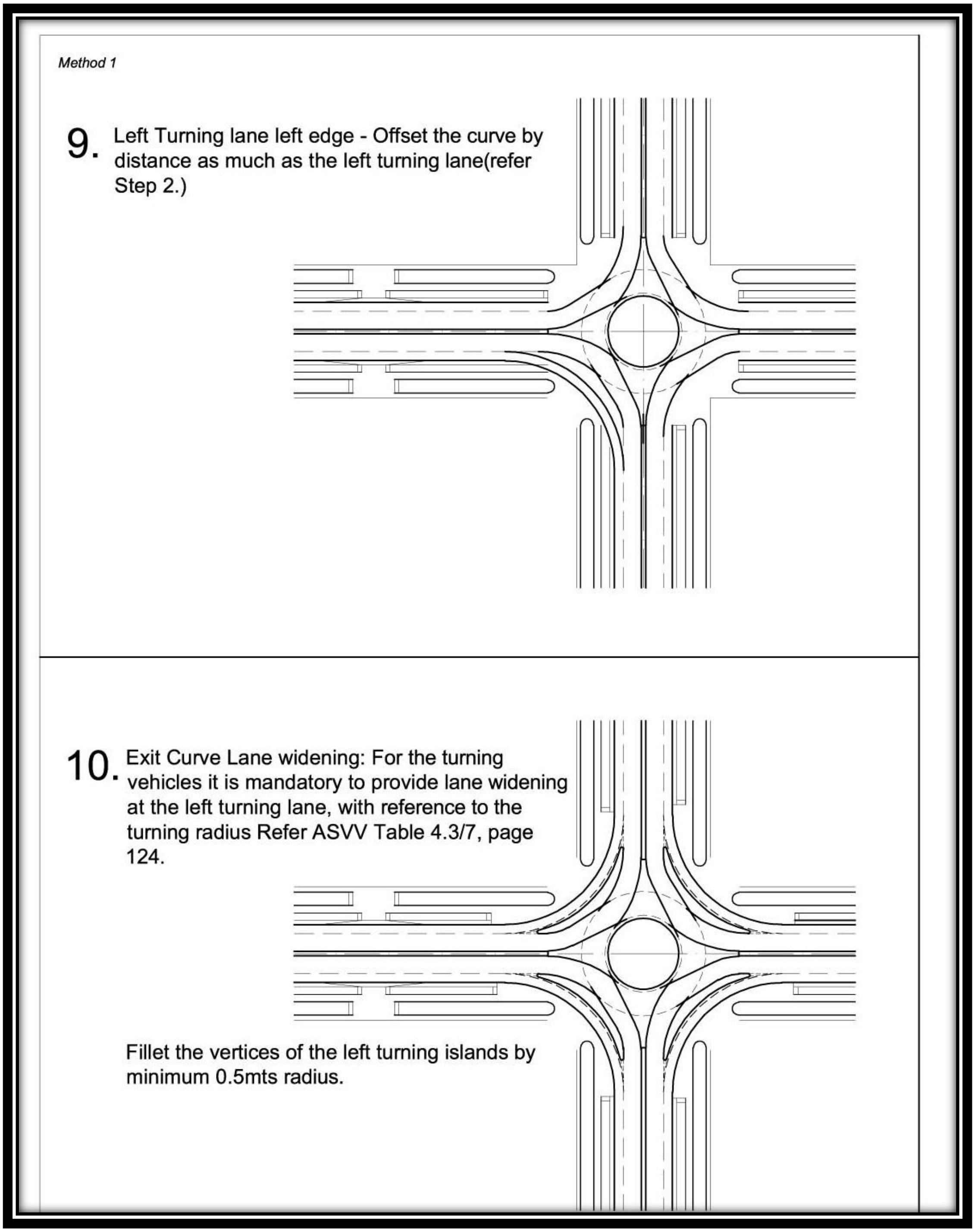


Figure 4-5 Tangential Method of Roundabout Designing (Step 9 & 10)

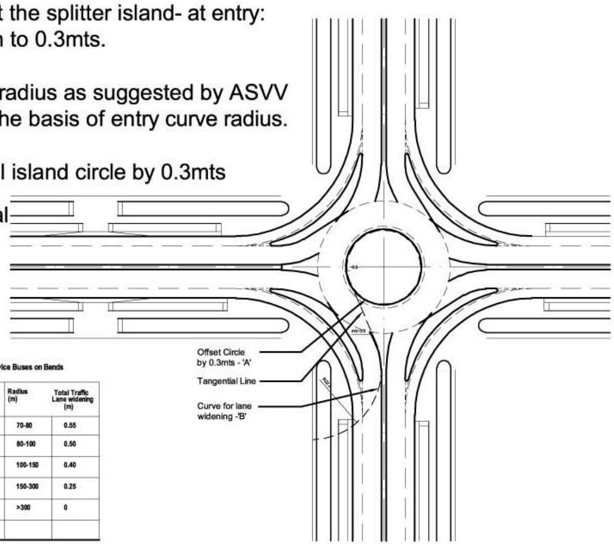
Method 1

11. Lane widening at the splitter island- at entry: offset 0.0m down to 0.3mts.

Make a curve of radius as suggested by ASVV Table 4.3/7, on the basis of entry curve radius.

Offset the central island circle by 0.3mts

Make a tangential line between circle 'A' and 'B'.



