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Geometric Design for Roadway Intersection Lines

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ABSTRACT: An intersection is an important part of a highway system because, to a great extent, the efficiency, safety, speed, cost of operation, and capacity depends on its design. Each intersection involves through or cross-traffic movements on one or more of the highways concerned and may involve turning movements between these highways. These movements may be handled by various means, such as signals, signing, and channelization, depending on the type of intersection.

Traffic loads are one of the key data elements required for the design and analysis of pavement structures. The MEPDG requires full axle-load spectrum mainly based on continuous site-specific Weigh-In-Motion (WIM) data sets for each axle type and axle-load group. Due to the fact that collecting high quality WIM data is expensive, challenging and analysing them requires extensive efforts and expertise, many state DOTs have to rely on traffic data from various acquisition technologies and length of time coverage for the implementation of MEPDG

This paper studies the impacts and variability of various traffic data collection efforts on MEPDG predicted performance. Geometric design process for modern roadway intersections. The contents of this document are intended to serve as guidance and not as an absolute standard or rule.

The impacts of traffic load level, WIM data coverage, vehicle distribution, axle loading, and using regional and national defaults on predicted pavement performance are evaluated. This study has recommended the minimum required traffic data collection efforts for highway agencies to prepare traffic data for the implementation of MEPDG.

The traffic characteristic of a corridor is required for design of pavement, fixing a number of traffic lanes, geometric design, design of intersections and economic appraisal. Traffic is the first thing to check before upgrading any facility. In this study, In order to understand the characteristics and the volume of traffic using the project road. Algorithm.

KEYWORDS: Geometric design, characteristic of traffic, pavement distress, economic appraisal.

I. INTRODUCTION

Image This course summarizes and highlights the geometric design process for modern roadway intersections. The contents of this document are intended to serve as guidance and not as an absolute standard or rule.

When you complete this course, you should be familiar with the general guidelines for at-grade intersection design. The course objective is to give engineers and designers an in-depth look at the principles to be considered when selecting and designing intersections.

Subjects include:

1. General design considerations – function, objectives, capacity
2. Alignment and profile
3. Sight distance – sight triangles, skew
4. Turning roadways – channelization, islands, superelevation
5. Auxiliary lanes
6. Median openings – control radii, lengths, skew
7. Left turns and U-turns
8. Roundabouts
9. Miscellaneous considerations – pedestrians, traffic control, frontage roads

10. Railroad crossings – alignments, sight distance

Geometric design is the assembly of the fundamental three-dimensional roadway features related to operational quality and safety: cross section (lanes and shoulders, curbs, medians, roadside slopes and ditches, sidewalks); horizontal alignment (tangents and curves); and vertical alignment (grades and vertical curves). Its basic objective is to provide a smooth-flowing, crash-free facility.

This document is intended to explain some principles of good roadway design and show the potential trade-offs that the designer may have to face in a variety of situations, including cost of construction, maintenance requirements, compatibility with adjacent land uses, operational and safety impacts, environmental sensitivity, and compatibility with infrastructure needs.

Geometric design is the assembly of the fundamental three-dimensional features of the highway that are related to its operational quality and safety.

Effective geometric design transmits knowledge from research and operational experience to the user. It reflects both human and vehicular characteristics and capabilities.

Despite this dynamic character, the primary objective of good design will remain as it has always been – to provide a safe, efficient and cost-effective roadway that addresses conflicting needs or concerns.

INTERSECTIONS

Intersections are unique roadway elements where conflicting vehicle streams (and sometimes non-motorized users) share the same space. This area encompasses all modes of travel including:

- Pedestrian • Bicycle
- Passenger vehicle • Truck
- Transit

Intersections also encompass auxiliary lanes, medians, islands, sidewalks and pedestrian ramps. These may further heighten the accident potential and constrain the operational efficiency and network capacity of the urban street system. However, the main objective of intersection design is to facilitate the roadway user and enhance efficient vehicle movement. The need to provide extra time for drivers to perceive, decide, and navigate through the intersection is central to intersection design controls and practices.

Designing to accommodate the appropriate traffic control are critical to good intersection design. Warrants and guidelines for selection of appropriate intersection control (including stop, yield, all-stop, or signal control) may be found in the MUTCD.

II. LITERATURE REVIEW

Min-Wook Kang et al. (2013). A fuel consumption model is developed based on highway geometric characteristics like grades, length and location of crest & vertical curves, speed & road surface type & condition. The output of fuel consumption model is the amount of fuel consumed by the vehicle while it travels along a highway at cruising speed.

