# Joint Roundabout Truck Study

Minnesota Department of Transportation

Wisconsin Department of Transportation

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Consultant's Report

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# Executive Summary of Joint Roundabout Truck Study

**Introduction**

The Joint Roundabout Truck Study was sponsored by the Wisconsin Department of Transportation (WisDOT) and the Minnesota Department of Transportation (MnDOT). The study team consisted of WisDOT and MnDOT staff and their consultant team (made up of DLZ National, Roundabouts and Traffic Engineering, and Short Elliot Hendrickson). A Technical Advisory Committee (TAC) consisted of representatives from local government agencies, the trucking industry, MnDOT, WisDOT, and the University of Wisconsin TOPS Lab. The TAC provided direction and reviewed deliverables at key junctures.

This study was undertaken to better understand and, where possible, to improve upon how trucks are accommodated at multilane roundabouts. The primary objectives of the project were: to define and study current design practices; to receive input from the trucking industry; and to develop design guidelines for accommodating trucks at multilane roundabouts on state trunk highways. The overall study was divided into four phases. Phase 1 of the study was a synthesis of current design practice regarding how trucks have been accommodated at constructed multilane roundabouts. Eighteen constructed roundabouts were studied in Phase 1, and three main design philosophies (or "Cases" as noted below) were identified. Although Phase 1 was not a statistically rigorous analysis, it did provide useful insight into various design techniques and operations for each. Phase 2 included additional video data collection for the 18 roundabouts studied in Phase 1. The results of Phases 1 and 2 are summarized in the report entitled *Joint Roundabout Truck Study: Report for Phase 1: Synthesis of Current Design Practice* (note: a separate Phase 2 report was not prepared). Phase 3 built upon the findings of Phase 1 and 2 as well as the collective experience of the study team and the TAC. Phase 3 provided design guidance and recommendations for how to accommodate trucks at multilane roundabouts. The results of Phase 3 are summarized in the report entitled *Joint Roundabout Truck Study: Report for Phase: 3 Design Guidelines.* Phase 4 (this document) summarizes the findings of previous study phases and recommends how to proceed with implementation and future research.

**Phase 1 Findings**

The purpose of Phase 1 was to evaluate and describe current design practices related to accommodating trucks at multilane roundabouts. The study defined "truck" as the vehicle classified by each state as the design vehicle on state trunk highways - MnDOT designs for WB-62, and WisDOT utilizes WB-65. Based on data collected from 18 representative roundabout intersections located in the states of Wisconsin, Minnesota, Michigan and Arizona, three "Case" types were defined to describe prevailing methods of multilane roundabout design in the US. The three prevailing methods have been:

- "Case 1" roundabouts which are designed to allow trucks to encroach into adjacent lanes as they approach and traverse the intersection
- "Case 2" roundabouts which are designed to accommodate trucks in lane as they approach/enter the roundabout, but may require trucks to encroach into adjacent lanes as they circulate and exit the intersection
- "Case 3" roundabouts which are designed to accommodate trucks in lane as they approach and traverse the entire intersection.

Thorough reviews of each of the 18 selected roundabouts were performed to identify common design characteristics for each of the three case types. As part of these analyses, the limitations and advantages associated with each case were assessed by roundabout design specialists through the use of electronic design plans, traffic volumes, crash data, video tape observations, and input from the trucking industry. This included an evaluation of potential trade-offs for each design methodology as well as identification of design features of specific interest with respect to truck accommodations. During Phase 1, questionnaires were also sent to trucking industry representatives, and the responses were evaluated and summarized.

Key findings and conclusions of the Phase 1 study are as follows:

1. **Well designed Case 2 and 3 roundabouts did not compromise accepted design principles as outlined in existing guidance documents (i.e., FHWA, WisDOT, MnDOT roundabout guides).** Case 2 and Case 3 designs can be developed such that their geometric parameters (i.e., ICDs, entry widths, entry angles, etc.) are fully compliant with direction provided in existing guidance documents. These designs are consistent with established design principles as they relate to speed control, safety, and traffic operations.
2. **There are specific geometric characteristics exhibited by each case type.** Based on Phase 1 investigations, the 18 study roundabouts exhibited similarities within case types. Collectively, each case type had unique geometric characteristics relative to other case types. Table 1 summarizes the frequently observed design characteristics by case types.

**Table 1 - Observed Design Characteristics for 18 Phase 1 Roundabouts**

| Item | Case 1 | Case 2 | Case 3 |
|---|---|---|---|
| **Entry Radii** | 64 to 75 feet | 63 to 138 feet | 120 to 130 feet |
| **Entry Radius Length** | less than 50 feet | 50 to 100 feet | 100 feet or more |
| **Entry Widths** | 24 to 28 feet | 32 to 34 feet | 32 to 34 feet |
| **Transitional Widening** | limited or no use of widening | was implemented | was implemented |
| **ICD** | 162 to 200 feet | 160 to 194 feet | 190 to 220 feet |
| **Approach Alignment** | Varies | Typically offset left | Typically offset left |

3. **There was no strong correlation between design vehicle volumes or total peak hour volumes entering the intersection and roundabout case type implemented.** Heavy vehicle percentages varied from 5.5% to 18.6%, and while Case 2 and Case 3 roundabouts did appear somewhat more likely to be used at the higher end of this range, this was not always the case. Similarly, higher volume intersections (all vehicles) did not strongly correlate to the use of Case 2 or Case 3 designs.
4. **Case 1 roundabouts in the study exhibit slightly more truck related crashes.** Of the five intersections for which crash data was available, sideswipe crashes ranked first among the different crash types, and the percentage of crashes involving trucks was observed to be higher in Case 1 roundabouts than Case 2, although a statistically rigorous analysis was not performed.
5. **Case 1 roundabouts cause delays at entries due to necessary truck encroachment.** Both passenger vehicles and trucks experience delay when trucks are required to encroach on adjacent lanes on the entries since trucks need to occupy or straddle both lanes. Likewise, delays are caused to both passenger vehicles and trucks when trucks cannot straddle both lanes due to adjacent traffic and must then mount curbs in order to proceed through the roundabout. No

noticeable capacity impacts were observed for Case 2 or Case 3 roundabouts at the entries because trucks were able to stay in lane on entries more easily.

6. **Trucking industry questionnaire responses indicated more information should be conveyed before the entry to establish whether trucks should stay in lane or use both lanes.** Other findings of the responses, representing over 200 truck drivers, indicate that although drivers are not confused by pavement markings or truck aprons while navigating roundabouts, truck drivers are concerned that the actions of passenger car drivers may cause conflicts, the majority of truck drivers prefer to stay in lane at roundabouts, and they recommend wider lanes and/or better signage be implemented.
7. **Each case type has advantages and disadvantages, and these tradeoffs need to be considered in the planning and design process.** All types of roundabouts are influenced by factors such as local site constraints, jurisdictional agency requirements, and designer preferences. One key tradeoff is that a Case 1 design may have operational disadvantages when trucks are present, but Case 1 designs can in some cases have lower right-of-way impacts and lower cost than Case 2 or Case 3 designs.

## Phase 2 Findings

Phase 2 included video data collection for select roundabouts studied in Phase 1. The main task was to collect and review video footage of peak hour traffic conditions at representative roundabouts to observe truck operations.

Key findings and conclusions of the Phase 2 study are as follows:

1. **Trucks at Case 1 roundabouts encroached on adjacent lanes.** A review of footage from Case 1 roundabouts showed that trucks were navigating the roundabouts as expected. Either the trucks were using both lanes, or on rare occasions driving over the outside entry curbs.
2. **Trucks at Case 2 and Case 3 roundabouts generally drove the intersections consistent with the design intent.** At Case 2 and Case 3 roundabouts, trucks stayed in lane on approach 91 percent of the time and stayed in lane while circulating 83 percent of the time when potentially conflicting traffic was present. When potentially conflicting traffic was present, trucks did not hesitate to utilize the central island truck apron when turning left or continuing through in order to avoid encroaching on other vehicles. When potentially conflicting traffic was not present, trucks stayed in lane on approach 71 percent of the time, but only stayed in lane while circulating 37 percent of the time. When potentially conflicting traffic was not present, trucks typically avoided using the central island truck apron regardless of the design case. In general, the findings of Phase 2 were that trucks operate mostly as expected at the various design case types, and that the presence of adjacent traffic influenced the 'driving in-lane behavior" of trucks while entering and circulating even in Case 2 and 3 designs.

## Phase 3 Findings

The purpose of Phase 3 was to provide design guidance for accommodating trucks at roundabouts (primarily two-lane roundabouts) on state trunk highways, to describe specific design methods, and to identify possible criteria for when to implement the various design cases. General geometric design techniques for multilane roundabouts can be found in established design guidance documents from the FHWA, WisDOT, and MnDOT. An iterative design process is typically used to verify compliance with the design performance measures described in these guides (speed control, geometrics, accommodation of design vehicle, sight distance, pedestrian crossing considerations, etc.), which are the highest priority objectives of roundabout design. The design methods for accommodating trucks described in the Phase 3 report are in addition to these higher priority requirements.

The findings from the Phase 1 and Phase 2 research were one important factor influencing the information presented in the Phase 3 report. Other factors which played a notable role were the collective experience of the project team, input/peer review from outside roundabout designers, policy direction from MnDOT and WisDOT, and direction from the TAC. The study team has collectively worked on designs for more than 700 roundabouts, 100 of which are Case 2 or Case 3 designs. The guidance in the Phase 3 report was collectively influenced by all of these factors.

Key findings of Phase 3 regarding criteria for implementing the various design case types are as follows:

1. **Designers should consider implementing a Case 3 design where practical/feasible.** In general, it is believed that a well designed Case 3 roundabout which meets applicable geometric design requirements will provide safe and efficient operations while providing optimal truck accommodations. Where costs or right-of-way impacts are prohibitively expensive or at locations where design truck numbers are very low, other design case types may be more advantageous. The respective state DOT's may ultimately develop thresholds for design truck volumes or other criteria that trigger consideration of a Case 3 design.
2. **Certain specific locations should warrant additional consideration of a Case 3 design.** These would include locations where designated Oversize/Overweight (OS/OW) routes exist, multilane approaches on arterial routes, at interchange ramps, near truck stops, and in industrial/warehouse districts.
3. **Should specific factors make a Case 3 design undesirable, a Case 2 design should be considered as a second choice.** If a Case 3 design is not practical, a Case 2 design should typically be considered as the next most desirable option.
4. **In locations where truck volumes are low and/or a Case 3 or Case 2 design would have undesirable impacts, a Case 1 roundabout can be considered.** Case 1 roundabouts can be advantageous in locations where available right-of-way is limited or other factors prevent the use of a Case 2 or Case 3 design. Where Case 1 designs are implemented at locations having flared approaches from one to two lanes, consideration should be given to using a short (approximately 100-foot) width transition which requires trucks to occupy both lanes through the intersection.

Depending heavily on site specific considerations, most two-lane roundabout designs will fall within the range of values listed in the table below. In addition to the geometric parameters in this table, the Phase 3 report also provides specific design guidance for each of the three cases. The general topics discussed include application of various geometric elements, tradeoffs and optimizing a design, approach curvature, speed control, interrelationships of design parameters, vertical profiles, truck aprons, pavement markings, and signing. Additionally, guidance is provided for single and three-lane roundabouts.

The following key findings are presented in the Phase 3 report (note: these are highly generalized recommendations and must be scrutinized carefully by the designer at each location, after reviewing the full Phase 3 report along with other applicable guidance).

1. **Case 3 Roundabouts should typically include** long and sweeping entry curvature with controlling radii of 100 to 130 feet; entries with gore areas between lanes striped out (typically 2 to 6 feet wide); an ICD of 180 to 220 feet; wider outside circulating lanes (15 to 18 feet) compared to inner lanes (13 to 15 feet); and exist that are straight or have large radii.
2. **Case 2 Roundabouts should typically include** the same approach characteristics as Case 3 designs (providing gradual, sweeping entries with longer curves and larger radii, gore areas between lanes, and wider entries), but use slightly smaller ICDs (160 to 210 feet), narrower circulating lanes following established guidance, and may allow for exits with smaller radii.

3. **Case 1 Roundabouts should typically include** geometrics that follow established guidance to accommodate trucks within the roadway (curb face to curb face with 2-foot buffer). This guidance is described in the FHWA, WisDOT, and MnDOT roundabout guides.

The guidelines discussed in the Phase 3 report may ultimately be incorporated into the WisDOT and MnDOT roundabout design guides. Although recommendations for when to apply certain design techniques are provided, WisDOT and MnDOT will ultimately decide at a later date which requirements to implement considering specific conditions within the respective states. The guidance in the Phase 3 report may be used in the interim until information is included in the respective states' guides.

### Limitations

Several limitations should be noted which affect the conclusions of the overall study. For the Phase 1 and Phase 2 investigations, a small sample size was available due to few Case 2 and 3 roundabouts being built at the time of the study. Crash data was not analyzed in Phase 1 using a rigorous statistical approach,

**Typical Design Parameters for Two-Lane Roundabouts***

| Item | Case 1 | Case 2 | Case 3 |
|---|---|---|---|
| **Inscribed Circle Diameter[a]** | 150' to 190' | 160' to 210' | 180' to 220' |
| **Inner Circulatory Lane Width[b]** | 11' to 13' | 11' to 13' | 13' to 15' |
| **Outer Circulatory Lane Width[b]** | 13' to 15' | 13' to 15' | 15' to 18' |
| **Approach Gore Widths** | Not used | 2' to 6' | 2' to 6' |
| **Entry Width[a]** | 28' to 32' | 32' to 34' | 32' to 34' |
| **Entry Radius** | 65' or greater | 65' or greater | 65' or greater |
| **Controlling Radius** | 65' or greater | 65' or greater,<br>100' to 130' typical | 65' or greater,<br>100' to 130' typical |
| **Controlling Radius Length** | No max, typically 70' or less | No max, typically 80' + | No max, typically 80' + |
| **Entry Angle** | 16 to 30 degrees | 16 to 30 degrees | 16 to 30 degrees |
| **Length of Two Full Lanes for Lane Add[c]** | Low V/C – Short length<br>Medium V/C – Medium length<br>High V/C – Long length | Low V/C – Short length<br>Medium V/C – Medium length<br>High V/C – Long length | Low V/C – Short length<br>Medium V/C – Medium length<br>High V/C – Long length |
| **Exit Widths[a]** | 28' to 32' | 28' to 32' | 28' to 32'<br>(where large radius or tangential exit used) |

* - Based on site conditions, ROW constraints, specific design vehicle, and other factors, designers may choose to implement geometrics outside these recommended ranges; however the overall design should comply with FHWA and WisDOT or MnDOT guidance documents

a - Measurements are from face of curb to face of curb (includes 2' gutter pans on each side)

b - Measurements are from edge gutter flange line to lane line

c - In addition to the segment with two full lanes, a taper following FDM guidance is needed to transition from one to two lanes both due to having insufficient information to conduct such analyses and limited budget. Finally, the sample of video observations in Phase 2 did not capture all roundabout design cases operating under saturated conditions, and truck operations under congested conditions for longer durations may vary somewhat from those which were observed.

### Future Research Opportunities

Several areas of uncertainty became apparent during the study and could be supplemented with future research. Additional research in these areas may better support future recommendations for implementing various design techniques. Potential topics for such research include:

- Conduct studies to identify the frequency and magnitude of safety and capacity issues caused by truck movements at entries and in the circulatory roadway for all roundabout case types.
- Perform rigorous statistical analysis of crashes involving trucks at roundabouts to generate a better understanding of which of the design techniques are most beneficial to safety.
- Undertake additional research regarding the relationship between speed-controlling geometric parameters, geometric parameters that accommodate trucks, and crashes (both truck and passenger vehicle) to determine if safety tradeoffs exist between the design case types.
- Research actual construction and right-of-way costs for built roundabouts to quantify the cost tradeoff of moving from a lower to a higher design case type.

### Next Steps

It is expected that the Wisconsin and Minnesota DOTs will revise their existing roundabout design guidance to include some or all of the findings of this study. It is recommended that these documents provide criteria for implementing the various design case types. The guidance documents should also discuss local factors which may also influence the decision on which design case to implement.

# Joint Roundabout Truck Study

## Report For Phase 1: Synthesis Of Current Design Practice

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# Executive Summary

This study was completed by a team of WisDOT and MnDOT staff and their consultants. Input was also received from a Technical Advisory Committee (TAC). Eighteen multilane roundabouts were selected for study, located primarily in Wisconsin and Minnesota, but also in Arizona and Michigan. Where available, geometric design information, traffic counts, crash data, and video footage of roundabout operations were obtained for these locations. The study defined trucks as vehicles classified as WB-65 by WisDOT and classified as WB-62 by MnDOT. The purpose of the study was to evaluate current design practice related to accommodating truck movements at roundabouts.

Based on the prevailing methods of multilane roundabout design in the US, three design "Cases" were identified to classify multilane roundabouts. Case 1 roundabouts are designed such that trucks encroach into adjacent lanes while entering, circulating, and exiting a roundabout. Case 2 roundabouts are designed such that trucks do not encroach on adjacent lanes on the entry, often utilizing a painted "gore" area between lanes on the entries, but may encroach into adjacent lanes when circulating and exiting the roundabout. Case 3 roundabouts are designed such that trucks stay within their lane as they enter, circulate, and exit the roundabout, often times utilizing painted "gore" areas on entries and the truck apron while circulating.

Although this study did not involve enough data collection to perform statistically rigorous analyses, the intent is to provide useful insight into characteristics and operations/safety for different design techniques which have been implemented to date. In addition to specific information collected for the 18 study intersections, general prevailing trends were noted to identify needs for future study. Beyond information collected for the 18 study intersections, other factors that played a role in the conclusions of this study were the collective experience of the study team, input/peer review from outside roundabout designers, policy direction from MnDOT and WisDOT, and direction from the TAC (made up of representatives from local government agencies, the trucking industry, MnDOT, WisDOT, and the University of Wisconsin TOPS Lab). Other study limitations included a small sample size (few Case 2 and Case 3 designs exist), inconsistency in available data for studied intersections, and not addressing the accommodation of overweight or oversize loads. This study provides only interim observations regarding Case 3 designs until more are built and can be studied further. Also, the study does not address the issue of whether or not pavement markings should be removed from the circulatory roadway for certain situations.

**Characteristics of Selected Intersections**

There does not appear to be a strong correlation between design volume and roundabout case type, however Case 2 and Case 3 roundabouts generally have higher truck percentages than Case 1 roundabouts. Of the five intersections for which crash data was available, the percentage of crashes involving trucks appears to be slightly higher than the percentage of trucks in the total intersection volume for Case 1 roundabouts.

All three cases types of roundabouts in the study provided ICDs within the FHWA recommendations. Entry radii varied from 64 to 75 feet for Case 1 roundabouts, from 63 to 138 feet for Case 2 roundabouts, and from 120 to 130 feet for Case 3 roundabouts. The lengths of entry radii were typically less than 50 feet for Case 1 roundabouts and varied to typically greater than 100 feet for Case 3 roundabouts. Although there were variations observed among various design parameters, the studied roundabouts did not appear to compromise accepted design principles as outlined in applicable guidance from FHWA, MnDOT, and WisDOT.

For circulatory roadway crown, the study team was unable to identify, based on the information available, whether either of the two design methods (i.e., using a crown or cross slope away from the central island) provided enhanced operations for trucks, improved safety or capacity, or created adverse results. Further analyses would be required to identify operational benefit or detriment.

Based on a limited sample size, the average truck apron width for Case 3 is wider than that for Case 2, and the average apron width for Case 2 is wider than that for Case 1. This does not indicate that there may be a trend or preference to supplement the Case 2 and 3 types with wider aprons, rather each design had its own truck requirements (including special permit loads) which dictated each design's truck apron width.

**Summary of Video Tape Review**
Trucks encroached on adjacent circulating and entry lanes at Case 1 roundabouts. At some of the Case 1 entries, trucks were observed to jump the right side curb on the entry to avoid encroaching on other vehicles. At Case 2 and Case 3 roundabouts, trucks stayed in lane on approach 91 percent of the time and stayed in lane while circulating 83 percent of the time when potentially conflicting traffic was present. When potentially conflicting traffic was present, trucks did not hesitate to utilize the truck apron when turning left or continuing through in order to avoid encroaching on other vehicles. When potentially conflicting traffic was not present, trucks stayed in lane on approach 71 percent of the time, but only stayed in lane while circulating 37 percent of the time. When potentially conflicting traffic was not present, trucks typically avoided using the truck apron regardless of the entry design.

**Input from the Trucking Industry**
Questionnaire responses received from managers representing over 200 truck drivers provided insight that was helpful to the study. The responses revealed that drivers are not confused by pavement markings or truck aprons while navigating roundabouts, but are concerned that the actions of passenger car drivers may cause conflicts. Because of this, the majority of truck drivers prefer to stay in lane at roundabouts. Wider lanes allowing trucks to stay in lane are preferred instead of allowing overlapping into adjacent lanes. Regardless, the drivers indicated that more information should be conveyed before the entry to establish whether trucks should stay in lane or use both lanes. The preferred method to accomplish this is with additional signage. Other concerns included whether using the truck apron may cause tire damage or load shifts.

**Capacity Impacts**
At Case 1 roundabouts, delays are caused to both passenger vehicles and trucks when trucks are required to encroach on adjacent lanes on the entries as trucks need to occupy or straddle both lanes. Likewise, delays are caused to both passenger vehicles and trucks when trucks cannot straddle both lanes due to adjacent traffic and must then mount curbs in order to proceed through the roundabout. When approaching a truck from behind at the yield line, most vehicles stayed behind and allowed it to enter, thus causing additional delay to be incurred. No noticeable capacity impacts were observed for Case 2 or Case 3 roundabouts at the entries because trucks were able to stay in lane on entries more easily. Potential delays because of the differential in acceleration and turning capabilities of passenger vehicles versus large trucks were most evident in the circulatory roadway of Case 1 and Case 2 roundabouts. Passenger cars were observed to stay behind trucks in the circulatory roadway despite the car and trucks using different lanes.

**Further Research Areas**
Further research is needed to identify the frequency and magnitude of both safety and capacity issues of truck movements through all roundabout case types. Additional research related to the geometric parameters that control speeds at all roundabout case types and how variation in the designs affect safety performance could help evaluate whether potential safety tradeoffs exist between the case types. Specifically, future research could focus upon whether Case 2 and Case 3 roundabout design parameters/speeds affect safety.

**Conclusions**
The conclusions presented in this study are based on trends and general observations rather than rigorous statistical analysis. This is due to there being few available constructed Case 2 and 3 roundabouts. In general, the varying roundabout diameters, entry angles, and half widths were not significant design factors for trucks. It can be acknowledged that Case 1 roundabouts have trade-offs, with potential advantages in size

# Executive Summary (Continued)

(when smaller diameters are used) but potential operational and safety disadvantages with trucks present. Similar tradeoffs may be present for Case 2 and Case 3 roundabouts in the sense that they provide benefits relative to truck accommodations, but in some cases can have larger diameters, and thereby possibly higher right-of-way (ROW) impacts and costs.

# Table of Contents

## List of Tables

# Table of Contents (Continued)

## List of Figures

## List of Appendices

## 1.0 Introduction

This report is a synthesis of current design practices used to accommodate trucks at multilane roundabouts (MLRs). This synthesis of current practices is the first phase of a proposed four-part study commissioned jointly by Wisconsin Department of Transportation (WisDOT) and Minnesota Department of Transportation (MnDOT). The overall purpose of this study is to develop recommendations for design practices to accommodate trucks at multilane roundabouts on state trunk highways.

This overall study is broken into four different phases. The first phase, summarized in this report, presents the synthesis of current design practice developed by collecting data from a representative set of roundabouts and studying how trucks were addressed in the designs of the selected sample. The main goals for Phase 1 include the following:

- Establish a baseline of current design practices for MLRs
- Assess design techniques, operations, safety performance of current design types
- Receive input from trucking industry
- Develop conclusions for consideration in subsequent phases of the study
- Identify areas for further research

Phase 2 of this study will involve collection of additional field data (if needed) to supplement the findings of Phase 1.

In Phase 3 of the study, information collected in the first two phases will be used to develop design guidelines for accommodating trucks at roundabouts for use by state DOTs. Recommendations for supplemental signage will be also provided in the Phase 3 report.

The final phase of the project will include documentation of the study methods and results in a summary document.

## 2.0 Background Information

A study team consisting of department staff from WisDOT and MnDOT, along with their consultants, was assembled to perform this study. In addition, a Technical Advisory Committee (TAC) consisting of DOT staff, local government representatives, other design consultants, and trucking industry representatives provided input throughout the process.

The study team initially performed extensive research and compiled a long list of potential candidate intersections for possible inclusion in the study. From this initial list, 18 multilane roundabouts were ultimately selected for inclusion in the study based on criteria such as geometric characteristics, traffic volumes, truck volumes and percentages, availability of data, geographic location, and representation of different design philosophies. These intersections represent a broad spectrum of design approaches and differing levels of truck accommodation. Questionnaires were sent to the road agencies having jurisdiction over each intersection. As part of this process, a variety of information and data were also collected for each location. Responses received from these agencies for the questionnaires sent are included in **Appendix A**.

In addition, input from the trucking industry was also solicited to better understand needs from a user's perspective. A questionnaire was sent to American Trucking Association

(ATA) affiliates in Wisconsin and Minnesota to solicit information. The questionnaire sent to ATA affiliates is included in **Appendix B**.

Crash data and video footage for some of the study roundabouts located in Wisconsin were available from Traffic Operations and Safety (TOPS) lab of University of Wisconsin, Madison. A summary of this crash data is included in **Appendix C**.

## 2.1 Truck Types

The recommended design vehicle for roundabouts is identified as WB-65 in the WisDOT's *Roundabout Guide* and as WB-62 in MnDOT's *Design Guidelines for Modern Roundabouts*. Accordingly, the truck types studied in this report include WB-62 and WB-65, which are typical design vehicles for multilane roundabouts on state trunk highways. The dimensions and turning radii of these truck types are summarized in **Table 1**. It should be noted that this study did not address accommodation of oversize/overweight permitted loads.

**Table 1 – Dimensions and Turning Radii of WB-62 and WB-65 Trucks**

| Design Vehicles | Dimensions | | | Design Radii | | |
|---|---|---|---|---|---|---|
| | Height (ft) | Width (ft) | Length (ft) | Minimum Design (ft) | Center Line (ft) | Minimum Inside (ft) |
| **WB-62** | 13.5 | 8.5 | 68.5 | 45 | 41 | 7.9 |
| **WB-65** | 13.5 | 8.5 | 73.5 | 45 | 41 | 4.4 |

Source: Exhibits (Tables) 2.2 and 2.3 and Exhibits (Figures) 2-15 and 2-16 of the 2004 *AASHTO manual.*

## 2.2 Classification of Roundabout Types

The three prevailing methods of MLR design in the U.S. have been: (a) to allow trucks to encroach into adjacent lanes as they approach and traverse the intersection, (b) to accommodate trucks in lane as they approach but allow them to encroach into adjacent lanes as they traverse the intersection, and (c) to accommodate trucks in lane as they approach and traverse the intersection. The first method has been utilized most often in the U.S.. However, the second and third methods have been gaining popularity and have become more common in the last few years with the recognition of the need to accommodate larger U.S.-sized trucks.

For the purpose of this study, multilane roundabouts have been classified into three groups based on whether they are designed to accommodate trucks in lane or whether trucks encroach into adjacent lanes. The three categories are as follows:

Case 1 – Case 1 roundabouts are designed such that trucks encroach into adjacent lanes while entering, circulating and exiting a roundabout. See **Figure 1** for an example of a Case 1 roundabout layout with a typical truck path shown.

## Figure 1 – Typical Case 1 Roundabout Layout

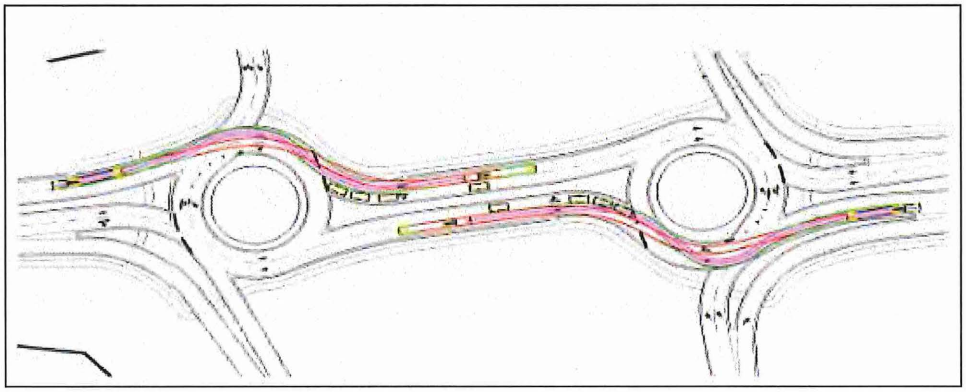

Image Source: Roundabouts & Traffic Engineering, Inc.

Case 2 – Case 2 roundabouts are designed such that trucks enter the roundabout without encroaching, but may encroach into adjacent lanes when circulating and exiting the roundabout. In many cases, Case 2 roundabouts have a painted "gore" area between lanes on the approaches, but this characteristic is not always present. See **Figure 2** for an example of a Case 2 roundabout layout with a typical truck path shown.

## Figure 2 – Typical Case 2 Roundabout Layout

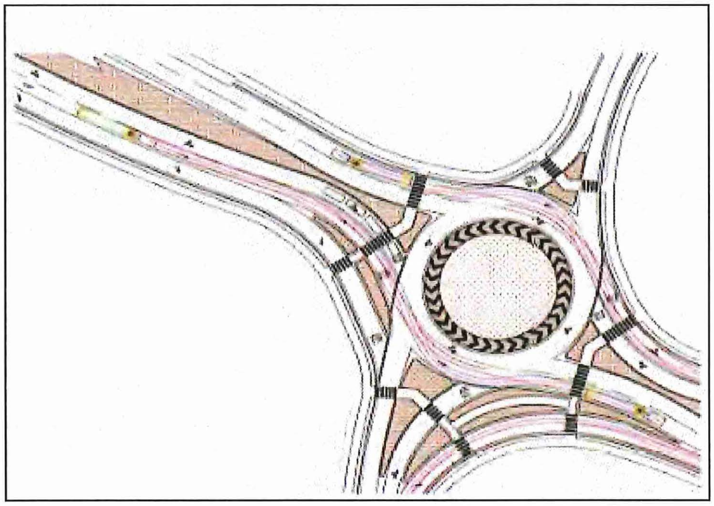

Image Source: Roundabouts & Traffic Engineering, Inc.

Case 3 – Case 3 roundabouts are designed such that trucks can stay within their lane as they enter, circulate, and exit the roundabout (i.e., no encroachment). In many cases, Case 3 roundabouts have a painted "gore" area between lanes on the approaches, but this characteristic is not always present. Typically, Case 3 roundabouts require a truck using the inside circulating lane to have its rear trailer tires track upon a truck apron in the central island in order to stay in lane, but this is not always the case. Often the outside circulating lane is wider than the inside lane to allow trucks to stay in lane. See **Figure 3** for an example of a Case 3 roundabout with a typical truck path shown.

**Figure 3 – Typical Case 3 Roundabout Layout**

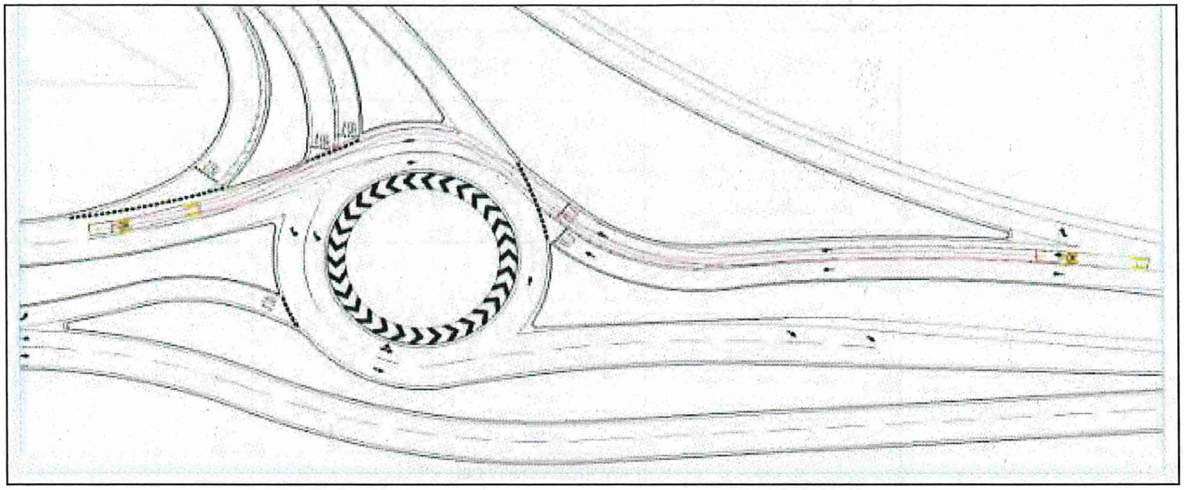

Image Source: Roundabouts & Traffic Engineering, Inc.

If a particular MLR had a combination of both Case 1 and Case 2 entries, that roundabout was designated as a Case 2 intersection. More detailed descriptions of the design characteristics of the three cases are provided below.

## 2.3 Study Intersections

After an extensive review of many dozens of roundabouts around the U.S., 18 roundabouts were selected by the study team for inclusion in this analysis. The selected MLRs are located across the states of Wisconsin, Minnesota, Michigan and Arizona, and they represent a broad spectrum of design approaches. The selected MLRs include the following characteristics:

- Cases 1, 2, and 3
- Varying ranges of traffic volumes and truck percentages
- Varying ranges of design parameters including inscribed circle diameter, entry, exit and circulatory widths and truck apron widths
- Two- and three-lane roundabouts

The 18 MLR intersections selected for evaluation are summarized in **Table 2**.

## Table 2 – Selected Intersections

| Intersection # | Intersecting Roads | Location | Case | Year Constructed |
|---|---|---|---|---|
| Roundabout # 1 | STH 32 & STH 57 | Depere, WI | 1 | 2007 |
| Roundabout # 2, 3 | I-43 & STH 42 | Sheboygan, WI | 1 | 2007 |
| Roundabout # 6 | STH 124 & Business 29 | Eau Claire, WI | 1 | 2008 |
| Roundabout # 7 | M-53 & 18.5 Mile Rd | Sterling Heights, MI | 1 | 2004 |
| Roundabout # 4,5 | STH 61 &Jamaica Ave. | Cottage Grove, MN | 2 | 2007 |
| Roundabout # 8 | USH 53 & Old Town Hall Rd | Eau Claire, WI | 2 | 2008 |
| Roundabout # 9 | STH 42 & Vanguard | Sheboygan, WI | 2 | 2007 |
| Roundabout # 10 | South Town Dr & Industrial Dr | Monona, WI | 2 | Not Available |
| Roundabout # 11, 12 | I-43 & Moorland Rd | New Berlin, WI | 2 | 2007-08 |
| Roundabout # 13 | US 93 & Tegner Street | Wickenburg, AZ | 2 | 2008 |
| Roundabout # 14 | US 93 & US 60 | Wickenburg, AZ | 2 | 2008 |
| Roundabout # 15 | US 89A & Road 4S | Chino Valley, AZ | 3 | 2009 |
| Roundabout # 16 | Ashland Ave & 8th St | Ashwaubenon, WI | 3 | 2010 |
| Roundabout # 17 | STH 13 & Ann's Way | Medford, WI | 3 | 2011 |
| Roundabout # 18 | Lien Road & Zeier Road | Madison, WI | 3 | 2010 |

For each of the 18 selected intersections, the study team collected information from the road agency having jurisdiction as well as from other sources. At most locations, the majority of information being sought was available. The information which was requested for each of the intersections is summarized on the next page. A summary of information collected by location is included in **Appendix D**.

- Roundabout Case type
- Average approach lane width
- Design vehicle
- Circulatory width
- Design year
- Number of circulatory lanes
- Projected design year AADT
- Average circulatory lane widths
- Projected design year truck percentage
- Exit Width
- Truck classifications
- Number of departure lanes
- Existing peak hour volume
- Average departure lane width
- Design year peak hour volume
- Feedback or complaints from users
- Design accommodations for trucks
- Maintenance requirements since built
- Inscribed circle diameter (ft)
- Operational concerns since built
- Width of truck apron (ft)
- Crash data
- Entry width
- Congestion issues since built
- Number of approach lanes
- Video footage
- Design files

### 2.4 Limitations of the Study & Areas for Further Research

Important limitations of this study should be noted, which are the result of two factors: (1) limited budget was available for the study and (2) there are very few Case 2 and Case 3 roundabouts in existence, with most of these being open for two years or less.

The first specific limitation to note is that the sample size for this project was relatively small for each of the three cases as well as for the total number of intersections. This factor limited the ability to perform rigorous statistical analysis. As a result, many conclusions are based on apparent trends and general observations. Specifically, statistically rigorous analysis was not conducted regarding the relationship between crash data and the geometrics for the three case types.

Additionally, there were inconsistencies in information available for the study intersections. In some situations, this limited the type and extent of analysis performed.

This study does not evaluate accommodation of oversized and overweight vehicles.

The study does not address the question of whether or not to include pavement markings in a circulatory roadway.

Based on these conditions, the results of this study are intended to serve as general observation of prevailing trends. It is further intended that the results of this study will serve as a basis to identify and establish needs for future research. All results of the Phase 1 study should be viewed within this overall context and should be considered as providing interim observations only for Case 3 roundabouts until more are built and they can be studied further.

Due to these stated limitations, further research would be beneficial to supplement the findings of this study and to explore areas outside the scope of this study. Specifically, further research is needed to identify the frequency and magnitude of both safety and capacity issues of truck movements through all roundabout case types. This research could determine whether any tradeoffs exist between truck accommodation and speeds/safety performance at all three case types. Last, although the trucking industry surveys have provided valuable input on methods to warn truckers of entry conditions, further research should be conducted to evaluate the expected effectiveness of such measures.

