Delaware Department of Transportation
Design Guidance Memorandum

Memorandum Number: 1-26

1. Road Design 2. Bridge Design 3. Utilities Design
4. Right of Way 5. Other

Title: Roundabouts Effective Date: 09/16/2024

I. Purpose

To provide guidance for the consideration, planning, and design of roundabouts in Delaware.

II. Applicability

This guidance is to be used when planning for and designing roundabouts, including mini roundabouts, compact roundabouts, single lane roundabouts, and multi-lane roundabouts. While not specifically discussed in this DGM, innovative roundabout designs such as turbo and teardrop roundabouts will be considered by the Department. Additionally, the following design guidance is a supplement to *NCHRP Report 1043, Guide for Roundabouts*[1] and *FHWA-SA-10-007 Mini-Roundabouts: Technical Summary*[2]. Designers should utilize the aforementioned publications, and any subsequent revisions, to develop a roundabout design that functions safely and efficiently within the context of a given location.

III. Design Process

Safety Analysis of Roundabouts and Other Intersection Control Alternatives

Roundabouts are a proven safety countermeasure for reducing intersection related crashes. The use of roundabouts as a form of traffic control is consistent with the Safe System Approach as roundabouts are intended to reduce operating speeds on the approaches to an intersection and reduce injury severity due to the angle of entry into the circulatory roadway. Roundabouts also provide safety benefits for vulnerable road users. The consideration of a roundabout at a given intersection should be compared to safety and operational performance of other intersection alternatives to determine the most appropriate long-term intersection treatment. Table 1, below, is a suggested guide of which control alternatives should be considered based on the existing intersection control. The designer should analyze other pertinent alternatives as appropriate (e.g., addition of turn lanes, movement restriction, channelization, etc.) and present a comparison matrix of performance measures.

Because roundabouts offer fewer and less-severe conflict points than a standard intersection, overall crash rates and crash severity may be expected to decrease with roundabout installation, compared to other intersection control alternatives. It is recommended to quantify these safety benefits in support of a roundabout alternative, particularly at high-crash locations. Research over the past decades of roundabouts in the United States led to the development of empirical based safety performance functions (SPF) and crash modification factors (CMF) that can estimate the expected

[1] NCHRP Report 1043, Guide for Roundabouts
[2] FHWA-SA-10-007 Mini-Roundabouts: Technical Summary

changes in crash frequency experienced at a roundabout. An SPF is an equation used to predict the average number of crashes per year at a location as a function of exposure (traffic volumes) and, in the case of roundabout evaluation, the number of entering and circulating lanes. SPFs are used alone or in conjunction with the crash history to estimate the long-term crash frequency for baseline conditions (without treatment), and CMFs are applied to estimate the crashes with treatment. *NCHRP Report 888: Development of Roundabout Crash Prediction Models and Methods*[3] provides roundabout-specific SPFs to be used for predictive crash frequency determination. The *Highway Safety Manual* provides SPFs for other intersection control alternatives. The *Crash Modification Clearinghouse*[4] should be consulted for CMFs related to roundabouts and other intersection control alternatives. Both the SPF and CMF methodologies should be used to determine a potential range of crash reduction benefits for roundabouts compared to other intersection control alternatives (see Table 1).

Table 1: Intersection Control Alternative Matrix

Existing Intersection Control	**Control Alternatives to Analyze**				
	Two-Way Stop	**All-Way Stop**	**Single-Lane Roundabout**	**Multi-Lane Roundabout**	**Traffic Signal**
Two-Way Stop	Yes	Yes	Yes	No*	Yes
All-Way Stop	No	Yes	Yes	No*	Yes
Roundabout	No	No	Yes	Yes	Yes
Traffic Signal	No	No	Yes	Yes	Yes

**Unless single-lane roundabout capacity is exceeded*

At high-crash locations where a roundabout is being considered, the designer should consider implementation of a low-cost safety countermeasure, such as an all-way stop control, as an interim safety improvement measure as the roundabout is moved through the programming, design, and construction processes. The designer should coordinate with the Traffic Engineering Section for low-cost safety countermeasure considerations.