Fuel consumption model limitations:

- It is only for passenger car units. It will be updated with consideration of other type of vehicles.
- It does not yet consider the effect of intersections & junction points with existing roads.
- It is not suitable for vehicle travelling along highway curved sections where acceleration and deceleration are needed due to variety design speeds.

Vikas Golakoti (2015). His thesis includes geometric factors of road and data collection and analysis of geometric parameters. The aim of this study is to find the role of the geometric factors of road on accident rate in the case of plain terrain and also find the extent to which these factors affect the accident rate for rural areas. The study aims to find the impact of factors like extra widening, horizontal radius, sight distance, K-value, super elevation, horizontal arc length, vertical arc length, vertical gradient on the accident rate and aims to study the significant factors causing accidents and to find the values for future design of roads.

Matthew G. Karlaftis and Ioannis Golias (2001). They focused on relationship between rural road geometric characteristics, accident rates and their prediction, using a rigorous non-parametric statistical methodology known as hierarchical tree-based regression. Their goal is twofold; first, it develops a methodology that quantitatively assesses the effects of various highway geometric characteristics on accident rates and second, it provides a straightforward, yet fundamentally and mathematically sound way of predicting accident rates on rural roads. The results show that although the importance of isolated variables differs between two-lane and multi-lane roads, „geometric design“ variables and „pavement condition“ variables are the two most important factors affecting accident rates.

III. BASIC TYPES OF INTERSECTIONS

An intersection or an at-grade junction is a junction where two or more roads converge, diverge, meet or cross at the same height, as opposed to an interchange, which uses bridges or tunnels to separate different roads. Major intersections are often delineated by gores and may be classified by road segments, traffic controls and lane design.

ROAD SEGMENTS

One way to classify intersections is by the number of road segments (arms) that are involved.

- A three-way intersection is a junction between three road segments (arms): a T-junction when two arms form one road, or a Y-junction, the latter also known as a fork if approached from the stem of the Y.
- A four-way intersection, or crossroads, usually involves a crossing over of two streets or roads. In areas where there are blocks and in some other cases, the crossing streets or roads are perpendicular to each other. However, two roads may cross at a different angle. In a few cases, the junction of two road segments may be offset from each when reaching an intersection, even though both ends may be considered the same street.
- Six-way intersections usually involve a crossing of three streets at one junction; for example, a crossing of two perpendicular streets and a diagonal street is a rather common type of 6-way intersection.
- Five, seven or more approaches to a single intersection, such as at Seven Dials, London, are not common

TYPES INTERSECTIONS

- Three-leg (T)
- Four-leg
- Multi-leg
- Roundabout



Fig no 1. Intersections

Three-Leg

The typical three-leg intersection configuration contains normal paving widths with paved corner radii for accommodating design vehicles. The angle of intersection typically ranges from 60 to 120 degrees.

Auxiliary lanes (left or right-turn lanes) may be used to increase roadway capacity and provide better operational conditions.

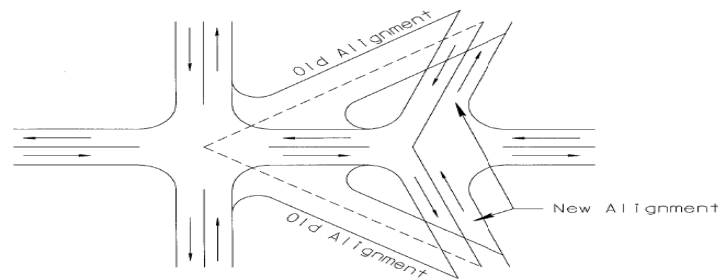
Channelization may be achieved by increasing corner radii to separate a turning roadway from the normal travelled ways by an island.

Four-Leg

Many of the three-leg intersection design considerations (islands, auxiliary lanes, channelization, etc.) may also be applied to four-leg intersections.

Multi-Leg

Intersection designs with multiple legs (5 or more) should not be used unless there is no other viable alternative. If multi-legs must be used, a common paved area where all legs intersect may be desirable for light traffic volumes and stop control.



MULTILEG INTERSECTION REALIGNMENT

Fig no 2 multiple intersection

INTERSECTION SIGHT DISTANCE

Intersection sight distance is the length of roadway along the intersecting road for the driver on the approach to perceive and react to the presence of potentially conflicting vehicles. Drivers approaching intersections should have a clear view of the intersection with adequate roadway to perceive and avoid potential hazards. Sight distance should also be provided to allow stopped vehicles a sufficient view of the intersecting roadway in order to enter or cross it. Intersection sight distances that exceed stopping sight distances are preferable along major roads to enhance traffic operations. Methods for determining intersection sight distances are based on many of the same principles as stopping sight distance.