## 3.0 Selection of Design Types

The questionnaire sent to agencies with jurisdiction requested specific information regarding the design approach they followed and the basis behind selecting a particular design approach. Many of the responses to the questionnaire obtained from the road agencies with jurisdiction over the study intersections indicated the reason behind selecting the Case 1, Case 2, or Case 3 design philosophy. Of the 18 intersections selected, specific explanations were provided for nine. Of these nine responses, six indicated that the truck percentages were the primary reason for choosing the Case type. Roundabouts at intersections with higher truck volumes were often designed as Case 2 or Case 3, while the roundabouts located at intersections with lower truck volume were often designed as Case 1. Two responses indicated that safety and concerns from the public were reasons for choosing Case 3 designs, and one response indicated that a Case 1 design was chosen because the guidance allowed the designers to do so. **Table 3** summarizes the expected design year truck percentages for each of the Case types.

**Table 3 – Roundabout Case Types and Design Year Truck Percentages**

| Roundabout Case Type Selected | Average Projected Design Year Truck Percentages |
|---|---|
| Case 1 (5 roundabouts) | 5.5% (data for 1 roundabout only) |
| Case 2 (9 roundabouts) | 9.5% (range - 9.00% to 11.0%) |
| Case 3 (4 roundabouts) | 14.2% (range - 5.4% to 18.60%) |

As can be seen in **Table 3**, there seems to be some correlation between design case selected and the truck percentage. Case 2 and Case 3 designs were generally preferred for locations with higher truck percentages.

## 4.0 Volume and Crash Data

The projected design year traffic volumes at the selected roundabouts were compared with the choice of the roundabout case types. **Table 4** summarizes the ranges of design year peak hour entering volume for each of the roundabout case types.

**Table 4 – Roundabout Case Types and Design Year Peak Hour Entering Volume**

| Roundabout Case Type Selected | Average Design Year Peak Hour Entering Volume (vph) |
|---|---|
| Case 1 (5 roundabouts) | 3,652 (range – 2,191 to 4,526) |
| Case 2 (9 roundabouts) | 3,266 (range - 618 to 6,442) |
| Case 3 (4 roundabouts) | 3,568 (range - 1,991 to 5,760) |

As can be seen from **Table 4**, based on the collected data, there does not appear to be a clear correlation between Case types and entering volumes.

Responses indicated that two Case 1 roundabouts experienced minor rear end crashes which could be attributable to encroachment.

A very limited amount of crash data was made available for the roundabouts located in Minnesota, while data was not provided for the roundabouts in Arizona.

However, intersection crash data for five of the 18 roundabouts located in Wisconsin was made available by the TOPS lab of University of Wisconsin, Madison. The five roundabouts are classified as Case 1 and Case 2. The crash data presented is classified into angle, rear-end, sides swipe and other crashes (such as single vehicle crashes, collision with fixed objects, collision with deer etc.). The average number of crashes involving trucks is also presented for each intersection.

A review of the crash data revealed that the number of sideswipe crashes ranks first among the different types. In addition, the percentage of crashes involving trucks is observed to be higher in Case 1 roundabouts than Case 2. However, due to the limited sample size of this analysis, care should be used when interpreting results. A summary of the crash data obtained is presented in **Table 5**.

**Table 5 – Summary of Crash Data – Average Annual Crashes By Type**

| Roundabout # / Case # | Intersection | Angle | Rear End | Side Swipe | Other | Total | Crashes Involving Trucks |
|---|---|---|---|---|---|---|---|
| 1 / 1 | STH 23/57 & Broadway | 3.25 | 4.06 | 7.32 | 0.00 | 14.63 | 5.27 |
| 2 / 1 | STH 42 & I-43 Ramps | 1.85 | 2.78 | 3.24 | 4.17 | 12.04 | 5.06 |
| 3 / 1 | | 0.93 | 1.39 | 1.62 | 2.09 | 6.02 | 2.53 |
| 8 / 2 | STH 53 & Old Town Hall | 0.00 | 0.00 | 0.00 | 0.83 | 0.83 | 0.00 |
| 9 / 2 | STH 42 & Vanguard | 1.39 | 0.00 | 1.39 | 2.31 | 5.09 | 1.37 |

## 5.0 Design Characteristics of Study Intersections

A thorough review of each of the eighteen selected roundabout designs was performed to identify common design characteristics for each of the three Case types. As part of this analysis, the limitations and advantages associated with each Case were assessed. This included an evaluation of potential trade-offs for each design methodology as well as identification of design features of specific interest with respect to truck accommodations. Each design was evaluated for truck capabilities, lane encroachment issues, the six basic geometric design parameters (E – entry width, L'- effective flare length, V – half width, R – entry radius, Phi – entry angle, D – inscribed circle diameter), lane configuration design choices, methods of design, and various available data such as pictures, videos, and field evaluations (where possible). The relevant results of these analyses are summarized for Cases 1, 2, and 3 roundabouts in the Sections 5.1 through 5.4.

Case 1 roundabouts require trucks to utilize more than one lane on a multi-lane entry in order to successfully navigate within the roundabout's geometry. This type may be advantageous over other types if large truck percentages are lower since they allow for smaller and tighter geometry (and possibly fewer ROW impacts/costs), with the design focusing primarily on passenger car accommodations. Case 1 roundabouts also allow for the widest variety of design methods, such as radial designs, to fit into tight right-of-way situations (A radial design is one that has roadway centerline(s) for the applicable leg(s) going through the center point of the roundabout – i.e., the center of the inscribed circle. This typically results in symmetrical entry and exit geometry on the applicable leg and straight approach alignments without deflection prior to the entry radius. Often, entries can become offset to the right of center with short and tight entry radii to keep speeds slow. See section 6.3.2 and Exhibit 6-10 of NCHRP Report 672 for more details regarding this topic.). Offset left approach alignments are also used for some Case 1 roundabouts. In some cases, installing Case 1 roundabouts can result in a smaller ICD and significant ROW cost savings which may be appropriate and advantageous in constrained urban areas with existing slow speeds. However, when other traffic is present, Case 1 roundabouts can also influence trucks to track over curbs to avoid other vehicles. It has been observed and reported that one of the drawbacks of Case 1 roundabouts is that they can create negative side effects upon traffic operations and safety in some situations. It should be pointed out that Case 1 roundabout design techniques and diameters can vary widely since the design of modern roundabouts are fairly recent in the U.S. with varying principles and skill levels, so it is difficult to draw specific conclusions based on general characteristics of the group as a whole. Or stated a different way, Case 1 roundabouts probably exhibit more variability in terms of design characteristics than Case 2 or Case 3 roundabouts since these types are observed as more recent developments in the roundabout design industry (based on the experience/opinion of the study team).

Another design option for Case 1 roundabouts entails a single lane roadway flaring to a two lane approach over a very short distance (less than one truck length). In these types of designs, the approach has a sufficiently short flare to preclude the ability of a passenger vehicle to drive adjacent to a truck through the approach and entry, thus categorizing it as a Case 1 roundabout. The large truck splits both lanes on approach and takes the entire entry as it proceeds into the intersection.

Case 2 roundabouts allow trucks to stay in lane within the entry. This type requires a slightly wider entry and different design methods to implement properly. By permitting trucks to stay in-lane within entry, Case 2 roundabouts can provide improved traffic operations, increased safety, and less curb maintenance than Case 1 roundabouts. However, unless a larger diameter is used, Case 2 roundabouts typically cannot use a radial design method and often require additional curve lengths to accommodate trucks well, based on the experience and opinion of the study team. In addition to being slightly more complex to design, this type may also require more striping maintenance and detailed plans if multiple entry striping or gore areas are used. In some situations, Case 2 roundabouts may have a larger footprint than Case 1 MLRs.

Although a relative new concept, Case 3 roundabouts allow trucks to stay in lane while entering, circulating, and exiting a roundabout. Although not required, this type often coincides with additional entry striping or gore areas and sometimes slightly larger diameters due to the design treatments and higher percentages of trucks. With only a few of the Case 3 roundabouts currently implemented, other potential disadvantages are not well known. Preliminary, there have been no known operational or safety issues noted to date with Case 3 roundabouts. In some situations, Case 3 roundabouts may have a larger footprint than Case 2 MLRs.

All types of roundabouts are influenced by existing conditions, site constraints, agency requirements, and designer preferences. In theory (based on the experience and opinion of the study team), Case 1 roundabouts can have smaller ICDs than Case 2 and 3 roundabouts because of the narrower entry widths required (the study intersections for this analysis do not exhibit this characteristic, but the sample may not be representative of all of the roundabouts within the U.S. - rather a sample of easily accessible roundabouts without significant design or operational issues). Case 1 roundabouts with diameters of less than about 160 feet can be challenging for designers to achieve an acceptable entry speed (R1 value) while maintaining truck accommodations, and this becomes exceedingly more difficult for Case 2 or 3 MLRs if trucks are to remain in-lane with smaller diameters. In addition, special attention must be given to the speed differential between entry speed (R1) and the circulating speeds (R2 or R4) to ensure a safe design is implemented. Another important consideration is exit speed as it relates to pedestrians. All of these factors and others are interrelated and must be balanced by the designer. Caution and skill must be exercised by designers to ensure other design parameters and safety measures are not degraded in an attempt to accommodate trucks in-lane (i.e., Case 2 and 3 designs), especially with smaller diameter roundabouts. This highlights some key tradeoffs involved in achieving a holistic, balanced design.

## 5.1 Case 1 Roundabout Reviews

Each design evaluated in this group demonstrated the need for trucks to overlap into adjacent lanes within curbs. However, at all of the Case 1 entries, field evidence confirmed some trucks tracked over the right side curb on entry, presumably to avoid encroaching on other vehicles. This situation stems from some combination of adjacent (potentially conflicting) traffic as well as the lane configuration and design method chosen. It should be noted that tracking over curbs is also not uncommon at "square" intersections controlled with traffic signals and stop signs.

One common design technique observed at the Case 1 study intersections was the use of significantly small and short entry radii. A 65-foot entry radius was the most common entry radius within the case studies. This situation typically required trucks to utilize more than one lane when traversing the roundabout. When other traffic is present and trucks are forced to stay in the right lane on approaches, field observations indicate that trucks often over-track the entry radius curbs. In these situations, the assumed truck operations of utilizing both lanes are not being realized, with trucks attempting to stay in-lane to avoid adjacent traffic. The degree to which this occurs may be related to traffic volumes, with curb over-tracking expected to be more common when volumes increase or when traffic platoons are present. Despite generally lower truck percentages at the Case 1 locations, observations suggest truck over-tracking of entry radius curbs as some trucks try to stay in the outside lane at entry. Field observations as well as discussions with road agency staff members confirm some trucks over-track entry radius curbs. This can result in the need for repairs to damaged curbs and sidewalks. Refer to **Figure 1** for an example of a truck path through a Case 1 roundabout.

The most frequently observed design characteristics of the Case 1 intersections were as follows:

- Small entry radii (R) with typical ranges between 64 and 75 feet
- Narrow entry widths (E) with typical ranges from 12 to 14 feet per lane
- Inner circulating lane width typical ranges between 12 and 14 feet

- Outer circulating lane width typical ranges between 15 and 16 feet
- Limited use or no flare (L') with typical values of zero (or V=E)
- Short entry radii (R) typically less than 50 feet
- Varying inscribed circular diameters (ICD) within typical FHWA ranges

With the exception of Location #7 (Sterling Heights, MI), all roundabouts within this group had distinctively small entry radii which was a primary contributing factor to trucks either utilizing more than one lane or tracking over curbs. Most approaches to these Case 1 roundabouts did not incorporate an average effective flare length (L') within the approach. This situation can contribute to trucks overlapping into adjacent lanes, especially when coupled with short and tight entry radii. The lack of flare within an entry did not allow vehicles to negotiate the entry well since they had only a small amount of space to maneuver within their lane on a small radius turn. Entries without flare increase side friction to drivers for less operating capacity.

In several case studies, the implemented lane configuration utilized a two-lane approach with a right turn only lane in the outside lane, thus requiring truck movements to utilize the left lane to make a right turn. In addition, several case studies used dual left turn lanes which required trucks to use the inside lane, a left turn only lane, in order to turn right across another left turning lane. In both of the cases, evidence revealed some trucks did not use both lanes in entry, rather, stayed in-lane and tracked over curbs to avoid other traffic or potential safety issues.

Two locations within the Case 1 group utilized a radial design method which also contributed to truck over-tracking and larger roundabout diameters. Although Case 1 roundabouts can typically be smaller than Case 2 and 3 roundabouts, these general trends were not found within these study intersections. The diameters of Case 1 roundabouts varied from roughly 163 feet to 200 feet for all two-lane roundabouts with an average ICD of 180 feet (throwing out the smallest and largest data points). This average size would appear to be larger than typical Case 1 roundabouts in many other locations (based on the experience of the study team consultants, who have collectively designed over 600 Case 1 roundabouts). No other design characteristics or parameters were notable with respect to truck operations or capabilities.

Figure 4 – Example of Case 1 Roundabout

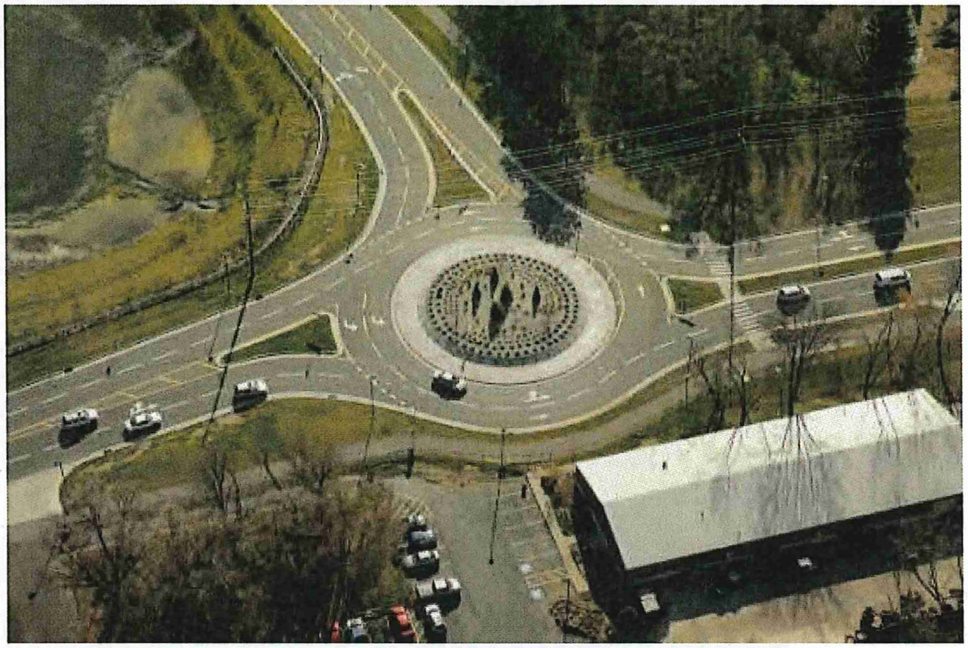

Image Source: DLZ National, Inc.

## 5.2 Case 2 Roundabouts

Each location evaluated in this group accommodated entering trucks in lane as intended. A noteworthy feature for this group was the varied design practices/geometric parameters used, especially for E, R and L'. Some locations used smaller entry radii with wider entry widths and gore widths. Other locations used larger and longer entry radii with less gore area and narrower entry widths. However, one common feature was the fact all designs successfully accommodated trucks in-lane within the entry. The observed design characteristics of the Case 2 intersections were as follows:

- Widely varying entry radii (R) ranging from 63 to 138 feet
- Wider entry widths (E) with typical ranges from 14 to 16 feet per lane
- Inner circulating lane width typical ranges between 12 and 15 feet
- Outer circulating lane width typical ranges between 14 and 17 feet
- Entry gore width at yield line typically ranges between 1.5 and 6 feet
- Effective flare was implemented (L') between curb faces
- Generally longer controlling entry radii with varying lengths ("controlling radii" are those with sufficient length to affect driver paths/assist with deflection prior to the crosswalk and yield line.)
- Varying inscribed circular diameters (ICD) within typical FHWA ranges

**Figure 5 – Example of Case 2 Roundabout**

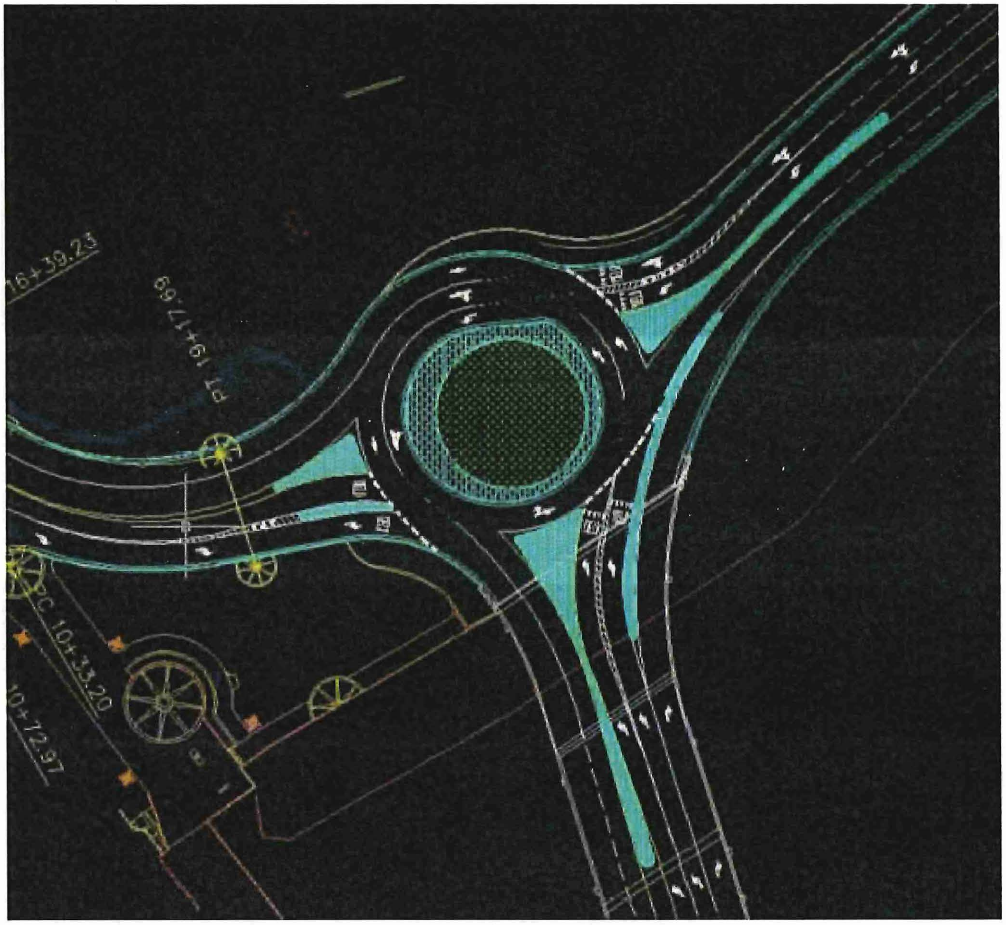

Image Source: Roundabouts & Traffic Engineering, Inc.

The design method utilized for all Case 2 approaches in this study was the offset-left method. Most of the designs within this group used slightly larger and longer entry radii versus the Case 1 intersections. This design feature allowed for additional truck maneuverability. Field observations did not show this group of roundabouts to have over-tracking of entry radius curbs, confirming that trucks are usually able to stay in-lane at entry. Refer to **Figure 2** for an example of a truck path through a Case 2 roundabout.

The roundabout diameters of these case studies varied within a similar range as the Case 1 group (however, as noted above, the Case 1 roundabout diameters for intersections in this study are probably larger than the average nationwide based on the experience of the study team). Several locations under Case 2 used larger diameters (190+ feet) either by preference or due to their future expandability to more lanes (more capacity). The largest Case 2 roundabout had six legs and an ICD of 220', although this may be considered an outlier. One case study used a radial design method which coincides with the larger diameter since proper approach (R1) speeds can be difficult to achieve with a multi-lane radial design method.

Several of the Case 2 roundabouts used flare effectively while others used flare within only the gore area striping, keeping lanes striped to 12 feet wide. Although this may negatively affect capacity, it was not common. Some locations within this group used wider gore areas between the lanes than necessary as a result of the entry widths and radii that were utilized. As the design practice for Case 2 roundabouts is better understood by experienced designers, methods will improve for a net result of a balanced design.

A feature of interest in the Case 2 locations was one project which accommodates trucks with consecutive legs having double left turn movements. Intersection #14 (Wickenburg, AZ) (see **Figure 5** above) accommodated WB-67 trucks in-lane within the approaches for two different approaches with dual left movements. These approaches have a three-foot gore area between lanes at the widest point and a relatively small 164-foot diameter on the two lane section.

Regarding the various design parameters that were evaluated, Case 2 roundabouts did not appear to compromise accepted design principles as outlined in applicable guidance (i.e., FHWA Roundabout Guide, WisDOT Roundabout Guide, MnDOT Roundabout Guide). However, it should be noted that wider entries for Case 2 designs require slightly longer crossing distances for pedestrians.

## 5.3 Case 3 Roundabouts

Only a handful of Case 3 MLRs are currently built in the U.S. since this design approach is fairly recent to the roundabout industry. For this case, the study intersections included two roundabouts that are built and two roundabouts that have been designed, but not built. Each intersection evaluated in this group fully accommodated trucks in lane as intended. None of the locations had small or short entry radii while providing extra entry width for trucks. None of the locations appeared to exhibit over-tracking of entry radius curbs in the outside lane. Refer to **Figure 3** for an example of a truck path through a Case 3 roundabout. The roundabout diameters of these case studies had slightly larger diameters but within a similar range as the Case 2 intersections included in this study with the exception of one location at 220 feet since it is expandable to a triple lane in the future.

The observed design characteristics of the Case 3 intersections were as follows:

- Generally larger entry radii (R) ranging from 120 to 130 feet
- Wide entry widths (E) with typical ranges from 32 to 34 feet
- Inner circulating lane width typical ranges between 12 and 14 feet
- Outer circulating lane width typical ranges between 17 and 18 feet
- Entry gore width at yield lines typically ranges between 1 and 6 feet
- Effective flare was implemented (L')
- Longer entry radii (R) of roughly 100 feet or more
- Inscribed circular diameters (ICD) approximately ranging from 190' to 220'

Figure 6 – Example of Case 3 Roundabout

Image Source: Roundabouts & Traffic Engineering, Inc.

Approach design methods varied between offset left and curvilinear alignments, depending on the roadway's posted speeds. Several locations within this group (three of the four Case 3 roundabouts) used relatively wide gore areas (i.e., greater than five feet) between the lanes. All designs incorporated appropriate use of geometric parameters. Case 3 roundabout diameters ranged from approximately 190 feet to 220 feet (for the future triple lane roundabout).

Regarding the various design parameters that were evaluated, Case 3 roundabouts did not appear to compromise accepted design principles as outlined in applicable guidance (i.e., FHWA Roundabout Guide, WisDOT Roundabout Guide, MnDOT Roundabout Guide). However, it should be noted that wider entries for Case 3 designs require slightly longer crossing distances for pedestrians.

### 5.4 Additional Comments

MLR designs are influenced by existing conditions, site constraints, agency requirements, and designer preferences. In many design locations, jurisdictions requiring trucks to remain in-lane (Case 2 or 3) sometimes build roundabouts with larger diameters for potential expansion of lanes in the future. It has been observed within this study most Case 2 and Case 3 roundabouts have been implemented at either interchanges or non-urban roadway environments. In addition this study recognizes most of the Case 1 intersections predicted future truck traffic percentages of 5 percent of less, whereas all Case 2 and 3 intersections presented 5 percent or more of the traffic as trucks.

As described in the Case 1 review section, the diameters of Case 1 roundabouts varied from 162 feet to 200 feet for all two-lane roundabouts with an average ICD of 180 feet (throwing out the smallest and largest data points). The previous discussion also noted that the Case 1 roundabouts in the current study are likely larger than average Case 1 roundabouts nationwide. Compared to the Case 2 roundabouts in this study (diameters from roughly 160 feet to 196 feet for all two-lane roundabouts with an average ICD of 180 feet) Case 1 roundabout diameters were very similar. However, had a larger data set been selected from a national cross section of roundabouts, it is likely that Case 1 roundabouts would have averaged 10 to 20 feet smaller than Case 2 roundabouts based on experience of the authors (the study team consultants have designed over 700 roundabouts, 100 being Case 2 or Case 3). Case 3 roundabouts had only four data points of about 189, 190, 202, and 220 feet. The average was 200 feet in diameter including all four data points. Hence, although limited data was available for Case 3 roundabouts, the diameters were 10 to 20 feet larger than the Case 2 intersections.

The varying roundabout diameters (sizes and shapes), entry angles, and half widths of the roadways were not a significant design factor for trucks in these case study intersections to identify noteworthy observations.

## 6.0 Summary of Video Tape Review

Video footage of representative roundabouts was reviewed as part of this study. The purpose of this evaluation was to determine if trucks navigate through Case 1, Case 2, and Case 3 roundabouts as intended by designers. Truck driving patterns were observed at roundabouts where video footage was available. Of the eight roundabouts where video footage was available, four roundabouts were Case 1, three roundabouts were Case 2, and one roundabout was Case 3.

### 6.1 Methodology

Video footage of representative roundabouts was provided by the TOPS lab and other sources for eight of the study roundabouts. Digital video cameras and cameras with special "mio-vision" lenses were deployed at most of the roundabouts to capture all traffic approaching and circulating through the roundabouts during both off peak and peak hour traffic conditions. The video footage from the applicable locations was reviewed, and observations of trucks (WB-62 or larger) and their tracking while entering and circulating through the roundabouts were logged.

Truck tracking at the approaches and in the circulatory roadway was assessed. The observations were further organized by whether potentially conflicting traffic was present or not. The presence of potentially conflicting traffic was defined as the condition where other vehicles were in the immediate vicinity of a truck. In this case it is likely that drivers were aware of each other and potentially adjusted driving behavior. Potentially conflicting traffic was typically reflective of "peak" traffic conditions and the absence of potentially conflicting traffic was typically indicative of "off peak" conditions.

There were some limiting factors related to the footage such as obstructions, camera positioning, and existing geometry which affected the number of observations that were logged. These limitations did not necessarily affect all legs or every truck observation.

Case 1 roundabouts reviewed included M-53 at 18.5 Mile Road in Sterling Heights, Michigan; State Highway 32 and State Highway 57 in De Pere, Wisconsin; and both roundabouts at the State Highway 43 interchange on I-43 in Sheboygan, Wisconsin;. Representative excerpts from each of the roundabouts were reviewed to confirm the expected behavior of trucks encroaching on adjacent lanes.

Video footage reviewed for the Case 2 and Case 3 roundabouts included both roundabouts at the interchange of Interstate 43 at Mooreland Road in New Berlin, Wisconsin; at the intersection of USH 53 and Old Town Hall Road in Eau Claire, Wisconsin; at the intersection of Lien Road and Zeier Road in Madison, WI; and at the roundabout at the intersection of State Highway 42 and Vanguard Drive in Sheboygan, Wisconsin. Approximately 35 hours of footage from seven approaches was reviewed, and approximately 235 observations of tracking were logged.

Although the roundabouts at the Mooreland/I-43 interchange were identified as Case 2, data for the northbound approach and for the eastbound approach of the south roundabout were not considered in the Case 2 analysis since these approaches appear to not fully accommodate trucks in lane.

## 6.2 Results

Representative excerpts of Case 1 roundabouts revealed that trucks encroach on the adjacent lanes on the entries as expected. The geometries of these roundabouts were not specifically designed to keep trucks in lane as they enter and circulate. Based on observations and responses from the trucking industry questionnaire (discussed further in Section 9.0), truck drivers may drive over the entry radius curb to avoid encroaching on traffic in the adjacent lane, which may cause damage to the curb or sidewalk. Radial design methods, dual left-turn lanes, and right-turn only lanes also contributed to truck over-tracking at Case 1 roundabouts.

A more detailed analysis of the footage provided for Case 2 and Case 3 roundabouts was performed in order to investigate if the designs had an impact on driver behavior. The two tables below summarize observations from the applicable approaches at the five roundabouts where footage was available. As discussed in the methodology section, observations were divided by whether conflicting traffic was present or not. The first table summarizes conditions at the approaches, and the second table summarizes conditions at the circulatory roadways. A detailed observation log is also attached in **Appendix E**.

**Table 6 – Observations at Case 2 and 3 Approaches**

| Location | Approach | Conflicting Traffic Present | | No Conflicting Traffic Present | |
|---|---|---|---|---|---|
| | | Number of Observations | % of time trucks stayed in lane | Number of Observations | % of time trucks stayed in lane |
| I-43 at Mooreland North | SB | 49 | 96% | 28 | 86% |
| I-43 at Mooreland South | SB | 27 | 89% | 25 | 36% |
| I-43 at Mooreland South | NB | 13 | 100% | 25 | 92% |
| STH 42 at Vanguard | EB | 11 | 82% | 10 | 70% |
| STH 42 at Vanguard | WB | 19 | 84% | 7 | 86% |
| Lien at Zeier | SB | 2 | 100% | 1 | 100% |
| USH 53 at Old Town Hall | SB | 3 | 67% | 15 | 60% |
| Totals | | 124 | 91% | **111** | **71%** |

### Table 7 – Observations at Case 2 and 3 Circulatory Roadways

| Location | Approach | Conflicting Traffic Present | | No Conflicting Traffic Present | |
|---|---|---|---|---|---|
| | | Number of Observations | % of time trucks stayed in lane | Number of Observations | % of time trucks stayed in lane |
| I-43 at Mooreland North | SB | 49 | 98% | 28 | 68% |
| I-43 at Mooreland South | SB | 27 | 85% | 25 | 24% |
| I-43 at Mooreland South | NB | 13 | 54% | 25 | 12% |
| STH 42 at Vanguard | EB | 11 | 82% | 10 | 70% |
| STH 42 at Vanguard | WB | 19 | 63% | 7 | 43% |
| Lien at Zeier | SB | 2 | 100% | 1 | 0% |
| USH 53 at Old Town Hall | SB | 3 | 67% | 15 | 20% |
| Totals | | 124 | 83% | 111 | 37% |

As shown in the tables, when potentially conflicting traffic is present, trucks (WB-62 or larger) stayed within lanes 91 percent of the time on the approaches and 83 percent of the time in the circulatory roadway. When potentially conflicting traffic is not present, 71 percent of trucks stayed within lane on the approaches, but only 37 percent stayed in lane in the circulatory roadway.

Although the Case 2 roundabouts observed were not specifically designed for trucks to stay in lane in the circulatory roadway, the video observations indicated that a relatively large percentage of trucks were actually able to do so. This observation is believed to be the result of driver skill and/or the conservative nature of the software programs (AutoTrack and AutoTurn) typically used by designers to assess truck paths (i.e., software program indicates trucks cannot stay in lane, but actual trucks can maneuver within smaller area and stay in lane).

Other noteworthy observations were as follows:

- When entering the roundabout in the presence of potentially conflicting traffic, trucks generally stayed in lane.
- When circulating in the presence of potentially conflicting traffic, trucks in the inside lane typically used the truck apron to avoid encroaching on the adjacent occupied lane.
- If no other potentially conflicting traffic was present, trucks making through or left-turn movements generally ignored lane lines and avoided driving on the central island truck apron.
- When approaching a truck from behind at the yield line, the vast majority of vehicles stayed behind the truck and allowed it to enter the roundabout rather than advancing to the yield line in the adjacent lane. This occurred regardless of whether the truck was encroaching into the adjacent lane.
- On entries not designed for trucks to stay within lane (i.e., Case 1 roundabouts), trucks using the outside lane for a through or right-turn movement as mounted the entry radius curb to avoid encroaching on adjacent lanes (this was based on observations of rutting behind the curb).

## 6.3 Conclusions

Trucks encroached on adjacent circulating and entry lanes at Case 1 roundabouts. At some of the Case 1 entries with short, small entry radii and conflicting traffic present, it is apparent (based on observations of rutting) that trucks jump the right side curb on the entry to avoid encroaching on other vehicles. At Case 2 and Case 3 roundabouts, trucks stayed in lane on approach 91 percent of the time and stayed in lane while circulating 83 percent of the time when potentially conflicting traffic was present. When potentially conflicting traffic was present, trucks did not hesitate to utilize the truck apron when turning left or continuing through in order to avoid encroaching on other vehicles. When potentially conflicting traffic was not present, trucks stayed in lane on approach 71 percent of the time, but only stayed in lane while circulating 37 percent of the time. When potentially conflicting traffic was not present, trucks typically avoided using the truck apron regardless of the entry design.

## 7.0 Circulatory Roadway Crown

Most of the study intersections had plans provided which could be used to identify if a circulatory roadway crown was implemented. A summary of the data collected from the plans regarding roadway crowns is summarized in **Table 8** below.

**Table 8 – Roadway Crown Information**

| Intersection # | Intersecting Roads | Location | Roadway Crown |
|---|---|---|---|
| Roundabout # 1 | STH 32 & STH 57 | Depere, WI | Crowned |
| Roundabout # 2, 3 | I-43 & STH 42 | Sheboygan, WI | Crowned |
| Roundabout # 6 | STH 124 & Business 29 | Eau Claire, WI | No data |
| Roundabout # 7 | M-53 & 18.5 Mile Rd | Sterling Heights, MI | Slopes Outward |
| Roundabout # 4,5 | STH 61 &Jamaica Ave. | Cottage Grove, MN | Slopes Outward |
| Roundabout # 8 | USH 53 & Old Town Hall Rd | Eau Claire, WI | Slopes Outward |
| Roundabout # 9 | STH 42 & Vanguard | Sheboygan, WI | Crowned |
| Roundabout # 10 | South Town Dr & Industrial Dr | Monona, WI | No data |
| Roundabout # 11, 12 | I-43 & Moorland Rd | New Berlin, WI | No data |
| Roundabout # 13 | US 93 & Tegner Street | Wickenburg, AZ | Crowned |
| Roundabout # 14 | US 93 & US 60 | Wickenburg, AZ | Crowned |
| Roundabout # 15 | US 89A & Road 4S | Chino Valley, AZ | Crowned |
| Roundabout # 16 | Ashland Ave & 8th St | Ashwaubenon, WI | Crowned |
| Roundabout # 17 | STH 13 & Ann's Way | Medford, WI | Crowned |
| Roundabout # 18 | Lien Road & Zeier Road | Madison, WI | No data |

Based on the information available, the study team was unable to identify whether either of the two design methods (i.e., using a crown or cross slope away from the central island) provided enhanced operations for trucks, improved safety or capacity, or created adverse results. Further analyses would be required to identify operational benefit or detriment.

## 8.0 Truck Apron

Truck apron widths are not provided in the typical design parameters published by WisDOT or MnDOT. However, these agencies recommend that AutoTurn software be used to determine the width of the apron, and WisDOT recommends a 12-foot minimum apron be used. Chapter 11-26-50.2 of WisDOT's *Facilities Development Manual* (FDM) provides additional information about truck aprons.

The truck apron width data was available for 12 of the 18 roundabouts. Of the 12 roundabouts, four were Case 1 roundabouts, six were Case 2 roundabouts, and two were Case 3 roundabouts. **Table 9** summarizes the ranges and averages of apron widths used for each of the roundabout case types

**Table 9 - Summary of Apron Width Ranges and Averages By Case Types**

| Roundabout Case Type Selected | Apron Width Ranges | Average Apron Width |
|---|---|---|
| Case 1 (4 roundabouts) | 5.0 ft to 14.5 ft | 10.88 ft |
| Case 2 (6 roundabouts) | 8.0 ft to 15.0 ft | 11.33 ft |
| Case 3 (3 roundabouts) | 10.0 ft to 21.5 ft | 15.50 ft |

As can be seen from **Table 9**, the average apron width for Case 3 is wider than that for Case 2, and the average apron width for Case 2 is wider than that for Case 1. This indicates that there may be a preference to supplement the Case 2 and 3 types with wider aprons. In other words, as the case type increased, the apron width provided also increased. However, it should be noted that these results are based on a limited sample size and should be confirmed based on a broader analysis with a larger sample size. The wider aprons may also be related to the narrower inside circulating lanes utilized with some Case 2 and 3 roundabouts (the assumption is that trucks will use the apron to stay in this narrower lane for through and left turn movements). Additionally, wider aprons allow plows to mount the aprons to clear snow and also help oversize / overweight permitted vehicles navigate through the roundabout. From that perspective, designers may be using the wider apron to make sure the total width available is adequate. Current WisDOT standards require a 12' minimum width for truck aprons.

## 9.0 Input from The Trucking Industry

Questionnaires were distributed to the Wisconsin Motor Carriers Association and the Minnesota Trucking Association in order to understand their potential concerns about navigating multilane roundabouts. The questionnaire was also made available to members through other communications such as newsletters. Twenty-seven responses were received from managers, trainers, and safety officers at trucking industry companies representing approximately 225 truck drivers. The questionnaires consisted of five questions (See **Appendix B** for example survey). A summary of the survey responses is listed in **Table 10** below.