Desired Traffic lane Widening for Public Service Buses on Bends

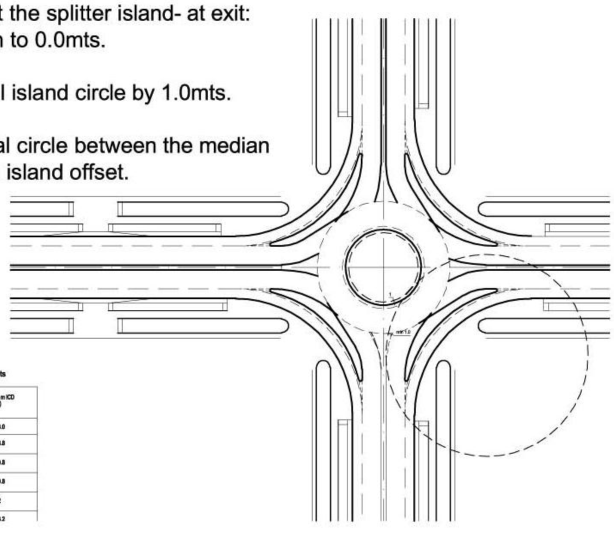
Radius (m)	Total Traffic Lane widening (m)	Radius (m)	Total Traffic Lane widening (m)	Radius (m)	Total Traffic Lane widening (m)
<9	3.30	30-35	1.35	70-80	0.55
9-13	3.10	35-40	1.15	80-100	0.50
13-16	2.70	40-45	1.00	100-150	0.40
16-20	2.30	45-50	0.85	150-300	0.25
20-25	2.00	50-60	0.75	>300	0
25-29	1.60	60-70	0.65		

Reference: From ASVV

12. Lane widening at the splitter island- at exit: offset 1.0m down to 0.0mts.

Offset the central island circle by 1.0mts.

Make a tangential circle between the median edge and central island offset.



Turning Widths Required for Smaller Normal Roundabouts

Central Island Diameter (m)	R2 - R1 (m)	Minimum ICD (m)
4.0	10.0	28.0
6.0	9.4	28.8
8.0	8.9	29.8
10.0	8.4	30.8
12.0	8.0	32
14.0	7.6	33.2

Figure 4-6 Tangential Method of Roundabout Designing (Step 11 & 12)

`

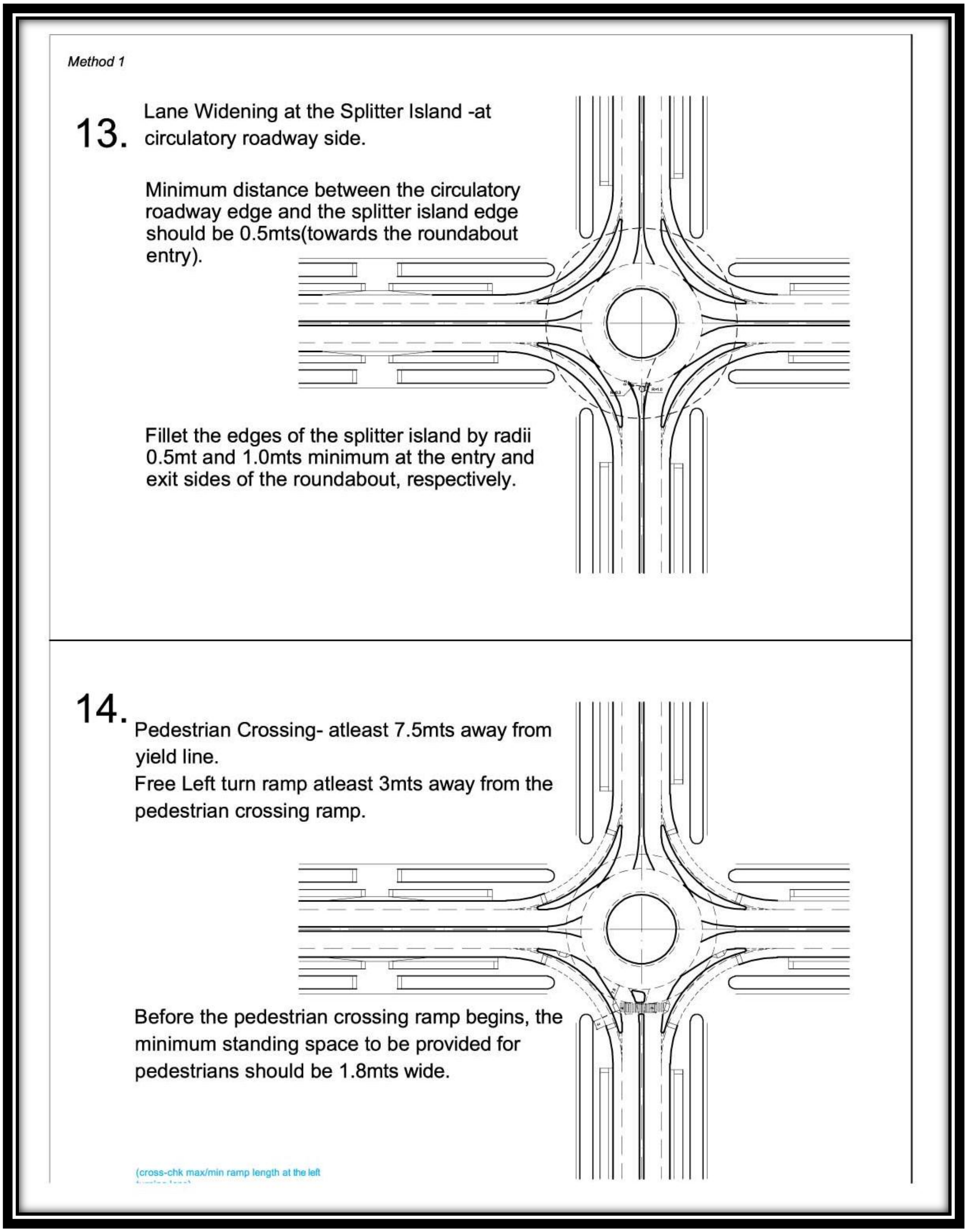


Figure 4-7 Tangential Method of Roundabout Designing (Step 13 & 14)