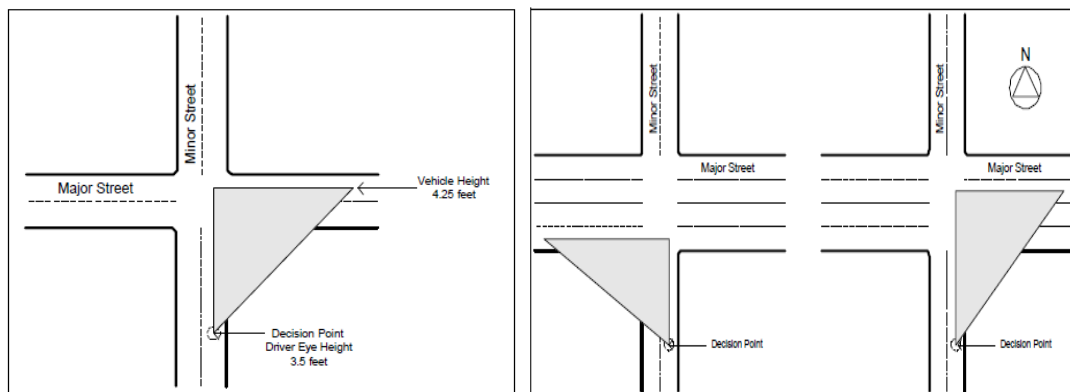


Fig no 3 heights pertaining to sight triangles Fig no 4 approach sight triangles

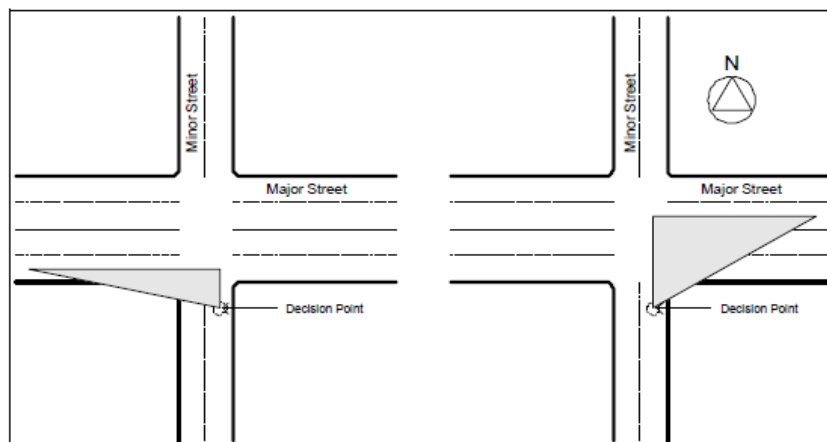


Fig no 5 departure sight triangles

DESIGN VEHICLES**Table no 1 design vehicles**

P	Passenger car
SU-30	Single-unit truck
SU-40	Single-unit truck (three axle)
CITY-BUS	City transit bus
WB-40	Intermediate semitrailer combination
WB-62 & 65	Interstate semitrailers
WB-92D	Rocky Mountain double semitrailer/trailer
WB-100T	Triple semitrailer/trailers combination
WB-109D	Turnpike double combination
S-BUS36	Conventional school bus
WB-67D	Trucks, articulated buses, motor homes, motor coaches, passenger cars pulling trailers or boats

Passenger Car (P) Design vehicles are used for parkway intersections requiring minimum turns, local/major road intersections with occasional turns; and intersections of two minor roads with low volumes. Single-unit truck (SU-30) is preferable if conditions permit. Minimum edge design is typically used since it better fits the design vehicle path.

Single-Unit Truck (Su-30 And Su-40) vehicles are recommended for minimum edge-of-traveled-way design for rural highways. Crucial turning movements (major highway, large truck volume, etc.) may require speed-change lanes and/or larger radii. Minimum travel way designs for single-unit trucks will also accommodate city transit buses.