## Table 10– Summary of Trucking Industry Survey Responses

| | |
|---|---|
| Question 1 - Any company policies regarding roundabouts? | • 4 Yes<br>• 22 No<br>• 2 No response |
| Question 2A – Are roundabout signing, pavement markings, or truck aprons confusing on approaches? | • 9 No<br>• 2 No but don't like signing<br>• 14 Yes (3 signing, 2 lane assignment/markings, 1 visibility, 2 other driver behavior unpredictable)<br>• 3 No response |
| Question 2B – Same elements confusing when circulating? | • 12 No<br>• 7 Yes<br>• 9 No specific response (1 tires rub on curbs) |
| Question 2C – Same elements confusing when exiting? | • 13 No<br>• 6 Yes (1 difficult to steer and read signs for exits)<br>• 9 No specific response |
| Question 2D – Provide good or bad examples of these elements at roundabouts | • Good Examples:<br>o Madison (unspecified location) if use both lanes<br>o Hwy 35 in Hudson has more room<br>o Mosinee Wisc. (unspecified location)<br>o Hwy 10 W. of Appleton,<br>o Hwy 45 in Oshkosh<br>• Bad Examples:<br>o Rice Lake (2)<br>o Wisc. Dells<br>o De Pere (2)<br>o New Berlin and Canal in Milwaukee too busy<br>o Town Square difficult to maneuver<br>o All Wisc. RABs too narrow<br>o I-94 & Hwy 12<br>o Mooreland & I-43 (2)<br>o Wisc. Rapids signs get run over |
| Question 3 – Would your drivers rather stay in lane or offtrack into inner lane while circulating? | • 12 Stay in Lane (1 don't use truck apron, 1 outside lane only and let other drivers know)<br>• 8 Offtrack (1 with signs, 1 not over curbs)<br>• 1 Use turn signals<br>• 1 Keep approaches single lane<br>• 6 No response |
| Question 4 – What is the best way to indicate if driver should stay in lane? | • 16 Better signs (1 with LED lights, 1 with pictures, 1 list what size trucks will fit)<br>• 2 Make lanes wider<br>• 1 Let trucks straddle lanes<br>• 1 Don't build roundabouts<br>• 8 No Response |
| Question 5 – Any features that could be improved for safety? | • 1 Apron on right side on entry<br>• 6 Better signing/sight lines<br>• 1 Space roundabouts further apart<br>• 3 Avoid truck tipping/curb strikes/apron use<br>• 5 Widen lanes/larger geometry<br>• 1 We avoid roundabouts<br>• 4 Better education and larger geometry<br>• 7 No Response |

The first question asked whether the recipient had any knowledge of company policies relating to driving through multilane roundabouts. Only four respondents had knowledge of a company policy in place. These polices included following WisDOT brochures, diagrams and videos, and special safety meetings, training, or orientation sessions.

The vast majority of respondents indicated that their drivers are not confused by pavement markings or truck aprons while circulating and exiting the roundabout. Many respondents indicated that entries are confusing because they do not provide adequate signage or advance warning to indicate whether trucks must stay in lane, use the truck apron, or off-track into the adjacent lane. Some indicated that there is an excess of signage on entries. Several also indicated that other drivers occasionally enter the roundabout from the wrong lane or encroach on trucks that are attempting to use both lanes.

A slight majority of drivers prefer wider lanes to allow trucks to stay in lane rather than allowing off-tracking into an adjacent lane or truck apron while circulating. Several respondents commented that using the truck apron may cause safety issues such as load shifting or tire damage. Although the drivers mostly indicated that they were not confused by the pavement markings in the circulating roadway, many were concerned about the actions of other drivers and preferred to stay in their own lane to avoid conflicts.

Many of the respondents indicated improved signage and wider lanes would help indicate to drivers whether or not they should stay in lane. Two respondents indicated signs with pictures on them may better demonstrate how trucks should approach the yield line. Several other respondents suggested a sign that states "Trucks Use Both Lanes" or "Do Not Pass Trucks in Roundabout" may better guide all users.

Several suggestions were received for features that may improve safety for trucks in multilane roundabouts. Improved signage, truck aprons on the right side curb on entries, larger diameters, and wider lanes were suggested to reduce conflicts between trucks and other vehicles. A few respondents voiced displeasure with roundabouts altogether and wanted them to be removed. Other concerns included truck tipping, accommodation of oversize/overweight trucks (not part of this study), lack of public awareness on how to navigate roundabouts, and spacing adjacent roundabouts further apart to reduce confusion.

## 10.0 Capacity Impacts

Qualitative observations were conducted to determine if any of the design methods (Case 1, 2, or 3) demonstrated improved or reduced capacity impacts with respect to trucks. These analyses did not include specific capacity calculations or delve into software methodology, analyses, or results from the varying designs and sites evaluated. Hence, the observations could not be related to the predicted capacity within RODEL since it was not possible to ascertain the impacts with the available information. Based on the available data and video observations for roundabouts designed to require trucks to encroach on adjacent lanes, other vehicles incurred extra delays when the trucks use more than one lane on the entry (not over-tracking curbs). Typically, these delays occurred when trucks were waiting for other cars to clear from an approach/entry and when cars backed up behind trucks negotiating a roundabout approach/entry. No noticeable capacity impacts were observed for Case 2 or Case 3 roundabouts at the entries.

Depending on the length/classification of truck traversing through the roundabout, the longer trucks (such as WB-67s) did display slight delays on occasion within the circulatory roadway for both Case 1 and Case 2 roundabouts. Shorter trucks typically stayed in-lane while circulating with other traffic present and showed only a few instances where they delayed other traffic within the circulatory roadway in Case 2 roundabouts. Based on the opinion of the study team, it is likely that for Case 3 roundabouts there are no reductions in capacity within entry (same as Case 2). Occasional insignificant delays are still expected within the circulatory roadway due to speed differentials between trucks and passenger vehicles as a result of acceleration capabilities (similar to Case 1 and Case 2). Based on previous video analyses, it is typical for passenger vehicles to follow slightly behind large trucks within the circulatory roadway despite the car and trucks using different lanes. Further research would be needed in the future to expand on this topic.

## 11.0 Conclusion

Based on the data collected from representative roundabout intersections located in the states of Wisconsin, Minnesota, Michigan and Arizona, analysis was conducted to prepare a synthesis of current design practices for truck accommodations at MLRs. Based on this analysis the following was concluded:

- Based on the projected design year truck percentages summarized in **Table 3**, Case 2 and Case 3 designs were generally utilized for locations with higher truck percentages (5 percent or higher) and Case 1 designs were generally utilized for locations with lower truck percentages (5 percent or lower). No conclusion could be made regarding a preferred design method based on truck percentages as numerous factors likely influenced the decision at each site.
- Based on the volume data collected and summarized in **Table 4**, there does not appear to be a clear correlation between Case types selected for design and the peak hour entering volumes.
- Based on a review of limited crash data (summarized in **Table 5**), sideswipe crashes ranked first among the different crash types, and the percentage of crashes involving trucks is observed to be higher in Case 1 roundabouts than Case 2. In addition, the responses from roundabout owners indicated that a few Case 1 roundabouts experienced rear-end collisions that may be attributable to truck encroachment.
- The most frequently observed design characteristics of the three Case types are summarized in the table below.

**Table 11 - Frequently Observed Design Characteristics By Case Types**

| **Item** | **Case 1** | **Case 2** | **Case 3** |
|---|---|---|---|
| **Entry Radii** | 64 to 75 feet | 63 to 138 feet | 120 to 130 feet |
| **Entry Widths** | 24 to 28 feet | 32 to 34 feet | 32 to 34 feet |
| **Effective Flare** | limited or no use of flare | was implemented | was implemented |
| **ICD (2-lane MLRs)** | 162 to 200 feet* | 160 to 194 feet | 190 to 220 feet |

*In the opinion of the study team, which has designed over 600 Case 1 roundabouts in total, the average ICD of Case 1 roundabouts nationwide would likely be between 160 and 170 feet (approximately 10 to 20 feet smaller than the sample set observed for this study. Other diameters outside this range may be used provided sufficient designer skill and a balanced design is achieved.

- Regarding the various design parameters that were evaluated, Case 2 and 3 roundabouts did not appear to compromise accepted design principles as outlined in applicable guidance (i.e., FHWA Roundabout Guide, WisDOT Roundabout Guide, MnDOT Roundabout Guide).

- The review of the video footage from the selected Case 1 roundabouts indicated that in the presence of conflicting traffic trucks tracked outside their lane on entry and while circulating, and in some situations tracked over and outside the entry radius curb.
- The review of video footage summarized in **Tables 6 and 7** indicated that the presence of conflicting traffic influenced the 'driving in-lane behavior' of the trucks while entering and circulating at Case 2 and Case 3 roundabouts. When potentially conflicting traffic was present, trucks were observed to stay within lanes 91 percent of the time on the approaches and 83 percent of the time in the circulatory roadway. When potentially conflicting traffic was not present, 71 percent of trucks stayed within lane on the approaches, but only 37 percent stayed in lane in the circulatory roadway.
- The video footage also indicated that at Case 2 and Case 3 roundabouts, trucks generally stayed in lane and used the apron while entering and circulating, respectively when potentially conflicting traffic was present. However, regardless of the roundabout Case type, if no other potentially conflicting traffic was present, trucks making through or left-turn movements generally ignored lane lines and avoided driving on the central island truck apron. When approaching a truck from behind at the yield line, majority of vehicles stayed behind the truck and allowed it to enter the roundabout rather than advancing to the yield line in the adjacent lane. At Case 1 roundabouts, trucks using the outside lane for a through or right-turn movement occasionally jumped the entry radius curb to avoid encroaching on adjacent lanes.
- Evaluation of the circulatory roadway crown designs yielded inconclusive results. The available data was insufficient to identify whether using a crown or cross slope away from the central island provided enhanced operations for trucks, improved safety or capacity, or created adverse results.
- Review of truck aprons indicated that as the case type increased from 1 to 2 to 3, the average apron width also increased.
- A qualitative analysis of capacity impacts indicated that encroaching trucks entering Case 1 roundabouts contributed delays to other vehicles within the approaches. No noticeable capacity impacts were observed for Case 2 or Case 3 roundabouts at the entries.
- The response received from the trucking industry indicated that generally drivers are not confused by pavement markings or truck aprons while circulating and exiting the roundabout, but indicated that advance signage was inadequate. Many respondants were concerned about the actions of other drivers and preferred to stay in their own lane to avoid conflicts. The respondents further suggested that improvements may be helpful in the areas of signage, truck aprons on the right side curb on entries, and wider lanes to reduce conflicts between trucks and other vehicles.

It should be noted that this study has a few important limitations. Due to the small number of Case 2 and Case 3 roundabouts that have been constructed, rigorous statistical analysis could not be performed. Due to the limited sample size, only interim observations can be provided for Case 2 and Case 3 designs. Many conclusions are based on apparent trends and general observations because a rigorous statistical analysis was not possible. The results of this study are intended to serve as general observation of prevailing trends and to serve as a basis to identify and establish needs for future research.

# Appendix A

Responses received from the Agencies to the Questionnaires Sent

STH 32 / 57 – De Pere

1. What is the design vehicle for this intersection? WB-62
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available. See attached.
3. What are the existing and design year peak hour volumes for the intersection? See attached.
4. What design accommodations were made for semi trucks to navigate the intersection? WB-65 for truck apron.
    a. Inscribed circle diameter? 182'
    b. Width of truck apron? 12'
    c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face? 27.7, 30.2, 32.3, 36.5
    d. Circulatory width at the widest part? 34'
    e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face? Don't know.
    f. Any other site specific accommodations that were made for semi trucks? No.
5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? Encroach into the adjacent lane. Why? That was the guidance at the time.
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? Encroach into the adjacent lane. Why? That was the guidance at the time.
7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? Encroach into the adjacent lane. Why? That was the guidance at the time.
8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? No.
9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc. There have been either sign or light pole knock downs. Also, some of the stamped, colored concrete sidewalk behind the outside curb had to be replaced due to overtracking.
10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? No.
11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? I think some of them would and some of them would not.
12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? No. What crash data is available for the intersection? See attached.
13. Can the design plans be made available in pdf and DWG/DGN format? Yes
14. Is video footage available for the intersection? Limited
15. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? This roundabout queues heavily in the AM rush hour for NB traffic and in the PM rush hour for EB traffic.

I-43 / STH 42 – these roundabouts were designed and constructed as part of a Traffic Impact Analysis. There was not a DSR completed or even a Table 1 sign off either because it was completed a number of years ago and it was done through the TIA process.

1. What is the design vehicle for this intersection? Not sure.
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available. See attached.
3. What are the existing and design year peak hour volumes for the intersection? See attached.
4. What design accommodations were made for semi trucks to navigate the intersection? WB-65 for truck apron. See #5 below.
    a. Inscribed circle diameter? 163', 162'
    b. Width of truck apron? 14.5' 12'
    c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face? N/A
    d. Circulatory width at the widest part? 28', 28'
    e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face? N/A
    f. Any other site specific accommodations that were made for semi trucks?
5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? Encroach into the adjacent lane. Why? After designed, I asked Mark Johnson why he had the trucks encroach into the adjacent lane at the interchange, but at STH 42 / Vanguard he provided for truck hatching on the entry. He really didn't have a definitive answer why he used one approach at the interchange and a different at the next intersection.
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? Encroach into the adjacent lane. Why? Not sure.
7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? Encroach into the adjacent lane. Why? Not sure.
8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? No.
9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc. Yes, concrete sidewalk was poured behind the outside right curb on the off ramp because the semi's were staying in their own lane on the off-ramp entry, that caused the wheels to overtrack behind the curb. This had created a maintenance problem for our staff, so we added concrete sidewalk behind the curb to minimize/eliminate the maintenance problem. Semi's are also staying in lane at they go under the bridge to the next roundabout. This has caused less severe rutting behind the outside right curb.
10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? Just what is mentioned in #9.
11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? I think some would stay in lane and some would not.
12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? No. What crash data is available for the intersection? None.

13. Can the design plans be made available in pdf and DWG/DGN format? No.
14. Is video footage available for the intersection? Limited.
15. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? No.

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July 27, 2010

Dear Mr. Fidler:

The Wisconsin and Minnesota Departments of Transportation are currently evaluating design processes and practices to accommodate non-permitted trucks at multi lane roundabouts. The non-permitted truck is defined as a large legal size truck that does not require a permit to operate on the highway system. This is typically an AASHTO WB-50 through WB-67 (where allowed) and is referred to in this questionnaire as a "semi truck." We are soliciting your expert advice regarding decisions made during the design process for the 2 roundabouts located at the interchange ramps at TH 61/Jamaica Ave. in Cottage Grove.

As roundabouts have proliferated throughout the country, more attention is being paid to how semi trucks are being accommodated at multi lane roundabouts. The purpose of this questionnaire is to get input on design decisions that were made specifically for semi trucks (not Oversized/Overweight vehicles). The answers you provide will be used to generate a synthesis of current design practice. This synthesis will serve as the basis for establishing design guidelines in the future.

For Wisconsin designs, please refer to the Design Study Report, as this document will answer many of the questions presented below. For projects outside of Wisconsin, please review the applicable project documents.

1. What is the design vehicle for this intersection? *WB-62 Tractor Trailer*
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available.
   *There is a high percentage of trucks at this interchange due to the use of car hauling trucks to/from the nearby railroad auto marshalling yard and the Anderson Windows distribution center. The car hauling trucks are probably more like WB-50s. Other even larger trucks (WB-62 or WB-67) are at more typical percentage levels. Probably 8-10% overall.*
3. What are the existing and design year peak hour volumes for the intersection?
   *I have uploaded the Geometric Layout to the FTP site – which includes the traffic volumes.*
4. What design accommodations were made for semi trucks to navigate the intersection?
   a. Inscribed circle diameter? *The south roundabout is 220' on average (it spirals out the second lane for a portion). The north roundabout is 160' on the east side and the other 3/4 of the roundabout is basically a single lane roundabout with a 136' diameter.*
   b. Width of truck apron? *12' south and 14' north (face to face)*
   c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face? *See attached – 34', 26', 33', 30', and 20' on the south, and 33', 20', and 20' on the north roundabout.*
   d. Circulatory width at the widest part? *31' north and south*

   e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face? On the south: *22' for most single lane exist and 33. On the north: 19' for the single lane exits and 31 for the dual lane exit.*
   f. Any other site specific accommodations that were made for semi trucks? *There are a number of painted gores including on some of the truck-heavy approaches between the entry lanes and in several locations adjacent to the splitter islands on the exit legs.*

5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? Why? *Some of the approaches are designed for staying in lane on the approaches. The two frontage road approach legs are not designed for trucks to remain in lane.*
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? Why? *The truck aprons are designed to allow a truck in the inside lane to remain in lane while trucks in the outside lane will need to encroach on the inside lane.*
7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? Why? *Again, trucks on the inside don't encroach while trucks in the outside lane will encroach.*
8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? *The truck traffic has been functioning exceptionally well and the two major nearby truck generators have had only positive reactions.*
9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc. *No, the City has not had these issues.*
10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? *No, I have seen some trucks take gaps that made approaching vehicles shy away, but mostly reasonable gap taking and a normal acclamation process for drivers new to roundabout.*
11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? *No, they typically underutilize the truck aprons and take both lanes. They are able to stay in lane on the approach, then after entering the circulatory road, they move to the middle.*
12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? What crash data is available for the intersection? *No, there has not been a predominance of truck related crashes. MnDOT and the City have crash data that can be made available.*
13. What is the most predominant crash type at the roundabouts? *Minor rear-ends and side wipes – non-injury crashes.*
14. Can the design plans be made available in pdf and DWG/DGN format? *Yes, I'll upload key files to the FTP site.*
15. Is video footage available for the intersection? *Yes, I'll upload some. We installed an intersection camera for MnDOT that collects videos continually so more could be acquired from MnDOT. I'll include a piece from that camera and some from other cameras.*
16. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? *No, if a queue develops, it is short lived and completely clears within a short time.*

Thank you for taking the time to provide your feedback. Your answers will be used moving forward as additional guidance is provided to designers.

If you should have any questions, please feel free to contact any of the three people listed below:

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If information being provided is too large to email, an ftp site is available. Details regarding access to the site can be obtained from Wes Butch whose contact information is noted above.

Regards,

Patrick Fleming, PE

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July 27, 2010

Dear Mr. Shermo:

The Wisconsin and Minnesota Departments of Transportation are currently evaluating design processes and practices to accommodate non-permitted trucks at multi lane roundabouts. The non-permitted truck is defined as a large legal size truck that does not require a permit to operate on the highway system. This is typically an AASHTO WB-50 through WB-67 (where allowed) and is referred to in this questionnaire as a "semi truck." We are soliciting your expert advice regarding decisions made during the design process for the roundabout intersection at STH 124/Bus 29 and the roundabout intersection at USH 53/Old Town Rd in Eau Claire.

As roundabouts have proliferated throughout the country, more attention is being paid to how semi trucks are being accommodated at multi lane roundabouts. The purpose of this questionnaire is to get input on design decisions that were made specifically for semi trucks (not Oversized/Overweight vehicles). The answers you provide will be used to generate a synthesis of current design practice. This synthesis will serve as the basis for establishing design guidelines in the future.

For Wisconsin designs, please refer to the Design Study Report, as this document will answer many of the questions presented below. For projects outside of Wisconsin, please review the applicable project documents.

Patrick Fleming completed the STH 124/Bus 29 questionnaire based on Table 1, FDM 11-26-5 and the DSR (3l3g intersection).

1. What is the design vehicle for this intersection? WB-65.
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available.
   STH 124/Bus 29 ~ 40,500 ADT entering the intersection (half ADT per leg).
   Truck % breakdown: 2D=1.6%; 3AX=1.6%; 2S1 +2S2=0.7%; 3-S2=1.3%; DBL-BTM=0.3%; Total =5.5%
3. What are the existing and design year peak hour volumes for the intersection?
   Traffic information is in the Turning Movement pdf.
4. What design accommodations were made for semi trucks to navigate the intersection?
   a. Inscribed circle diameter? 200'/212'
   b. Width of truck apron? 5'
   c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face? N leg=28'; S leg=18'; E leg=28'
   d. Circulatory width at the widest part? 42' (check in dgn file)
   e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face? Measure from dgn file.
   f. Any other site specific accommodations that were made for semi

5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? No. Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? Yes. Why? Low truck volume.
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? No. Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? Yes. Why? Low truck volume.
7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? No. Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? Yes. Why? Low truck volume.
8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? Unaware of any operational problems.
9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc. No. unaware of any problems.
10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? No.
11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? N/A
12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? What crash data is available for the intersection? See UW-Tops lab study.
13. What is the most predominant crash type at the roundabouts? Unknown.
14. Can the design plans be made available in pdf and DWG/DGN format? Yes, sent in.
15. Is video footage available for the intersection? Unkown.
16. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? No.

Thank you for taking the time to provide your feedback. Your answers will be used moving forward as additional guidance is provided to designers.

If you should have any questions, please feel free to contact any of the three people listed below:

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Regards,

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July 27, 2010

Dear Mr. Souaid:

The Wisconsin and Minnesota Departments of Transportation are currently evaluating design processes and practices to accommodate non-permitted trucks at multi lane roundabouts. The non-permitted truck is defined as a large legal size truck that does not require a permit to operate on the highway system. This is typically an AASHTO WB-50 through WB-67 (where allowed) and is referred to in this questionnaire as a "semi truck." We are soliciting your expert advice regarding decisions made during the design process for the roundabout located at M-53/18.5 Mile Road in Sterling Heights.

As roundabouts have proliferated throughout the country, more attention is being paid to how semi trucks are being accommodated at multi lane roundabouts. The purpose of this questionnaire is to get input on design decisions that were made specifically for semi trucks (not Oversized/Overweight vehicles). The answers you provide will be used to generate a synthesis of current design practice. This synthesis will serve as the basis for establishing design guidelines in the future.

For Wisconsin designs, please refer to the Design Study Report, as this document will answer many of the questions presented below. For projects outside of Wisconsin, please review the applicable project documents.

1. What is the design vehicle for this intersection? WB-62
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available. I have attached the most recent traffic counts at the roundabout taken in 2009 and a study that was done 2008 but unfortunately I have no breakdown of vehicle classification. DLZ is also providing the original intersection study report which has the 2025 forecast. Please note that this roundabout essentially exceeded the 2025 traffic projection in the first year of operation, so the 2025 projections are not of much use.
3. What are the existing and design year peak hour volumes for the intersection? See answer to #2 above.
4. What design accommodations were made for semi trucks to navigate the intersection? All of these parameters are available from the DLZ .dgn file and report. This three-lane roundabout design is based on the assumption that trucks will overlap into adjacent lanes, so no specific accommodations were included for trucks other than the central island apron.
    a. Inscribed circle diameter?
    b. Width of truck apron?
    c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face?
    d. Circulatory width at the widest part?
    e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face?

    f. Any other site specific accommodations that were made for semi trucks?

5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? Why? Designed for trucks to encroach into adjacent lanes. It was designed this way in 2003 based on the belief that safety benefits of keeping the geometry as small as possible outweighed the increased risk of truck-related crashes.
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? No. Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? Why? See #5 above.
7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? No. Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? Why? See #5 above.
8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? No such comments or concerns received to date.
9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc. No maintenance work has been required at the roundabout due to tracking of semi-trucks. Both the HMA pavement and the concrete curb are still in good condition. We have had few guide signs that have been damaged due accidents.
10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? We have not experienced any operational concerns with the flow of semi-trucks.
11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? N/A
12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? No significant concerns. What crash data is available for the intersection? We have requested this from MDOT central office and will forward when available.
13. What is the most predominant crash type at the roundabouts? See #12 above.
14. Can the design plans be made available in pdf and DWG/DGN format? Provided by DLZ.
15. Is video footage available for the intersection? Provided by DLZ.
16. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? In the PM peak traffic hours (2:30 to 7:00) the EB 18.5 Mile leg into the roundabout experiences some queuing, but the congestion clears up fairly quickly. In the future adding a third lane on EB 18.5 Mile Road would be recommended.

Thank you for taking the time to provide your feedback. Your answers will be used moving forward as additional guidance is provided to designers.

If you should have any questions, please feel free to contact any of the three people listed below:

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If information being provided is too large to email, an ftp site is available. Details regarding access to the site can be obtained from Wes Butch whose contact information is noted above.

Regards,

Patrick Fleming, PE

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July 27, 2010

Dear Mr. Shermo:

The Wisconsin and Minnesota Departments of Transportation are currently evaluating design processes and practices to accommodate non-permitted trucks at multi lane roundabouts. The non-permitted truck is defined as a large legal size truck that does not require a permit to operate on the highway system. This is typically an AASHTO WB-50 through WB-67 (where allowed) and is referred to in this questionnaire as a "semi truck." We are soliciting your expert advice regarding decisions made during the design process for the roundabout intersection at STH 124/Bus 29 and the roundabout intersection at **USH 53/Old Town Rd** in Eau Claire.

As roundabouts have proliferated throughout the country, more attention is being paid to how semi trucks are being accommodated at multi lane roundabouts. The purpose of this questionnaire is to get input on design decisions that were made specifically for semi trucks (not Oversized/Overweight vehicles). The answers you provide will be used to generate a synthesis of current design practice. This synthesis will serve as the basis for establishing design guidelines in the future.

For Wisconsin designs, please refer to the Design Study Report, as this document will answer many of the questions presented below. For projects outside of Wisconsin, please review the applicable project documents.

Pat Fleming completed the questionnaire for the USH 53/Old Town Rd roundabout. Karl Kopacz was asked to check the information provided..

1. What is the design vehicle for this intersection? WB-67 to stay in-lane at the entrance. Ask Scott but I believe he commented that the circulatory roadway allowed a WB-50 or possibly a WB-62 to stay in-lane in the circulatory roadway for the through movement. Scott Ritchie should verify the design.
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available.
   Design year AADT (2026) = 6,188. The truck are 11%. There is no breakdown by truck classification.
3. What are the existing and design year peak hour volumes for the intersection?
   Existing & design year peak hour volumes are not provided. Typically the pear hour is 10% - 12% of AADT.
4. What design accommodations were made for semi trucks to navigate the intersection?
   a. Inscribed circle diameter? 190'
   b. Width of truck apron? 9'
   c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face? N leg=33', W=18', S=32', E=20'
   d. Circulatory width at the widest part? 32' is shown on completed FDM 11-26-5, Table 1. Typically the design should be 1.0 to 1.2 times wider than the widest entry? Scott may know this as well?

   e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face? Not provided.
   f. Any other site specific accommodations that were made for semi trucks? The northbound and southbound entries on USH 53 have separated lanes with the gore, between lanes.

5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Yes, for N & S leg traffic. Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? Yes, for E & W legs. Why? E & W legs have lower volume of trucks.
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? Check with Scott, but I believe for a through movement and with a WB-50 or possibly a WB-62. Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? Why?
7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? Check with Scott. It appears other folks in the Region are unfamiliar with that level of design effort. Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? Why?
8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? No comments from the Region.
9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc. None that the Region has identified.
10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? No concerns expressed.
11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? I believe the TOPS lab was going to video tape. Other than that there is no info available.
12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? What crash data is available for the intersection? UW TOPS lab would have the data..
13. What is the most predominant crash type at the roundabouts? Unkown.
14. Can the design plans be made available in pdf and DWG/DGN format? Yes, that has been sent in/provided.
15. Is video footage available for the intersection? I believe this is a location the UW TOPS lab video taped.
16. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? Very, very low AADT. I would not anticipate any congestion.

Thank you for taking the time to provide your feedback. Your answers will be used moving forward as additional guidance is provided to designers.

If you should have any questions, please feel free to contact any of the three people listed below:

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Regards,

Patrick Fleming, PE

STH 42 / Vanguard Drive – this roundabout was designed and constructed as part of a Traffic Impact Analysis. There was not a DSR completed or even a Table 1 sign off either because it was completed a number of years ago and it was done through the TIA process.

1. What is the design vehicle for this intersection? Not sure.
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available. See attached.
3. What are the existing and design year peak hour volumes for the intersection? See attached.
4. What design accommodations were made for semi trucks to navigate the intersection? WB-65 for truck apron. See #5 below.
    a. Inscribed circle diameter? 196'
    b. Width of truck apron? 14.5
    c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face? N/A
    d. Circulatory width at the widest part? 28'
    e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face? N/A
    f. Any other site specific accommodations that were made for semi trucks?
5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? The entry was designed for semi trucks to stay in their lane to the yield line. Why? Mark Johnson felt it was important because this intersection was near a Wal-Mart, Menards and truck stop.
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? Encroach into the adjacent lane. Why? Not sure.
7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? Encroach into the adjacent lane. Why? Not sure.
8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? No.
9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc. No.
10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? No.
11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? It is designed to stay in lane on entry and they generally do on entry, but they need to overtrack throughout the roundabout.
12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? No. What crash data is available for the intersection? None.
13. Can the design plans be made available in pdf and DWG/DGN format? Yes
14. Is video footage available for the intersection? Limited
15. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? No.

1. What is the design vehicle for this intersection?

   WB-65

2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available.

   Moorland has 48,400 NB and 29,500 SB for the projected year A.A.D.T. 2026. The truck percentage is 5.3, but there is no breakdown by truck classification.
   Please see attached *Exhibit A, Plan Cover Sheet.*

3. What are the existing and design year peak hour volumes for the intersection?

   Please see attached *Exhibit B, Peak Design Hour Traffic Volumes.*

4. What design accommodations were made for semi trucks to navigate the intersection?

   Truck aprons at the central islands, painted chevrons between the entry lanes, and wide outside lanes at both roundabouts.

   a. Inscribed circle diameter?

      North roundabout – 280' face of curb to face of curb (f/c to f/c) for 3-lane section, 250' f/c to f/c for 2-lane section.
      South roundabout – 192' f/c to f/c

   b. Width of truck apron?

      North roundabout – 10'
      South roundabout – 8' and a spiral

   c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face?

      North roundabout –
      46.6' f/c to f/c SB Moorland,
      32' f/c to f/c NB Moorland,
      19' f/c to f/c SB I-43 off-ramp through/left,
      22.9' f/c to f/c SB I-43 off-ramp right, and
      30.7' f/c to f/c SB I-43 off-ramp protected right
      South roundabout –
      32.3' f/c to f/c SB Moorland,
      35.25' f/c to f/c NB Moorland,
      24.8' f/c to f/c Rockridge Road (movie theatre exit), and
      32.8' f/c to f/c NB I-43 exit

   d. Circulatory width at the widest part?

      North roundabout – 48.5' f/c to f/c (3-lanes)
      South roundabout – 32' f/c to f/c (2-lanes)

e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face?

North roundabout –
    40.7' f/c to f/c SB Moorland (3-lanes) and
    31.5' f/c to f/c NB Moorland
South roundabout –
    30.0' f/c to f/c SB Moorland,
    29.0' f/c to f/c NB Moorland, and
    24.2' f/c to f/c Rockridge Road (movie theatre entrance)

f. Any other site specific accommodations that were made for semi trucks?

5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? Why?

   The roundabout was designed for semi-trucks (WB-65) to encroach into adjacent lanes for both entering the roundabout and circulating the roundabout.

   The roundabouts were designed by Mark Johnson. The original design had semi-trucks encroaching into adjacent lanes. We were not comfortable with this and requested that Mark make some modifications to increase the road width and add painted gores between some of the lanes at the entry. At a minimum we wanted there to be 8' between a trucks encroachment and the curb and gutter so a car would have refuge without being forced onto the truck apron. However, after he made this design he discussed it with Barry Crown. Fastest path speeds were being violated due to the widening to accommodate trucks which Barry Crown found to be unacceptable. The design was then made to be as wide as possible with the fastest path design criteria being met. The painted gores were added at the entries to help accommodate trucks and keep passenger vehicles in their lane.

6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? Why?

   Please see question 5. Also, the middle and outside lanes were designed to be wider to help accommodate semi-trucks.

7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? Why?

   No, the design was developed for semi-trucks to encroach into adjacent lanes during some exit movements.

8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout?

   Before construction began a New Berlin truck company had contacted us. However, since then we have not been formally contacted by any truck drivers or trucking companies regarding the roundabout design.

9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc.

   Yes, there has been curb damage, over tracking the curb and gutter, and sign knock downs. We have added a concrete pads behind the curb and gutter on the south roundabout at the southwest, northeast and northwest quadrants to control the rutting in the topsoil and curb damage due to semi-trucks over tracking the curb and gutter. This concrete pad was located mainly at the entry radii. Signs that were knocked down were replaced, but were offset from the roadway further. Also, "WIDE TURNING TRUCKS" signs have been added to notify drivers of semi-trucks over tracking lanes while circulating the roundabout.

10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks?

   Yes, there are some operational concerns regarding the flow of semi trucks. However, this concern is with the need to educate the driving public not to enter and circulate a roundabout next to a semi-truck. At this particular roundabout, the addition of "WIDE TURNING TRUCKS" signs has been made to notify drivers.

11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way?

   The roundabouts were not designed to accommodate trucks staying in lane. However, it has been observed, mostly in the SB outside lane in the north roundabout, that when trucks drive at appropriate speeds, they are able to navigate the roundabouts without lane over tracking. When trucks go too fast, which is more often the case, they over track.

12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? What crash data is available for the intersection?

   There have been five crashes involving a semi-truck, two on the north roundabout and three at the south roundabout. All of the crashes were due to the trailer over tracking lanes while another vehicle was in an adjacent lane.

   Please see attached *Exhibit C, Recorded Crash Data* and *Exhibit D, Police Reports –Truck Crashes* for more crash data.

13. What is the most predominant crash type at the roundabouts?

   As said in question 5, there have been five crashes; there is not a pattern of recurring crash. In two of the three crashes in the south roundabout the truck was traveling NB; those two crashes were from over two years ago and have not occurred since.

   The one similarity between the crashes is that the semi-truck was in the outside lane and encroached into the adjacent inside or middle lane. If the truck was driving the inside lane it would have obviously tracked onto the truck apron and not struck a vehicle.

   Since the roundabouts have been fully operational we have seen patterns with passenger vehicles. Predominate crashes at the north roundabout are rear ends of vehicles traveling SB Moorland. The rear ends are due to one vehicle yielding, but the second vehicle failing to yield and strike the first vehicle. Predominate crashes at the south roundabout is of vehicles exiting the NB I-43 off ramp entering the roundabout and fail to yield, misjudge the gap, or do not understand circulating traffic movements and sideswipe a vehicle circulating the roundabout.

14. Can the design plans be made available in pdf and DWG/DGN format?

    Yes, the plans are located N:\PDS\Projects\10901770\pse\10901770_pln.pdf. There have been changes to the plan in construction in order to meet FDM standards and address crash concerns.

    The south roundabout originally had a spiral designated only by pavement marking. That was replaced with a mountable curb and gutter spiral in June of 2009. Overhead signing with lane designation replaced the diagrammatic sign SB Moorland on the south roundabout in April of 2009. All pavement marking in the roundabouts were replaced with high visibility and anti skid pavement marking (see asbuilt attached for exact locations). Fish-hook pavement marking was not used. All pavement marking arrows were made to match signage.

    Please see attached *Exhibit E, RNDABTCHANGES.DGN* for a Microstation plan view of the updated roundabouts.
    *Exhibit F, Asbuilt PM* for plan view of the roundabout changes that are going to be submitted with the asbuilts along with the *Exhibit G, Overhead Sign –SB Moorland, S. Rndabt* that was added for SB Moorland the south roundabout.

15. Is video footage available for the intersection?

    Yes, we have recorded video and the traffic cameras for I-43 can be turned to view the roundabouts with some obstructed views.

16. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches?

    As you may be aware, the SB I-43 off-ramp at the north roundabout experienced major back-ups that queued onto the auxiliary lane of the freeway. This was only a temporary problem due to the construction at I-43/Racine (CTH Y), the next exit to the south on I-43. That interchange had been constructed under closed traffic conditions and the detour was sent to the Moorland interchange which drastically increased the volume at the I-43/Moorland interchange - specifically more than DOUBLING THE DESIGN YEAR VOLUME of the SB I-43 off ramp at the North roundabout. To mitigate the increased volume, flagging was used at the north roundabout NB Moorland traffic to allow gaps for the SB off ramp traffic to clear. On November 3rd 2009 the I-43/Racine (CTH Y) interchange roundabout opened up and we have not experienced this problem since.

    Also, the signalized intersection of Moorland and Beloit – close proximity north of the north roundabout – was under construction to update the intersection for a Children's Hospital satellite building on the NW quadrant. The temporary signals that were used during construction were not timed properly and created queues that backed up into the north roundabout. On November 16th 2009 signal improvements at the intersection were finished and the queuing problem went away.

    Otherwise, since the roundabout has been fully operational and these problems have been dealt with the queuing that occurs are within expectations.

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July 27, 2010

Tegner Street and US 93 Roundabout

Opened in September 2009

For Wisconsin designs, please refer to the Design Study Report, as this document will answer many of the questions presented below. For projects outside of Wisconsin, please review the applicable project documents.

1. What is the design vehicle for this intersection?
Answer: WB 67
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available.
3. What are the existing and design year peak hour volumes for the intersection?
4. What design accommodations were made for semi trucks to navigate the intersection?
    a. Inscribed circle diameter? Answer: See attachments
    b. Width of truck apron? Answer: See attachments
    c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face? Answer: See attachments
    d. Circulatory width at the widest part? Answer: See attachments
    e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face? Answer: See attachments
    f. Any other site specific accommodations that were made for semi trucks?
5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? Why? Answer: Approaches are designed for WB-67 semitrucks to stay in lane. Truck make up over 25% of the overall volumes.
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? Why? Answer: Roundabout does not accommodate trucks to stay in lane inside roundabout. Roundabout was redesigned after the footprint was established to a dual SB left turn movement, based on traffic information.
7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? Why?
8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? Answer: No.
9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc. Answer: No.

10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? Answer: No.
11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? Answer: Trucks use the extra width on approaches when necessary.
12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? What crash data is available for the intersection? Answer: A complete accident report is not available yet.
13. What is the most predominant crash type at the roundabouts? Answer: I don't have the official information yet, however according to sources, it is drivers not allowing sufficient space for semi-truck tracking as the trucks navigate thru the roundabout.
14. Can the design plans be made available in pdf and DWG/DGN format? Answer: yes.
15. Is video footage available for the intersection? Answer: No.
16. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? Answer: No

Thank you for taking the time to provide your feedback. Your answers will be used moving forward as additional guidance is provided to designers.

If you should have any questions, please feel free to contact any of the three people listed below:

Patrick Fleming, P.E.
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If information being provided is too large to email, an ftp site is available. Details regarding access to the site can be obtained from Wes Butch whose contact information is noted above.

Regards,

Patrick Fleming, PE

**Wisconsin Department of Transportation**

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July 27, 2010

Tegner Street and US 93 Roundabout

Opened in September 2009

For Wisconsin designs, please refer to the Design Study Report, as this document will answer many of the questions presented below. For projects outside of Wisconsin, please review the applicable project documents.