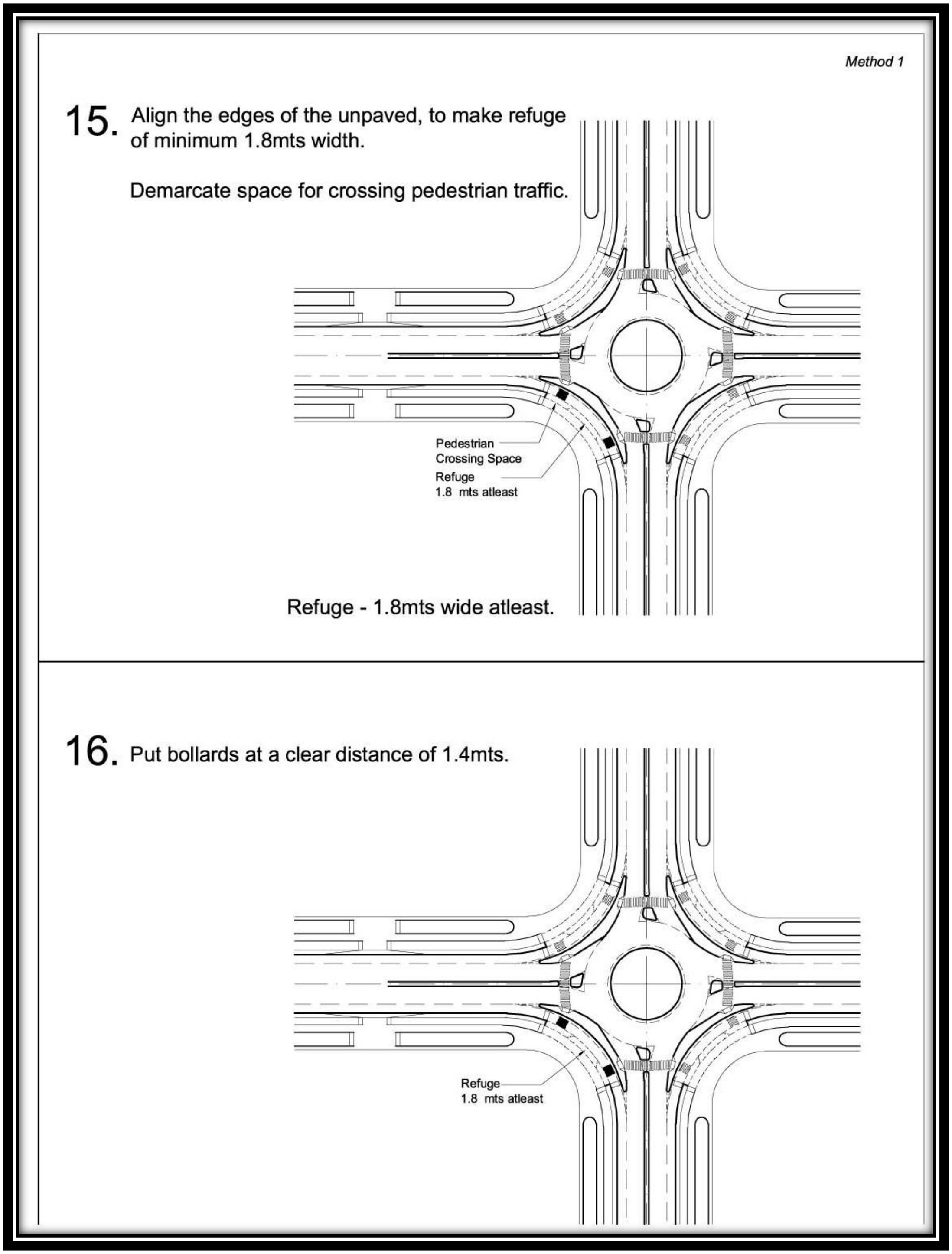


Figure 4-8 Tangential Method of Roundabout Designing (Step 15 & 16)

Geometric Design of a Roundabout - METHOD 2 – Lane widening at the Splitter Island at circulatory roadway side