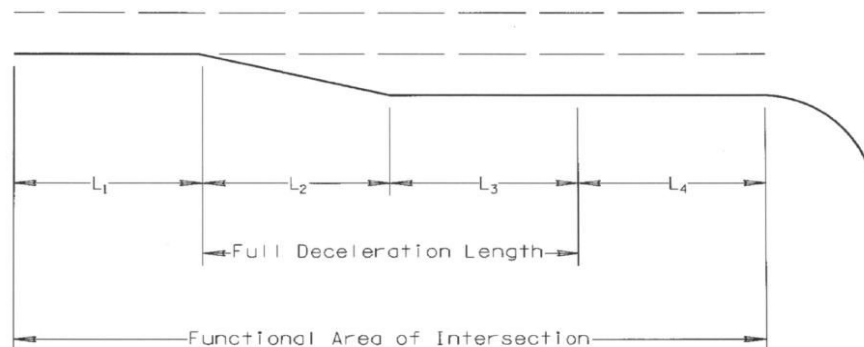
Semitrailer Combination (Wb Series) design vehicles are used at locations with repetitive truck combination turns. An asymmetrical setup of three-centered compound curves is better suited for sites with large volumes of smaller truck combinations. Semitrailer combination designs may need larger radii and corner triangular islands due to their large paved areas.

DECELERATION LANES

The physical length for a deceleration lane entails the following components:

- Entering taper length (L_2)
- Deceleration length (L_3)
- Storage length (L_4)

Moderate rates of deceleration are typically accepted within the through lanes with taper lengths considered as part of the deceleration.



L_1 = distance traveled during perception-reaction time
 L_2 = taper distance
 L_3 = distance traveled to complete deceleration to a stop
 L_4 = storage length

Fig no 6 deceleration lane length components

LEFT-TURN LANE DESIGN

The accommodation of left-turning traffic is the single most important consideration in intersection design. The principal controls for intersection type and design are:

- Design-hour traffic volume
- Traffic character/composition
- Design speed

Traffic volume (actual/relative traffic volumes for turning and through movements) is considered to be the single most significant factor in determining intersection type.

Table no 2 median widths

Intersections	Median Width	Status
Single median lane	20-ft minimum	Desirable
	16 to 18 feet	Adequate
Two median lanes	28-ft minimum (two 12-ft lanes with 4-ft separator)	Desirable

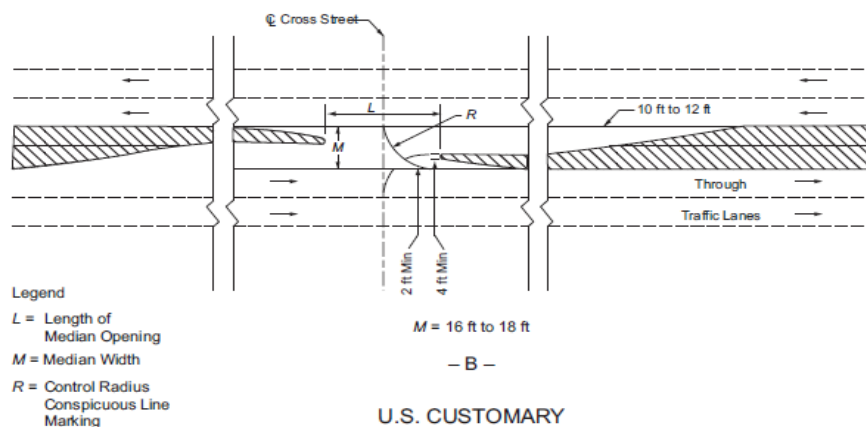


Fig no 7 median width left turn

MEDIAN OPENINGS

Median openings should be consistent with site characteristics, through/turning traffic volumes, type of turning vehicles, and signal spacing criteria. For locations with low traffic volumes where the majority of vehicles travel on the divided roadway, the simplest and most economic design may be adequate. However, at locations with high speed/high volume through traffic or sites with considerable cross and turning movements, the median opening should allow little or no traffic interference or lane encroachment.

Median Opening Design Steps:

- Consider traffic to be accommodated
- Choose a design vehicle
- Determine large vehicle turns without encroachment
- Check for capacity

Table no 3 control radius

Control Radius	Design Vehicle
40 feet	P, SU-30 (occasional)
50 feet	SU-30, SU-40/WB-40 (occasional)
75 feet	SU-40, WB-40, WB-62
130 feet	WB-62, WB-67 (occasional)

The semicircle median opening designs are simple for narrow medians. More desirable shapes are typically used for median widths greater than 10 feet.