1. What is the design vehicle for this intersection?
Answer: WB 67
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available.
3. What are the existing and design year peak hour volumes for the intersection?
4. What design accommodations were made for semi trucks to navigate the intersection?
    a. Inscribed circle diameter? Answer: See attachments
    b. Width of truck apron? Answer: See attachments
    c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face? Answer: See attachments
    d. Circulatory width at the widest part? Answer: See attachments
    e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face? Answer: See attachments
    f. Any other site specific accommodations that were made for semi trucks?
5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? Why? Answer: Approaches are designed for WB-67 semitrucks to stay in lane. Truck make up over 25% of the overall volumes.
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? Why? Answer: Roundabout does not accommodate trucks to stay in lane inside roundabout. Roundabout was redesigned after the footprint was established to a dual SB left turn movement, based on traffic information.
7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? Why?
8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? Answer: No.
9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc. Answer: No.

10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? Answer: No.
11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? Answer: Trucks use the extra width on approaches when necessary.
12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? What crash data is available for the intersection? Answer: A complete accident report is not available yet.
13. What is the most predominant crash type at the roundabouts? Answer: I don't have the official information yet, however according to sources, it is drivers not allowing sufficient space for semi-truck tracking as the trucks navigate thru the roundabout.
14. Can the design plans be made available in pdf and DWG/DGN format? Answer: yes.
15. Is video footage available for the intersection? Answer: No.
16. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? Answer: No

Thank you for taking the time to provide your feedback. Your answers will be used moving forward as additional guidance is provided to designers.

If you should have any questions, please feel free to contact any of the three people listed below:

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If information being provided is too large to email, an ftp site is available. Details regarding access to the site can be obtained from Wes Butch whose contact information is noted above.

Regards,

Patrick Fleming, PE

From: Fleming, Patrick - DOT [Patrick.Fleming@dot.wi.gov]
Sent: Monday, August 02, 2010 9:44 AM
To: 'AStump@azdot.gov'
Cc: Wes Butch
Subject: FW: Joint MnDOT/WisDOT roundabout study
Attachments: ORE_R4S Review Package 080401.pdf; ORE_R4S Fast Paths 3ln 080619.pdf; ORE_R4S Ultimate Geometry.pdf; SR 89 Lane Configuration 070301.pdf; SR 89 Analysis_3 Lane Ultimate_.pdf

Alvin, Thank you so much for your help in collecting this information. Would it be possible to get the plan sheets you have included as pdf's in a dgn or dwg format?

I look forward to receiving the information for the Wickenburg roundabouts.

I forwarded your information to DLZ in Michigan who is the lead consultant in this effort.

Pat

From: Alvin Stump [mailto:AStump@azdot.gov]
Sent: Monday, August 02, 2010 7:31 AM
To: Fleming, Patrick - DOT
Subject: RE: Joint MnDOT/WisDOT roundabout study

Pat,

Here are the answers your questions on the Chino roundabout. I have also attached project files. I will send separate emails for the Wickenburg roundabouts.

Thanks,

Alvin

1. What is the design vehicle for this intersection? WB-67
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available. See attachment
3. What are the existing and design year peak hour volumes for the intersection? See attachment
4. What design accommodations were made for semi trucks to navigate the intersection? See attachment
a. Inscribed circle diameter?
b. Width of truck apron?
c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face?
d. Circulatory width at the widest part?
e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face?
f. Any other site specific accommodations that were made for semi trucks?
5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? Why? The roundabout approaches were designed for WB-67s to utilize the truck cross hatching between lanes, so that they will not encroach into the other lane. The reasoning is that there was a large public concern about trucks needing to stay in lane, along with future capacity.
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into

adjacent lanes while circulating through the roundabout? Why? The roundabout is designed for WB-67s to stay in lane for thru movements. The roundabout is not designed for circulating WB-67 trucks to stay in lane. The reason for the "in lane" design on thru movements was in response to local requirement.

7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? Why? Yes (attachments). Reason: same as above.

8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? No.

9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc. No.

10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? No.

11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? My personal observation is that they do when they have adjacent traffic. If they enter the roundabout alone, they will track over.

12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? What crash data is available for the intersection? Accident data has not been collected yet.

13. What is the most predominant crash type at the roundabouts? Accident data has not been collected yet.

14. Can the design plans be made available in pdf and DWG/DGN format? Yes.

15. Is video footage available for the intersection? No.

16. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? Yes.

Alvin Stump, P.E.
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From: Fleming, Patrick - DOT [mailto:Patrick.Fleming@dot.wi.gov]
Sent: Tuesday, July 27, 2010 12:21 PM
To: Alvin Stump
Subject: Joint MnDOT/WisDOT roundabout study

I have attached a letter requesting design and operations information for roundabouts I believe you were involved with. If this should go to someone else please let me know who that is, or please forward to that person.... Thank you.

Patrick Fleming, PE
WisDOT, Standards Development Engineer
4802 Sheboygan Ave, Room 651
Madison, WI 53707

Telephone: 608-266-8486
Email: patrick.fleming@dot.wi.gov

Ashland / 8th & 9th

1. What is the design vehicle for this intersection? WB-67.
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available. See attached.
3. What are the existing and design year peak hour volumes for the intersection? See attached.
4. What design accommodations were made for semi trucks to navigate the intersection? #5 below.
    a. Inscribed circle diameter? 196'
    b. Width of truck apron? 14.5
    c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face? 34', 28', 34', 26.9'
    d. Circulatory width at the widest part? 28'
    e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face? N/A
    f. Any other site specific accommodations that were made for semi trucks? N/A
5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? The entry was designed for semi trucks to stay in their lane to the yield line. Why? We as a Region felt it was a good location to try this design practice.
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? Encroach into the adjacent lane. Why? Not sure.
7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? Encroach into the adjacent lane. Why? Not sure.
8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? The roundabout just opened on 8-6-10.
9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc. The roundabout just opened on 8-6-10.
10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? The roundabout just opened on 8-6-10.
11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? The roundabout just opened on 8-6-10.
12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? The roundabout just opened on 8-6-10.What crash data is available for the intersection? The roundabout just opened on 8-6-10.
13. Can the design plans be made available in pdf and DWG/DGN format? Yes
14. Is video footage available for the intersection? No.
15. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? The roundabout just opened on 8-6-10.

**Wisconsin Department of Transportation**

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July 27, 2010

Dear Mr. Berthold:

The Wisconsin and Minnesota Departments of Transportation are currently evaluating design processes and practices to accommodate non-permitted trucks at multi lane roundabouts. The non-permitted truck is defined as a large legal size truck that does not require a permit to operate on the highway system. This is typically an AASHTO WB-50 through WB-67 (where allowed) and is referred to in this questionnaire as a "semi truck." We are soliciting your expert advice regarding decisions made during the design process for the 2 roundabouts in Medford at STH 13/Ann's Way and STH 13/Allman Ave.

As roundabouts have proliferated throughout the country, more attention is being paid to how semi trucks are being accommodated at multi lane roundabouts. The purpose of this questionnaire is to get input on design decisions that were made specifically for semi trucks (not Oversized/Overweight vehicles). The answers you provide will be used to generate a synthesis of current design practice. This synthesis will serve as the basis for establishing design guidelines in the future.

For Wisconsin designs, please refer to the Design Study Report, as this document will answer many of the questions presented below. For projects outside of Wisconsin, please review the applicable project documents.

Patrick Fleming has completed this questionnaire from DSR information as shown in red..

1. What is the design vehicle for this intersection? WB-65 for both roundabouts.
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available.
   Ann's Way ~ 21,800 ADT entering; Allman Ave. ~ 27,250 ADT
   Truck % breakdown: 2D = 3.3%; 3AX = 8.7%; 2S1+2S2 = 1.4%; 3-S2 = 5.1%; DBL-BTM = 0.1%; Total = 18.6%
3. What are the existing and design year peak hour volumes for the intersection?
   Traffic information is in the DSR Exhibit 4:
4. What design accommodations were made for semi trucks to navigate the intersection?
   a. Inscribed circle diameter? Ann's Way = 188'/209'; Allman Ave.= 190'
   b. Width of truck apron? 10' for both roundabouts.
   c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face? Ann's Way- N & E legs =34'; W & S legs = 28';
   Allman Ave. – N leg=32',W = 20.4', S=33.7', E=18'
   d. Circulatory width at the widest part? Ann's Way = 36'; Allman Ave. = 32'
   e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face? Ann's Way – N leg=31', W=18', S=30', E =20';
   Allman Ave – N leg=27', W =17', S=31', E=18'

   f. Any other site specific accommodations that were made for semi trucks? Yes.

5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Yes, both roundabouts are designed to allow trucks to stay in-lane at entry along STH 13. Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? No. Why? 18.6% trucks.
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? Yes, for both roundabouts along STH 13 the through movement which is the predominant movement for trucks. Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? No. Why? 18.6% trucks.
7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? Yes, for both roundabouts along STH 13. Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? From the side road. Why? 18.6% trucks.
8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? Scheduled construction is 2011.
9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? For example, has there been any problems with curb damage, sign knock downs, etc. Scheduled construction is 2011.
10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? Scheduled construction is 2011.
11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? Scheduled construction is 2011.
12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? What crash data is available for the intersection? Scheduled construction is 2011.
13. What is the most predominant crash type at the roundabouts? Scheduled construction is 2011.
14. Can the design plans be made available in pdf and DWG/DGN format? Yes, sent in already.
15. Is video footage available for the intersection? No, Scheduled construction is 2011..
16. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? Scheduled construction is 2011.

Thank you for taking the time to provide your feedback. Your answers will be used moving forward as additional guidance is provided to designers.

If you should have any questions, please feel free to contact any of the three people listed below:

Patrick Fleming, P.E.

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November 3, 2010

Dear Bob:

The Wisconsin and Minnesota Departments of Transportation are currently evaluating design processes and practices to accommodate non-permitted trucks at multi lane roundabouts. The non-permitted truck is defined as a large legal size truck that does not require a permit to operate on the highway system. This is typically an AASHTO WB-50 through WB-67 (where allowed) and is referred to in this questionnaire as a "semi truck." We are soliciting your expert advice regarding decisions made during the design process for the roundabout intersection at the Lien Rd/Thompson Dr intersection in Madison near East Town.

As roundabouts have proliferated throughout the country, more attention is being paid to how semi trucks are being accommodated at multi lane roundabouts. The purpose of this questionnaire is to get input on design decisions that were made specifically for semi trucks (not Oversized/Overweight vehicles). The answers you provide will be used to generate a synthesis of current design practice. This synthesis will serve as the basis for establishing design guidelines in the future.

For Wisconsin designs, please refer to the Design Study Report, as this document will answer many of the questions presented below. For projects outside of Wisconsin, please review the applicable project documents.

1. What is the design vehicle for this intersection? WB-67 to curb face.
2. What are the projected design year traffic volumes (AADT) and truck percentages for the intersection? A breakdown of percent trucks by classification of truck would be very helpful if available.
3. What are the existing and design year peak hour volumes for the intersection?
4. What design accommodations were made for semi trucks to navigate the intersection?
    a. Inscribed circle diameter? 202'
    b. Width of truck apron? 21.5' face to face
    c. Entry width at a point just prior to entering the circle, measured between the splitter island curb face and the outside curb face? North – 32.65', West – 33.00', South – 32.85', East – 32.42'
    d. Circulatory width at the widest part? 33.00'
    e. Exit width at a point just after leaving the circle, measured between the splitter island curb face and the outside curb face? North – 33.30', West -33.41, South – 32.83', East 29.19'
    f. Any other site specific accommodations that were made for semi trucks? No
5. For trucks entering the roundabout, was the design developed for a semi truck to stay in lane? Yes. Or was the design developed for a semi truck to encroach into adjacent lanes to enter the roundabout? No. Why? There are many delivery truck that use this route to go-to and from East Town Mall.
6. For trucks circulating in the roundabout, was the design developed for the semi truck to stay in lane? Yes. The inside lane was designed to be marked as 15' wide, from the face of curb. A WB67 in the circulatory roadway

infringes on that 15' marked lane, but a 12' lane width remains clear adjacent to the WB67. The inside lane was designed a little wider than the usual 13' or 14' width to reduce some potential path overlap on exit and to encourage buses and trucks to use both entry lanes. A City Bus can use the inside lane without having to mount the truck apron. Or was the design developed for the semi truck to encroach into adjacent lanes while circulating through the roundabout? See above. Why? To better accommodate delivery trucks to-from East Town.

7. For trucks exiting the roundabout, was the design developed for the semi truck to stay in lane? Yes. Or was the design developed for the semi truck to encroach into adjacent lanes to exit the roundabout? No. Why? To better accommodate delivery trucks to-from East Town Mall.
8. Since the roundabout has been built, have truck drivers or trucking companies contacted you with any concerns regarding the design of the roundabout? No.
9. Since the roundabout has been built, have there been maintenance requirements due to the tracking of semi trucks? No. For example, has there been any problems with curb damage, sign knock downs, etc.
10. Since the roundabout has been built, do you have any operational concerns regarding the flow of semi trucks? No.
11. If the roundabout was designed to accommodate semi trucks staying in lane, do semi trucks actually drive this way? I have observed some large trucks intentionally taking both lanes during times of lower volumes. Behavior during high volumes will be observed during peak shopping season.
12. Since the roundabout has been built, do you have any concerns regarding crashes involving semi trucks? What crash data is available for the intersection?
13. What is the most predominant crash type at the roundabouts?
14. Can the design plans be made available in pdf and DWG/DGN format? Thanks Bob, you already provided them.
15. Is video footage available for the intersection? The videos you are taking the day after Thanksgiving would be great if you feel they may be available soon after the taping...
16. During peak traffic hours, does the roundabout experience congestion/queuing on any of the approaches? No congestion yet, but will observe during peak shopping days.

Thank you for taking the time to provide your feedback. Your answers will be used moving forward as additional guidance is provided to designers.

If you should have any questions, please feel free to contact any of the three people listed below:

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If information being provided is too large to email, an ftp site is available. Details regarding access to the site can be obtained from Wes Butch whose contact information is noted above.

Regards,

Patrick Fleming, PE

# Appendix B

## Questionnaire Sent to ATA Affiliates

## QUESTIONNAIRE SENT TO AMERICAN TRUCKING ASSOCIATION (ATA) AFFILIATES

1.) Do you have company policies (or specific training) for your drivers as it relates to navigating multilane roundabouts (roundabouts with two or more lanes)?

2.) Please review the roundabout diagram below. Have your drivers expressed difficulty in any one of the following scenarios:

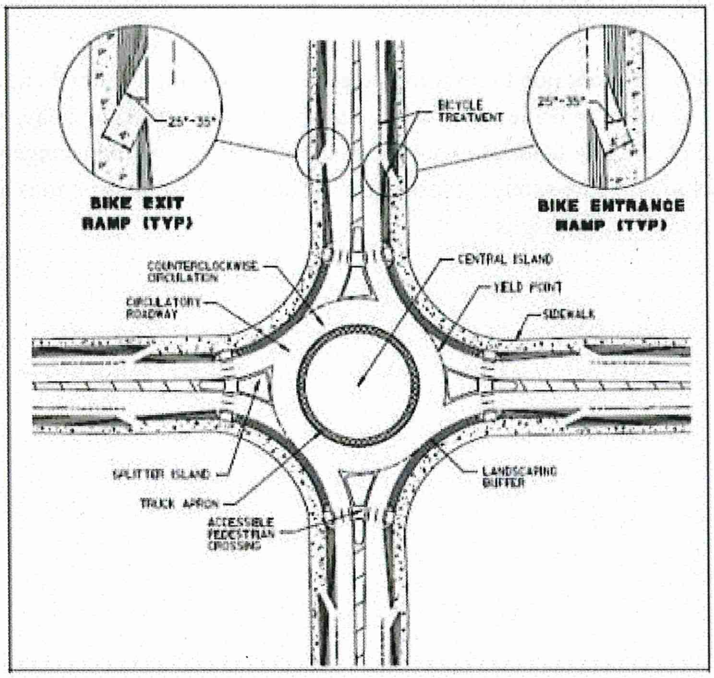


*Figure 1. Roundabout Features*

a.) When approaching a roundabout, the signage, pavement marking, or colored truck apron is confusing?: Yes or No

b.) When circulating in a roundabout, the signage, pavement marking, or colored truck apron is confusing?: Yes or No

c.) When exiting a roundabout, the signage, pavement marking, or colored truck apron is confusing?: Yes or No

d.) Please have your drivers cite specific examples and locations of roundabouts that provide adequate signing and marking or roundabouts that pose concern with regard to signing and marking?

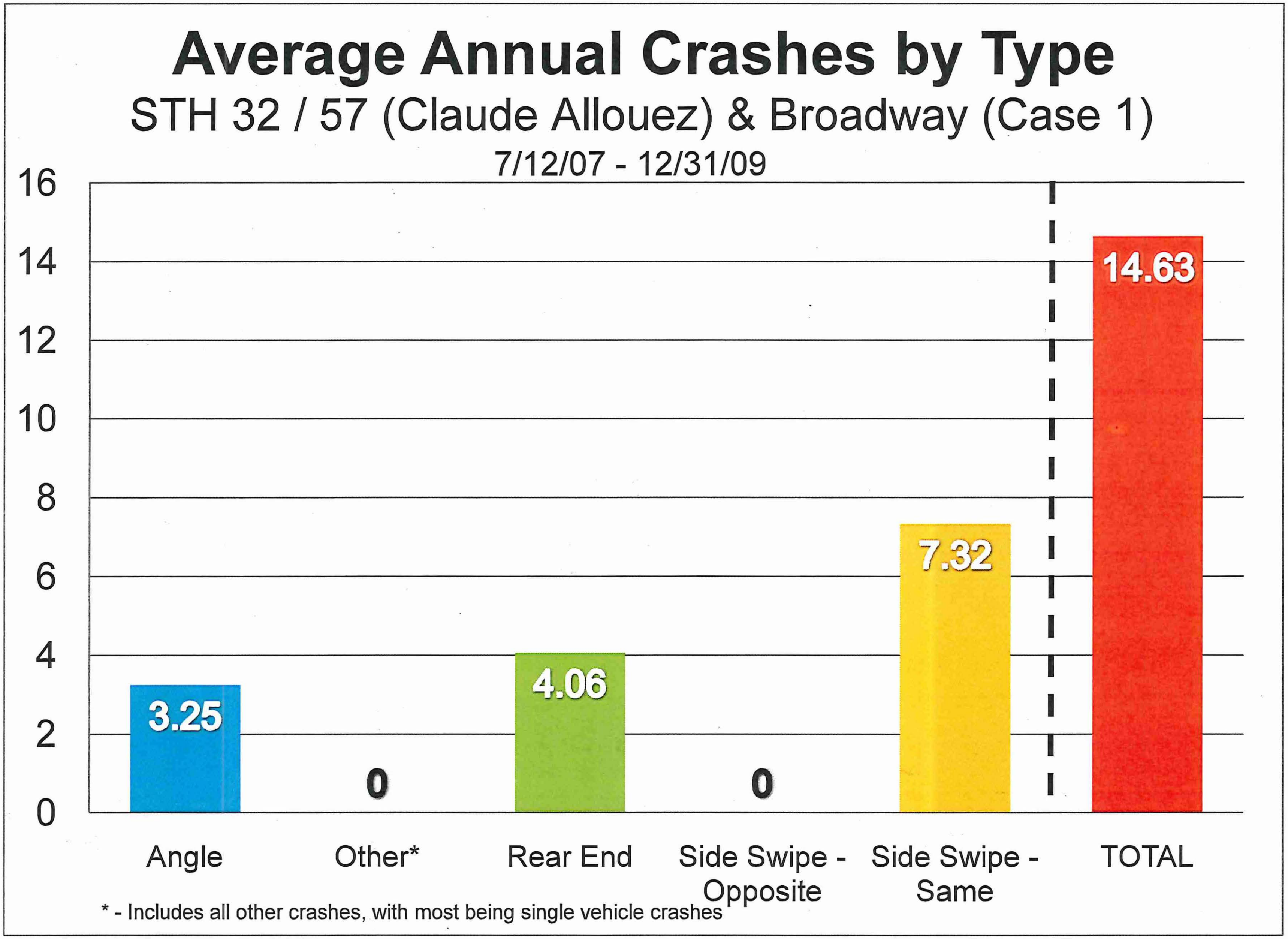
3.) In multilane roundabouts semi trucks are allowed to off track on the truck apron for the inside lane within the roundabout. For the additional or outer lane(s) would it be better to stay in lane or allow trucks to off track into the inside circulating lane?

4.) The ultimate goal in design is to balance the needs of the traveling public with the physical constraints of the intersection. There are times when the physical constraints of the intersection require modifications to the design which lead to inconsistencies for trucks. When these modifications are made, what would be the preferred indicator to notify the truck driver entering a roundabout whether or not the driver should stay in lane or if the driver is required to straddle lanes on entry and exit of a multi lane roundabout?

5.) Roundabouts will continue to be constructed due to their high safety benefits. The key will be how to design them to achieve the safety benefits without creating delays or bottlenecks for freight. Are there any features about roundabouts that you would change to make it better for semi trucks to navigate safely? Please provide any specific intersections and locations of preferred roundabout designs.

## Appendix C

Crash Data Obtained from TOPS Lab

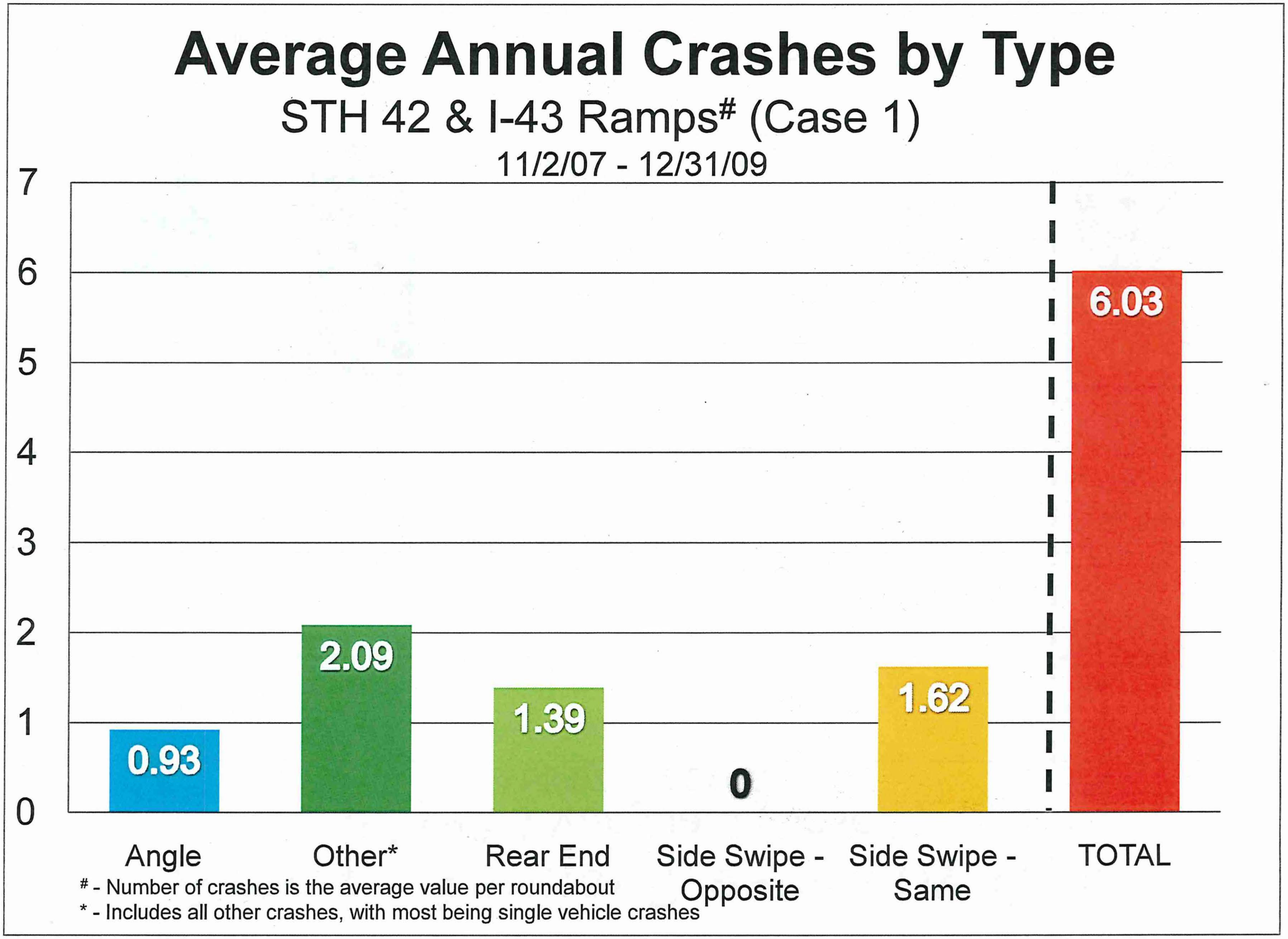


Average Annual Crashes by Type

STH 32 / 57 (Claude Allouez) & Broadway (Case 1)

7/12/07 - 12/31/09

* - Includes all other crashes, with most being single vehicle crashes



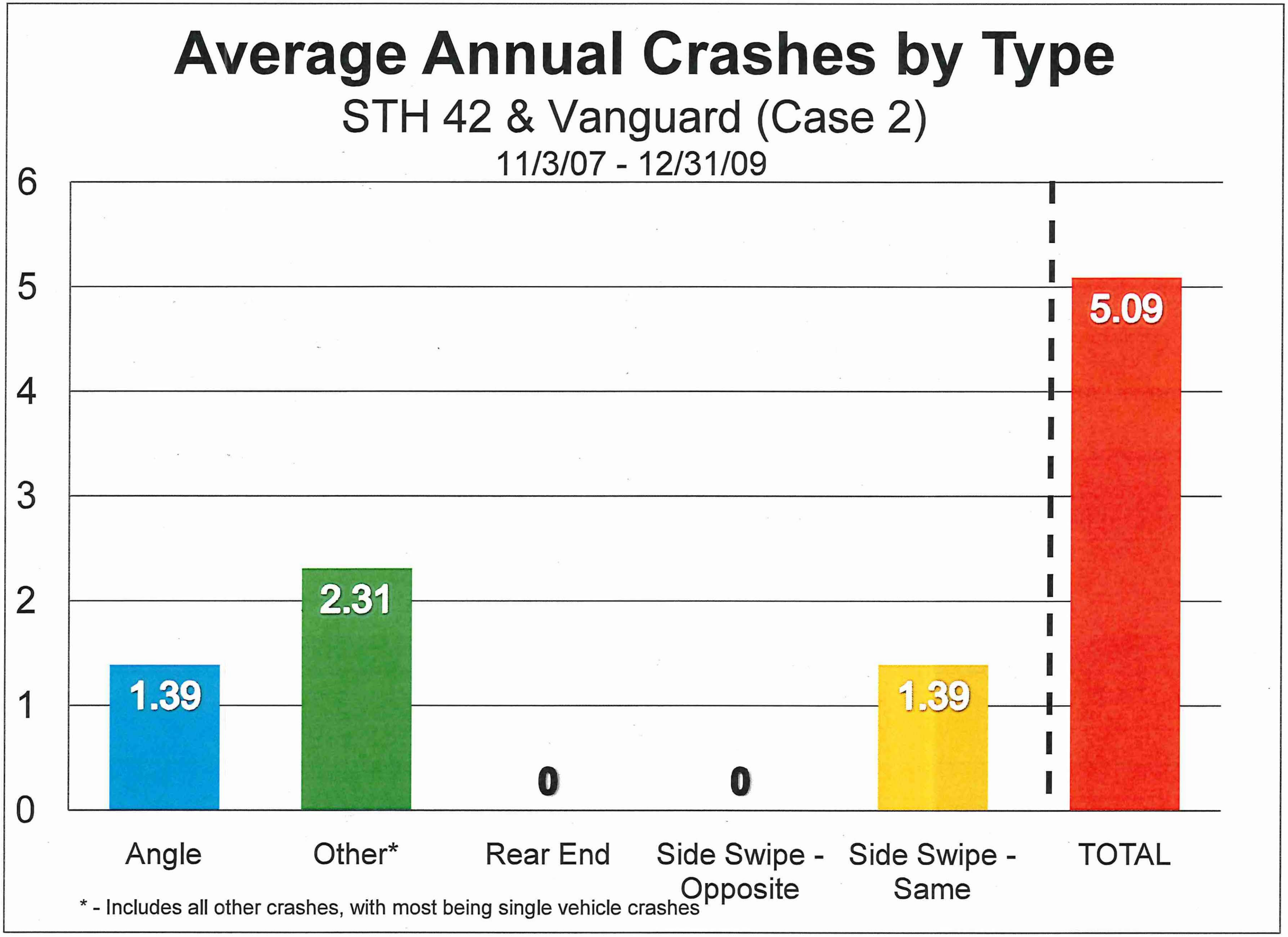
## Average Annual Crashes by Type

STH 42 & I-43 Ramps# (Case 1)

11/2/07 - 12/31/09

# - Number of crashes is the average value per roundabout

* - Includes all other crashes, with most being single vehicle crashes



Average Annual Crashes by Type

STH 42 & Vanguard (Case 2)