Roundabout Traffic Operational Analysis

The following three performance measures should be calculated for roundabout alternatives utilizing the analytic methods presented in the latest version of the *Highway Capacity Manual (HCM)* accepted by DelDOT. Analysis tools/software packages such as *HCS* and *Synchro* are typically able to report these performance measures; however, for atypical designs, more robust programs like *SIDRA* or *VISSIM* should be utilized.

- **Volume-to-Capacity Ratio** – Volume-to-capacity (v/c) ratios are the primary measure of effectiveness for evaluation. V/c ratios for roundabouts are calculated based on the entry demand and capacity for the most critical approach (i.e., approach with the highest v/c ratio) for single-lane roundabouts and the most critical lane (i.e., individual lane with the highest v/c ratio) for multi-lane roundabouts. A v/c ratio under 0.85 - 1.0 during the design year is desired, but other factors like queuing, delay, and potential safety implications need to be considered. For preferred alternatives where the design year is at or over capacity, see "*Design Year Considerations*" section below to provide additional context regarding the capacity concerns.

[3] NCHRP Report 888: Development of Roundabout Crash Prediction Models and Methods
[4] Crash Modification Clearinghouse

- **Delay** – Delay is a standard parameter used to measure the performance of an intersection. Control delay is the standard measure used in the *HCM* to represent the delay component of a roundabout performance, as it is the same measure used to represent the delay for other types of intersections. Vehicular delay can also be used to estimate emissions that result from various forms of intersection control. Delay is also commonly summarized as an easy-to-understand Level of Service (LOS) as defined in the *HCM*.
- **Queue Length** – Queue length is important for assessing the adequacy of the geometric design of the roundabout approaches and potential interactions with adjacent intersections. The 95th-percentile queue length is determined to estimate the design queue for a given lane. The queue length should be checked against available storage to assess potential interactions with adjacent lanes, intersections, and highway-rail grade crossings. Average queue lengths should be reported for all approaches to gain an understanding of typical vehicular stacking.

Design Year Considerations

Phased Approach – While it is important to plan for future traffic volumes and capacity needs, the immediate effects on all road users should also be considered including costs. If the safety analysis indicates a need to implement low-cost safety countermeasures while a roundabout is moved through the design process, the designer should have the interim improvements evaluated to ensure that capacity thresholds are not exceeded prior to implementation of the roundabout alternative. Once complete, the designer should coordinate with the Traffic Engineering Section.

A roundabout should be designed to accommodate future traffic volumes, changes in vehicle mix, and accommodate future capacity needs. The design year should be selected based on guidance from the DelDOT *Road Design Manual.* If design year traffic projections indicate that a multi-lane roundabout should be considered, the designer should consider a phased implementation approach where the right-of-way needs for a multi-lane roundabout are acquired but a single lane roundabout is initially constructed that meets traffic needs for an interim 10-year design (from the current year). The current users' needs will be accommodated while still providing an opportunity for the roundabout to be expanded for future traffic volume growth. The projected interim year that the intersection will reach capacity should be calculated. When using a phased approach, it is important to design the full build layout footprint to ensure right-of-way is secured for future planned improvements. It is also beneficial to plan the construction of the roundabout to potentially allow for easier expansion in the future, minimizing impacts to traffic during future construction.

Off-peak Operational Analysis – Most traditional traffic analysis focuses solely on two or three peak hours when traffic volumes are likely to be the highest. While this is important to determine worst-case performance metrics and general feasibility of intersection control alternatives, it may also be important to understand how frequent or how long the critical delays or queues would be expected to occur throughout the day. This is particularly helpful information in "borderline" cases – e.g., for roundabouts, generally where a single-lane alternative is near or slightly over capacity in the design year. Using available data (turning movement counts, automatic traffic recorder (ATR) counts, diurnal volume tables by functional classification, DelDOT's ITMS network of "real-time" data, etc.) to project performance metrics during each hour of a typical day in the design year, it can be determined if capacity problems are isolated to a single hour or are more likely to persist throughout the day.

Sensitivity Analysis – In future/design year analyses, projected intersection volumes contain many inherent uncertainties. As a result, it is common practice to consider intersection performance

measures using volumes slightly higher or lower (5- to 10-percent) than the projected volumes to gauge how much impact volume variations may be expected to have on intersection performance.

