Roundabout Design Aid

This document will assist the designer in the design of roundabouts by providing clarification and preferences used by MDOT. Further information and detail may be found in NCHRP Report 672.

Design Parameters

The following are to be completed by the designer and submitted to the MDOT Geometrics Unit for review:

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Leg 1</th>
<th>Leg 2</th>
<th>Leg 3</th>
<th>Leg 4</th>
<th>Leg 5</th>
<th>Leg 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half width, ft, (V=)</td>
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<td>Entry width, ft, (E=)</td>
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<td>Effective Flare, ft, (L’=)</td>
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<td>Entry Radius, ft, (R=)</td>
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<td>Entry Angle (Ø=)</td>
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<tr>
<td>$R_1$ Radius (ft) / $V_1$ Speed (mph) *</td>
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<tr>
<td>$R_2$ Radius (ft) / $V_2$ Speed (mph) *</td>
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<tr>
<td>$R_3$ Radius (ft) / $V_3$ Speed (mph) *</td>
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<tr>
<td>$R_4$ Radius (ft) / $V_4$ Speed (mph) *</td>
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<tr>
<td>$R_5$ Radius (ft) / $V_5$ Speed (mph) *</td>
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<tr>
<td>Inscribed Circle Diameter, ft, =</td>
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</tbody>
</table>

* These $R_x$ and $V_x$ variables are further defined and explained in the “Speed Management” section of this Design Aid.

- Design Vehicle: _________________________________
- Circulating Roadway Width: _____________________
- Truck Apron Width, if present: ___________________
- Stopping Sign Distance: ________________________
- Intersection Sight Distance: ____________________
General Notes

**Single Lane Roundabout**
Entry width  14 - 18 ft
Circulatory width  16 - 20 ft
Entry radius  50 ft minimum
Exit radius  greater than 50 ft (recommended 100 - 200 ft)

**Multilane Roundabout**
Entry width  24 - 30 ft
Circulatory width  28 - 32 ft
Entry radius  > 65 ft minimum

**Inscribed Circle Diameter**
The following ranges are typical of roundabout diameters assuming the Department practice of an AASHTO WB-67 being used as the design vehicle. Other values may be appropriate given different design vehicle assumptions.
Single Lane  130-180 ft
Double Lane  165-220 ft
Triple Lane  220-300 ft

**Splitter Islands**
Splitter islands should generally be 50 ft to 100 ft in length
On high-speed approaches (>45 mph), splitter islands should desirably be a minimum of 150 ft in length
The splitter island should be extended beyond the end of the exit curve

**Circulatory Width**
Circulatory widths should be at least as wide as the maximum entry width - and may be up to 120 percent of the maximum entry width.

**Entry Angle**
Entry angles should be between 20 and 40 degrees (with 30 degrees considered optimal).

**Cross-Slope**
Cross-slopes should be 1.5% or 2.0% towards the outside of the roundabout (i.e. sloped away from the central island). A 1.5% cross-slope is preferable to a 2.0% cross-slope.

**Truck Apron**
Truck aprons should generally be 10 ft to 15 ft in width and should be constructed in the same plane (have the same 1.5% or 2.0% cross-slope) as the circulatory roadway.

**Curb and Gutter**
- **Splitter Islands**: Detail B or Detail F curb and gutter should be used. (Detail F curb and gutter is preferred where pedestrians are prevalent).
- **Entering and Exiting Radii**: Detail B curb and gutter should be used.
- **Truck Apron**: Detail D curb and gutter should be used.
- **Central Island**: Detail E curb should be used.

**Sight Distance**
See section 6.7.3 of NCHRP Report 672. It is important to note that that unlimited sight distance may not be desirable. Limiting sight distance by mounding up the central island or obscuring sight distance to an extent on the approaches may lessen the chances of vehicles ‘racing’ to enter before a vehicle on another approach. This may have a beneficial effect on entry speeds and yielding behavior.
Case 1, Case 2, and Case 3 Truck Operations
Multi-lane roundabouts are designed to accommodate truck turning movements in one of three ways:

Case 1 Operations – Case 1 roundabouts are designed such that trucks may encroach into adjacent lanes while approaching, entering, circulating, and exiting the roundabout.

Case 2 Operations – Case 2 roundabouts are designed such that trucks are accommodated within their own lane as they approach and enter the roundabout, but may encroach into adjacent lanes while circulating, and exiting the roundabout.

Case 3 Operations – Case 3 roundabouts are designed such that trucks are accommodated within their own lane while approaching, entering, circulating, and exiting the roundabout (i.e. there is no encroachment).