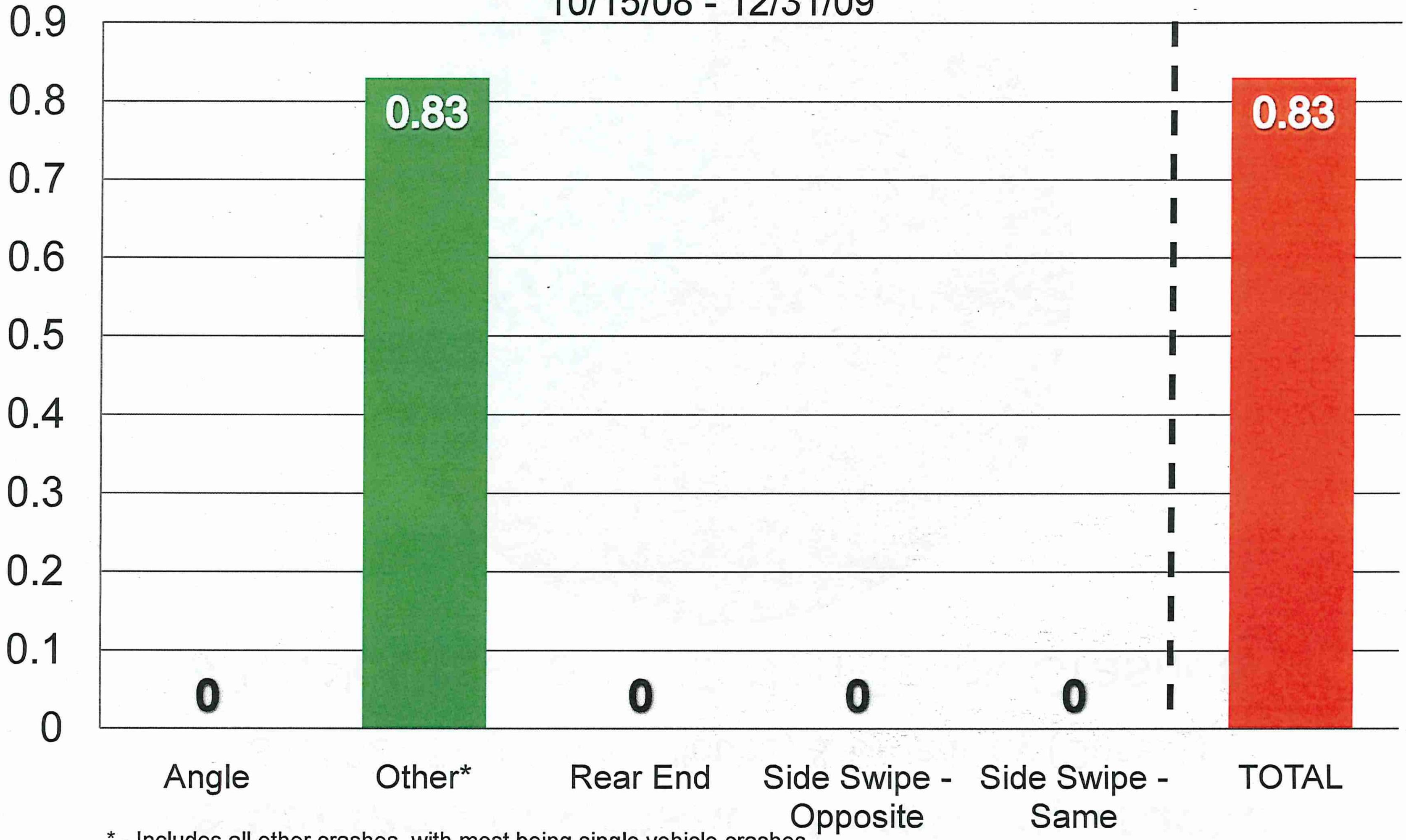
11/3/07 - 12/31/09

* - Includes all other crashes, with most being single vehicle crashes

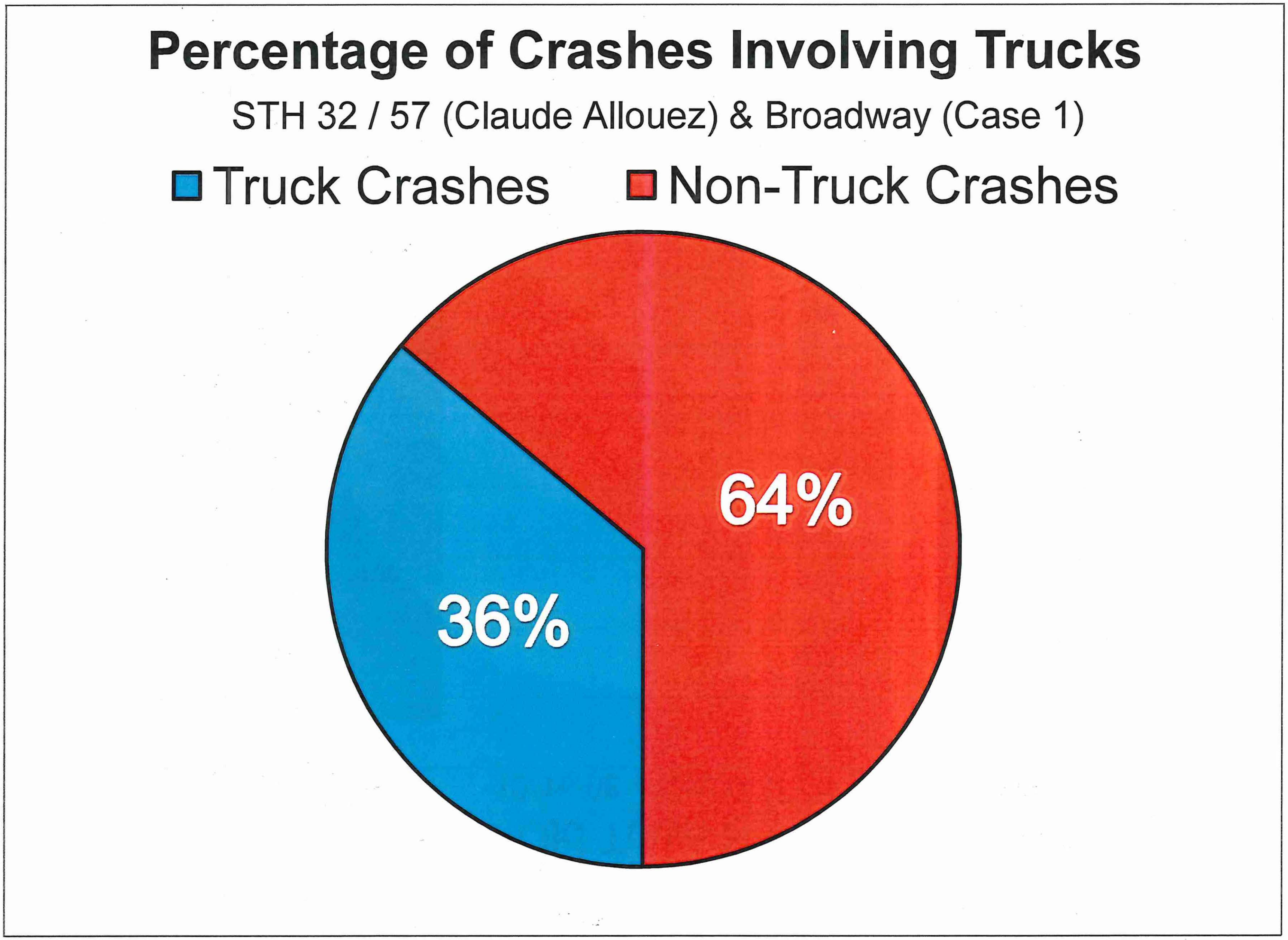
# Average Annual Crashes by Type

## STH 53 & Old Town Hall (Case 2)

10/15/08 - 12/31/09



* - Includes all other crashes, with most being single vehicle crashes

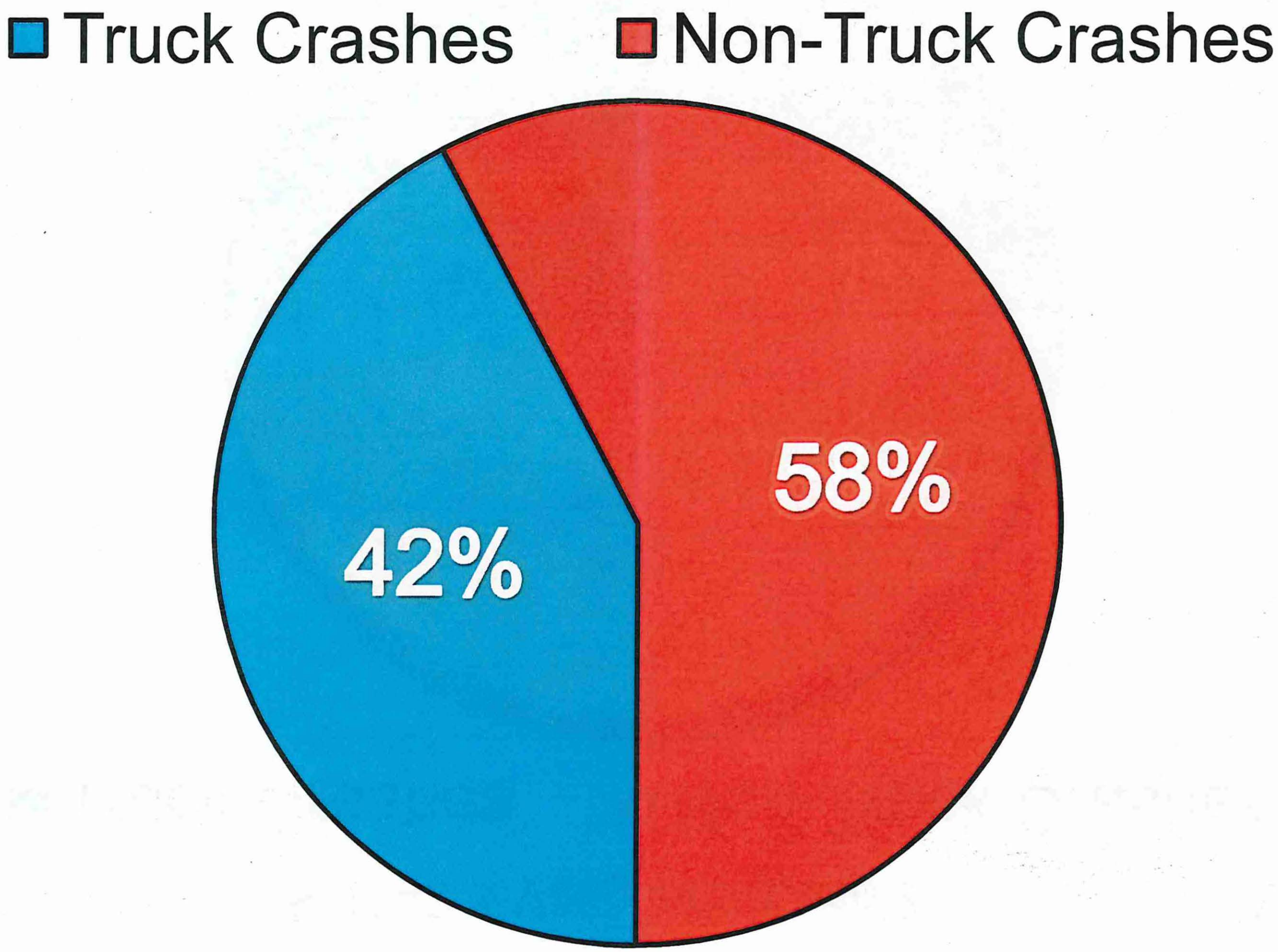


Percentage of Crashes Involving Trucks

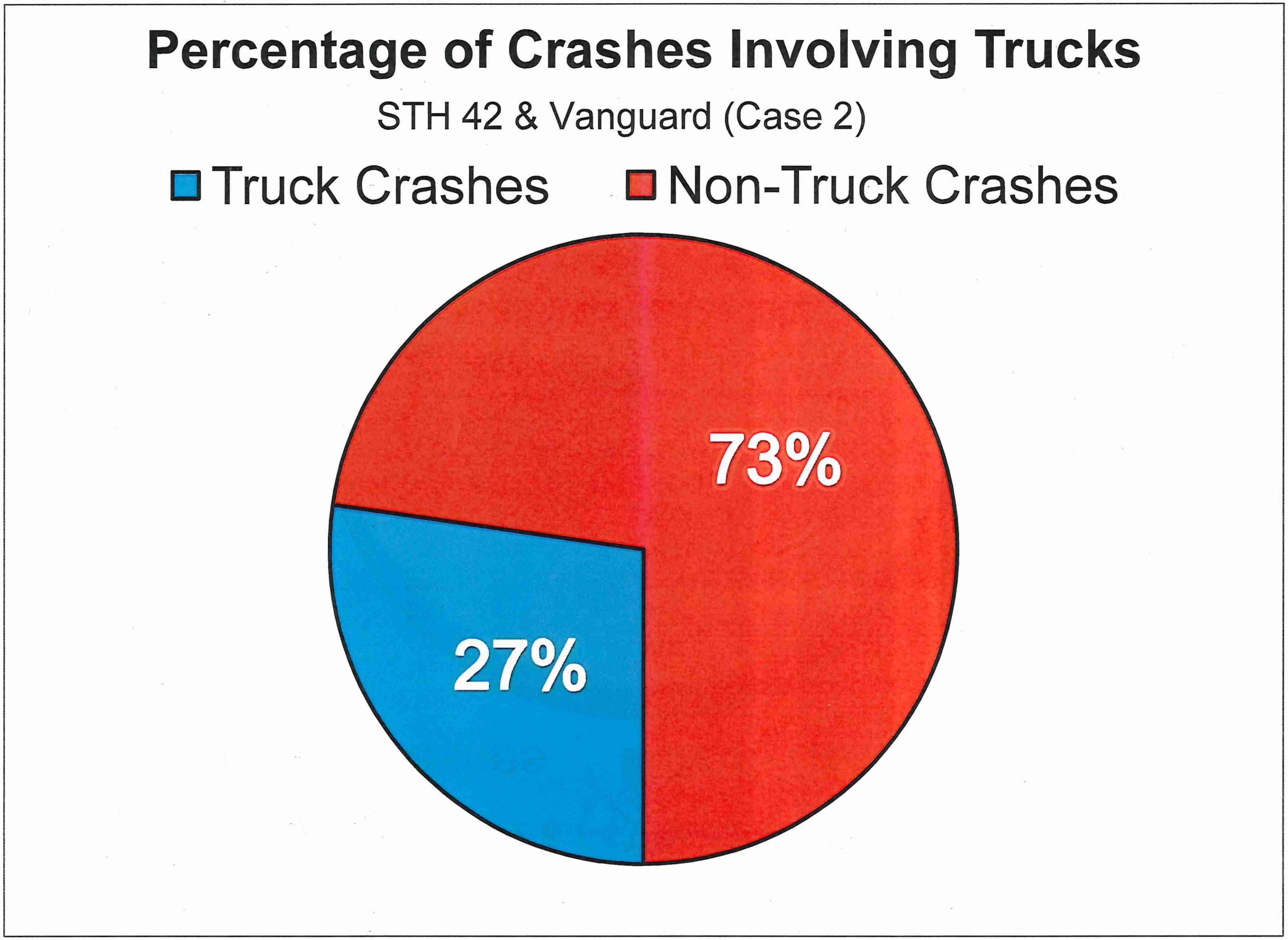
STH 32 / 57 (Claude Allouez) & Broadway (Case 1)

# Percentage of Crashes Involving Trucks

STH 42 & I-43 Ramps* (Case 1)

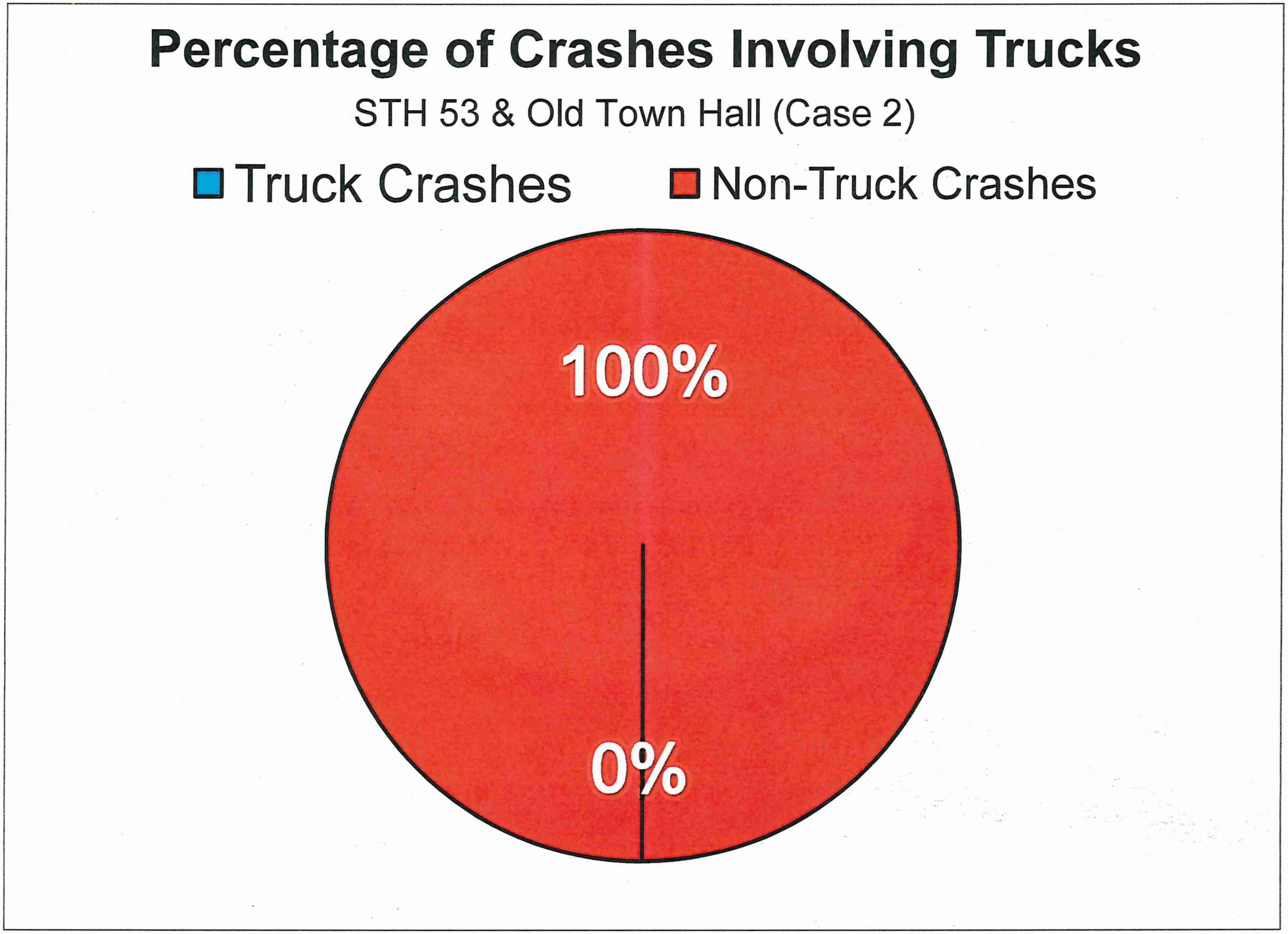


* - Percentage of crashes is the average value per roundabout



Percentage of Crashes Involving Trucks

STH 42 & Vanguard (Case 2)



Percentage of Crashes Involving Trucks

STH 53 & Old Town Hall (Case 2)

# Appendix D

Summary of Information Collected For Study Intersections

|  | ROUNDABOUT # 1 |  |  |  | ROUNDABOUT # 2 |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  | STH 32/ STH 57 De Pere, WI |  |  |  | I-43 West Ramps @ STH 42, SHEBOYGAN, WI |  |  |  |
| Roundabout Case # (based on DLZ initial review) | 1 |  |  |  | 1 |  |  |  |
| Design Vehicle | WB-62 |  |  |  | NA |  |  |  |
| Design Year | 2026 |  |  |  | 2015 |  |  |  |
| Projected Design Year AADT | 48,150 |  |  |  |  |  |  |  |
| Projected Design Year Truck % | NA |  |  |  |  |  |  |  |
| % Trucks by Classification | NA |  |  |  |  |  |  |  |

|  |  | NBL | NBT | NBR | SBL | SBT | SBR | EBL | EBT | EBR | WBL | WBT | WBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Existing Peak Hour Volume | 2009 AM | 703 | 367 | 44 | 2 | 124 | 319 | 215 | 238 | 486 | 16 | 398 | 6 |
|  | 2009 PM | 457 | 240 | 94 | 12 | 303 | 312 | 195 | 292 | 792 | 35 | 333 | 10 |
| Design Year Peak Hour Volume | 2026 AM | 615 | 719 | 31 | 15 | 317 | 514 | 259 | 288 | 401 | 70 | 606 | 12 |
|  | 2026 PM | 539 | 468 | 65 | 69 | 592 | 314 | 320 | 668 | 810 | 70 | 522 | 15 |

|  |  | NBL | NBT | NBR | SBL | SBT | SBR | EBL | EBT | EBR | WBL | WBT | WBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Existing Peak Hour Volume | NA |  |  |  |  |  |  |  |  |  |  |  |  |
|  | NA |  |  |  |  |  |  |  |  |  |  |  |  |
| Design Year Peak Hour Volume | AM |  |  |  | 102 |  | 99 |  | 677 | 416 | 193 | 811 |  |
|  | PM |  |  |  | 131 |  | 167 |  | 1089 | 360 | 269 | 1492 |  |

|  | ROUNDABOUT # 1 |  |  |  | ROUNDABOUT # 2 |  |  |  |
|---|---|---|---|---|---|---|---|---|
| Design Accommodations for Semis- |  |  |  |  |  |  |  |  |
| Inscribed Circle Diameter (ft) | 182 |  |  |  | 163 |  |  |  |
| Width of Truck Apron (ft) | 12 |  |  |  | 14.5 |  |  |  |
|  | NB | SB | EB | WB | NB | SB | EB | WB |
| Entry Width at a point just prior to entering the circle measured between the splitter island curb face and the outside curb face (ft) | 27.7 | 30.2 | 32.3 | 36.5 | Not Applicable | 28 | 28 | 28 |
| Number of Approach Lanes | 2 | 2 | 2 | 2 |  | 2 | 2 | 2 |
| Average Approach Lane widths | 10 | 11 | 12 | 12 |  | 12 | 12 | 12 |
| Circulatory width at the widest part (ft) | 34 |  |  |  | 28 |  |  |  |
| Number of Lanes | 2 |  |  |  | 2 |  |  |  |
| Average Lane widths | 17 |  |  |  | 14 |  |  |  |
| Exit width at a point just after leaving the circle measured between the splitter island curb face and the outside curb face (ft) | 29 | 29 | 29 | 29 | Not Applicable | 28 | 28 | 28 |
| Number of Departure Lanes | 2 | 2 | 2 | 2 |  | 2 | 2 | 2 |
| Average Departure Lane Width | 13 | 13 | 13 | 13 |  | 14 | 14 | 14 |
| Any other site specific accommodations | None |  |  |  | None |  |  |  |
| For Trucks Entering -<br>the design developed for a semi truck was to | Encroach |  |  |  | Encroach |  |  |  |
| Reason | Guidance |  |  |  | NA |  |  |  |
| For Trucks Circulating -<br>the design developed for a semi truck was to | Encroach |  |  |  | Encroach |  |  |  |
| Reason | Guidance |  |  |  | NA |  |  |  |
| For Trucks Exiting -<br>the design developed for a semi truck was to | Encroach |  |  |  | Encroach |  |  |  |
| Reason | Guidance |  |  |  | NA |  |  |  |
| Complaints from Truckers | No | None received |  |  | No | None received |  |  |
| Maintenance Requirements Since Built (due to tracking) | Yes<br>1. sign or light pole knock downs<br>2. replacement of concrete sidewalk beind outside curb - overtracking |  |  |  | Yes<br>Semis entering roundabout stayed in their lane at exit ramp. The wheels over tracked on to sidewak and damaged it. Concrete was repoured. |  |  |  |
| Operational Concerns (flow of semis) Since Built | No |  |  |  | Semis entering roundabout stayed in their lane at exit ramp. The wheels over tracked on to sidewak and damaged it. |  |  |  |
| If designed to keep semis in the lane, would semis stay in the lane ? | Not Applicable |  |  |  | Not Applicable |  |  |  |
|  |  | # of Crashes |  |  |  |  |  |  |
| Reported Crash Concerns Regarding Semis | August 07 - December 07 | 15 |  |  | No |  |  |  |
| Crash Data | January 08 - December 08 | 30 |  |  | NA |  |  |  |
|  | January 09 - December 09* | 47 |  |  |  |  |  |  |
|  | * 17 crashes occurred between February 09 and July 09 during WIS 172 construction |  |  |  |  |  |  |  |
| Reported Congestion | Yes |  |  |  | No |  |  |  |
| Time | AM | PM | (as reported, no further data available) |  |  |  |  |  |
| Approach | NB | EB |  |  |  |  |  |  |

NA - No information available

| | ROUNDABOUT # 3 | ROUNDABOUT # 4 |
|---|---|---|
| | I-43 East Ramps @ STH 42, SHEBOYGAN, WI | Jamaica Avenue @ I-10 Interchange North Ramps, COTTAGE GROVE, MN |
| Roundabout Case # (based on DLZ initial review) | 1 | 2 Note: At least 1 approach designed for encroachment while entry. |
| Design Vehicle | NA | WB-62 Tractor Trailer |
| Design Year | 2015 | |
| Projected Design Year AADT | | |
| Projected Design Year Truck % | | 8 - 10 % |
| % Trucks by Classification | | |

| | | NBL | NBT | NBR | SBL | SBT | SBR | EBL | EBT | EBR | WBL | WBT | WBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Existing Peak Hour Volume | NA | | | | | | | | | | | | |
| | NA | | | | | | | | | | | | |
| Design Year Peak Hour Volume | AM | 273 | | 227 | | | | 92 | 688 | | | 732 | 179 |
| | PM | 511 | 4 | 278 | | | | 171 | 1048 | | | 1195 | 163 |

| | NBL | NBT | NBR | SBL | SBT | SBR | EBL | EBT | EBR | WBL | WBT | WBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 - AM | 143 | 314 | | | 340 | 522 | | | | 120 | 2 | 50 |
| 2005 - PM | 159 | 866 | | | 429 | 330 | | | | 41 | 1 | 159 |
| 2027 - AM | 275 | 535 | | | 655 | 1005 | | | | 230 | 4 | 100 |
| 2027 - PM | 305 | 1650 | | | 825 | 635 | | | | 80 | 5 | 305 |

| | | |
|---|---|---|
| Design Accommodations for Semis- | | |
| Inscribed Circle Diameter (ft) | 162 | 160 3/4th 136 1/4th |
| Width of Truck Apron (ft) | 12 | 14 |

| | NB | SB | EB | WB | NB | SB | WB |
|---|---|---|---|---|---|---|---|
| Entry Width at a point just prior to entering the circle measured between the splitter island curb face and the outside curb face (ft) | 28 | Not Applicable | 28 | 28 | 33 | 20 | 20 |
| Number of Approach Lanes | 2 | | 2 | 2 | 2 | 1 | 1 |
| Average Approach Lane widths | 12 | | 12 | 12 | 12.5 | 15.5 | 12.5 |
| Circulatory width at the widest part (ft) | 28 | | | | 31 | | |
| Number of Lanes | 2 | | | | 2 | | |
| Average Lane widths | 14 | | | | 15.5 | | |

| | NB | SB | EB | WB | NB | SB | WB |
|---|---|---|---|---|---|---|---|
| Exit width at a point just after leaving the circle measured between the splitter island curb face and the outside curb face (ft) | 24 | Not Applicable | 28 | 28 | 30 | 19 | 22 |
| Number of Departure Lanes | 1 | | 2 | 2 | 2 | 1 | 1 |
| Average Departure Lane Width | 20 | | 12 | 12 | 13.5 | 16.5 | 18 |

| | | |
|---|---|---|
| Any other site specific accommodations | None | There are a number of painted gores including on some of the truck-heavy approaches between the entry lanes and in several locations adjacent to the splitter islands on the exit legs. |
| For Trucks Entering -<br>the design developed for a semi truck was to | Encroach | Some of the approaches are designed for staying in lane on the approaches. |
| Reason | NA | NA |
| For Trucks Circulating -<br>the design developed for a semi truck was to | Encroach | The truck aprons are designed to allow a truck in the inside lane to remain in lane while trucks in the outside lane will need to encroach on the inside lane. |
| Reason | NA | NA |
| For Trucks Exiting -<br>the design developed for a semi truck was to | Encroach | trucks on the inside don't encroach while trucks in the outside lane will encroach |
| Reason | NA | NA |
| Complaints from Truckers | No None received | The truck traffic has been functioning exceptionally well and the two major nearby truck generators have had only positive reactions |
| Maintenance Requirements Since Built (due to tracking) | Yes<br>Semis entering roundabout stayed in their lane at exit ramp. The wheels over tracked on to sidewak and damaged it. Concrete was repoured. | No, the City has not had these issues. |
| Operational Concerns (flow of semis) Since Built | Semis entering roundabout stayed in their lane at exit ramp. The wheels over tracked on to sidewak and damaged it. | No. Some trucks take gaps that made approaching vehicles shy away, but mostly reasonable gap taking and a normal acclamation process for drivers new to roundabout |
| If designed to keep semis in the lane, would semis stay in the lane ? | Not Applicable | No, they typically underutilize the truck aprons and take both lanes. They are able to stay in lane on the approach, then after entering the circulatory road, they move to the middle |
| Reported Crash Concerns Regarding Semis | No | No, there has not been a predominance of truck related crashes. |
| Crash Data | NA | MnDOT and the City have crash data that can be made available.<br>Side Note: Minor rear-ends and side wipes – non-injury crashes. |
| Reported Congestion | No | No.<br>if a queue develops, it is short lived and completely clears within a short time. |
| Time | | |
| Approach | | |

NA - No information available

| | ROUNDABOUT # 5 | ROUNDABOUT # 6 |
|---|---|---|
| | Jamaica Avenue @ I-10 Interchange South Ramps, COTTAGE GROVE, MN<br>(> 4 approaches) | STH 124 and Business 29 Eau Claire, WI |
| Roundabout Case # (based on DLZ initial review) | 2 Note: At least 1 approach designed for encroachment while entry. | 1 |
| Design Vehicle | WB-62 Tractor Trailer | WB-65 |
| Design Year | | 2030 |
| Projected Design Year AADT | | 40,500 |
| Projected Design Year Truck % | 8 - 10 % | 5.50% |
| % Trucks by Classification | | ADT entering the intersection (half ADT per leg) |

| 2D | 3AX | 2S1+2S2 | 3S2 | DB |
|---|---|---|---|---|
| 1.6% | 1.6% | 0.7% | 1.3% | 0.3% |

| | Entering | NB | SB | WB | SEB | NEB |
|---|---|---|---|---|---|---|
| Existing Peak Hour Volume | 2005 - AM | 310 | 465 | 32 | 323 | 74 |
| | 2005 - PM | 427 | 545 | 24 | 667 | 256 |
| Design Year Peak Hour Volume | 2027 - AM | 605 | 890 | 65 | 630 | 150 |
| | 2027 - PM | 825 | 905 | 55 | 1275 | 495 |

| | | NBL | NBT | NBR | SBL | SBT | SBR | EBL | EBT | EBR | WBL | WBT | WBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Existing Peak Hour Volume | 2010 - Peak | | 270 | 620 | 540 | 490 | | | | | 600 | | 310 |
| Design Year Peak Hour Volume | 2030 - Peak | | 320 | 1210 | 740 | 580 | | | | | 1280 | | 470 |

| | ROUNDABOUT # 5 | ROUNDABOUT # 6 |
|---|---|---|
| Design Accommodations for Semis- | | |
| Inscribed Circle Diameter (ft) | 220 | 200 |
| Width of Truck Apron (ft) | 12 | 5 |

| | NB | SB | WB | SEB | NEB | | NB | SB | WB |
|---|---|---|---|---|---|---|---|---|---|
| Entry Width at a point just prior to entering the circle measured between the splitter island curb face and the outside curb face (ft) | 34 | 26 | 33 | 30 | 20 | | 18 | 28 | 28 |
| Number of Approach Lanes | 2 | 1 | 1 | 2 | 2 | | 1 | 2 | 2 |
| Average Approach Lane widths | 12 | 14 | 12 | 12 | 12 | | 11.5 | 12 | 12 |
| Circulatory width at the widest part (ft) | 31 | | | | | | 42 | | |
| Number of Lanes | 2 | | | | | | 3 | | |
| Average Lane widths | 15.5 | | | | | | 14 | | |

| | NB | SB | WB | SEB | NEB | | NB | SB | WB |
|---|---|---|---|---|---|---|---|---|---|
| Exit width at a point just after leaving the circle measured between the splitter island curb face and the outside curb face (ft) | 33 | 22 | | 20 | 28 | 29 | 17 | 24 | 24 |
| Number of Departure Lanes | 2 | 1 | | 1 | 1 | 1 | 1 | 2 | 2 |
| Average Departure Lane Width | 14 | 16 | | 12 | 13 | 20 | 16 | 12 | 12 |

| | ROUNDABOUT # 5 | ROUNDABOUT # 6 |
|---|---|---|
| Any other site specific accommodations | There are a number of painted gores including on some of the truck-heavy approaches between the entry lanes and in several locations adjacent to the splitter islands on the exit legs. | None |
| For Trucks Entering -<br>the design developed for a semi truck was to | Mostly Stalying in lane. Frontage approaches not designed for trucks to remain in lane. | Encroach |
| Reason | NA | Low Volume |
| For Trucks Circulating -<br>the design developed for a semi truck was to | The truck aprons are designed to allow a truck in the inside lane to remain in lane while trucks in the outside lane will need to encroach on the inside lane. | Encroach |
| Reason | NA | Low Volume |
| For Trucks Exiting -<br>the design developed for a semi truck was to | trucks on the inside don't encroach while trucks in the outside lane will encroach | Encroach |
| Reason | | Low Volume |
| Complaints from Truckers | The truck traffic has been functioning exceptionally well and the two major nearby truck generators have had only positive reactions | No None received |
| Maintenance Requirements Since Built (due to tracking) | No, the City has not had these issues. | No |
| Operational Concerns (flow of semis) Since Built | No, Some trucks take gaps that made approaching vehicles shy away, but mostly reasonable gap taking and a normal acclamation process for drivers new to roundabout | No |
| If designed to keep semis in the lane, would semis stay in the lane ? | No, they typically underutilize the truck aprons and take both lanes. They are able to stay in lane on the approach, then after entering the circulatory road, they move to the middle | Not Applicable |
| Reported Crash Concerns Regarding Semis | No, there has not been a predominance of truck related crashes. | NA Ditrected to UW TOPS Lab |
| Crash Data | MnDOT and the City have crash data that can be made available.<br>Side Note: Minor rear-ends and side wipes – non-injury crashes. | |
| Reported Congestion | No. | No |
| Time | if a queue develops, it is short lived and completely clears within a short time. | |
| Approach | | |

NA - No information available

| | ROUNDABOUT # 7 | ROUNDABOUT # 8 |
|---|---|---|
| | Van Dyke Avenue and 18.5 mile Road, Sterling Heights, MI | USH 53 and Old Town Hall Rd, EAU CLAIRE, WI |
| Roundabout Case # (based on DLZ initial review) | 1 | 2 Note: Not designed to keep WB 67 in lane while entry. |
| Design Vehicle | WB-62 | WB-67 |
| Design Year | 2025 | 2026 |
| Projected Design Year AADT | | 6,188 |
| Projected Design Year Truck % | | 11.00% |
| % Trucks by Classification | | NA |

| | | NBL | NBT | NBR | SBL | SBT | SBR | EBL | EBT | EBR | WBL | WBT | WBR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Existing Peak Hour Volume | 2005 - AM | 120 | 310 | 0 | 79 | 1103 | 226 | 47 | 193 | 157 | 0 | 242 | 102 | NA |
| | 2005 - PM | 141 | 934 | 0 | 247 | 762 | 62 | 105 | 236 | 124 | 0 | 146 | 157 | |
| Design Year Peak Hour Volume | 2025 - AM | 237 | 363 | 0 | 328 | 1307 | 222 | 131 | 454 | 306 | 0 | 580 | 148 | NA |
| | 2025 - PM | 275 | 1120 | 0 | 363 | 882 | 170 | 294 | 569 | 245 | 0 | 366 | 242 | |

| | | |
|---|---|---|
| Design Accommodations for Semis-<br>Inscribed Circle Diameter (ft) | 246 | 190 |
| Width of Truck Apron (ft) | | 9 |

| | NB | SB | EB | WB | NB | SB | EB | WB |
|---|---|---|---|---|---|---|---|---|
| Entry Width at a point just prior to entering the circle measured between the splitter island curb face and the outside curb face (ft) | 39.8 | 39.8 | 28 | 27.8 | 32 | 33 | 18 | 20 |
| Number of Approach Lanes | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 1 |
| Average Approach Lane widths | 12 | 12 | 12 | 12 | 13 | 13 | 13 | 16 |

| | | |
|---|---|---|
| Circulatory width at the widest part (ft) | 45 | 32 |
| Number of Lanes | 3 | 2 |
| Average Lane widths | 15 | 16 |

| | NB | SB | EB | WB | | | | |
|---|---|---|---|---|---|---|---|---|
| Exit width at a point just after leaving the circle measured between the splitter island curb face and the outside curb face (ft) | 42 | 41 | 24 | 29 | 33 | 32 | 24 | 18 |
| Number of Departure Lanes | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 1 |
| Average Departure Lane Width | 12 | 12.5 | 12 | 12.5 | 14 | 14 | 19 | 15 |

| | | |
|---|---|---|
| Any other site specific accommodations | None | The northbound and southbound entries on USH 53 have separated lanes with the gore, between lanes. |
| For Trucks Entering -<br>the design developed for a semi truck was to | Encroach | Not Encroach for NB and SB. Encroach for EB and WB. |
| Reason | It was designed this way in 2003 based on the belief that safety benefits of keeping the geometry as small as possible outweighed the increased risk of truck-related crashes. | EB and WB approaches have lower truck volume. NB and SB have more. |
| For Trucks Circulating -<br>the design developed for a semi truck was to | Encroach | Not Encroach for WB 50 and WB 62. But, encroach for WB 67 |
| Reason | It was designed this way in 2003 based on the belief that safety benefits of keeping the geometry as small as possible outweighed the increased risk of truck-related crashes. | NA |
| For Trucks Exiting -<br>the design developed for a semi truck was to | Encroach | NA |
| Reason | It was designed this way in 2003 based on the belief that safety benefits of keeping the geometry as small as possible outweighed the increased risk of truck-related crashes. | NA |
| Complaints from Truckers | No None received | No None received |
| Maintenance Requirements Since Built (due to tracking) | No<br>But, a few guide signs that have been damaged due accidents. | No |
| Operational Concerns (flow of semis) Since Built | No | No |
| If designed to keep semis in the lane, would semis stay in the lane ? | Not Applicable | NA |
| Reported Crash Concerns Regarding Semis | No | NA |
| Crash Data | NA | NA |
| Reported Congestion | Yes | No Cited low AADT |
| Time | PM 2:30 to 7:00 | No |
| Approach | EB | No |

NA - No information available

|  | ROUNDABOUT # 9 |  |  |  | ROUNDABOUT # 10 |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  | **Vanguard Drive @ STH 42, SHEBOYGAN, WI** |  |  |  | **South Tower Drive and Industrial Drive, MONONA, WI** |  |  |  |
| Roundabout Case # (based on DLZ initial review) | 2 | Note: Survey respondent indicated that this is a case 2 roundabout. |  |  | 1 & 2 |  |  |  |
| Design Vehicle | NA |  |  |  | WB 65 |  |  |  |
| Design Year | 2015 |  |  |  | 2015 |  |  |  |
| Projected Design Year AADT | NA |  |  |  | NA |  |  |  |
| Projected Design Year Truck % | NA |  |  |  | > 5% |  |  |  |
| % Trucks by Classification | NA |  |  |  | NA |  |  |  |

|  |  | NBL | NBT | NBR | SBL | SBT | SBR | EBL | EBT | EBR | WBL | WBT | WBR |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Existing Peak Hour Volume | 2005 AM | 82 | 0 | 214 | 4 | 0 | 8 | 11 | 525 | 66 | 247 | 239 | 8 | NA |  |
|  | 2005 PM | 135 | 0 | 354 | 10 | 0 | 7 | 11 | 349 | 105 | 389 | 550 | 13 | NA |  |
| Design Year Peak Hour Volume | 2015 AM | 80 | 17 | 206 | 161 | 14 | 68 | 20 | 700 | 64 | 235 | 385 | 265 | AM | 2190 |
|  | 2015 PM | 131 | 36 | 339 | 428 | 36 | 130 | 27 | 652 | 101 | 374 | 711 | 544 | PM | 2765 |

|  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
| Design Accommodations for Semis- |  |  |  |  |  |  |  |  |
| Inscribed Circle Diameter (ft) | 196 |  |  |  | ~ 128 | accurate diameter not reported. |  |  |
| Width of Truck Apron (ft) | 15 |  |  |  | NA |  |  |  |
|  | NB | SB | EB | WB | SB | SB | EB | WB |
| Entry Width at a point just prior to entering the circle measured between the splitter island curb face and the outside curb face (ft) | 21 | 28 | 28 | 32 | 36 | 33 | 26 | 25 |
| Number of Approach Lanes | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Average Approach Lane widths | 17 | 12 | 12 | 14 | 10 | 12 | 11 | 9 |
| Circulatory width at the widest part (ft) | 28 |  |  |  | 32 |  |  |  |
| Number of Lanes | 2 |  |  |  | 2 |  |  |  |
| Average Lane widths | 14 |  |  |  | 16 |  |  |  |
| Exit width at a point just after leaving the circle measured between the splitter island curb face and the outside curb face (ft) | 30 | 24 | 30 | 30 | 30 | 22 | 18 | 21 |
| Number of Departure Lanes | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 1 |
| Average Departure Lane Width | 12 | 18 | 12 | 12 | 13.5 | 14 | 11 | 16 |
| Any other site specific accommodations | None |  |  |  | SB entry due to WallMart deliveries two lane approach to two lane entry therefore provided hatched widened entry. |  |  |  |
| For Trucks Entering - the design developed for a semi truck was to | not encroach |  |  |  | Encroach on all movements except SB. SB movement does not encroach. |  |  |  |
| Reason | considering the location proximity to WalMart and Menards. |  |  |  | Heavy SB volume. Light volumes on other approaches. |  |  |  |
| For Trucks Circulating - the design developed for a semi truck was to | Encroach |  |  |  | Encroach on all movements except SB. SB movement does not encroach. |  |  |  |
| Reason | NA |  |  |  | Heavy SB volume. Light volumes on other approaches. |  |  |  |
| For Trucks Exiting - the design developed for a semi truck was to | Encroach |  |  |  | Encroach on all movements except SB. SB movement does not encroach. |  |  |  |
| Reason | NA |  |  |  | Heavy SB volume. Light volumes on other approaches. |  |  |  |
| Complaints from Truckers | No | None received |  |  | No | None received |  |  |
| Maintenance Requirements Since Built (due to tracking) | No |  |  |  | No |  |  |  |
| Operational Concerns (flow of semis) Since Built | No |  |  |  | No |  |  |  |
| If designed to keep semis in the lane, would semis stay in the lane ? | Not Applicable |  |  |  | Observed most over the road deliver truck staying in lane SB. Observed smaller local deliver trucks not driving correctly SB at entry. Advised that there should be a standard over lane LT only lane on SB. |  |  |  |
| Reported Crash Concerns Regarding Semis | No |  |  |  | No | 1 side swipes involving cars and trucks reported. |  |  |
| Crash Data | NA |  |  |  | NA |  |  |  |
| Reported Congestion | No |  |  |  | No |  |  |  |
| Time |  |  |  |  |  |  |  |  |
| Approach |  |  |  |  |  |  |  |  |