Reporting

The safety and traffic operational analysis should be packaged into a summary report with recommendations and shared with DelDOT Project Management for review. By considering and analyzing the items described throughout the section, DelDOT leadership can make well-informed design decisions efficiently, without requiring significant/repeated follow-up with the planner or designer.

IV. Roundabout Design Guidance

The following design guidance is a supplement to *NCHRP Report 1043, Guide for Roundabouts*[5] and *FHWA-SA-10-007 Mini-Roundabouts: Technical Summary*[6]. Designers should utilize the aforementioned publications, and any subsequent revisions, to develop a roundabout design that functions safely and efficiently for all road users within the context of a given location.

Design and Check Vehicle Selection

An important consideration for determining the overall size of a roundabout is to understand the volume and type of vehicles traveling through the intersection. There are two types of vehicles that are important to accommodate in the design of a roundabout, the design vehicle and check vehicle.

The ***design vehicle*** is the largest vehicle that is expected to frequently make specific movements through an intersection. With the exception of mini-roundabouts, all roundabouts should be designed to accommodate the design vehicle within the traveled way, without off-tracking onto any truck apron and while maintaining separation between the truck and the face of curb. Both AASHTO WB-40 trucks and BUS-45 should be used as the baseline design vehicle for all single lane and multilane roundabouts. Roundabouts should also be able to accommodate smaller vehicles within the traveled way such as single-unit trucks and all classes of school buses, transit buses, and emergency vehicles serving the surrounding area. The design vehicle for mini or compact roundabouts should be an appropriate vehicle based on the roundabout location and vehicle classification data collected for the location.

Check vehicles are less frequent users of the roundabout that need to be accommodated and may require design features such as additional truck aprons along the exterior, hardened surfaces beyond the curb, passageways through splitter islands or the central island, removable signs, or other treatments. The AASHTO WB-67 should be used as the check vehicle for roundabouts placed on US Routes and roadways within close proximity (1-2 miles) to Interstate/freeway/expressway ramps used to access local businesses. The WB-67 should also be the check vehicle for all multi-lane roundabouts. Check vehicles for a mini or compact roundabout could be a single-unit truck or a WB-40 dependent upon the location of the roundabout and vehicle classification data collected for the location. A WB-62 should be used for all other roadways.

Designing all movements for the largest possible truck can lead to negative safety and operational performance issues for other users of the roundabout, particularly vulnerable road users.

[5] NCHRP Report 1043, Guide for Roundabouts
[6] FHWA-SA-10-007 Mini-Roundabouts: Technical Summary

Additionally, accommodation of less frequent larger truck movements leads to designs that require unnecessary right-of-way and environmental impacts. To help ensure roundabouts are sized appropriately for a given location, designers must consider the following items when determining the design and check vehicles for all roundabouts:

- Existing vehicle classification percentages at the intersection. Vehicle classification count data should be obtained for an average week (minimum) on each approach to the intersection where the roundabout is being considered. This data should be analyzed to determine the frequency of tractor-trailers and other heavy vehicles using the intersection.
- Existing and future land use (i.e., existing farm vehicles in rural settings and possible commercial land uses that may generate increased truck traffic or more frequent larger trucks using the intersection)
- Design vehicle for the existing layout of the intersection
- Truck access (i.e., a truck may need to occupy the entire roundabout or straddle multiple circulating lanes to complete intersection maneuvers, the existing roadway network may accommodate an alternative access for trucks, trucks may need to utilize the entire center island to complete intersection maneuvers)

Once the above considerations are evaluated, designers should develop recommendations to accommodate truck movements in the various scenarios while maintaining an adequate roundabout size. Accommodations may include elimination of signage in the center island, a completely mountable center island, or other design features to accommodate off-tracking of trucks. Designers should consult with DelDOT staff, local agencies, and other stakeholders, such as the local emergency medical services/fire companies and representatives from the agricultural community, early in the project development process to aid in identifying the appropriate design and check vehicles. CADD based turning templates using the design and check vehicles should be developed for all approaches and all movements. For multi-lane roundabouts, it is important to check for the potential path overlap between two entering vehicles. Refer to *NCHRP Report 1043* for additional guidance regarding the selection of design and check vehicles.