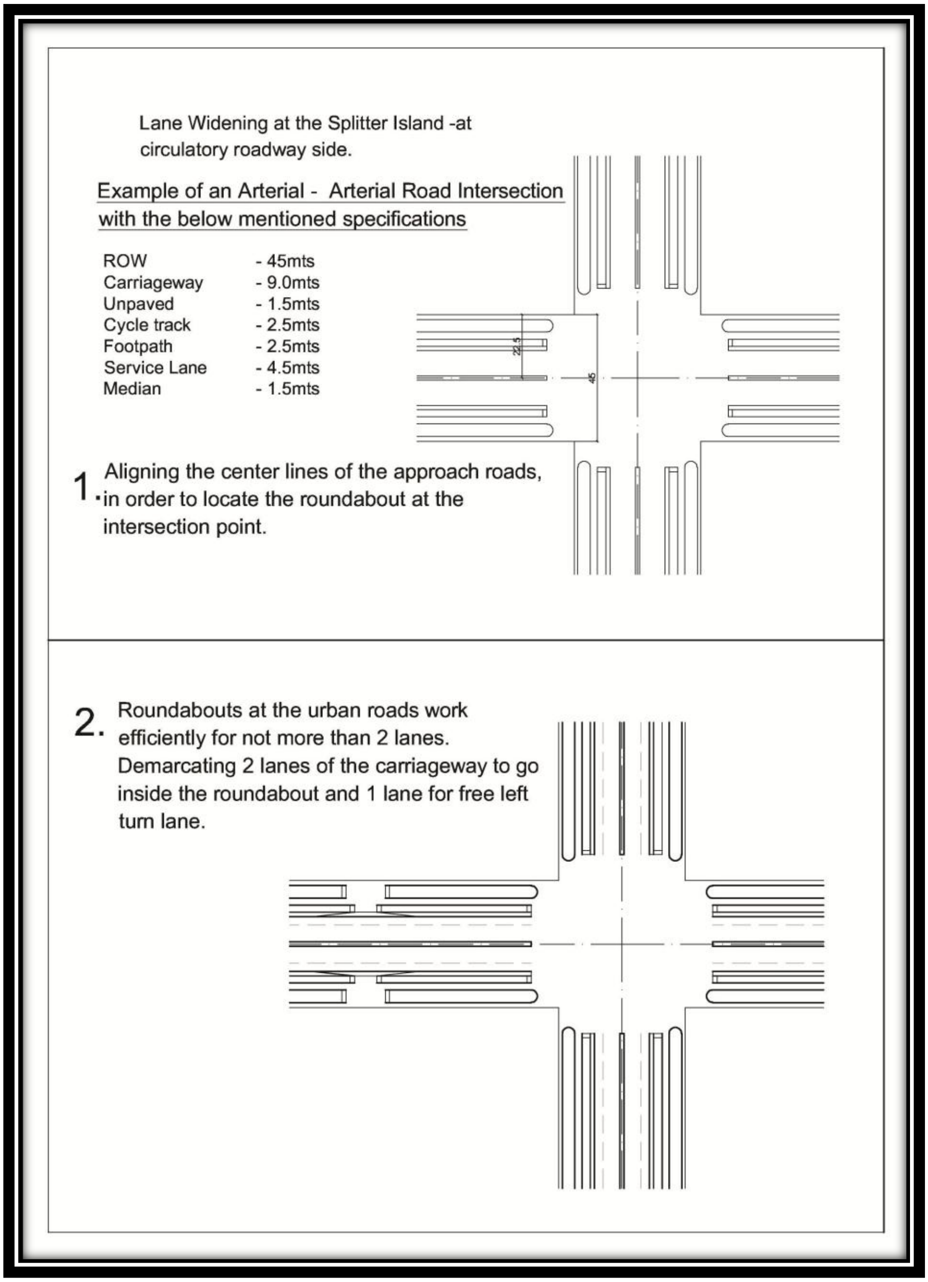
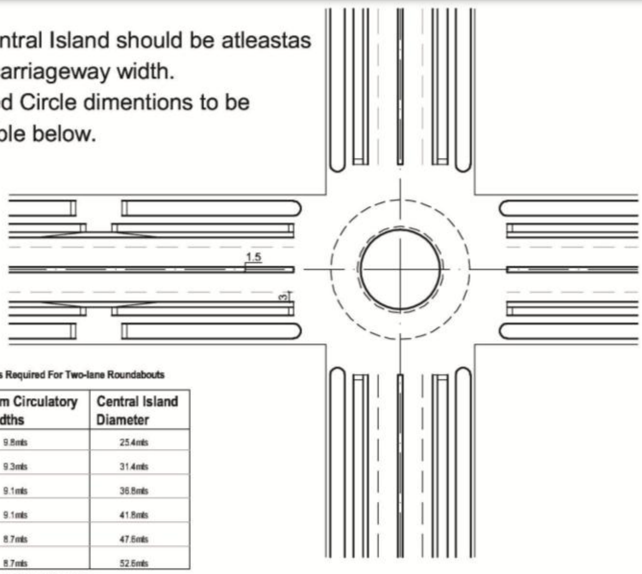


Figure 4-9 Lane widening at Splitter Island at circulatory roadway side Method of Roundabout Designing (Step 1 & 2)

3. Diameter of the Central Island should be atleastas much as the total carriageway width.
Apron and Inscribed Circle dimentions to be refered from the table below.



Minimum Circulatory Lane widths Required For Two-lane Roundabouts

Inscribed Circle Diameter	Minimum Circulatory lane Widths	Central Island Diameter
45mts	9.8mts	25.4mts
50mts	9.3mts	31.4mts
55mts	9.1mts	36.8mts
60mts	9.1mts	41.8mts
65mts	8.7mts	47.6mts
70mts	8.7mts	52.6mts

Reference: From Geometric design

4. For the Entry Width to increase from the carriageway down to the Circulatory Roadway width, Tangential Circle is introduced between Inscribed Circle and Carriageway.

With Average Effective Flare Length of 20-30mts.

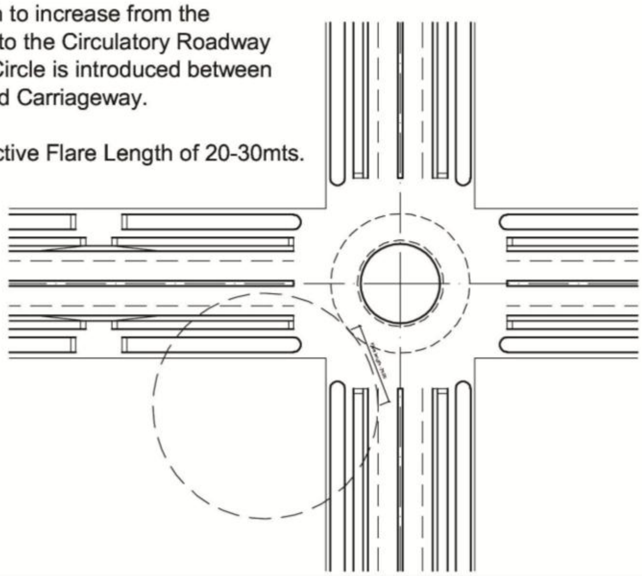


Figure 4-10 Lane widening at Splitter Island at circulatory roadway side Method of Roundabout Designing (Step 3 & 4)