NA - No information available

| | ROUNDABOUT # 11 | ROUNDABOUT # 12 |
|---|---|---|
| | Moorland Road and I-43 North Ramps, NEW BERLIN, WI | Moorland Road and I-43 South Ramps, NEW BERLIN, WI |
| Roundabout Case # (based on DLZ initial review) | 1 & 2 | 1 & 2 |
| Design Vehicle | WB-65 | WB-65 |
| Design Year | 2026 | 2026 |
| Projected Design Year AADT | 77,900 | 77,900 |
| Projected Design Year Truck % | 5.30% | 5.30% |
| % Trucks by Classification | | |

| | | NBL | NBT | NBR | SBL | SBT | SBR | EBL | EBT | EBR | WBL | WBT | WBR | | NBL | NBT | NBR | SBL | SBT | SBR | EBL | EBT | EBR | WBL | WBT | WBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Existing Peak Hour Volume | 2006 AM | 42 | 1329 | | | 739 | 152 | | | | 293 | 0 | 1230 | 2006 AM | | 791 | 250 | 481 | 551 | | 580 | 0 | 106 | | | |
| | 2006 PM | 113 | 1095 | | | 1933 | 514 | | | | 377 | 0 | 849 | 2026 AM | | 882 | 249 | 1003 | 1307 | | 326 | 0 | 59 | | | |
| Design Year Peak Hour Volume | 2026 AM | 54 | 1074 | | | 1018 | 209 | | | | 372 | 0 | 1562 | 2006 PM | | 1019 | 321 | 663 | 772 | | 739 | 0 | 134 | | | |
| | 2026 PM | 145 | 1397 | | | 2649 | 704 | | | | 476 | 0 | 1071 | 2026 PM | | 1128 | 318 | 1375 | 1750 | | 414 | 0 | 75 | | | |

| | ROUNDABOUT # 11 | ROUNDABOUT # 12 |
|---|---|---|
| Design Accommodations for Semis- | | |
| Inscribed Circle Diameter (ft) | 280 for 3 lane section 250 for 2 lane section | 192 |
| Width of Truck Apron (ft) | 10 | 8 and spiral |

| | NB | SB | SBU | RAMP | SBTL | SBR | SB Pt | WBR | WB Pt Rt | NB | SB | Rockridge Road | NB Exit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Entry Width at a point just prior to entering the circle measured between the splitter island curb face and the outside curb face (ft) | 32 | 45.0 | | 18 | | 22 | | 23 | 30.7 | 35.3 | 32.3 | 25 | 32.8 |
| Number of Approach Lanes | 2 | 3.0 | | 1 | | 1 | | 1 | 1 | 2.0 | 2.0 | 1 | 2 |
| Average Approach Lane widths | 13 | 12.0 | | 15 | | 18 | | 13 | 14 | 12.0 | 12.0 | 20 | 12 |

| | ROUNDABOUT # 11 | ROUNDABOUT # 12 |
|---|---|---|
| Circulatory width at the widest part (ft) | 48.5 | 32 |
| Number of Lanes | 3 | 2 |
| Average Lane widths | 16.2 | 16 |

| | NB | SB | NB | SB | Rockridge Road |
|---|---|---|---|---|---|
| Exit width at a point just after leaving the circle measured between the splitter island curb face and the outside curb face (ft) | 31.5 | 40.7 | 29.0 | 30.0 | 24.2 |
| Number of Departure Lanes | 2.0 | 3.0 | 2.0 | 2.0 | 1.0 |
| Average Departure Lane Width | 13.5 | 12.0 | 12.5 | 13.0 | 17.0 |

| | ROUNDABOUT # 11 | ROUNDABOUT # 12 |
|---|---|---|
| Any other site specific accommodations | Striped gore between lanes on NB and WB approaches. | Striped gore between lanes on EB approach and SB departure. |
| For Trucks Entering -<br>the design developed for a semi truck was to | Encroach | Encroach |
| Reason | Design Constraints | Design Constraints |
| For Trucks Circulating -<br>the design developed for a semi truck was to | Encroach | Encroach |
| Reason | Design Constraints | Design Constraints |
| For Trucks Exiting -<br>the design developed for a semi truck was to | Encroach in some exits and not encroach in others | Encroach in some exits and not encroach in others |
| Reason | | |
| Complaints from Truckers | No None received | No None received |
| Maintenance Requirements Since Built (due to tracking) | Yes<br>1. Curb Damages and sign knockdowns<br>2. Concrete poured, signs replaced and placed at an offset, "Wide Turning Trucks" sign installed. | Yes<br>1. Curb Damages and sign knockdowns<br>2. Concrete poured, signs replaced and placed at an offset, "Wide Turning Trucks" sign installed. |
| Operational Concerns (flow of semis) Since Built | Yes. Lack of education of drivers. "Wide Turning Trucks" sign installed. | Yes. Lack of education of drivers. "Wide Turning Trucks" sign installed. |
| If designed to keep semis in the lane, would semis stay in the lane ? | NA | NA |
| Reported Crash Concerns Regarding Semis | Yes | Yes |
| Crash Data | 3 crashes reported. Similarities in causes of crashes - Encroachment.<br>Note: The recorded crashes may have been influenced by the construction activity in the vicinity of this intersection. | 3 crashes reported. Similarities in causes of crashes - Encroachment. |
| Reported Congestion | Not more than expected. | Not more than expected. |
| Time | | |
| Approach | | |

NA - No information available

| | ROUNDABOUT # 13 | ROUNDABOUT # 14 |
|---|---|---|
| | Tegner Street and US 93, WICKENBERG, AZ | US 60 and US 93, WICKENBERG, AZ |
| Roundabout Case # (based on DLZ initial review) | 2 | 2 |
| Design Vehicle | WB-67 | WB-67 |
| Design Year | NA | NA |
| Projected Design Year AADT | NA | NA |
| Projected Design Year Truck % | NA | NA |
| % Trucks by Classification | NA | NA |

| | ROUNDABOUT # 13 | NB AP | SB AP | WB AP | ROUNDABOUT # 14 | NB AP | SB AP | WB AP |
|---|---|---|---|---|---|---|---|---|
| Existing Peak Hour Volume | NA | | | | | | | |
| Design Year Peak Hour Volume | NA | | | | Design AM | 624 | 553 | 1507 |
| | | | | | Design PM | 936 | 824 | 1314 |

| | ROUNDABOUT # 13 | ROUNDABOUT # 14 |
|---|---|---|
| Design Accommodations for Semis- | | |
| Inscribed Circle Diameter (ft) | NA | NA |
| Width of Truck Apron (ft) | NA | NA |
| Entry Width at a point just prior to entering the circle measured between the splitter island curb face and the outside curb face (ft) | NA | NA |
| Number of Approach Lanes | | |
| Average Approach Lane widths | | |
| Circulatory width at the widest part (ft) | NA | NA |
| Number of Lanes | | |
| Average Lane widths | | |
| Exit width at a point just after leaving the circle measured between the splitter island curb face and the outside curb face (ft) | NA | NA |
| Number of Departure Lanes | | |
| Average Departure Lane Width | | |
| Any other site specific accommodations | None | Striped gore between lanes on SB and NB approaches. |
| For Trucks Entering - | | |
| the design developed for a semi truck was to | Not to Encroach | Not to Encroach |
| Reason | Design accommodation | Design accommodation |
| For Trucks Circulating - | | |
| the design developed for a semi truck was to | Encroach | Encroach |
| Reason | NA | NA |
| For Trucks Exiting - | | |
| the design developed for a semi truck was to | Encroach | Encroach |
| Reason | NA | NA |
| Complaints from Truckers | No None received | No None received |
| Maintenance Requirements Since Built (due to tracking) | No | No |
| Operational Concerns (flow of semis) Since Built | No | No |
| If designed to keep semis in the lane, would semis stay in the lane ? | NA | NA |
| Reported Crash Concerns Regarding Semis | NA | NA |
| Crash Data | NA | NA |
| Reported Congestion | No | No |
| Time | | |
| Approach | | |

NA - No information available

| | ROUNDABOUT # 15 | ROUNDABOUT # 16 |
|---|---|---|
| | Outer Loop Road and SR 89, CHINO VALLEY, AZ | North Ashland Avenue and North 8th Street, ASHWAUBENON, WI |
| Roundabout Case # (based on DLZ initial review) | 3 Note: Survey respondent indicated that this is a case 2 roundabou | 3 Note: Survey respondent indicated that this is a case 2 roundabout. |
| Design Vehicle | WB-67 | WB 67 |
| Design Year | 2030 | 2030 |
| Projected Design Year AADT | NA | 24,100 |
| Projected Design Year Truck % | NA | 5.40% |
| % Trucks by Classification | NA | 2D 1.6<br>3AX 1.6<br>2S1+2S2 0.7<br>3-S2 1.2<br>DBL-BTM 0.3 |

Existing Peak Hour Volume / Design Year Peak Hour Volume — Roundabout # 15

| | NBL | NBT | NBR | SBL | SBT | SBR | EBL | EBT | EBR | WBL | WBT | WBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| 2030 AM | 120 | 1520 | 120 | 120 | 2480 | 120 | 210 | 220 | 210 | 210 | 220 | 210 |
| 2030 PM | 210 | 2590 | 210 | 210 | 1180 | 210 | 120 | 150 | 120 | 120 | 150 | 120 |

Existing Peak Hour Volume / Design Year Peak Hour Volume — Roundabout # 16

| K = 10.4% | NEL | NET | NER | SBL | SBT | SBR | EBL | EBT | EBR | NBL | NBT | NBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 Daily | 0 | 4671 | 0 | 2727 | 4203 | 21 | 0 | 0 | 13 | 0 | 0 | 3200 |
| 2005 Peak | 0 | 486 | 0 | 284 | 437 | 2 | 0 | 0 | 1 | 0 | 0 | 333 |
| 2030 Daily | 815 | 4415 | 35 | 4440 | 6828 | 611 | 494 | 2529 | 786 | 42 | 2171 | 5210 |
| 2030 Peak | 85 | 459 | 4 | 462 | 710 | 64 | 51 | 263 | 82 | 4 | 226 | 542 |

| | ROUNDABOUT # 15 | ROUNDABOUT # 16 |
|---|---|---|
| Design Accommodations for Semis- | | |
| Inscribed Circle Diameter (ft) | 222 | 196 |
| Width of Truck Apron (ft) | | 15 |

Roundabout # 15

| | NB | SB | EB | WB |
|---|---|---|---|---|
| Entry Width at a point just prior to entering the circle measured between the splitter island curb face and the outside curb face (ft) | 33.0 | 33.0 | 32.0 | 20.0 |
| Number of Approach Lanes | 2.0 | 2.0 | 2.0 | 1.0 |
| Average Approach Lane widths | 14.0 | 14.0 | 12.0 | 16.0 |
| Circulatory width at the widest part (ft) | 36 | | | |
| Number of Lanes | 2 | | | |
| Average Lane widths | 18 | | | |
| Exit width at a point just after leaving the circle measured between the splitter island curb face and the outside curb face (ft) | 31.0 | 30.0 | 23.0 | 23 |
| Number of Departure Lanes | 2.0 | 2.0 | 1.0 | 1 |
| Average Departure Lane Width | 14.0 | 14.0 | 16.0 | 16 |

Roundabout # 16

| | NE | SB | EB | NB |
|---|---|---|---|---|
| Entry Width at a point just prior to entering the circle measured between the splitter island curb face and the outside curb face (ft) | 34.0 | 28.0 | 34 | 27 |
| Number of Approach Lanes | 2.0 | 1.0 | 1 | 1 |
| Average Approach Lane widths | 12.0 | 13.0 | 10 | 12 |
| Circulatory width at the widest part (ft) | 28 | | | |
| Number of Lanes | 2 | | | |
| Average Lane widths | 14 | | | |
| | NEB | NWB | SEB | SWB |
| Exit width at a point just after leaving the circle measured between the splitter island curb face and the outside curb face (ft) | 29.0 | 30.0 | 30.0 | 32 |
| Number of Departure Lanes | 2.0 | 1.0 | 2.0 | 2 |
| Average Departure Lane Width | 12.5 | 25.0 | 12.0 | 14 |

| | ROUNDABOUT # 15 | ROUNDABOUT # 16 |
|---|---|---|
| Any other site specific accommodations | Striped gore between lanes on all approaches. | Spearation between NB and SB approach lanes. |
| For Trucks Entering - the design developed for a semi truck was to | Not Encroach | Not Encroach |
| Reason | The reasoning is that there was a large public concern about trucks needing to stay in lane, along with future capacity. | We as a Region felt it was a good location to try this design practice |
| For Trucks Circulating - the design developed for a semi truck was to | Encroach | Encroach |
| Reason | The reason for the "in lane" design on thru movements was in response to local requirement. | NA |
| For Trucks Exiting - the design developed for a semi truck was to | Encroach | Encroach |
| Reason | The reason for the "in lane" design on thru movements was in response to local requirement. | NA |
| Complaints from Truckers | No None received | No Roundabout just opened on 8-6-10 None received |
| Maintenance Requirements Since Built (due to tracking) | No | No Roundabout just opened on 8-6-10 |
| Operational Concerns (flow of semis) Since Built | No | No Roundabout just opened on 8-6-10 |
| If designed to keep semis in the lane, would semis stay in the lane ? | May be | NA Roundabout just opened on 8-6-10 |
| Reported Crash Concerns Regarding Semis | NA | No Roundabout just opened on 8-6-10 |
| Crash Data | NA | NA Roundabout just opened on 8-6-11 |
| Reported Congestion | Yes | No Roundabout just opened on 8-6-10 |
| Time | | |
| Approach | | |

NA - No information available

ROUNDABOUT # 17

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Ann's Way and North 8th Street, MEDFORD, WI** | | | | | | | | | | | | |
| Roundabout Case # (based on DLZ initial review) | 3 | | | | | | | | | | | | |
| Design Vehicle | WB-65 | | | | | | | | | | | | |
| Design Year | 2031 | | | | | | | | | | | | |
| Projected Design Year AADT | 21,800 | | | | | | | | | | | | |
| Projected Design Year Truck % | 18.60% | **2D** | | **3AX** | | **2S1+2S2** | | **3-S2** | | **DBL-BTM** | | | |
| % Trucks by Classification | | 3.3 | | 8.7 | | 1.4 | | 5.1 | | 0.1 | | | |
| | | **NBL** | **NBT** | **NBR** | **SBL** | **SBT** | **SBR** | **EBL** | **EBT** | **EBR** | **WBL** | **WBT** | **WBR** |
| Existing Peak Hour Volume | NA | | | | | | | | | | | | |
| | NA | | | | | | | | | | | | |
| Design Year Peak Hour Volume | 2030 AM | 0 | 288 | 716 | 63 | 239 | 0 | 0 | 0 | 0 | 628 | 0 | 57 |
| | 2030 PM | 0 | 616 | 502 | 44 | 327 | 0 | 0 | 0 | 0 | 452 | 0 | 44 |
| Design Accommodations for Semis- | | | | | | | | | | | | | |
| Inscribed Circle Diameter (ft) | 189 | 209 | | | | | | | | | | | |
| Width of Truck Apron (ft) | 10 | | | | | | | | | | | | |
| | **NB** | **SB** | **EB** | **WB** | | | | | | | | | |
| Entry Width at a point just prior to entering the circle measured between the splitter island curb face and the outside curb face (ft) | 34.0 | 28.0 | 34.0 | 28.0 | | | | | | | | | |
| Number of Approach Lanes | 2.0 | 2.0 | 2.0 | 2.0 | | | | | | | | | |
| Average Approach Lane widths | 12.0 | 12.0 | 12.0 | 12.0 | | | | | | | | | |
| Circulatory width at the widest part (ft) | 36 | | | | | | | | | | | | |
| Number of Lanes | 2 | | | | | | | | | | | | |
| Average Lane widths | 18 | | | | | | | | | | | | |
| | **NB** | **SB** | **EB** | **WB** | | | | | | | | | |
| Exit width at a point just after leaving the circle measured between the splitter island curb face and the outside curb face (ft) | 31.0 | 30.0 | 20.0 | 18.0 | | | | | | | | | |
| Number of Departure Lanes | 2.0 | 2.0 | 1.0 | 1.0 | | | | | | | | | |
| Average Departure Lane Width | 13.5 | 12.5 | 16.0 | 14.0 | | | | | | | | | |
| Any other site specific accommodations | Yes. | Striped gore between lanes on NB and SB approaches. | | | | | | | | | | | |
| For Trucks Entering - | | | | | | | | | | | | | |
| the design developed for a semi truck was to | Not Encroach | | | | | | | | | | | | |
| Reason | High truck volume | | | | | | | | | | | | |
| For Trucks Circulating - | | | | | | | | | | | | | |
| the design developed for a semi truck was to | Not Encroach | | | | | | | | | | | | |
| Reason | High truck volume | | | | | | | | | | | | |
| For Trucks Exiting - | | | | | | | | | | | | | |
| the design developed for a semi truck was to | Not Encroach | | | | | | | | | | | | |
| Reason | High truck volume | | | | | | | | | | | | |
| Complaints from Truckers | Not constructed yet. Scheduled 2011. | | | | | | | | | | | | |
| Maintenance Requirements Since Built (due to tracking) | Not constructed yet. Scheduled 2011. | | | | | | | | | | | | |
| Operational Concerns (flow of semis) Since Built | Not constructed yet. Scheduled 2011. | | | | | | | | | | | | |
| If designed to keep semis in the lane, would semis stay in the lane ? | Not constructed yet. Scheduled 2011. | | | | | | | | | | | | |
| Reported Crash Concerns Regarding Semis | Not constructed yet. Scheduled 2011. | | | | | | | | | | | | |
| Crash Data | Not constructed yet. Scheduled 2011. | | | | | | | | | | | | |
| Reported Congestion | Not constructed yet. Scheduled 2011. | | | | | | | | | | | | |
| Time | | | | | | | | | | | | | |
| Approach | | | | | | | | | | | | | |

ROUNDABOUT # 18

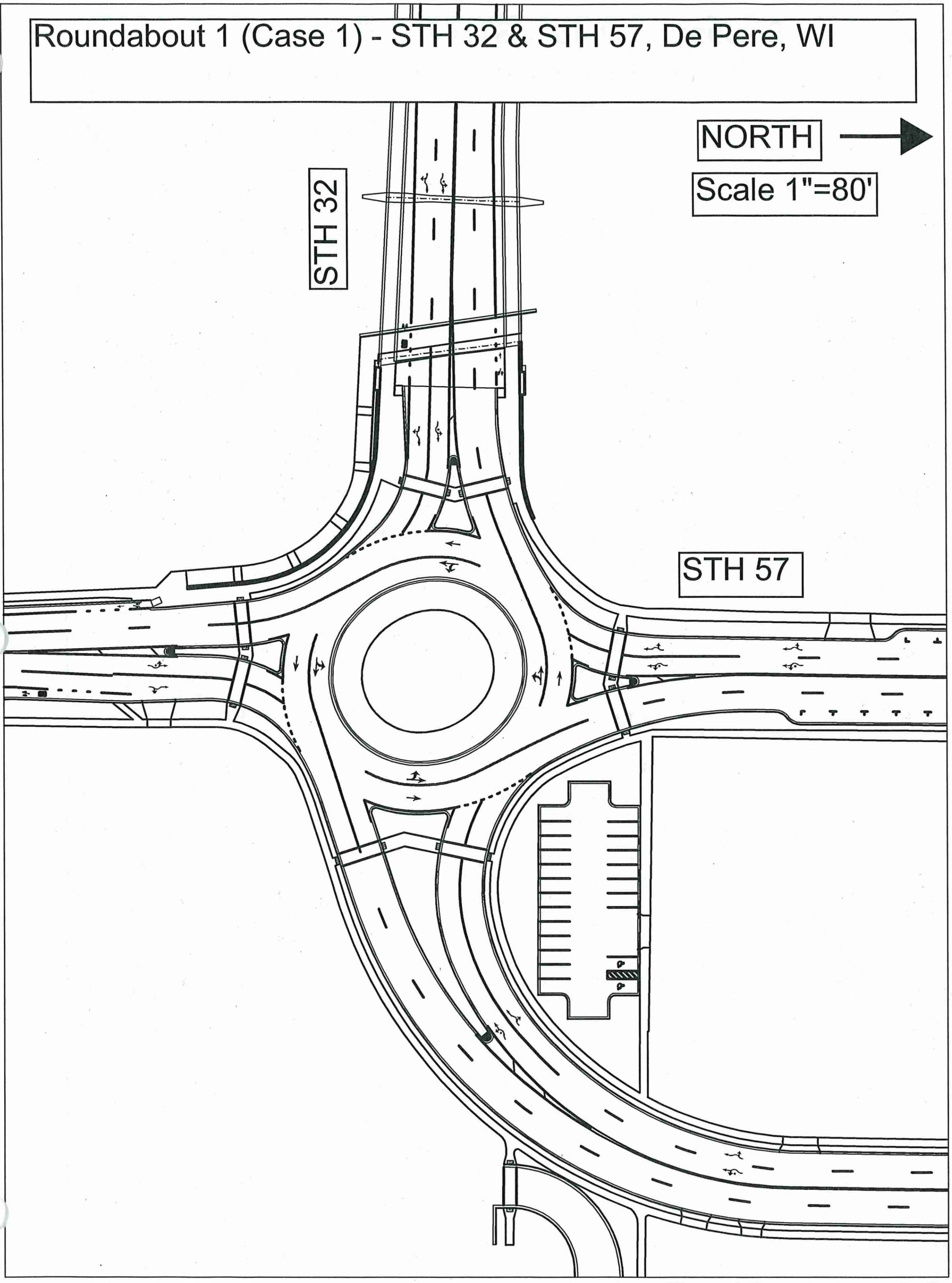
| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Lien Road and Thompson Drive Madison, WI** | | | | | | | | | | | | |
| Roundabout Case # (based on DLZ initial review) | 2 | | | | | | | | | | | | |
| Design Vehicle | WB-67 | | | | | | | | | | | | |
| Design Year | | | | | | | | | | | | | |
| Projected Design Year AADT | | | | | | | | | | | | | |
| Projected Design Year Truck % | | | | | | | | | | | | | |
| % Trucks by Classification | | | | | | | | | | | | | |
| | | **NBL** | **NBT** | **NBR** | **SBL** | **SBT** | **SBR** | **EBL** | **EBT** | **EBR** | **WBL** | **WBT** | **WBR** |
| Existing Peak Hour Volume | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Design Year Peak Hour Volume | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Design Accommodations for Semis- | | | | | | | | | | | | | |
| Inscribed Circle Diameter (ft) | 202 | | | | | | | | | | | | |
| Width of Truck Apron (ft) | 21.5 | | | | | | | | | | | | |
| | **NB** | **SB** | **EB** | **WB** | | | | | | | | | |
| Entry Width at a point just prior to entering the circle measured between the splitter island curb face and the outside curb face (ft) | 33.0 | 33.0 | 33.0 | 32.0 | | | | | | | | | |
| Number of Approach Lanes | 2.0 | 2.0 | 2.0 | 2.0 | | | | | | | | | |
| Average Approach Lane widths | 9.5 | 11.5 | 12.3 | 12.0 | | | | | | | | | |
| Circulatory width at the widest part (ft) | 33 | | | | | | | | | | | | |
| Number of Lanes | 2 | | | | | | | | | | | | |
| Average Lane widths | 16 | | | | | | | | | | | | |
| | **NB** | **SB** | **EB** | **WB** | | | | | | | | | |
| Exit width at a point just after leaving the circle measured between the splitter island curb face and the outside curb face (ft) | 33.0 | 33.0 | 32.0 | 33.0 | | | | | | | | | |
| Number of Departure Lanes | 2.0 | 2.0 | 2.0 | 2.0 | | | | | | | | | |
| Average Departure Lane Width | 14.0 | 14.0 | 13.0 | 14.0 | | | | | | | | | |
| Any other site specific accommodations | Striped gore between lanes on all approaches. | | | | | | | | | | | | |
| For Trucks Entering - | | | | | | | | | | | | | |
| the design developed for a semi truck was to | Not Encroach | | | | | | | | | | | | |
| Reason | | | | | | | | | | | | | |
| For Trucks Circulating - | | | | | | | | | | | | | |
| the design developed for a semi truck was to | Encroach | | | | | | | | | | | | |
| Reason | | | | | | | | | | | | | |
| For Trucks Exiting - | | | | | | | | | | | | | |
| the design developed for a semi truck was to | | | | | | | | | | | | | |
| Reason | | | | | | | | | | | | | |
| Complaints from Truckers | Just openned on 10.01.10 | | | | | | | | | | | | |
| Maintenance Requirements Since Built (due to tracking) | Just openned on 10.01.10 | | | | | | | | | | | | |
| Operational Concerns (flow of semis) Since Built | Just openned on 10.01.10 | | | | | | | | | | | | |
| If designed to keep semis in the lane, would semis stay in the lane ? | Just openned on 10.01.10 | | | | | | | | | | | | |
| Reported Crash Concerns Regarding Semis | Just openned on 10.01.10 | | | | | | | | | | | | |
| Crash Data | Just openned on 10.01.10 | | | | | | | | | | | | |
| Reported Congestion | Just openned on 10.01.10 | | | | | | | | | | | | |
| Time | | | | | | | | | | | | | |
| Approach | | | | | | | | | | | | | |

NA - No information available

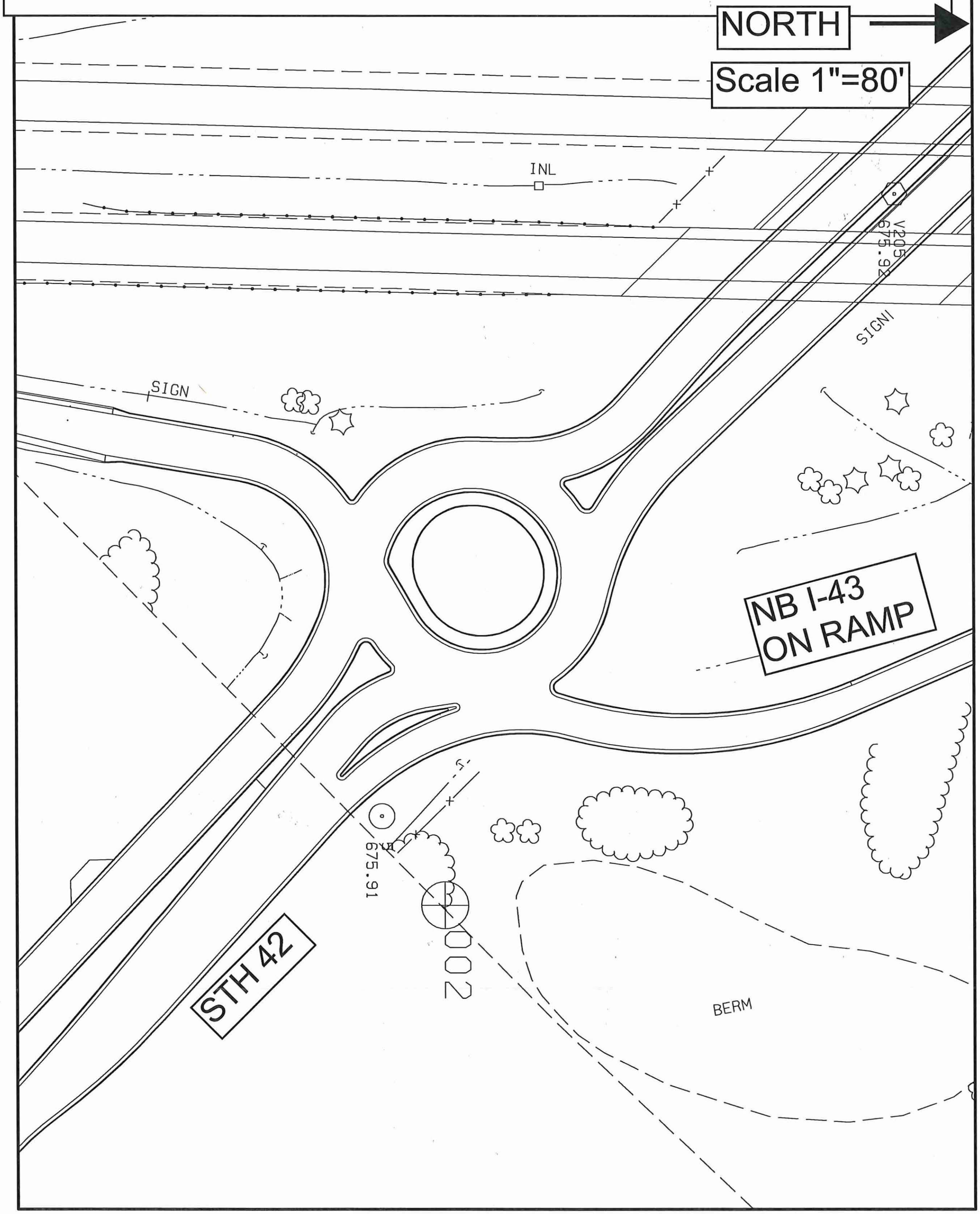
# Appendix E

Roundabout Layouts

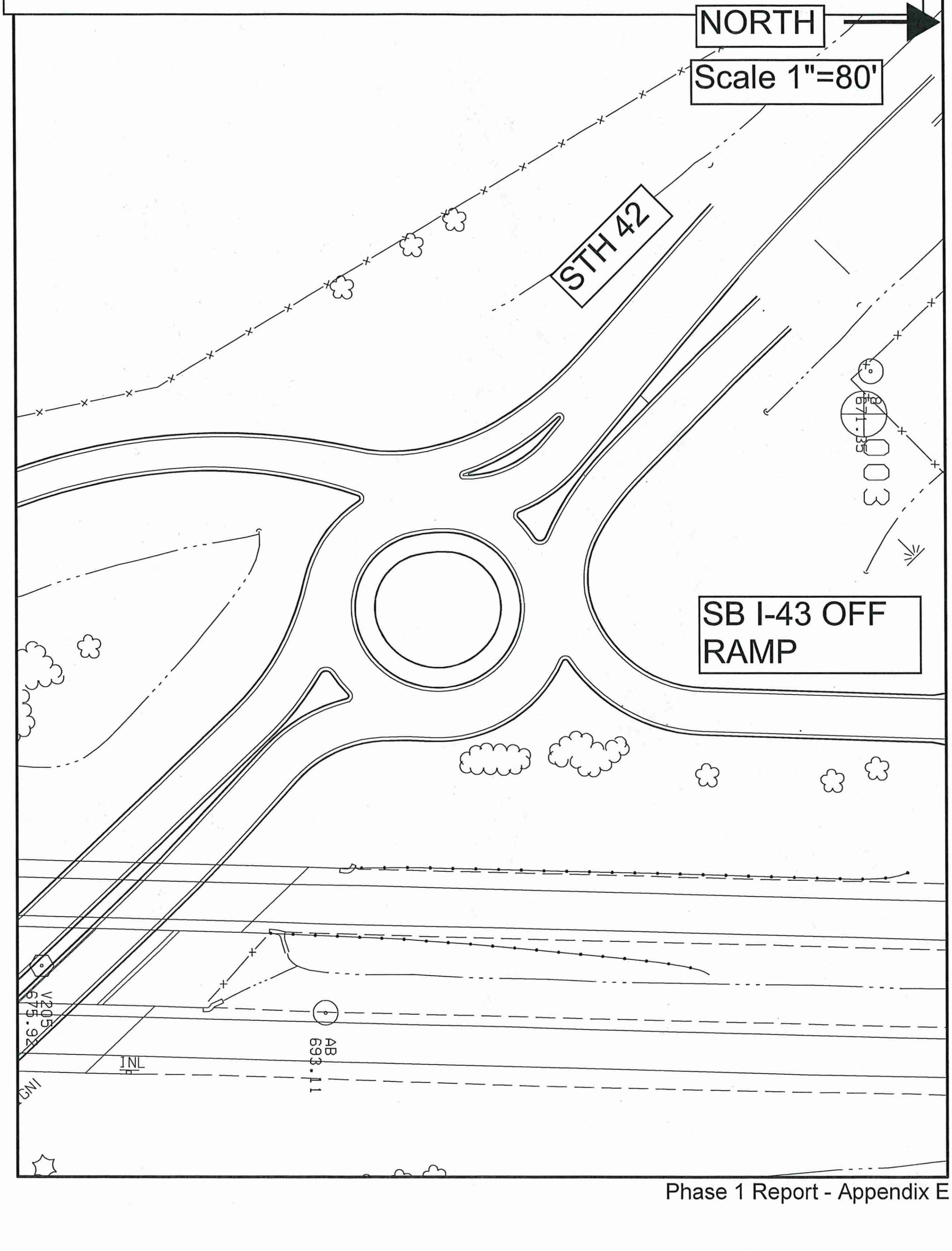
# Roundabout 1 (Case 1) - STH 32 & STH 57, De Pere, WI



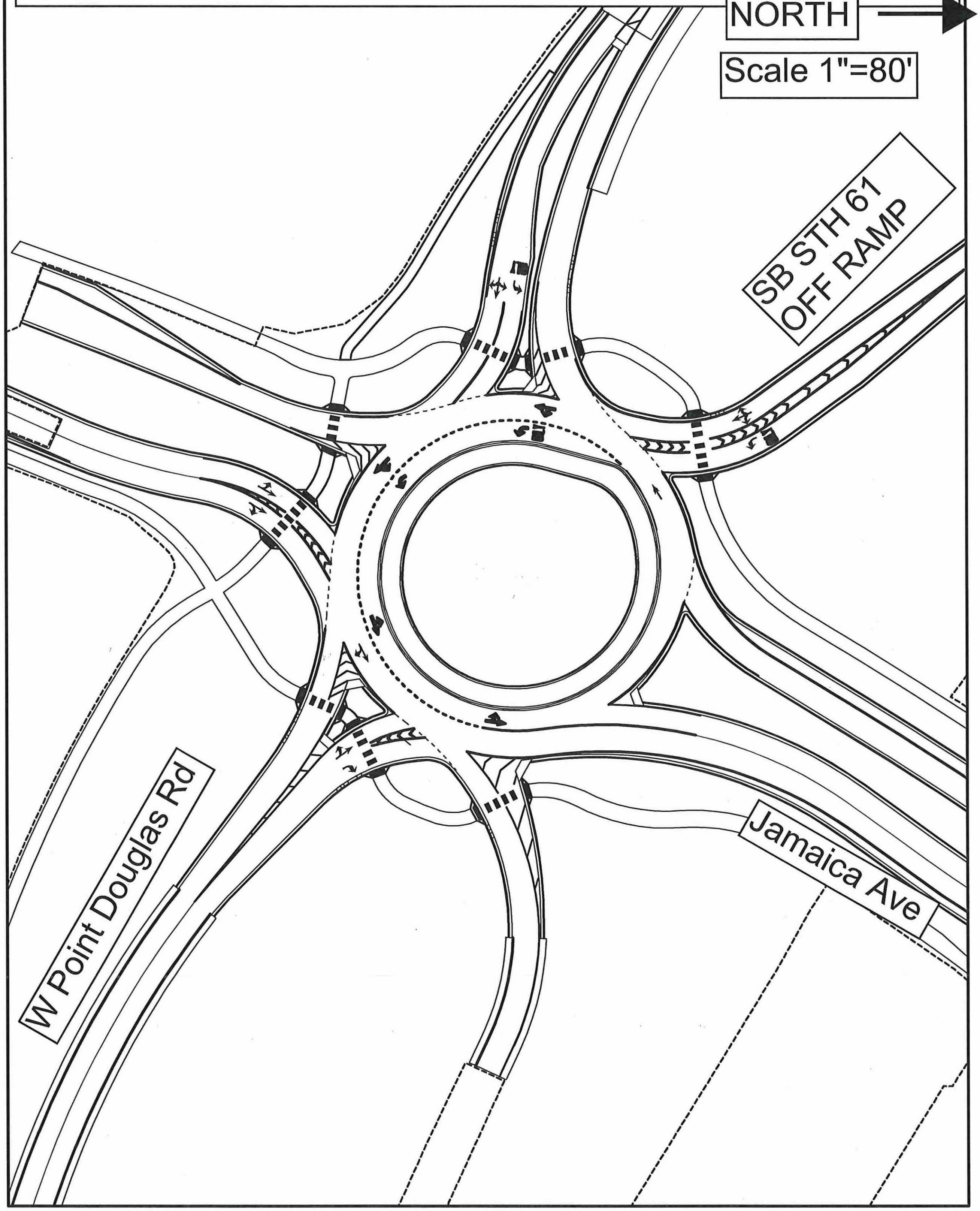
# Roundabout 2 (Case 1) - I-43 & STH 42 NB Ramps, Sheboygan WI (pavement markings layer unavailable)



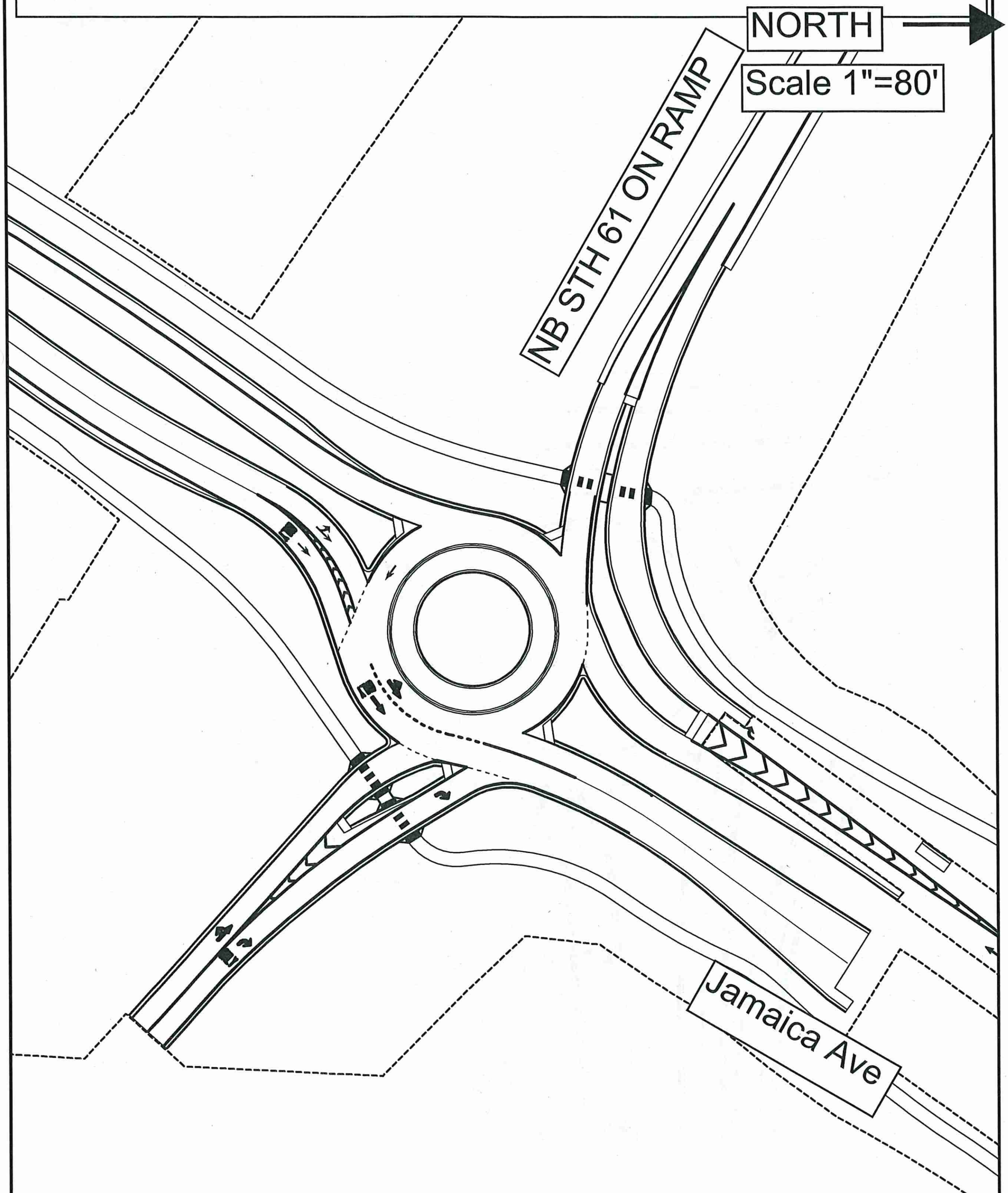
# Roundabout 3 (Case 1) - I-43 & STH 42 SB Ramps, Sheboygan, WI (pavement markings layer unavailable)