Speed Control and Deflection

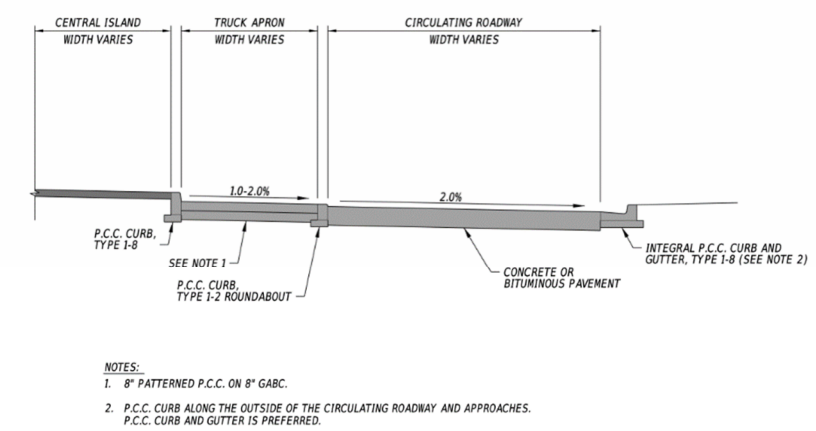
One of the primary characteristics of roundabouts that contributes to improved safety is decreased vehicle speeds on the approaches and low speed differentials between vehicles entering the roundabout and vehicles already in the roundabout. Speed control is achieved by providing adequate deflection using horizontal and vertical design. Horizontal and vertical design is an iterative process involving design checks to ensure proper balance of competing needs. Designers should consider developing Fastest Path diagrams to evaluate speed differentials as a performance check. *NCHRP Report 1043* provides guidance regarding the development of Fastest Path diagrams. In environments with high approach speeds, it may be appropriate to apply speed management treatments such as approach curvature or other treatments consistent with guidance in *NCHRP Report 613: Guidelines for Selection of Speed Reduction Treatments at High-Speed Intersections*[7].

Typical Sections

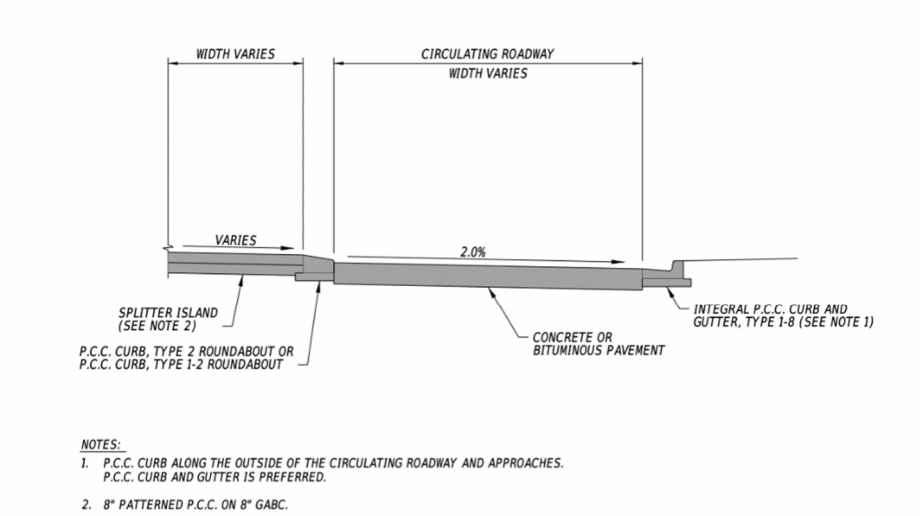
The following typical sections should be used for the design of all single and multi-lane roundabouts. All single and multi-lane roundabouts and approaches should be curbed in accordance

[7] NCHRP Report 613: Guidelines for Selection of Speed Reduction Treatments at High-Speed Intersections

with the typical sections. While it is preferred that mini-roundabouts and approaches are curbed to improve conspicuity, it is not required. The typical sections denote preferred circulatory and approach roadway cross slopes. However, site conditions and drainage may require slopes outside these ranges. Refer to the *Delaware Traffic Calming Design Manual*[8] for the Department's preferred mini-roundabout typical section design.