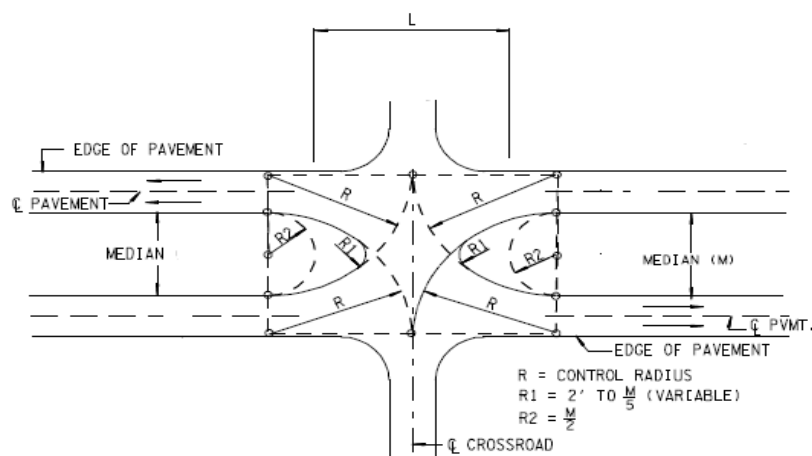


Fig no 8 semicircle median opening

The bullet nose design contains two parts of the control radius arcs with a small radius to round the nose. This form fits the inner rear wheel path with less pavement and shorter opening lengths. The bullet nose is preferable for median widths greater than 10 feet. This design positions left-turning vehicles to or from the crossroad centerline, whereas semicircular forms direct left off movements into the crossroad's opposing traffic lane.

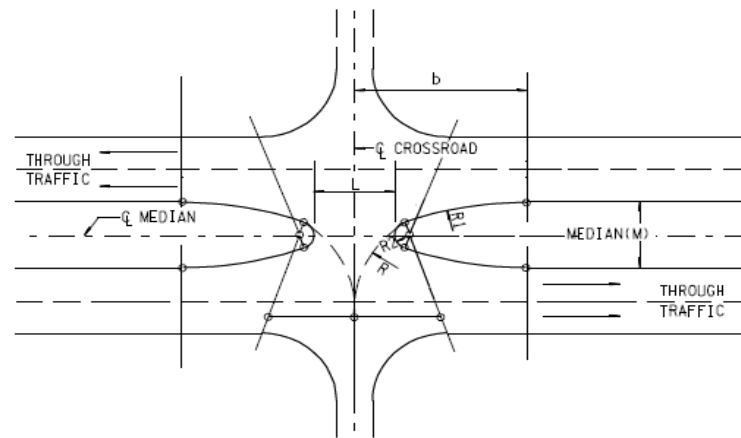


Fig no 9 bullet nose

Median U-Turn Crossover Roadways

Median U-Turn crossovers move left-turning traffic to median crossover roadways beyond intersections. For major road crossovers, drivers pass through the intersection and turn left to make a U-turn at the crossover, and veer right at the cross road. For minor road median crossovers, major road traffic turns right on the minor road, and then left through the crossover roadway. Roundabouts may be considered to be a variation of U-turn crossovers.

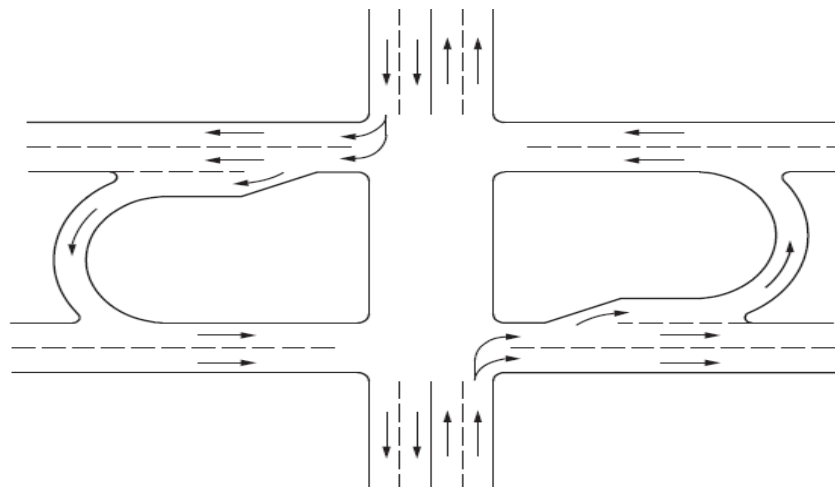


fig no 10 median u-turn crossover roadways

IV. GEOMETRIC DESIGN

ROUNDAABOUT GEOMETRIC ELEMENTS:

Central Island: Raised area (not necessarily circular) in the center of the roundabout which is bordered by circulating traffic.

Splitter Island: Raised or painted approach area for delineating, deflecting and slowing traffic. It also permits non-motorist crossings.