It is typical MDOT practice to design for Case 2 truck operations. However, Case 1 or Case 3 truck operations may be appropriate in some circumstances.

Entry Speeds
The recommended maximum theoretical entry design speeds for roundabouts are as follows:

- Single-Lane 20 mph to 25 mph
- Multi-Lane 25 mph to 30 mph

NCHRP 672, Chapter 6, Exhibit 6-47, Modified

Please note that all the ranges are meant to guide the designer in designing the roundabout. Small deviations from these ranges may not affect the performance of the roundabout.

Speed Management
Defining and Measuring Fastest Paths

NCHRP 672, Chapter 6, Exhibit 6-46
<table>
<thead>
<tr>
<th>Radius ($R_x$)</th>
<th>Description</th>
<th>Range of Speeds ($V_x$)</th>
</tr>
</thead>
</table>
| Entry Path Radius, $R_1$ | The minimum radius on the fastest through path prior to the yield line. This is not the same as Entry Radius. | Single Lane 20 to 25 mph*  
Multilane 25 to 30 mph* |
| Circulating Path Radius, $R_2$ | The minimum radius on the fastest through path around the central island. | 15 to 25 mph |
| Exit Path Radius, $R_3$ | The minimum radius on the fastest through path to the exit. | $V_2 +$ Acceleration over the path to the exit crosswalk* |
| Left Turn Path Radius, $R_4$ | The minimum radius on the path of the conflicting left-turn movement. | 10 to 20 mph |
| Right Turn Path Radius, $R_5$ | The minimum radius on the fastest path of a right-turning vehicle. | 15 to 20 mph* |

WisDOT, FDM Chapter 11-26, Table 30.2, Modified

* Notes: Under conditions where sufficient numbers of pedestrians are present, desirable values for fastest path speeds should be lower than maximum values shown in the table.

The $V_2$ variable is further defined and explained in the “Vehicle Speed Estimation” section of this Design Aid.

**Speed Consistency**

In addition to achieving the appropriate design speed for the fastest path movements, the relative speeds between consecutive geometric elements should be minimized as well as between conflicting traffic streams. Ideally, the relative differences between all speeds within the roundabout will be no more than 10 to 15 mph with 12 mph desirable. Typically, the $R_2$ values are lower than the $R_1$ values. With either single or multilane entries, $R_2$ values should be lower than the $R_3$ values.

The desirable maximum $R_1$ radius is 275 ft. Generally, for urban roundabouts with pedestrian accommodations a lower speed entry is desirable. A typical $R_1$ may range between 150 and 230 feet. Rural roundabouts typically allow slightly higher entry speed than urban roundabouts. The $R_1$ and $R_2$ should be used to control exit speed. Typically, the speed relationships between $R_1$, $R_2$, and $R_3$ as well as between $R_1$ and $R_4$ are of primary interest. Along the through path, the desired relationship is $R_1 > R_2 < R_3$, where $R_1$ is also less than $R_3$. Similarly, the relationship along the left-turning path is $R_1 > R_4$.

For most designs, the $R_1 - R_4$ relationship will be the most restrictive for speed differential at each entry.

**Construction and Measurement of Vehicle Fastest Paths**

To determine the speed of a roundabout, the fastest path allowed by the geometry is drawn. This is the smoothest, flattest path possible for a single vehicle, in the absence of other traffic and ignoring all lane markings, traveling through the entry, around the central island, and out the exit. The design speed of the roundabout is determined from the smallest radius along the fastest allowable path. The smallest radius usually occurs on the circulatory roadway as the vehicle curves to the left around the central island. The centerline of the vehicle path is drawn with the following distances to the particular geometric features of the roundabout:

- 5 ft from a curb face
- 5 ft from a roadway centerline
- 3 ft from a painted edge line
Fastest Vehicle Path Through a Roundabout

The following figure illustrates the construction of the fastest vehicle path through a roundabout:
(Note: A two-lane roundabout is shown)

The entry path radius, $R_1$, is a measure of the deflection imposed on a vehicle prior to entering the roundabout. The ability of the roundabout to control speed at the entry is a proxy for determining the potential safety of the roundabout and whether drivers are likely to yield to circulating traffic. The construction of the fastest path should begin at least 165 ft in advance of the yield line, using the appropriate offsets as identified in the previous discussion. The $R_1$ radius should be measured as the smallest best-fit circular curve over a distance of at least 65 ft to 80 ft, in the vicinity of the yield line. The following figure illustrates the procedure for drawing and measuring the $R_1$ radius:
Vehicle Speed Estimation