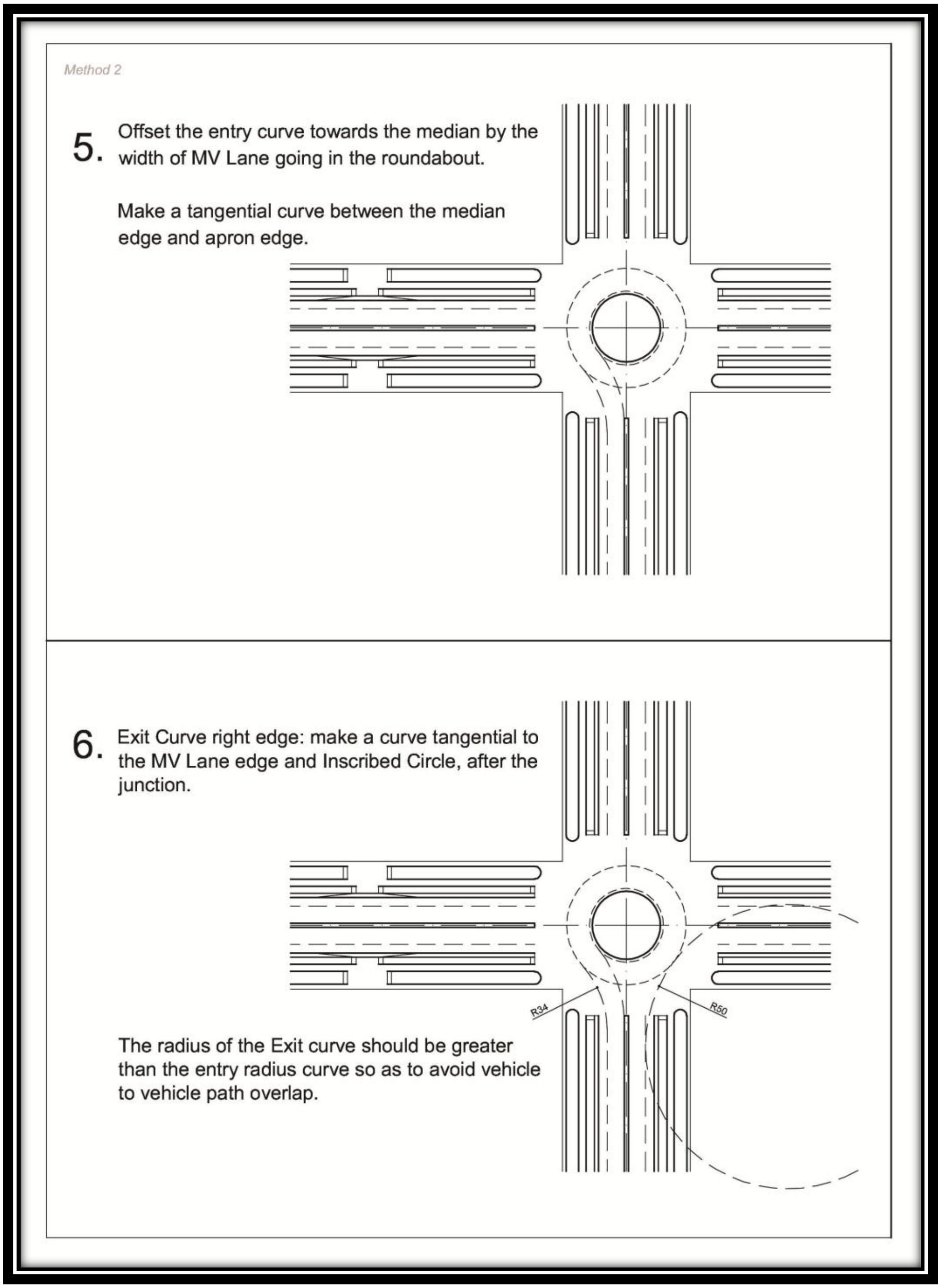


Figure 4-11 Lane widening at Splitter Island at circulatory roadway side Method of Roundabout Designing (Step 5 & 6)