Circulatory Roadway: Curved vehicle path for counterclockwise travel around the central island.

Apron: Optional mountable part of the central island for accommodating large vehicle wheel tracking.

Yield Line: Pavement marking for entry point to the circulatory roadway. Entry vehicles must yield to circulating traffic before crossing the yield line onto the circulatory path.

Accessible Pedestrian Crossings: Non-motorist access that is setback from the entrance line and cut through the splitter island.

Landscape Strip: Optional areas for separating vehicle/non-motorist traffic, designating crossing locations, and providing aesthetic improvements.

Roundabout design is a creative process that is specific for each individual intersection. No standard template or “cookie-cutter” method exists for all locations. Geometric designs can range from easy (mini-roundabouts) to

moderate (single lane roundabouts) to very complex (multi-lane roundabouts). How the intersection functions as a single traffic control unit is more important than the actual values of the individual design components. It is crucial that these individual geometric parts interact with each other within acceptable ranges in order to succeed.

SPEED MANAGEMENT

The design speed of vehicles is a critical factor for roundabout design. Speed management is often a combination of managing speeds at the roundabout plus the approaching legs. Forecasting these vehicular speeds when traveling through a proposed roundabout is fundamental for attaining good safety performance.

Table no 4 speed management

Site Category	Entry Design Speed
Mini-Roundabout	25 km/h (15 mph)
Urban Compact	25 km/h (15 mph)
Urban Single Lane	35 km/h (20 mph)
Urban Double Lane	40 km/h (25 mph)
Rural Single Lane	40 km/h (25 mph)
Rural Double Lane	50 km/h (30 mph)

LANE ARRANGEMENTS

The entry movements assigned to each lane within a roundabout are critical to its overall design. An operational analysis can help determine the required number of entry lanes for each approach. Pavement marking may also be used in the preliminary phase to ensure lane continuity through the various design iterations. Roundabouts are typically designed to accommodate design year traffic volumes (normally projected 20 years in the future).

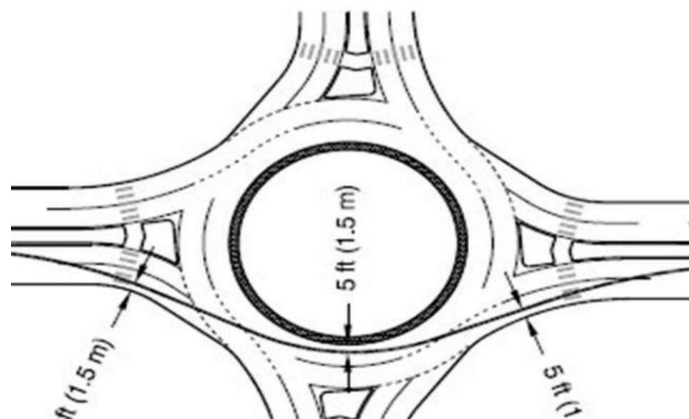


Figure 11 Fastest Vehicle Path through a Single-Lane Roundabout

DESIGN VEHICLE

A primary factor in determining the design of a roundabout is the choice of the largest vehicle (design vehicle) that will use the facility. Turning path requirements will have a direct effect on many of the dimensions of the roundabout (inscribed circle diameter, approach re-alignment, etc.).

The appropriate design vehicle consideration is dependent on the following criteria:

- Roadway classification
- Input from local authorities
- Surrounding environmental characteristics

Table no 5 design vehicle

Design Vehicle	Location
Passenger Car (P)	Parking lots or series of parking lots
Single-unit Truck (SU)	Residential streets and park roads
City Transit Bus (CITY-BUS)	Highway intersections with city streets designated bus routes
Large or Conventional School Bus (S-BUS36 or 40)	Highway intersections with local roads under 400 ADT
Interstate Semitrailer (WB-65 or 67)	Freeway ramps with arterial crossroads or high volume traffic roadways

NON-MOTORIZED DESIGN USERS

Roundabouts are designed to meet the needs of all facility users. The safe and efficient accommodation of all non-motorized users (bicyclists, drivers, pedestrians, disabled or impaired persons, strollers, skaters, etc.) is as important as the considerations made for vehicles.