Roundabouts are typically constructed with a 1.5% or 2.0% cross-slope. Therefore, as vehicles traverse the roundabout, they will experience superelevation rates \( e \) of +0.015 and -0.015 (for 1.5% cross-slopes) or +0.020 and -0.020 (for 2.0% cross-slopes) as they travel through the various curves along their paths. Based on the AASHTO equations relating design speed to horizontal curve radius, side friction factor, and superelevation rate, the vehicle speeds through the roundabout can be estimated. The following two equations may be used to predict the vehicle speeds. It should be noted that while these equations are based on a 2.0% cross-slope, they are appropriate for use with 1.5% cross-slopes, as well:

\[ V = 3.4415R^{0.3861} \]  
(for \( e = +0.015 \) or +0.020) \( \text{NCHRP 672, Chapter 6, Equation 6-1, Modified} \)

\[ V = 3.4614R^{0.3673} \] \( \text{for } e = -0.015 \) or -0.020) \( \text{NCHRP 672, Chapter 6, Equation 6-2, Modified} \)

Where: \( V \) = Predicted speed (mph), \( R \) = Radius of curve (ft), \( e \) = Superelevation (ft/ft)

The following Exhibit illustrates this speed-radius relationship in a graphical format. Again, this Exhibit is based on a 2.0% cross-slope, but is appropriate for use with 1.5% cross-slopes, as well:

These speed-radius relationship equations and graph generally provide a reasonable prediction for the left-turn and through movement circulating speeds. However, this method of speed determination does not consider the effects of acceleration and, therefore, may under-predict exit speeds in cases where the exit path radius is large. At locations with a large exit radius, the acceleration characteristics of the vehicles will govern the actual speeds that can be achieved. Therefore, it is recommended that the above equations and/or graph be used strictly for estimating the \( R_1 \), \( R_2 \), \( R_4 \), and \( R_5 \) speeds (correspondingly denoted as \( V_1 \), \( V_2 \), \( V_4 \), and \( V_5 \)). To better predict the actual exit speeds \( (V_3) \), the following equation should be used to account for acceleration of vehicles from the circulating \( (V_2) \) speed (as estimated based on the \( R_2 \) path radius in accordance with the previously described procedures) to a point of interest along the exit leg (typically a crosswalk):

\[ V_3 = \left(1.47V_2^2 + 13.8d_{23}\right)^{1/3}/1.47 \] \( \text{NCHRP 672, Chapter 6, Equation 6-4, Modified} \)

Where: \( V_3 \) = Actual exit speed (mph), \( V_2 \) = Circulatory speed for through vehicles based on \( R_2 \) path radius (mph), \( d_{23} \) = Distance along vehicle path between midpoint of \( R_2 \) path and point of interest on exit path (mph)
**Measuring Entry Angle (Phi)**

The entry angle is the angle created between entering and circulating traffic paths. Multi-lane entrances or exits are assumed to be measured for the center of the approach or exit, not the center of each lane in particular.

**Method 1**

Method 1, WisDOT, FDM Chapter 11-26, Figure 30.21- Modified

Method 1 is used when the distance from the left side of the nearest entry to the beginning of the next exit is less than 100 feet. This yields a measurement of $2\phi$ as shown above. The 100 feet dimension is taken from the edge of the splitter island to the projection of point $d$ at the curb line.

**Method 2**

Method 2, WisDOT, FDM Chapter 11-26, Figure 30.22

Method 2 is used when the distance from the left side of the nearest entry to the beginning of the next exit is more than 100 feet (or does not exist, such as at a T intersection). This yields a measurement of $\phi$ as shown above, not $2\phi$ as in Method 1.
Path Overlap Check

Path overlap occurs in multilane roundabouts when that natural path of a vehicle overlaps the path of another vehicle from the adjacent lane. This can be prevented by creating a short tangent distance of 1 to 2 vehicles in length (25 to 50 feet) in the area between the circulatory roadway and the entry or exit curve. This distance is measured from a point at the middle of the approach or exit in question at the yield line to the center of the circulatory roadway.

A simple check to determine the proper alignment of an approach and to generally avoid path overlap is to continue the splitter island curve into the circulatory roadway. This curve should run tangentially to the central island at a minimum. If it crosses into the central island, the approach may not be properly aligned and may need to be realigned. Note that this does not necessarily verify the tangent distance as specified above.

WisDOT, FDM Chapter 11-26, Figure 30.17- Modified