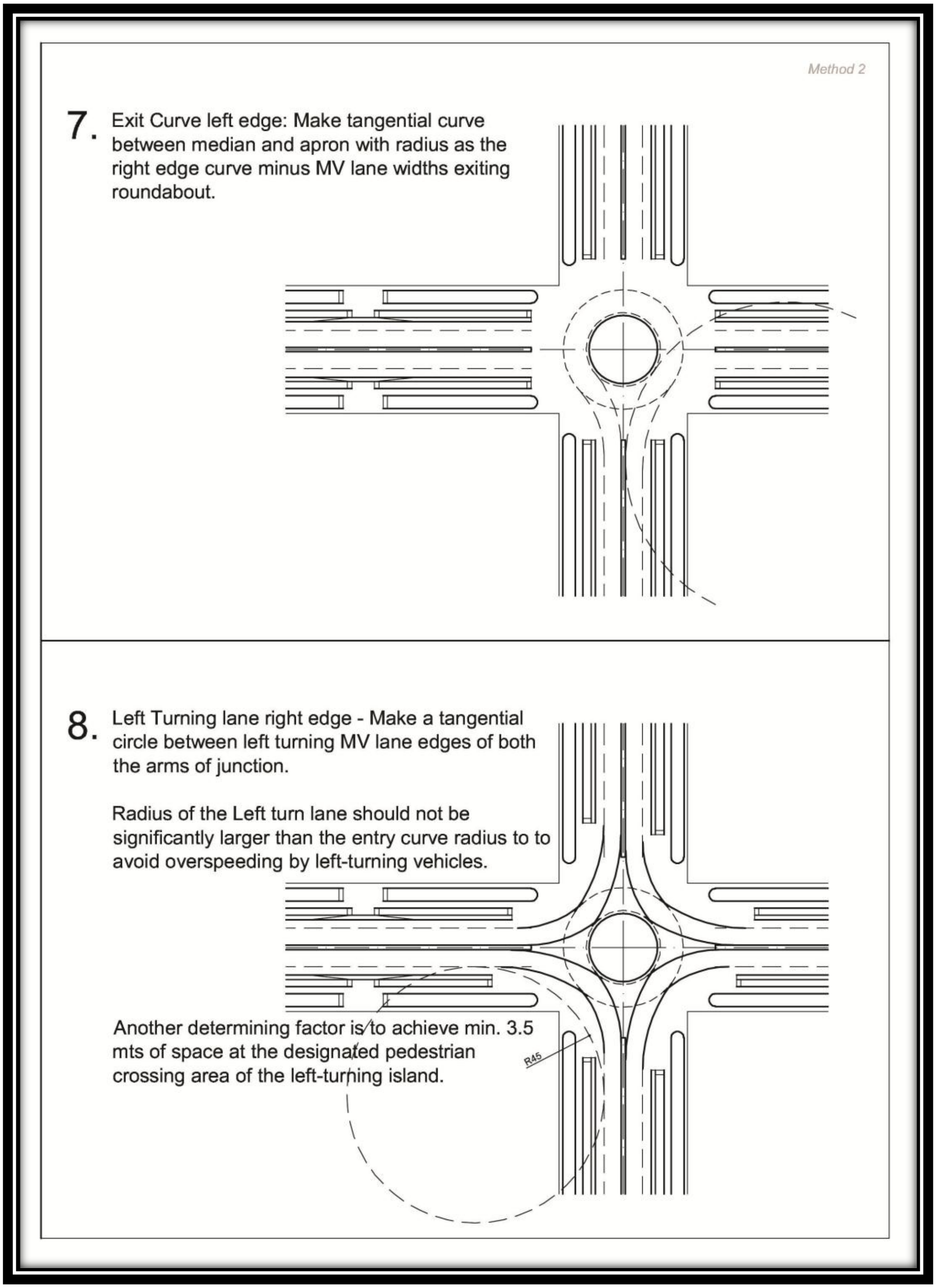


Figure 4-12 Lane widening at Splitter Island at circulatory roadway side Method of Roundabout Designing (Step 7 & 8)