Table no 6 Non-motorized Design Users

User	Dimension	Affected Roundabout Features
Bicyclist		
Length	5.9 ft	Splitter island width at crosswalk
Minimum operating width	4 ft	Bike lane width on approach roadways; shared use path width
Pedestrian (walking)		
Width	1.6 ft	Sidewalk width, crosswalk width
Wheelchair user		
Minimum width	2.5 ft	Sidewalk width, crosswalk width
Operating width	3.0 ft	Sidewalk width, crosswalk width
Person pushing stroller		
Length	5.6 ft	Splitter island width at crosswalk
Skaters		
Typical operating width	6 ft	Sidewalk width

BICYCLE DESIGN CONSIDERATIONS

Research has shown that bicyclists are the most vulnerable users of roundabouts with over 50 percent of bike crashes at roundabouts involving entering vehicles and circulating bicycles.

Modern roundabouts are typically designed to accommodate bicyclists of different skills and experience levels.

When designing a roundabout for bicycle safety and travel, the following general methods may be used to accommodate bicyclists:

Motor Vehicle Method - Mixed Flow With Regular Traffic

Typical bicycle (12 – 20 mph) and design vehicle entry (20 – 30 mph) speeds are similar and compatible for low-speed, single-lane roundabouts with low potential conflicts.

Pedestrian Method - Shared Use Paths

Bicycle safety tends to deteriorate at high-speed, multiple lane roundabouts and many cyclists may be more comfortable and safer using bike ramps connected to a sidewalk or shared use path around the outside of the roundabout. The typical sidewalk width should be a minimum of 10 ft in order to accommodate both pedestrians and bicyclists. Bicycle lanes or shoulders used on approach roadways, should end at least 100 feet before the edge of the circulatory roadway.

SIGHT DISTANCE AND VISIBILITY

Adequate visibility and sight distance for approaching vehicles is crucial for providing safe roundabout operation. For roundabouts, the two most relevant parts of sight distance are stopping sight distance and intersection sight distance.

Table no 7 sight distance and visibility

Speed (km/h)	Computed Distance* (m)	Speed (mph)	Computed Distance* (ft)
10	8.1	10	46.4
20	18.5	15	77.0
30	31.2	20	112.4
40	46.2	25	152.7
50	63.4	30	197.8
60	83.0	35	247.8
70	104.9	40	302.7
80	129.0	45	362.5
90	155.5	50	427.2
100	184.2	55	496.7

Size, Position, And Alignment Of Approaches

The design of a roundabout involves optimizing the following design decisions to balance design principles and objectives:

- Size
- Position
- The alignment of the approach legs

Table no 8 size, position, and alignment of approaches

Road Type	Normal Capacity
Single-lane circulatory road	1400 to 2400 vehicles/hour
Two-lane circulatory road	2200 to 4000 vehicles/hour
Road type	Maximum Capacity
Single-lane entry	1300 vehicles/hour
Two-lane entry	1800 vehicles/hour

SINGLE-LANE ROUNDABOUTS

Single-lane roundabout design consists of single-lane approaches at all legs and a single-lane circulatory roadway around a central island. This design permits slightly higher operation speeds for the entry, exit and the circulatory roadway. Like all roundabouts, the size of single-lane design is largely dependent on the type of design vehicle and available right-of-way.

Single-Lane Geometric Design Characteristics:

- Larger inscribed circle diameters
- Raised splitter islands

- Non-traversable central island
- Crosswalks
- Truck apron

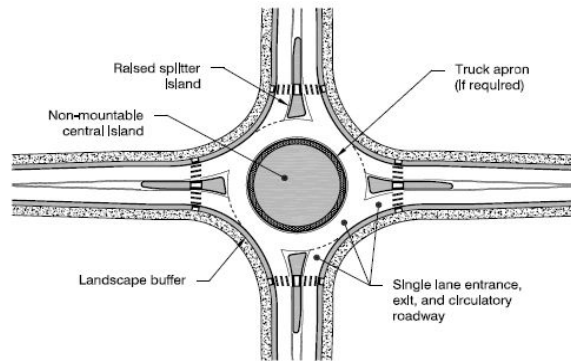


Fig no 12 illustrates the distinguishing features of typical single-lane roundabouts.

MULTILANE ROUNDABOUTS

Multilane roundabouts contain a minimum of one entry (two or more lanes) and require wider circulatory roadways to accommodate more than one vehicle traveling side by side. The roundabouts may have a different number of lanes or transitions on one or more legs. The number of lanes should be the minimum needed for the anticipated traffic demand. The design speeds at the entry, on the circulatory roadway, and at the exit may be slightly higher than those for single-lane roundabouts. Multilane roundabouts include raised splitter islands, truck aprons, a non-traversable central island, and appropriate entry path deflection.

The size of a multilane roundabout is typically determined by balancing two critical design objectives:

- The need to achieve deflection; and
- Providing sufficient natural vehicle path alignment.