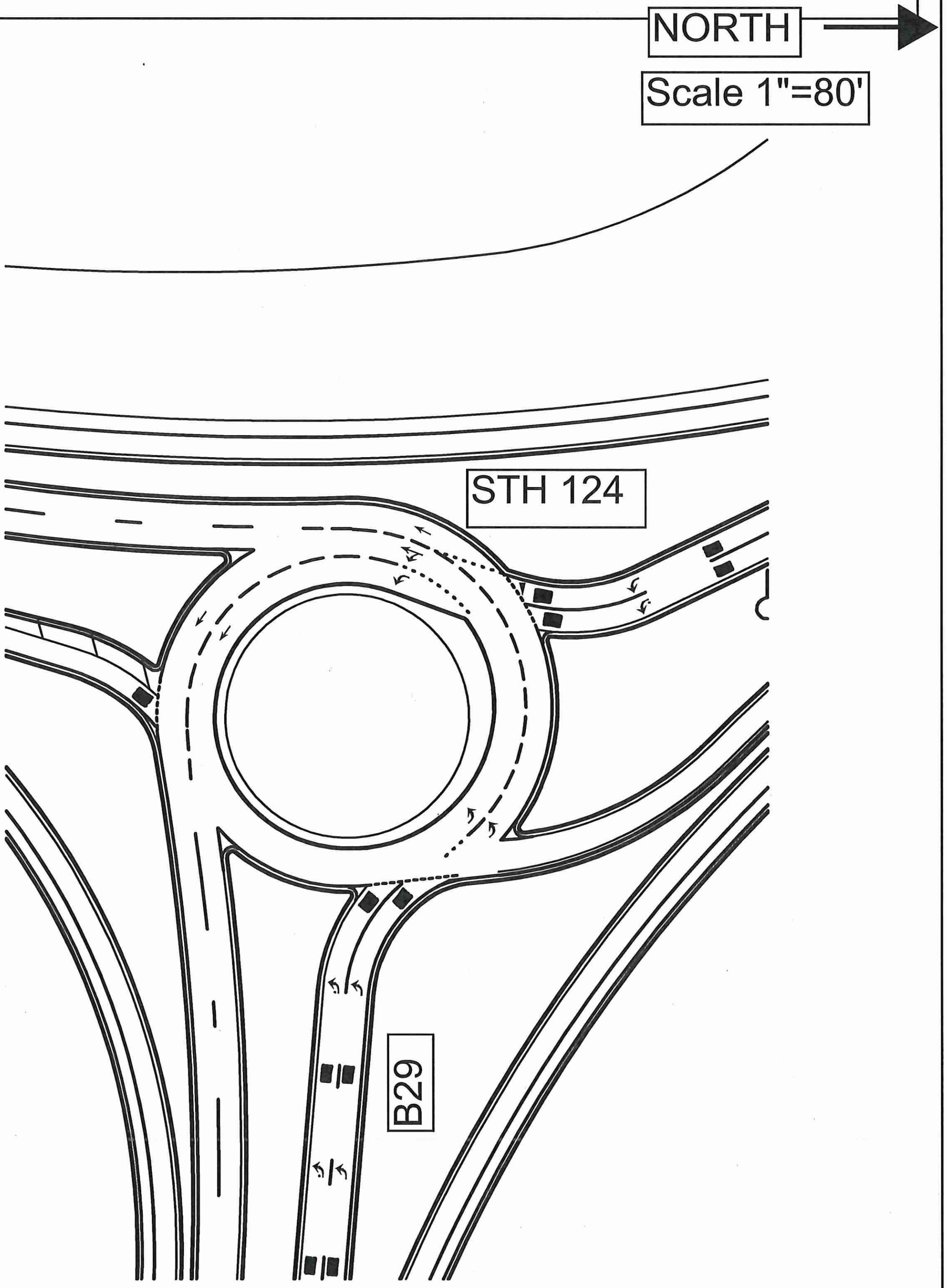
# Roundabout 4 (Case 2) - STH 61 & Jamaica Ave SB Ramps, Cottage Grove, MN



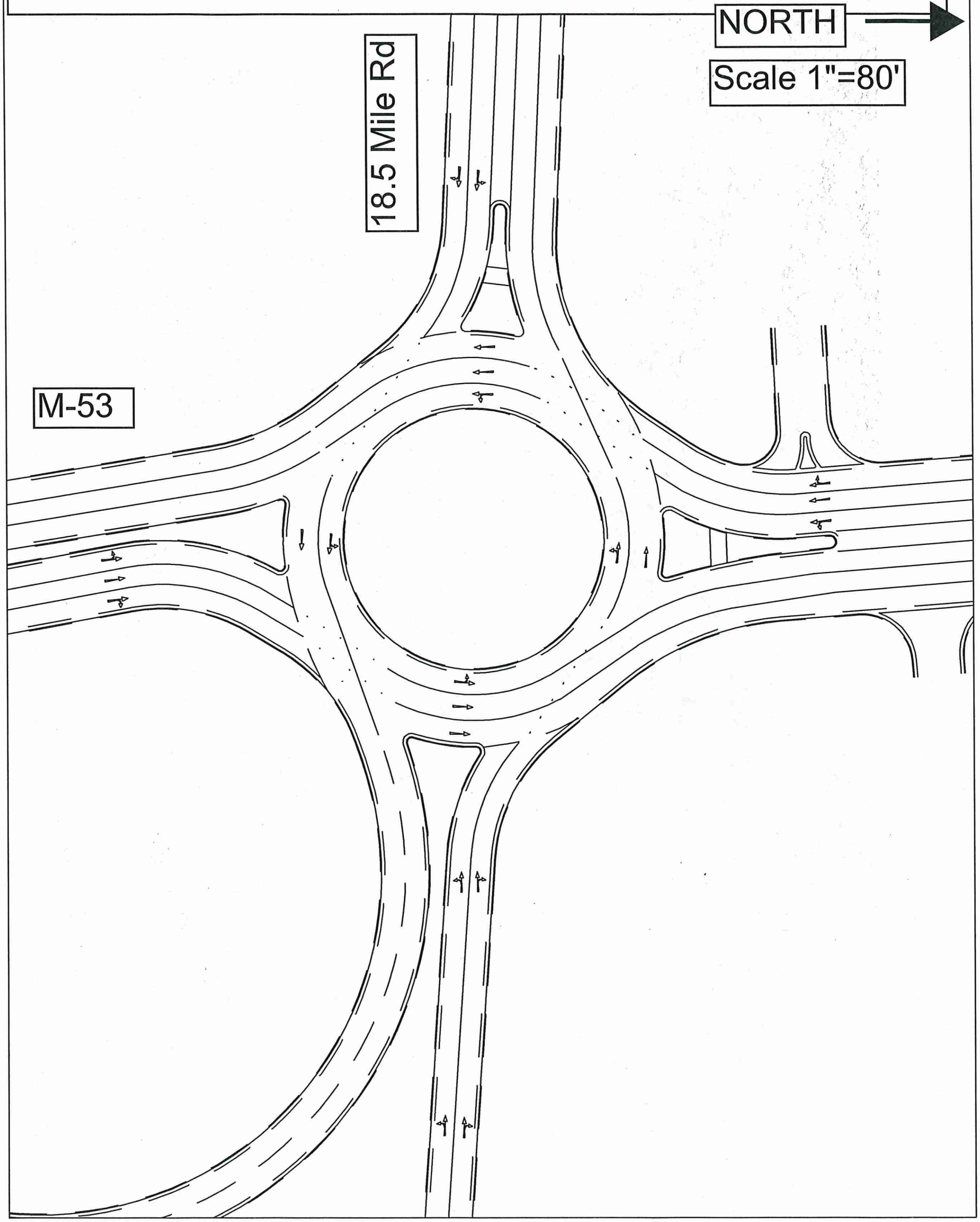
# Roundabout 5 (Case 2) - STH 61 & Jamaica Ave NB Ramps, Cottage Grove, MN



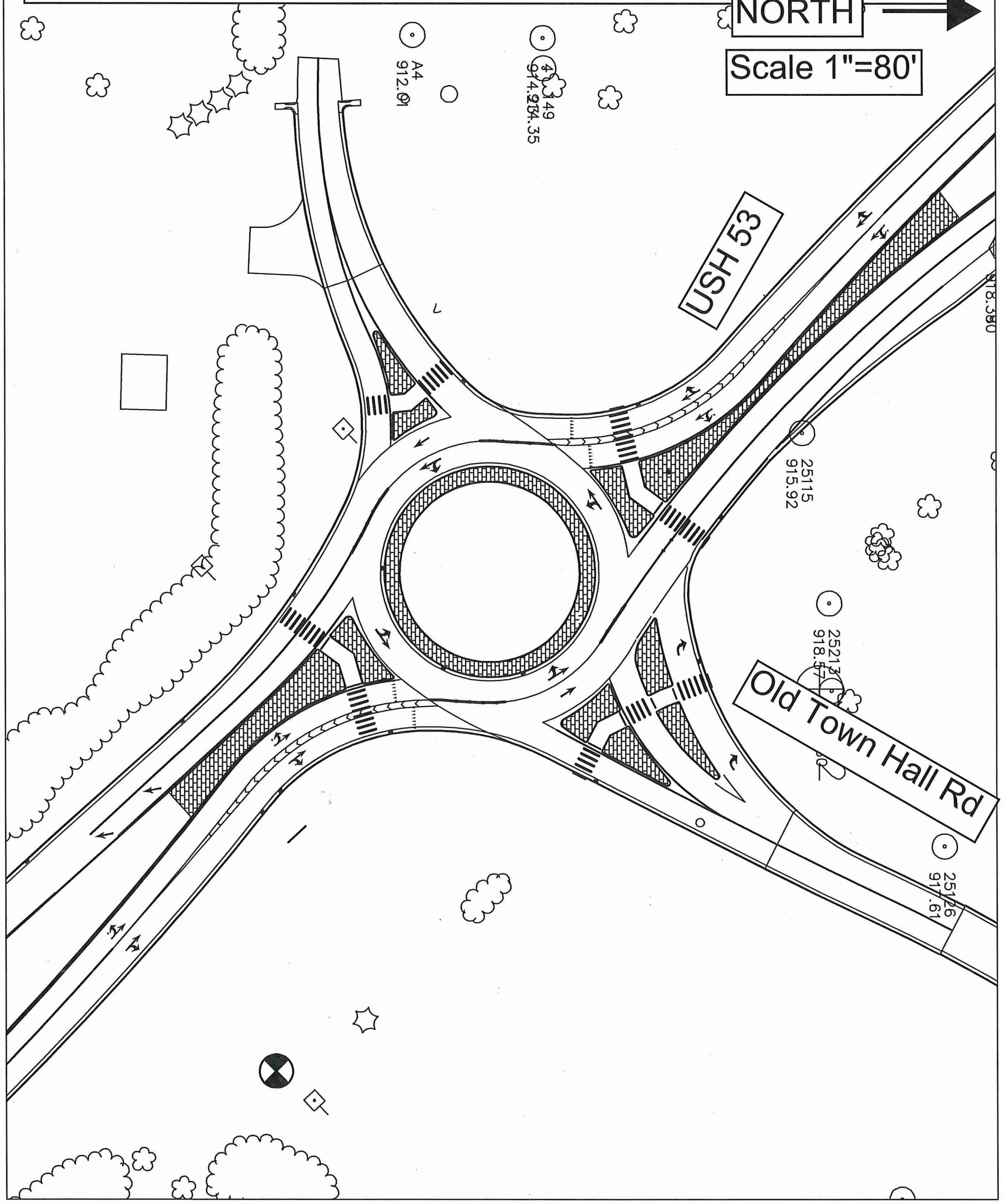
# Roundabout 6 (Case 1) - STH 124 & Business 29, Eau Claire, WI



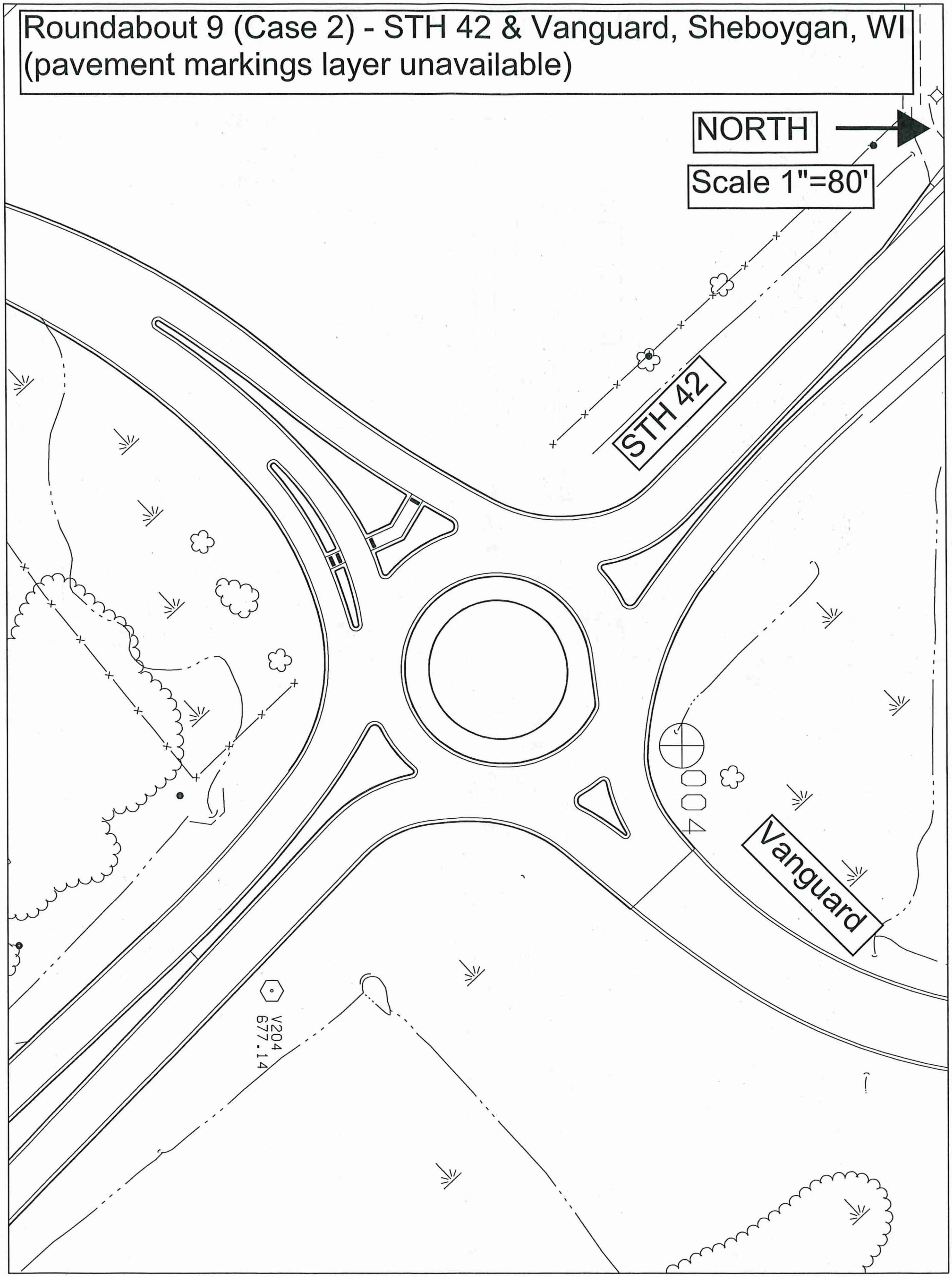
# Roundabout 7 (Case 1) - M-53 & 18.5 Mile Rd, Sterling Heights, MI



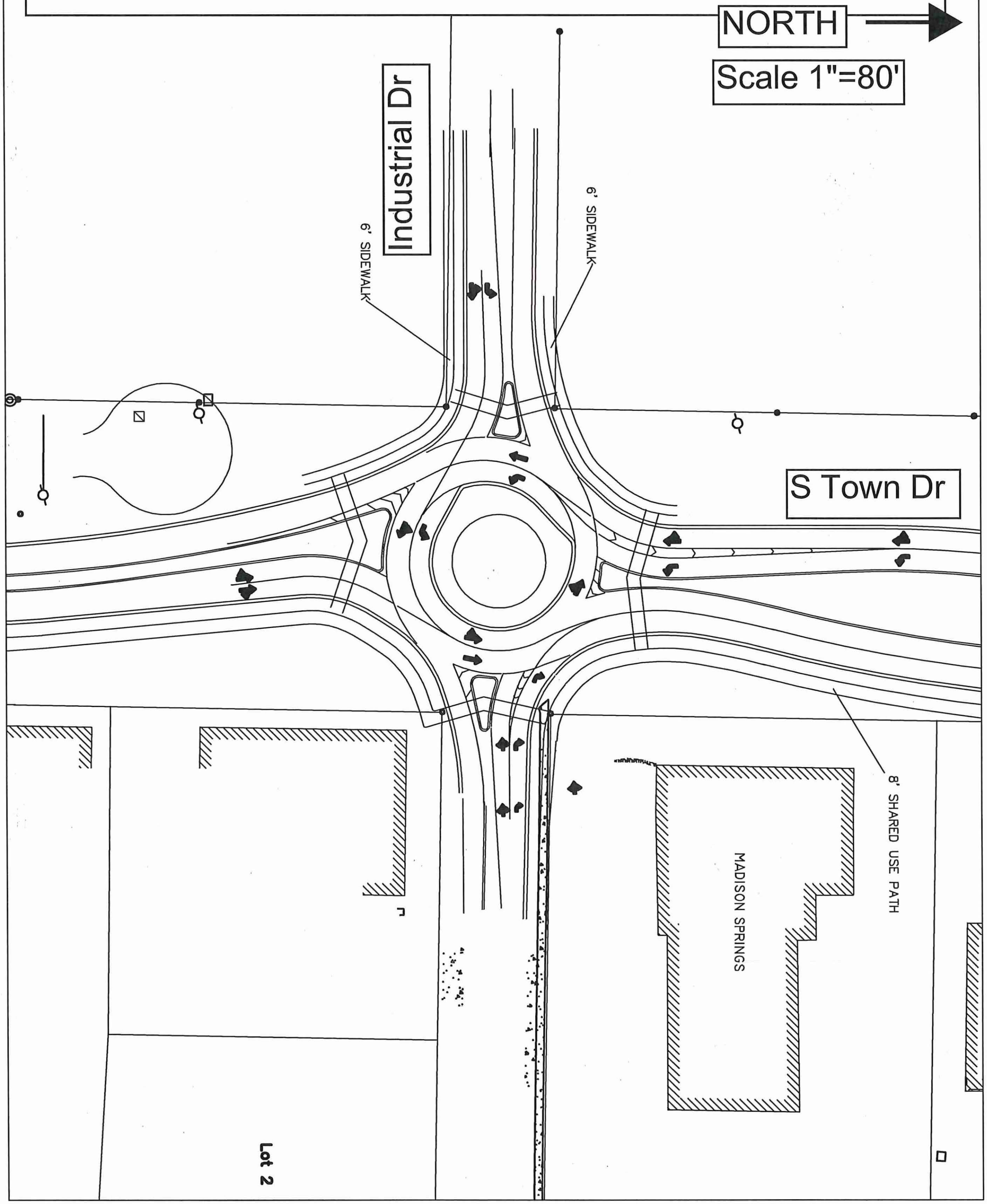
# Roundabout 8 (Case 2) - USH 53 & Old Town Hall Rd, Eau Claire, WI



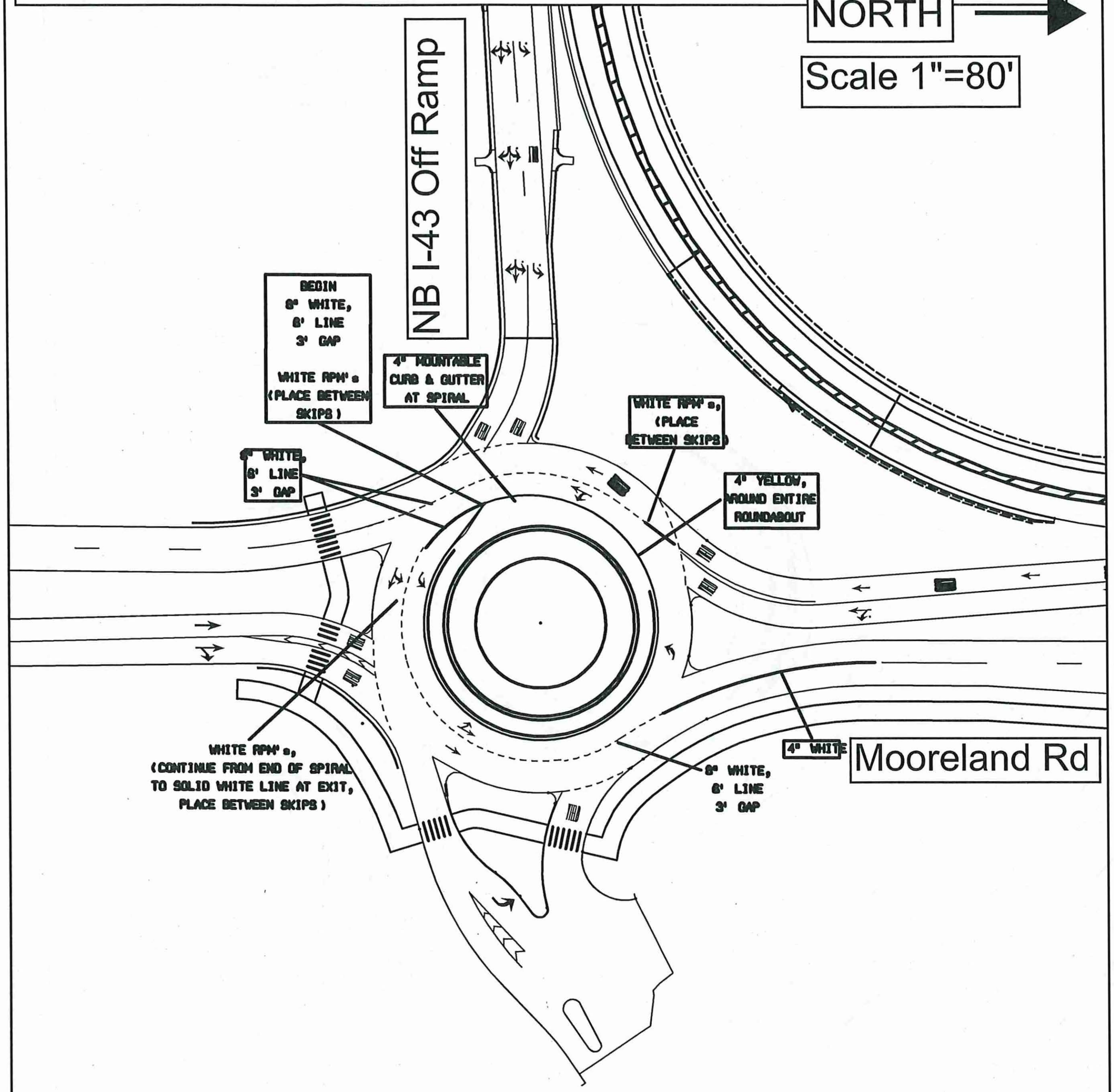
# Roundabout 9 (Case 2) - STH 42 & Vanguard, Sheboygan, WI
(pavement markings layer unavailable)



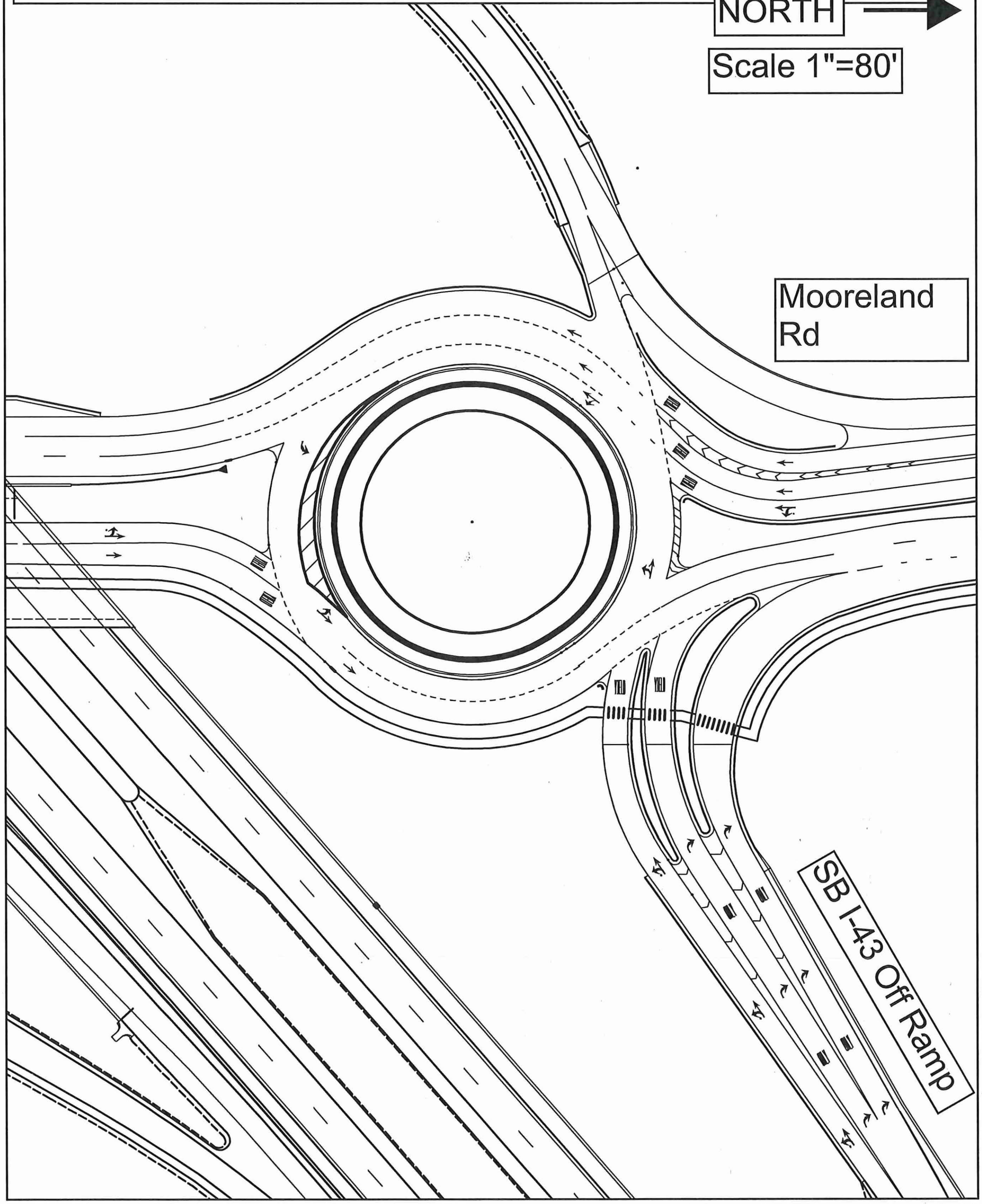
# Roundabout 10 (Case 2) - South Town Dr & Industrial Dr, Monona, WI



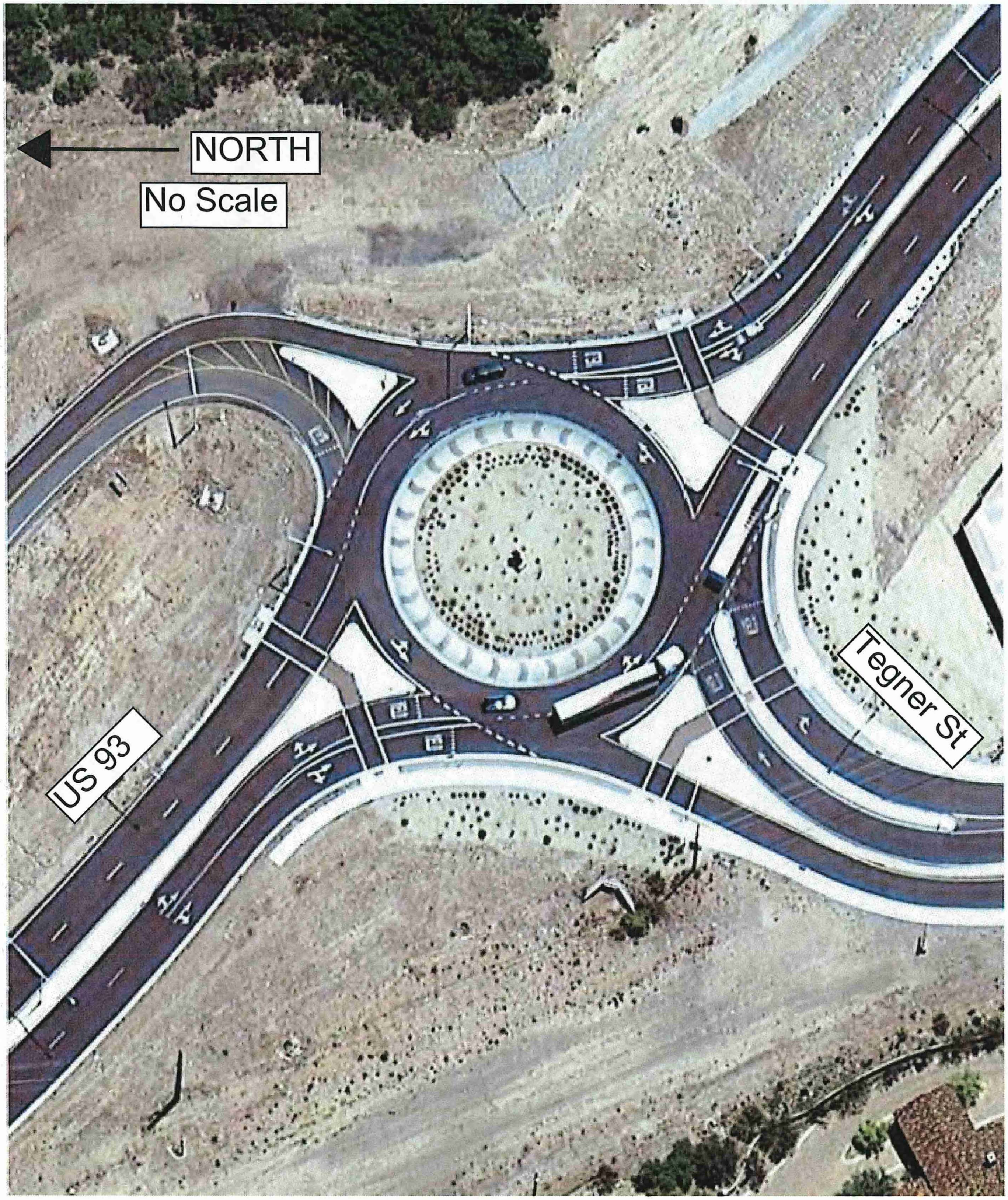
# Roundabout 11 (Case 2) - I-43 & Mooreland Rd South Ramps, New Berlin, WI



# Roundabout 12 (Case 2) - I-43 & Mooreland Road North Ramps, New Berlin, WI

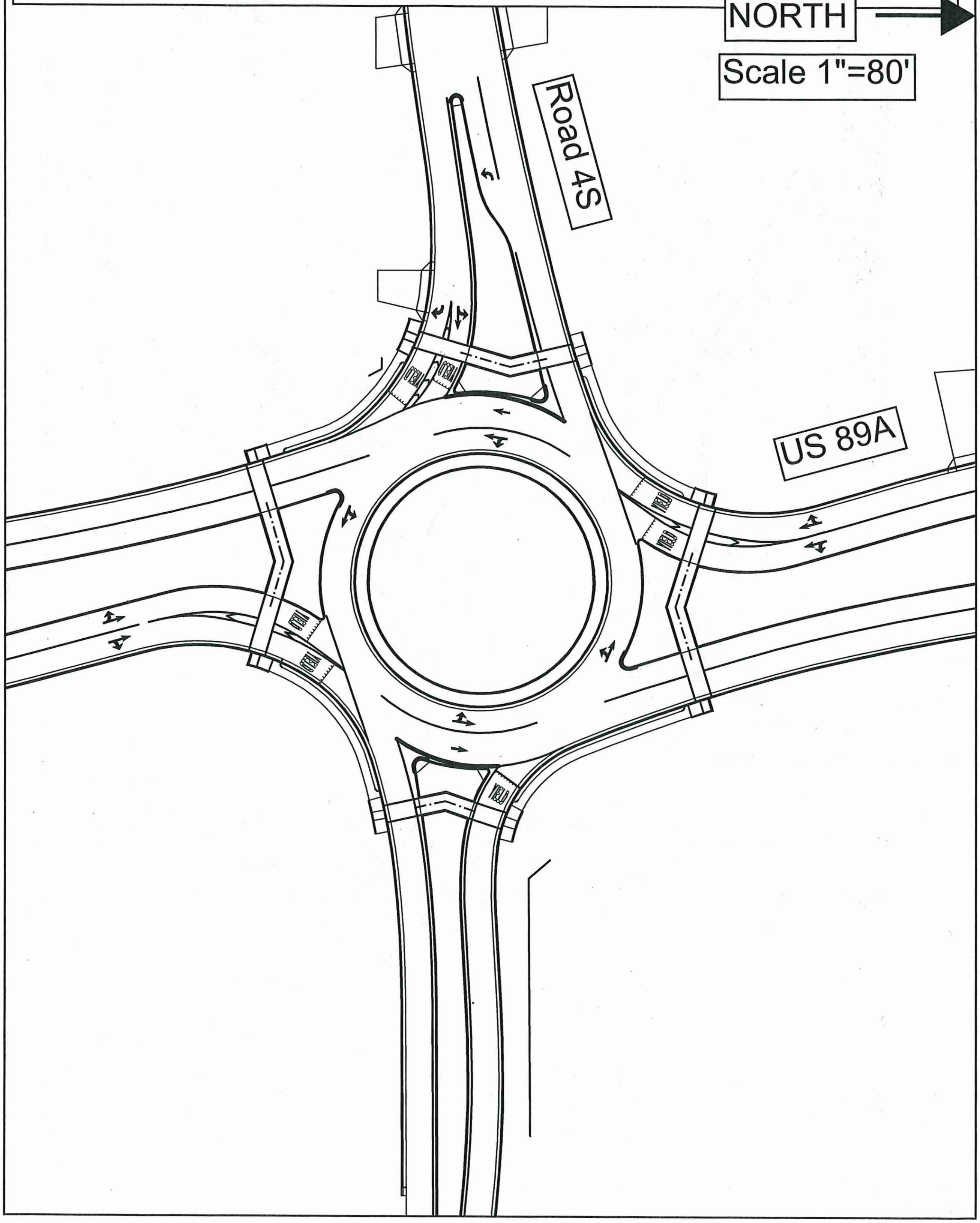


# Roundabout 13 (Case 2) - US 93 & Tegner St, Wickenburg, AZ

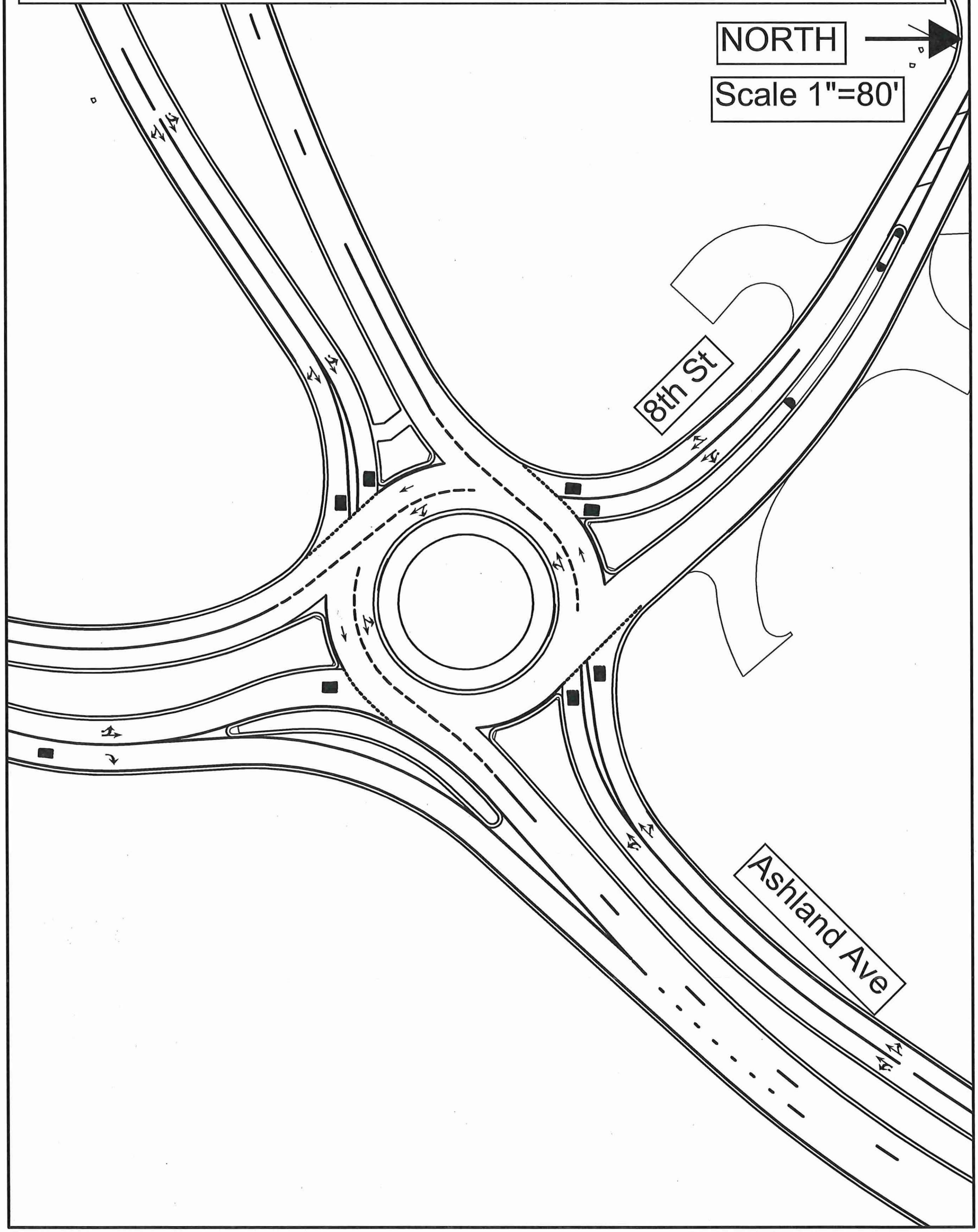


# Roundabout 14 (Case 2) - US 93 & US 60, Wickenburg, AZ

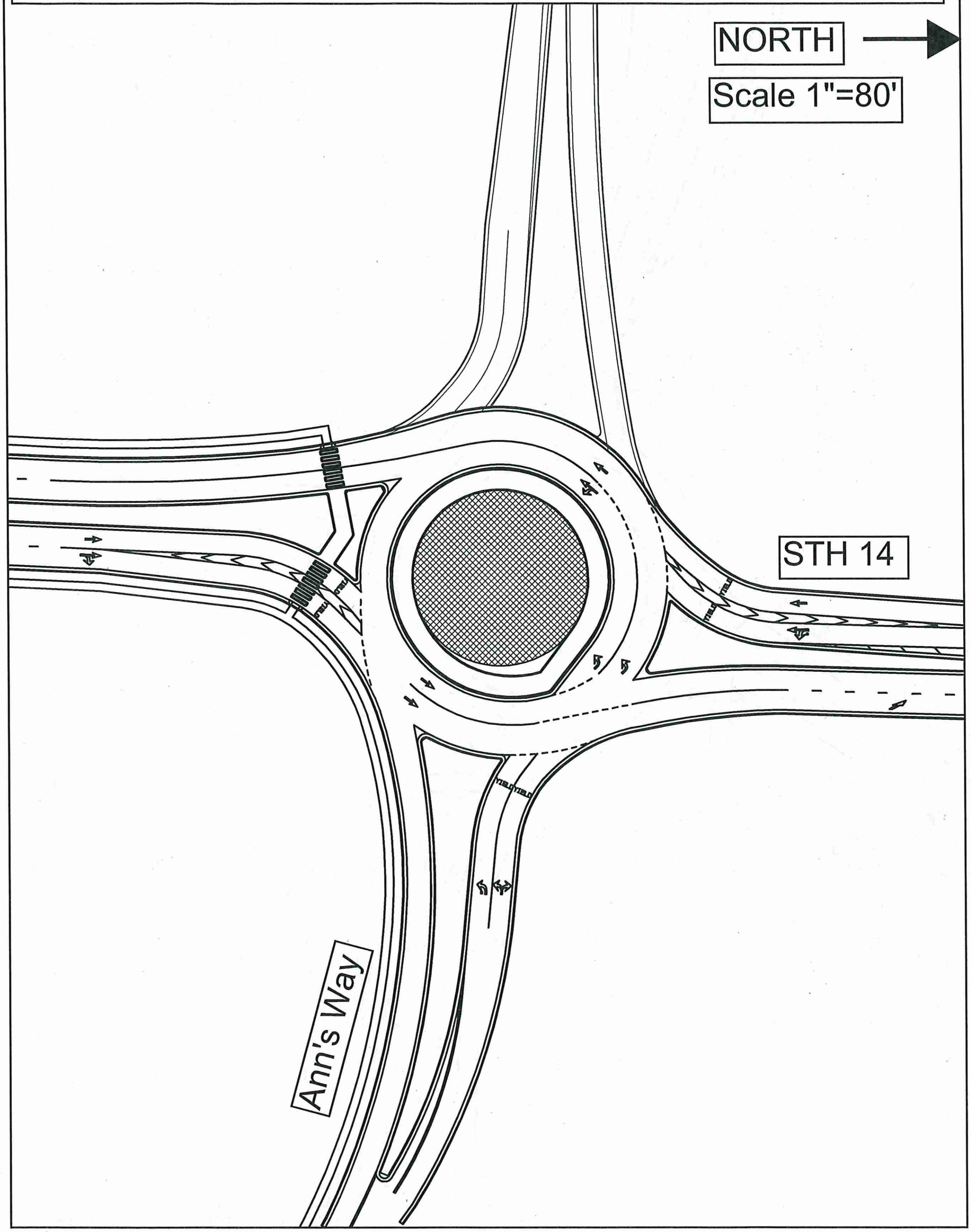
# Roundabout 15 (Case 3) - US 89A & Road 4S, Chino Valley, AZ