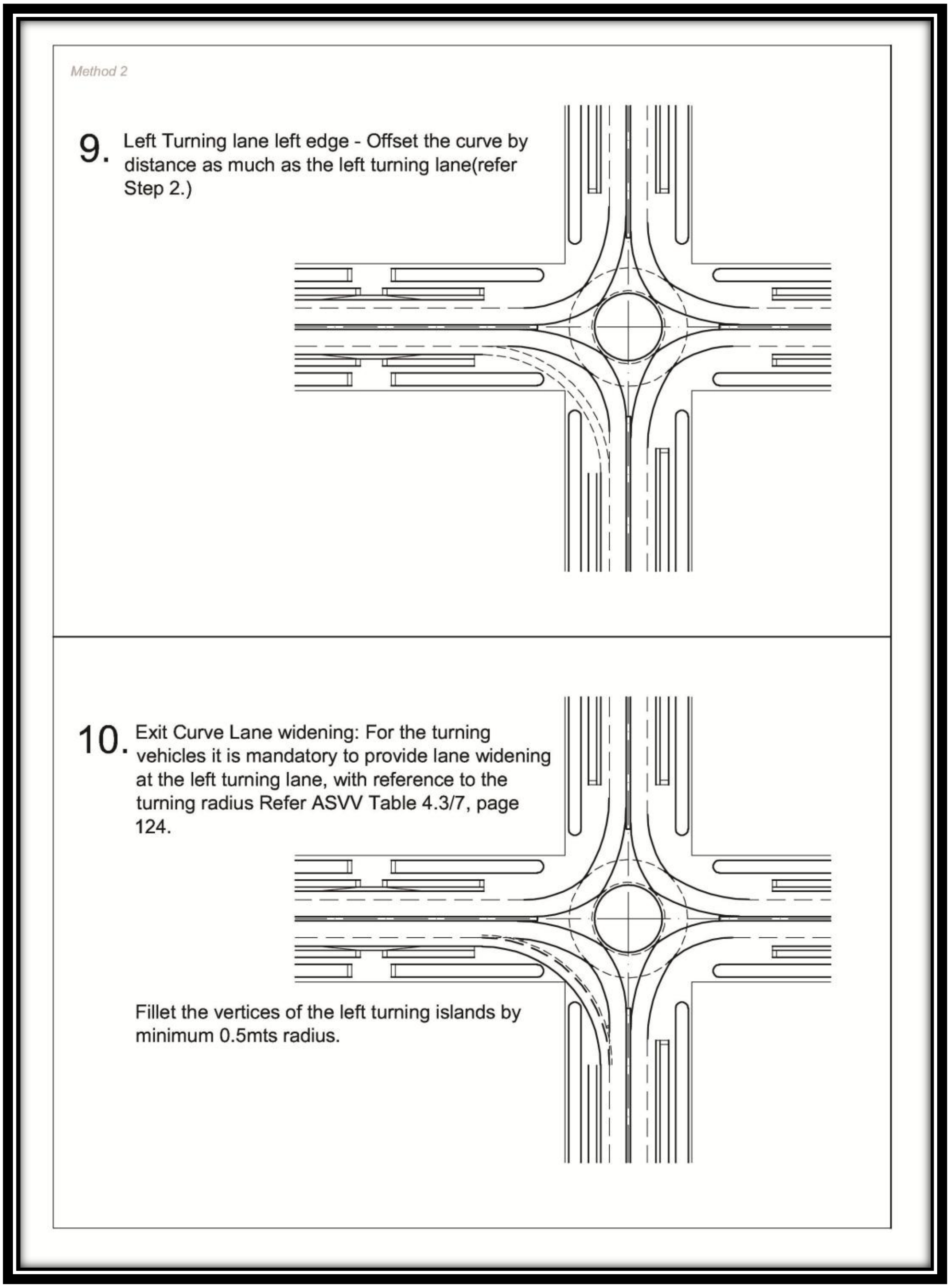


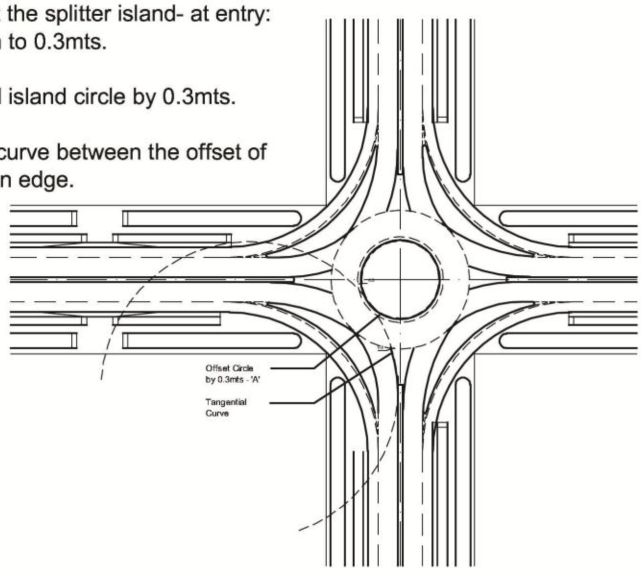
Figure 4-13 Lane widening at Splitter Island at circulatory roadway side Method of Roundabout Designing (Step 9 & 10)

Method 2

11. Lane widening at the splitter island- at entry: offset 0.0m down to 0.3mts.

Offset the central island circle by 0.3mts.

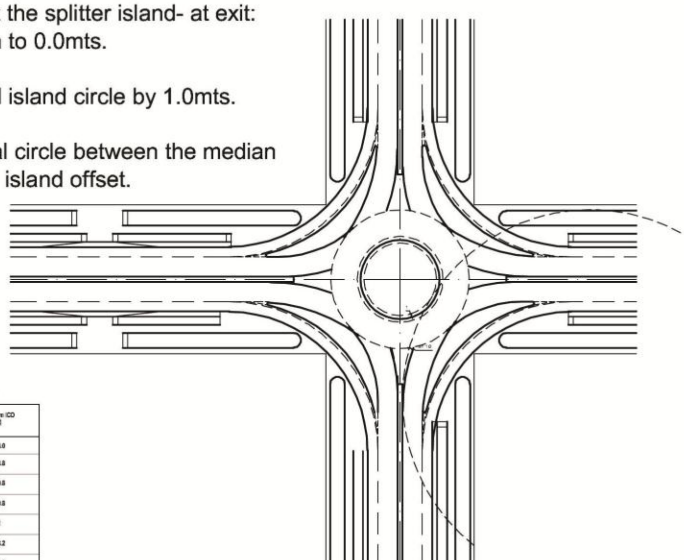
Make tangential curve between the offset of apron and median edge.



12. Lane widening at the splitter island- at exit: offset 1.0m down to 0.0mts.

Offset the central island circle by 1.0mts.

Make a tangential circle between the median edge and central island offset.



Turning Widths Required for Smaller Normal Roundabouts

Central Island Diameter (m)	R2 - R1 (m)	Minimum ICD (m)
4.0	10.0	28.0
6.0	9.4	28.8
8.0	8.9	29.8
10.0	8.4	30.8
12.0	8.0	32
14.0	7.6	33.2
16.0	7.3	34.6
18.0	7.0	36

Reference: From ASVV

Figure 4-14 Lane widening at Splitter Island at circulatory roadway side Method of Roundabout Designing (Step 11 & 12)