To achieve both of these objectives, a diameter larger than those used for single-lane roundabouts is required. Generally, the inscribed circle diameter of a multilane roundabout ranges from 150 to 220 ft (two-lane) and 200 to 300 ft (three-lane) for achieving adequate speed control and alignment. Truck aprons are recommended to accommodate larger design vehicles and keep the inscribed circle diameter reasonable.

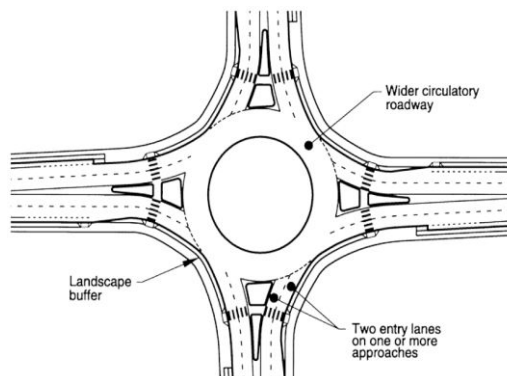


Fig no 13 Typical Urban Double-Lane Roundabout

MINI-ROUNDABOUTS

Mini-roundabouts are small intersection designs with a fully traversable central island that are commonly used in low-speed urban environments (average operating speeds of 30 mph or less). The small footprint of a mini-roundabout (inscribed circle diameter less than 90 ft) can be useful in such environments where conventional roundabout design is limited by right-of-way constraints. The small diameter is made possible by using a fully traversable central island for accommodating heavy vehicles. Passenger cars should be able to exit the mini-roundabout without running over the central island. The overall design should naturally guide entering vehicles along their intended path and minimize traversing the central island.

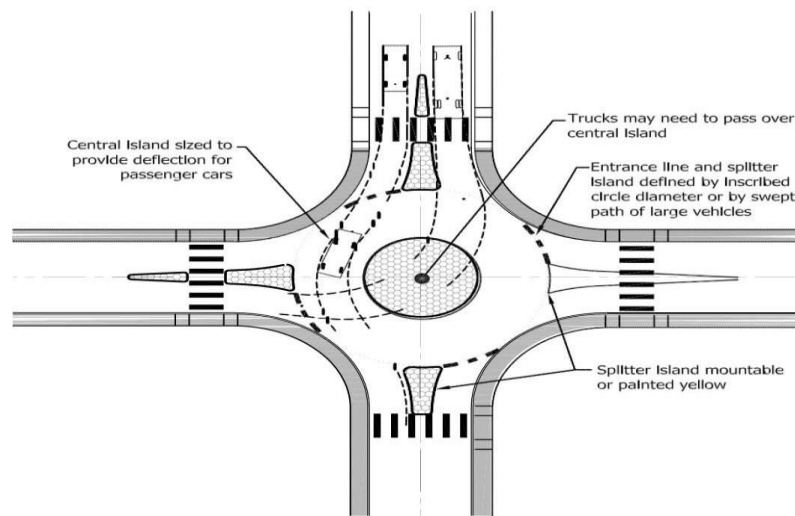


Figure 14 Design Features of a Mini-Roundabout

V. CONCLUSION

This course summarized and highlighted the geometric design process for modern at-grade intersection design. The objective was to provide an in-depth look at the principles to be considered when selecting and designing intersections. There are clearly many considerations, including cost of construction, maintenance requirements, compatibility with adjacent land uses, operational and safety impacts, environmental sensitivity, and compatibility with infrastructure needs. This document is intended to explain some principles of good roadway design and show the potential trade-offs that the designer may have to face in a variety of situations in order to provide safe, efficient, and cost-effective transportation of people and goods.

The contents of this document were intended to serve as guidance and not as an absolute standard or rule. Course topics included: general design considerations; alignment and profile; sight distance; turning roadways; auxiliary lanes; median openings; left turns and U-turns; roundabouts; railroad crossings; and other miscellaneous considerations.

Intersections are similar to other major infrastructure projects – they consume valuable resources and often adversely affect users. Resource protection parties normally expect any adverse effects to be addressed in roadway planning and design. The mere application of design standards and criteria to „solve“ a problem is inadequate – there is no “cookie-cutter” solution. Complex safety and operational relationships behind the design guidelines and criteria must be clearly understood. Roadway designers need to be able to present the reasons for an at-grade intersection design, and be prepared to develop any alternatives. This is possible only if the designer understands how all elements of the roadway contribute to its safety and operation in the region.

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