TYPICAL SECTION - ROUNDABOUT CIRCULATING ROADWAY



TYPICAL SECTION - ROUNDABOUT APPROACH

Aesthetics

All truck aprons and splitter islands should be patterned concrete. All center islands should be grass or patterned concrete. Grass or similar low maintenance landscaping is the preferred central island treatment for roundabouts on state-maintained roads. More elaborate landscaping or other aesthetic features may be acceptable if a maintenance agreement is made with the municipality or other local entity, the landscaping or features can be safely accessed by the maintaining entity, and the features do not interfere with driver sight distance. While some vertical growth is desirable to provide enhanced visual cues to drivers, adequate stopping and intersection sight distances, calculated using

[8] Delaware Traffic Calming Design Manual

methodologies described in *NCHRP Report 1043,* should be assured, and sustained when plantings mature. The crashworthiness of aesthetic features should also be taken into consideration. Aesthetic features that make noise, such as fountains, should not be used due to considerations for cues for the visually impaired. All non-traversable splitter islands should include flexible delineators on all corners of the splitter island.

Mini and Compact Roundabout Considerations

Mini and compact roundabouts are often considered when there is a desire to minimize impacts outside the footprint of the existing intersection. Both roundabout types generally operate in the same manner as regular single-lane roundabouts and provide many of the same benefits, but within a smaller footprint. Mini roundabouts typically have inscribed diameters between 45 and 90 feet and are characterized by fully traversable or painted center and splitter islands with no signs. Compact roundabouts are a hybrid between mini and single-lane roundabouts, containing features of both, and typically having inscribed diameters between 65 and 120 feet. Mini or compact roundabouts should be designed as large as possible within the intersection constraints; therefore, the existing curb line is often used as a starting point for determining the size of the roundabout.

Roundabout Education

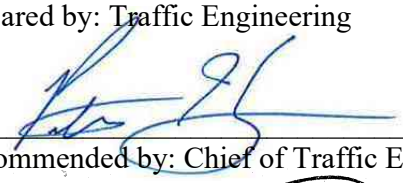
Roundabout best practices and research continues to evolve. The Department should remain informed of current design practices and provide training opportunities to ensure best practices are sustained. Periodic discussions or meetings may occur to understand evolving changes and to achieve long-term consistent standards throughout the Department.

The Department should also continue to maintain and update the roundabout informational website as an educational resource for the public.

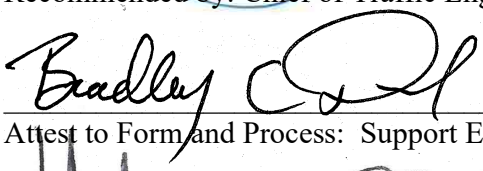
V. Justification

The appropriate design, construction and use of roundabouts has the potential for significant improvements to safety and traffic operations.

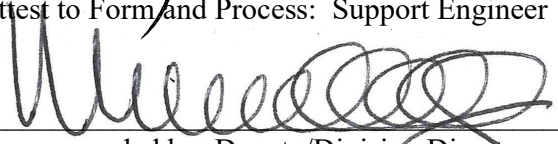
Prepared by: Traffic Engineering — Date: 04/09/2024



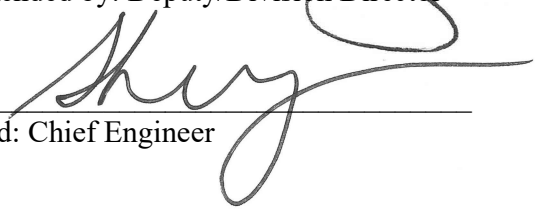
Recommended by: Chief of Traffic Engineering — 4/22/2024 Date



Attest to Form and Process: Support Engineer — 5/3/2024 Date



Recommended by: Deputy/Division Director — 26 July 2024 Date



Approved: Chief Engineer — 09/16/2024 Date

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