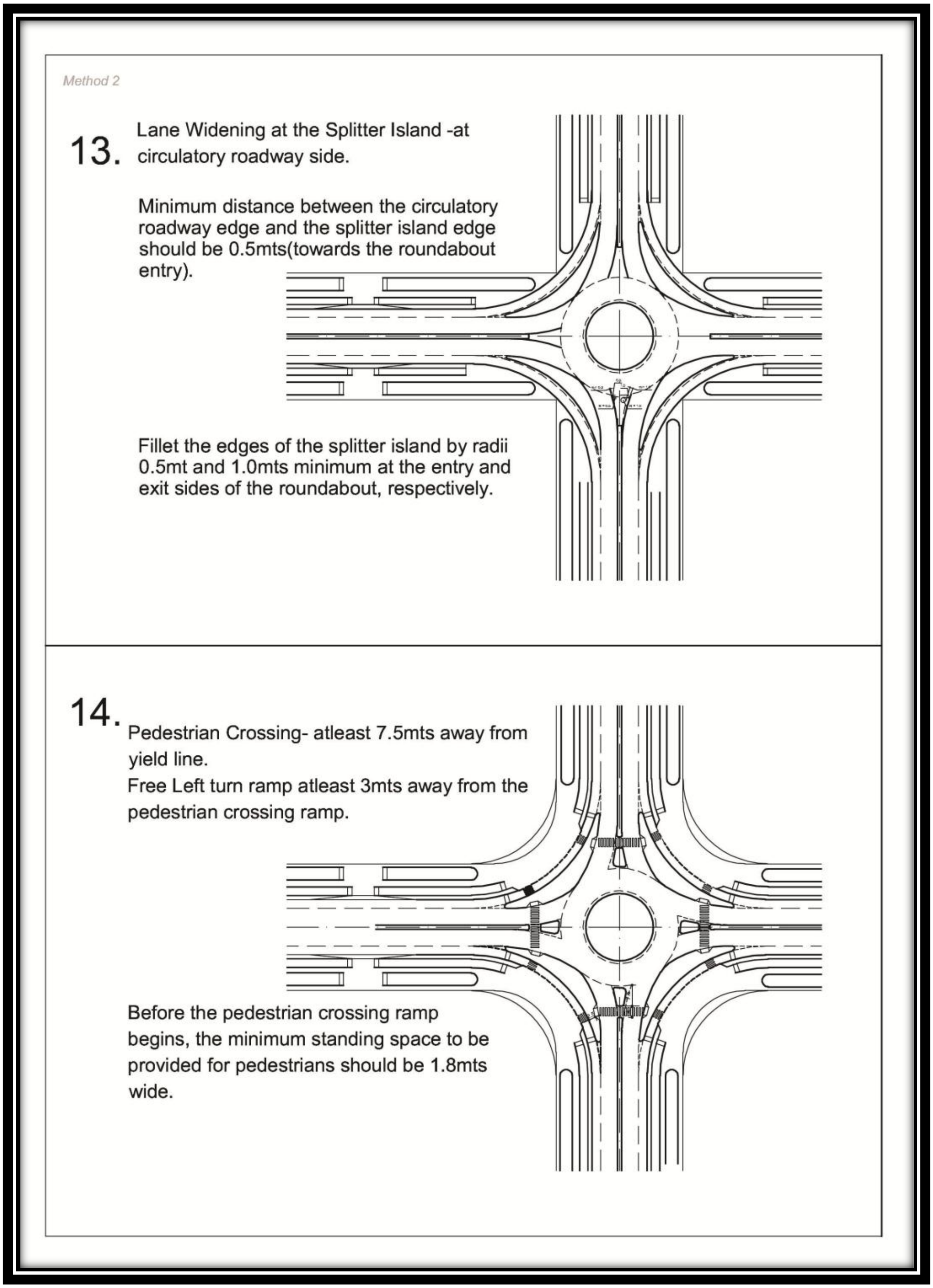


Figure 4-15 Lane widening at Splitter Island at circulatory roadway side Method of Roundabout Designing (Step 13 & 14)

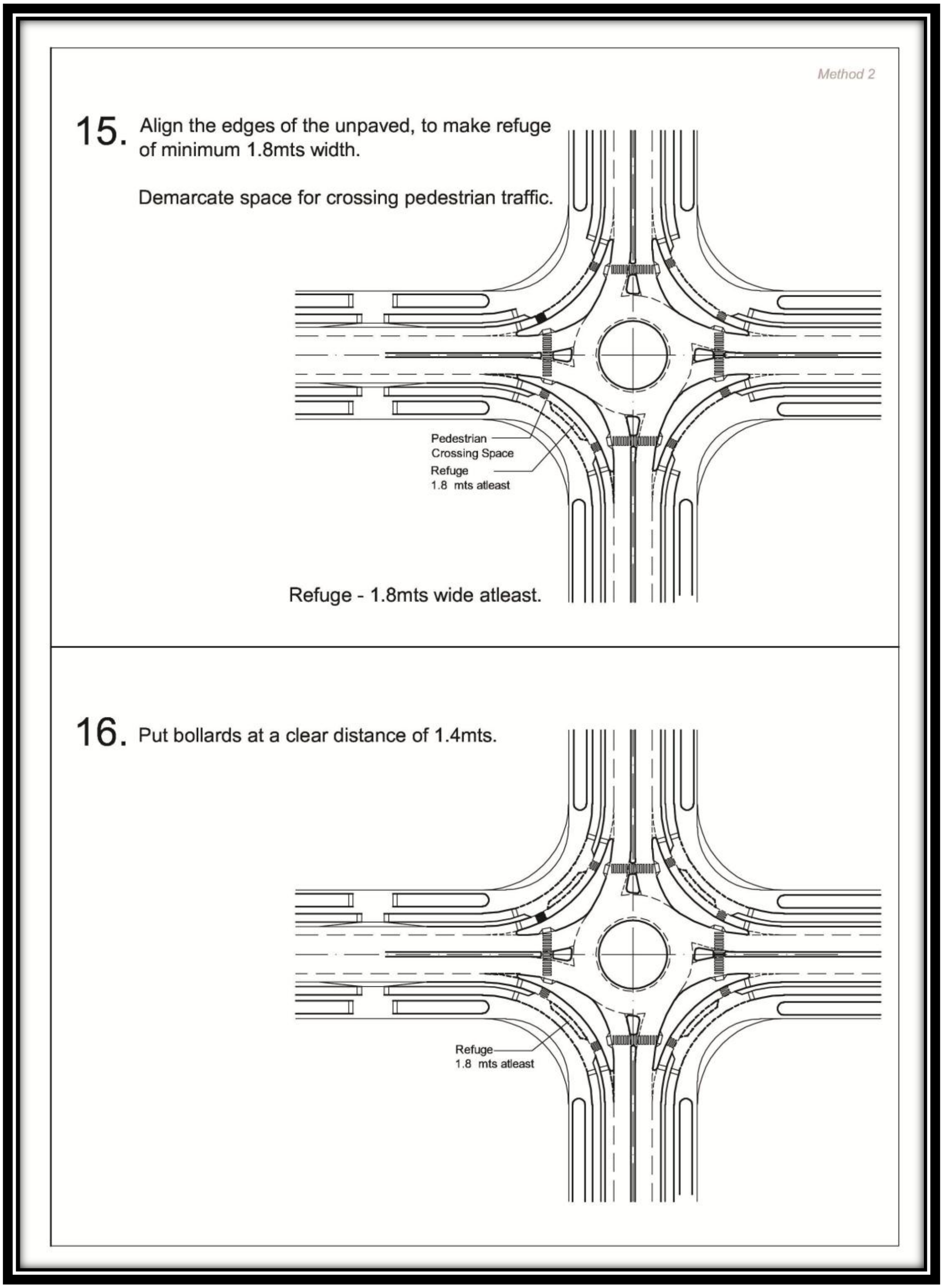


Figure 4-16 Lane widening at Splitter Island at circulatory roadway side Method of Roundabout Designing (Step 15 & 16)