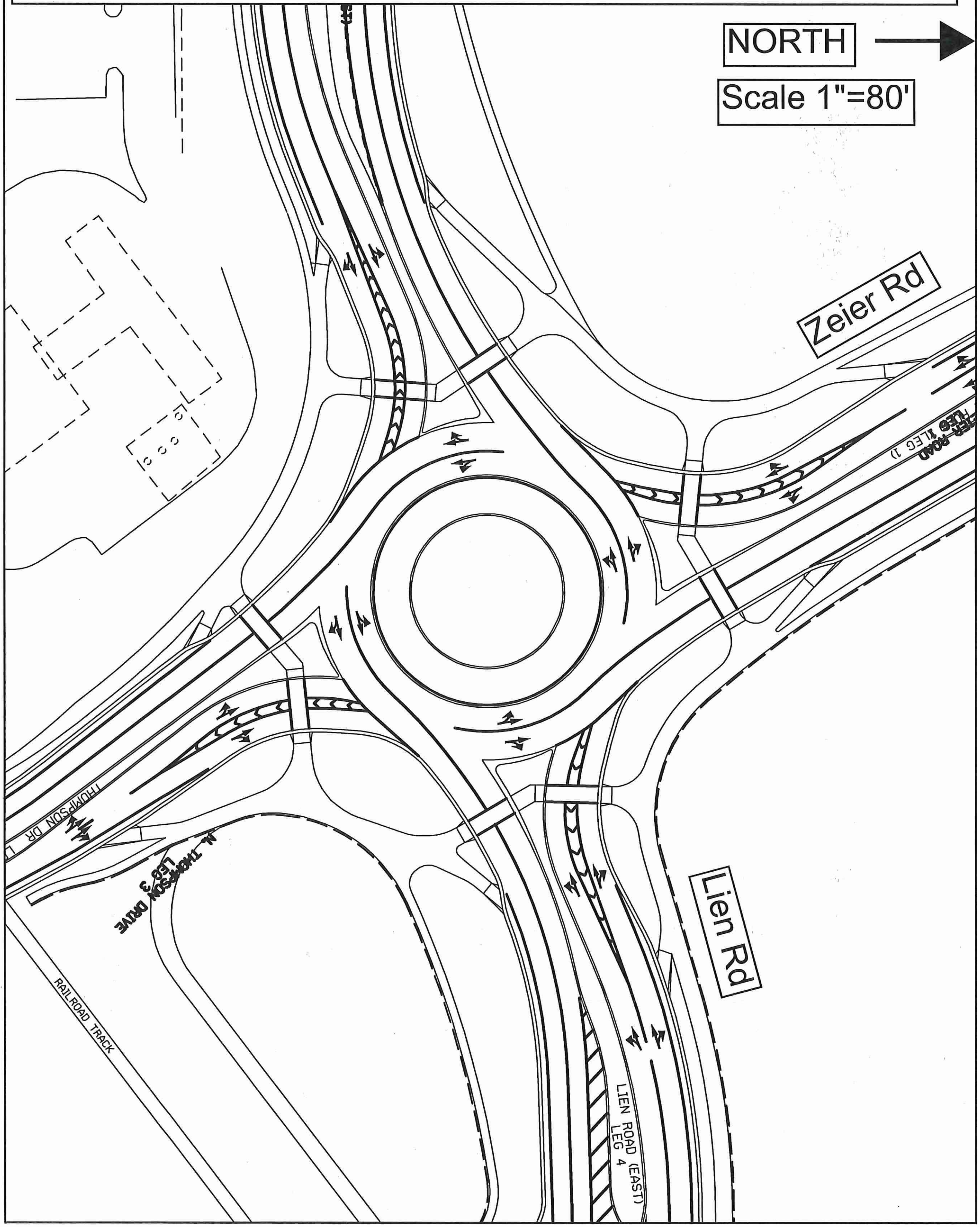
# Roundabout 16 (Case 3) - Ashland Ave & 8th St, Ashwaubenon, WI



# Roundabout 17 (Case 3) - STH 14 & Ann's Way, Medford, WI



# Roundabout 18 (Case 3) - Lien Rd & Zeier Rd, Madison, WI



# Appendix F

Video Observation Log

| Intersection | Approach (File) | Case | Video Timestamp | Approach Conditions | | | | Circulating Conditions | | | | Observation Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Conflicting Traffic Present | | No Conflicting Traffic | | Conflicting Traffic Present | | No Conflicting Traffic | | |
| | | | | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | |
| I-43 & Mooreland North | Northbound | 1 | 1:24 | | | X | | | | X | | truck through |
| I-43 & Mooreland North | Northbound | 1 | 7:24 | | | X | | | | | X | truck through |
| I-43 & Mooreland North | Northbound | 1 | 17:33 | | | X | | | | | X | truck through |
| I-43 & Mooreland North | Northbound | 1 | 25:30 | | X | | | | X | | | truck left with queue behind it did not use truck apron and encroached on unoccupied 2nd lane |
| I-43 & Mooreland North | Northbound | 1 | 47:13 | | | | X | | | | X | truck through appeared to cross lane line at entry |
| I-43 & Mooreland North | Northbound | 1 | 48:33 | X | | | | X | | | | truck through movement car approached from behind and circulated side by side |
| I-43 & Mooreland North | Northbound | 1 | 52:28 | | | X | | | | | X | truck through from right lane crossed into inner lane to turn left at next downstream intersection |
| I-43 & Mooreland North | Northbound | 1 | 53:00 | | | X | | | | | X | truck through from right lane crossed into inner lane to turn left at next downstream intersection |
| I-43 & Mooreland North | Northbound | 1 | 54:22 | | | X | | | | X | | truck through from left lane |
| I-43 & Mooreland North | Northbound | 1 | 56:39 | | | X | | | | | X | truck through from right lane slightly encroached while circulating |
| I-43 & Mooreland North | Northbound | 1 | 1:01:50 | | | X | | | | X | | truck through from right lane stayed in lane |
| I-43 & Mooreland North | Northbound | 1 | 1:05:28 | | | X | | | | | X | truck through from right lane clipped entry radius curb, slightly encroached while circulating |
| I-43 & Mooreland North | Northbound | 1 | 1:10:00 | X | | | | X | | | | truck through from right lane in |
| I-43 & Mooreland North | Northbound | 1 | 1:10:10 | X | | | | X | | | | truck through from left lane used truck apron to stay in lane |
| I-43 & Mooreland North | Northbound | 1 | 1:14:12 | | X | | | | X | | | truck through from right lane encroached on other lanes |
| I-43 & Mooreland North | Northbound | 1 | 1:20:40 | X | | | | X | | | | truck through from right lane |
| I-43 & Mooreland North | Northbound | 1 | 1:29:02 | | | | X | | | X | | truck through from left lane |
| I-43 & Mooreland North | Northbound | 1 | 1:48:27 | X | | | | X | | | | truck left turn from left lane did not appear to use truck apron |
| I-43 & Mooreland North | Northbound | 1 | 1:51:55 | X | | | | X | | | | truck through from right lane |
| I-43 & Mooreland North | Northbound | 1 | 1:52:40 | X | | | | | X | | | truck left from right lane changed lanes in circ roadway |
| I-43 & Mooreland North | Northbound | 1 | 1:59:28 | | | | X | | | | X | truck through from right lane changed to left lane near traffic but not adjacent entering |
| I-43 & Mooreland North | Northbound | 1 | 2:05:25 | | | X | | | | X | | truck through from left lane |
| I-43 & Mooreland North | Northbound | 1 | 2:07:09 | | | X | | | | | X | truck through from right lane changed to left lane in circ roadway |
| I-43 & Mooreland North | Northbound | 1 | 2:14:26 | X | | | | X | | | | truck through from left lane used truck apron to stay in lane |
| I-43 & Mooreland North | Northbound | 1 | 2:24:18 | | | X | | | | | X | truck through from left lane crossed lanes in circ roadway and exited from left lane |
| I-43 & Mooreland North | Northbound | 1 | 2:38:33 | | X | | | | X | | | truck through from right lane side by side with motorcycle, slightly encroached |
| I-43 & Mooreland North | Northbound | 1 | 3:25:03 | | | X | | | | | X | truck through from right lane encroached while circulating |
| I-43 & Mooreland North | Northbound | 1 | 3:30:02 | | X | | | | X | | | truck through from right lane encroached on other lanes following cars stayed back |
| I-43 & Mooreland North | Northbound | 1 | 3:55:33 | | | X | | | | | X | truck through from right lane slightly encroached while circulating |
| I-43 & Mooreland North | Northbound | 1 | 3:59:40 | | | | X | | | | X | truck through from left lane avoided apron and encroached on outer lane |
| I-43 & Mooreland North | Northbound | 1 | 4:17:05 | | | | X | | | | X | truck left from left lane avoided truck apron |
| I-43 & Mooreland North | Northbound | 1 | 4:22:02 | | X | | | | X | | | truck through from right lane encroached while entering and circulating causing simultaneously entering pickup to brake |
| I-43 & Mooreland North | Northbound | 1 | 4:23:05 | X | | | | | X | | | truck through from right lane encroached while circulating following vehicles braked to stay behind |
| I-43 & Mooreland North | Northbound | 1 | 4:31:04 | | | X | | | | | X | truck through from right lane changed lanes in circ roadway to exit in left lane |
| I-43 & Mooreland North | Northbound | 1 | 4:32:55 | | | | X | | | X | | truck through from left lane encroached on entry only |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 2:15 | X | | | | X | | | | truck through from center lane used hatched out area to right |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 5:10 | X | | | | X | | | | truck through from center lane used hatched out area to right |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 7:05 | | | X | | | | X | | truck through from outer lane, appeared to stay in lane and use hatched area to left |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 7:08 | X | | | | X | | | | truck through from center lane did not appear to use hatched area |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 10:30 | X | | | | X | | | | truck through from outer lane used hatched area |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 13:09 | | | X | | | | X | | truck through from center lane may have used hatched area |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 16:00 | | | X | | | | X | | truck through from outer lane yielded and used hatched area |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 19:50 | | | X | | | | X | | truck through from center lane |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 22:57 | | | | X | | | | X | truck through from center lane appeared to encroach on right lane entering and on center lane circulating |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 28:40 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 36:22 | | | X | | | | X | | truck through from center lane |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 36:44 | | | X | | | | X | | truck through from center lane |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 38:00 | | | | X | | | | X | truck through from center lane occupied hatched area and may have encroached on left circ lane |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 38:23 | | | X | | | | X | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 40:18 | | | | X | | | | X | truck through from center lane occupied hatched area and may have encroached on left circ lane |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 43:20 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 44:12 | | | X | | | | X | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 51:00 | X | | | | X | | | | truck through from center lane used hatched out area to right |
| I-43 & Mooreland North | Southbound (4_57) | 2 | 52:52 | | | X | | | | X | | truck through from center lane used hatched out area to right |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 4:14 | | | X | | | | | X | truck through from outer lane used hatched area |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 7:30 | | | X | | | | X | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 10:44 | X | | | | X | | | | truck through from outer lane used hatched area |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 12:46 | X | | | | X | | | | truck through from outer lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 14:48 | | | X | | | | X | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 14:53 | X | | | | | X | | | truck through from right lane changed lanes in circ roadway to exit in center lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 17:05 | X | | | | X | | | | truck through from center lane used hatched out area to right |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 18:28 | X | | | | X | | | | truck through from right lane used hatched area |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 20:10 | X | | | | X | | | | truck through from right lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 21:05 | X | | | | X | | | | truck through from right lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 24:10 | X | | | | X | | | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 27:42 | X | | | | X | | | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 37:14 | X | | | | X | | | | truck through from right lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 42:12 | X | | | | X | | | | truck through from left lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 43:12 | | | X | | | | | X | truck through from center lane appeared to change lanes in circ roadway |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 47:46 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 47:59 | X | | | | X | | | | truck through from center lane |

| Intersection | Approach (File) | Case | Video Timestamp | Approach Conditions | | | | Circulating Conditions | | | | Observation Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Conflicting Traffic Present | | No Conflicting Traffic | | Conflicting Traffic Present | | No Conflicting Traffic | | |
| | | | | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 48:22 | X | | | | X | | | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 53:20 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 54:56 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 57:45 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_01) | 2 | 58:57 | | | | X | | | | X | truck through from right lane changed lanes in circ roadway |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 1:48 | X | | | | X | | | | truck through from outside lane used hatched area |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 5:30 | | | X | | | | X | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 9:30 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 12:00 | | | X | | | | | X | truck through from left lane avoided apron and encroached on center |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 14:59 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 15:10 | | X | | | X | | | | truck through from center lane encroached on left lane on entry, stayed in center lane in circ roadway |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 18:00 | | | X | | | | | X | truck through from center lane encroached on left lane in circ roadway |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 18:18 | X | | | | X | | | | truck through from outer lane used hatched area |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 19:39 | X | | | | X | | | | truck through from outside line |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 25:10 | | | X | | | | | X | truck through from outside lane used hatched area and encroached on center lane in circ roadway |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 29:20 | | | X | | | | X | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 34:40 | X | | | | X | | | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 35:30 | | X | | | X | | | | truck through from center lane encroached on unoccupied left lane on entry, stayed in center lane through circ roadway |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 40:40 | X | | | | X | | | | truck through from center lane following vehicles braked and backed off |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 42:50 | | | X | | | | X | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 48:12 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 49:46 | X | | | | X | | | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_05) | 2 | 55:20 | X | | | | X | | | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 0:48 | X | | | | X | | | | truck through from outside lane used hatched area |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 1:43 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 7:25 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 13:00 | | | X | | | | X | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 13:40 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 15:20 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 18:47 | X | | | | X | | | | truck through from center lane used hatched out area to right |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 26:35 | X | | | | X | | | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 29:45 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 34:25 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 35:39 | X | | | | X | | | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 36:40 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 38:25 | | | X | | | | X | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 38:49 | | | X | | | | X | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 39:34 | X | | | | X | | | | truck through from outside used hatched area |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 43:20 | X | | | | X | | | | truck through from outside used hatched area |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 48:50 | X | | | | X | | | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 50:25 | X | | | | X | | | | truck through from outside lane used hatched area |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 52:13 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_10) | 2 | 57:00 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_14) | 2 | 3:06 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_14) | 2 | 5:00 | X | | | | X | | | | truck through from center lane |
| I-43 & Mooreland North | Southbound (05_14) | 2 | 7:20 | | | X | | | | X | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_14) | 2 | 7:55 | X | | | | X | | | | truck through from outside lane |
| I-43 & Mooreland North | Southbound (05_14) | 2 | 22:01 | | | X | | | | X | | truck through from left lane |
| I-43 & Mooreland South | Southbound | 2 | 25:54 | X | | | | X | | | | truck through right lane tire in gutter |
| I-43 & Mooreland South | Southbound | 2 | 26:07 | X | | | | X | | | | truck through left lane used truck apron |
| I-43 & Mooreland South | Southbound | 2 | 26:15 | X | | | | | X | | | truck through right lane rear tire encroached on left lane |
| I-43 & Mooreland South | Southbound | 2 | 27:07 | X | | | | X | | | | truck through left lane used truck apron |
| I-43 & Mooreland South | Southbound | 2 | 33:07 | X | | | | X | | | | truck through left lane used truck apron |
| I-43 & Mooreland South | Southbound | 2 | 34:50 | | X | | | X | | | | truck through left lane slightly encroached on entry and used truck apron in circ roadway |
| I-43 & Mooreland South | Southbound | 2 | 35:12 | | | | X | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 37:44 | | | | X | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 38:00 | | | | X | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 43:45 | | X | | | X | | | | truck left in left lane slight encroachment on entry |
| I-43 & Mooreland South | Southbound | 2 | 54:27 | | | | X | | | X | | truck through left lane used truck apron |
| I-43 & Mooreland South | Southbound | 2 | 59:04 | | | | X | | | | X | truck through right lane moved to left lane in circ roadway and exited from right lane |
| I-43 & Mooreland South | Southbound | 2 | 1:00:55 | | | | X | | | X | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 1:03:55 | | | X | | | | | X | truck through right lane slight encroachment in circ roadway |
| I-43 & Mooreland South | Southbound | 2 | 1:08:34 | | | X | | | | X | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 1:22:15 | X | | | | X | | | | truck through right lane ran over entry radius curb |
| I-43 & Mooreland South | Southbound | 2 | 1:34:22 | X | | | | X | | | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 1:36:14 | | | | X | | | X | | truck through left lane |
| I-43 & Mooreland South | Southbound | 2 | 1:39:30 | | | X | | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 1:43:44 | X | | | | X | | | | truck through left lane used truck apron |
| I-43 & Mooreland South | Southbound | 2 | 1:52:55 | | | X | | | | | X | truck through right lane encroached on left lane in circ roadway |
| I-43 & Mooreland South | Southbound | 2 | 1:54:52 | | | | X | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 1:57:45 | X | | | | X | | | | truck through right lane |

| Intersection | Approach (File) | Case | Video Timestamp | Approach Conditions | | | | Circulating Conditions | | | | Observation Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Conflicting Traffic Present | | No Conflicting Traffic | | Conflicting Traffic Present | | No Conflicting Traffic | | |
| | | | | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | |
| I-43 & Mooreland South | Southbound | 2 | 2:03:26 | | | | X | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 2:08:16 | | | X | | | | X | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 2:09:30 | X | | | | X | | | | truck through left lane used truck apron |
| I-43 & Mooreland South | Southbound | 2 | 2:10:30 | | | X | | | | X | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 2:15:06 | X | | | | X | | | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 2:18:36 | | | | X | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 2:19:48 | | X | | | | X | | | truck through right lane caused several following vehicles to brake when taking up both lanes |
| I-43 & Mooreland South | Southbound | 2 | 2:20:12 | X | | | | | X | | | truck through right lane slightly encroached on circ roadway |
| I-43 & Mooreland South | Southbound | 2 | 2:23:25 | X | | | | X | | | | truck through right lane slowed to stay in lane |
| I-43 & Mooreland South | Southbound | 2 | 2:38:55 | X | | | | X | | | | truck through left lane used truck apron |
| I-43 & Mooreland South | Southbound | 2 | 2:42:20 | | | | X | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 2:45:26 | X | | | | X | | | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 2:45:38 | | | | X | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 2:58:35 | X | | | | X | | | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 3:06:28 | | | | X | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 3:43:34 | | | | X | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 4:05:11 | X | | | | X | | | | truck through left lane used truck apron |
| I-43 & Mooreland South | Southbound | 2 | 4:20:10 | X | | | | X | | | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 4:29:08 | X | | | | X | | | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 4:31:30 | X | | | | X | | | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 4:33:20 | X | | | | X | | | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 4:35:38 | X | | | | X | | | | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 4:39:12 | X | | | | | X | | | truck through right lane slightly encroached on circ roadway |
| I-43 & Mooreland South | Southbound | 2 | 4:40:48 | | | | X | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 4:50:00 | | | X | | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 4:52:28 | X | | | | X | | | | truck through left lane used truck apron |
| I-43 & Mooreland South | Southbound | 2 | 4:53:50 | | | X | | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 5:05:46 | | | | X | | | | X | truck through right lane |
| I-43 & Mooreland South | Southbound | 2 | 5:09:54 | | | X | | | | | X | truck through right lane |
| I-43 & Mooreland South | Eastbound | 1 | 2:18 | | X | | | | X | | | truck left stradled lane line and used both lanes and avoided truck apron, following cars stayed back |
| I-43 & Mooreland South | Eastbound | 1 | 27:30 | X | | | | X | | | | truck right ran over entry radius curb |
| I-43 & Mooreland South | Eastbound | 1 | 30:18 | | | X | | | | X | | truck right ran over entry radius curb |
| I-43 & Mooreland South | Eastbound | 1 | 31:53 | | | | X | | | X | | truck right slightly encroached on left lane but avoided curb |
| I-43 & Mooreland South | Eastbound | 1 | 37:24 | | | | X | | | X | | truck left encroached on right lane but stayed in circ lane may have used apron |
| I-43 & Mooreland South | Eastbound | 1 | 49:20 | X | | | | X | | | | truck right ran over entry radius curb |
| I-43 & Mooreland South | Eastbound | 1 | 1:33:35 | | | | X | | | X | | truck right encroached on left lane to clear curb |
| I-43 & Mooreland South | Eastbound | 1 | 1:54:12 | | | | X | | | | X | truck left stradled lane line and used both lanes and avoided truck apron |
| I-43 & Mooreland South | Eastbound | 1 | 2:00:38 | | | | X | | | | X | truck left stradled lane line and used both lanes and avoided truck apron |
| I-43 & Mooreland South | Eastbound | 1 | 2:18:40 | | | | X | | | | X | truck left stradled lane line and used both lanes and avoided truck apron |
| I-43 & Mooreland South | Eastbound | 1 | 2:29:38 | X | | | | X | | | | truck right may have jumped curb near the end of the turn |
| I-43 & Mooreland South | Eastbound | 1 | 2:32:25 | | X | | | | X | | | truck left stradled lane line, following car attempted to enter side by side but braked in circ roadway, delaying sb vehs |
| I-43 & Mooreland South | Eastbound | 1 | 2:37:10 | | | | X | | | | X | truck left stradled lane line and used both lanes and avoided truck apron |
| I-43 & Mooreland South | Eastbound | 1 | 3:06:20 | | | | X | | | | X | truck left stradled lane line and used both lanes and avoided truck apron |
| I-43 & Mooreland South | Eastbound | 1 | 3:27:50 | X | | | | | X | | | truck left stayed in left lane but slightly encroached on right circ lane and may have used truck apro |
| I-43 & Mooreland South | Eastbound | 1 | 3:36:38 | | X | | | X | | | | truck left encroached on right lane but stayed in circ lane may have used apron |
| I-43 & Mooreland South | Eastbound | 1 | 3:58:10 | X | | | | X | | | | truck left from right lane jumped entry radius curb but stayed in lane through circ roadwa |
| I-43 & Mooreland South | Eastbound | 1 | 4:19:37 | | X | | | X | | | | truck right encroached on left lane but jumped curb when cars joined adjacent lane |
| I-43 & Mooreland South | Northbound (Synch2) | 2 | 13:15 | | | X | | | | | X | truck through right lane slightly encroached on left lane in circ roadway |
| I-43 & Mooreland South | Northbound (Synch2) | 2 | 17:30 | X | | | | X | | | | truck right turn |
| I-43 & Mooreland South | Northbound (Synch2) | 2 | 19:33 | | | X | | | | | X | truck through from right lane crossed into inner circ lane |
| I-43 & Mooreland South | Northbound (Synch2) | 2 | 28:41 | | | X | | | | | X | truck through from right lane crossed into inner circ lane |
| I-43 & Mooreland South | Northbound (Synch2) | 2 | 32:10 | X | | | | | X | | | truck through from right lane slightly encroached while circulating |
| I-43 & Mooreland South | Northbound (Synch2) | 2 | 36:55 | | | X | | | | | X | truck through from right lane slightly encroached while circulating |
| I-43 & Mooreland South | Northbound (Synch2) | 2 | 37:10 | X | | | | X | | | | truck through from left lane used hatched area on entry and used gutter pan along islan |
| I-43 & Mooreland South | Northbound (Synch2) | 2 | 37:45 | | | X | | | | | X | truck through from right lane slightly encroached while circulating |
| I-43 & Mooreland South | Northbound (Synch2) | 2 | 48:40 | X | | | | X | | | | truck through from left lane used truck apron to stay in lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 9:05 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 17:13 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 33:35 | X | | | | | X | | | truck through from right lane used hatched area and crossed into left circulating lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 34:25 | | | X | | | | | X | truck through from left lane slightly encroached on right lane while circulating |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 36:15 | X | | | | X | | | | truck through from left lane used truck apron to stay in lane and avoid adjacent vehicle |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 38:05 | | | X | | | | X | | truck through from left lane used truck apron |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 38:40 | | | X | | | | | X | truck through from right lane enchroached on left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 41:35 | | | | X | | | | X | truck through from left lane stradled lane line |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 1:03:55 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 1:09:10 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 1:09:20 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 1:14:30 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 1:15:40 | X | | | | | X | | | truck through from left lane only slightly encroached on right lane could have used apron |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 1:17:10 | X | | | | | X | | | truck through from left lane only slightly encroached on right lane could have used apron |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 1:23:00 | | | X | | | | | X | truck through from right lane crossed into left circ lane |

| Intersection | Approach (File) | Case | Video Timestamp | Approach Conditions | | | | Circulating Conditions | | | | Observation Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Conflicting Traffic Present | | No Conflicting Traffic | | Conflicting Traffic Present | | No Conflicting Traffic | | |
| | | | | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 1:37:29 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 1:40:20 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 1:50:15 | | | X | | | | X | | truck through from left lane used apron |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 1:52:50 | X | | | | X | | | | truck through from left lane used apron |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 2:05:28 | | | | X | | | | X | truck through from right lane stradled lane line on entry and circulating |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 2:10:47 | X | | | | | X | | | truck through from right lane slightly encroached while circulating |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 2:12:15 | X | | | | X | | | | truck through from left lane used apron |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 2:15:10 | | | X | | | | X | | truck through from left lane used apron gutter |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 2:17:20 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 2:24:00 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 2:38:25 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 2:42:00 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 3:04:10 | X | | | | | X | | | truck through from right lane separated from traffic and crossed into left circ lane |
| I-43 & Mooreland South | Northbound (Synch3-6) | 2 | 3:19:40 | X | | | | X | | | | truck through from left lane used truck apron |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 8:57 | X | | | | X | | | | truck right turn |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 52:38 | | X | | | | X | | | truck through stradled lane line (hatched area) and took up both lanes, following cars stayed back |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 1:07:35 | X | | | | X | | | | truck through from right lane |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 1:25:00 | X | | | | X | | | | truck through from right lane used hatched area |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 1:39:40 | | | X | | | | X | | truck through from right lane used hatched area |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 1:41:10 | | | X | | | | X | | truck through from right lane used hatched area |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 1:50:00 | | | X | | | | X | | truck through from right lane used hatched area |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 1:52:55 | | | X | | | | X | | truck through from left lane |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 1:54:50 | X | | | | X | | | | truck through from left lane appeared to use truck apron to avoid adjacent car |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 1:56:35 | | | | X | | | | X | truck through from right lane stradled lane line on entry |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 2:10:45 | X | | | | X | | | | truck through from left lane appeared to use truck apron |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 2:38:10 | | X | | | | X | | | truck through right lane stradled lane line and following traffic stayed back |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 2:40:10 | | | | X | | | | X | truck through left lane avoided apron |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 3:05:06 | X | | | | X | | | | truck through from right lane |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 3:19:10 | | | | X | | | | X | truck through right lane stradled lane line to avoid truck apron |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 3:26:55 | X | | | | X | | | | truck through from right lane jumped entry radius curb, adjacent cars slowed but proceedec |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 3:34:38 | | | X | | | | X | | truck through from right lane used hatched area |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 3:58:20 | | | X | | | | X | | truck through from right lane used hatched area |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 4:20:30 | X | | | | X | | | | truck left appeared to use truck apron |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 4:32:45 | | | X | | | | X | | truck through from right lane |
| STH 42 & Vanguard | Eastbound STH 42 | 2 | 4:53:15 | X | | | | X | | | | truck through from right lane |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 4:01 | X | | | | X | | | | truck left turn used apron |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 18:05 | X | | | | | X | | | truck through from right lane crossed lane line in circ roadway |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 27:20 | X | | | | | X | | | truck left turn slowed and crossed into right circ lane, following traffic stayed behind |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 32:40 | X | | | | | X | | | truck right turn used hatched area |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 36:20 | | | | X | | | X | | truck left turn used apron |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 45:03 | X | | | | X | | | | truck right turn used hatched area |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 45:10 | | X | | | | X | | | truck through from right lane stradled lane line, following cars slowed and stayed behinc |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 55:40 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 56:00 | | X | | | | X | | | truck through stradled lane line (hatched area) and took up both lanes, following cars stayed back |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 56:25 | X | | | | | X | | | truck through from right lane crossed into left circ lane |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 1:03:25 | | | X | | | | X | | truck right turn used hatched area |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 1:10:08 | | | X | | | | | X | truck through from right lane crossed into left circ lane |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 1:31:07 | X | | | | X | | | | truck through from left lane used truck apron |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 1:38:18 | X | | | | X | | | | truck right turn used hatched area |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 1:38:50 | X | | | | X | | | | truck right turn used hatched area |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 1:40:10 | X | | | | X | | | | truck left turn used apron |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 1:51:23 | | | X | | | | | X | truck through from right lane used hatched area and crossed into left circulating lane |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 1:59:28 | X | | | | X | | | | truck right turn used hatched area |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 2:16:45 | X | | | | X | | | | truck right turn used hatched area |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 2:19:30 | | | X | | | | | X | truck through from right lane used hatched area and crossed into left circulating lane |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 2:35:30 | X | | | | X | | | | truck right turn used hatched area |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 3:33:10 | X | | | | X | | | | truck right turn used hatched area |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 3:34:55 | X | | | | X | | | | truck right turn used hatched area |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 3:44:00 | X | | | | X | | | | truck right turn used hatched area |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 3:44:50 | | X | | | | X | | | truck turned left from right lane and occupied both circ lanes, following traffic stayed back |
| STH 42 & Vanguard | Westbound STH 42 | 2 | 3:50:00 | | | X | | | | X | | truck through from right lane, used hatched area |
| STH 32 & STH 57 | (08_048) | 1 | | X | | | | X | | | | truck left used apron |
| STH 32 & STH 57 | (08_048) | 1 | | | | X | | | | X | | truck left used apron |
| STH 32 & STH 57 | (08_048) | 1 | | X | | | | | X | | | truck right |
| STH 32 & STH 57 | (08_048) | 1 | | X | | | | | X | | | truck through used both lanes in circ roadway |
| STH 32 & STH 57 | (08_048) | 1 | | | | | X | | | | X | truck left avoided apron |
| STH 32 & STH 57 | (08_048) | 1 | | X | | | | X | | | | truck left used apron |
| STH 32 & STH 57 | (08_048) | 1 | | | | | X | | | X | | truck left encroached on entry but used apron |
| STH 32 & STH 57 | (08_048) | 1 | | | | | X | | | X | | truck left encroached on entry but used apron |
| STH 32 & STH 57 | (08_048) | 1 | | | | | X | | | X | | truck left encroached on entry but used apron |
| STH 32 & STH 57 | (08_048) | 1 | | | X | | | | X | | | truck through used both lanes following traffic stayed back |

| Intersection | Approach (File) | Case | Video Timestamp | Approach Conditions | | | | Circulating Conditions | | | | Observation Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Conflicting Traffic Present | | No Conflicting Traffic | | Conflicting Traffic Present | | No Conflicting Traffic | | |
| | | | | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | Stayed in Lane | Didn't Stay in Lane | |
| STH 32 & STH 57 | (08_048) | 1 | | | | | X | | | X | | truck left used apron |
| STH 32 & STH 57 | (08_52) | 1 | | | X | | | | X | | | truck through used both lanes |
| STH 32 & STH 57 | (08_52) | 1 | | | | | X | | | X | | truck left used apron |
| STH 32 & STH 57 | (08_52) | 1 | | | X | | | | X | | | truck right from left lane |
| STH 32 & STH 57 | (08_52) | 1 | | X | | | | | X | | | truck through from right lane crossed into left lane in circ roadway following traffic stayed back |
| STH 32 & STH 57 | (08_52) | 1 | | X | | | | X | | | | truck left used apron |
| STH 32 & STH 57 | (08_52) | 1 | | | X | | | X | | | | truck right slightly encroached on left lane on entry |
| STH 32 & STH 57 | (08_52) | 1 | | | | | X | | | | X | truck left avoided apron |
| STH 32 & STH 57 | (08_52) | 1 | | | | | X | | | X | | truck left used apron |
| STH 32 & STH 57 | (08_52) | 1 | | | X | | | X | | | | truck left used apron |
| STH 32 & STH 57 | (08_52) | 1 | | | | X | | | | X | | truck right |
| STH 32 & STH 57 | (08_52) | 1 | | | | | X | | | X | | truck left used apron |
| STH 32 & STH 57 | (08_52) | 1 | | X | | | | | X | | | truck through from right lane crossed into left lane in circ roadway following traffic stayed back |
| STH 32 & STH 57 | (08_52) | 1 | | | X | | | X | | | | truck left used apron |
| STH 32 & STH 57 | (08_52) | 1 | | X | | | | | X | | | truck left from right lane crossed used wrong lane |
| STH 32 & STH 57 | (08_52) | 1 | | X | | | | X | | | | truck through from right lane |
| STH 32 & STH 57 | (08_52) | 1 | | | | X | | | | | X | truck through from right lane crossed into left lane in circ roadway |
| STH 32 & STH 57 | (08_52) | 1 | | | | X | | | | X | | truck left used apron |
| STH 32 & STH 57 | (08_52) | 1 | | | | | X | | | | X | truck left used apron |
| STH 32 & STH 57 | (08_52) | 1 | | X | | | | X | | | | truck left used apron |
| STH 32 & STH 57 | (08_52) | 1 | | | X | | | X | | | | truck through from right lane adjusted to allow adjacent car to circulate with |
| STH 32 & STH 57 | (08_52) | 1 | | X | | | | | X | | | truck through from left lane following traffic attempted to enter adjancent but stayed back |
| STH 32 & STH 57 | (08_52) | 1 | | | | | X | | | | X | truck right following cars stayed back |
| Lien & Thopmson | SB raw_1 | 3 | 44:26:00 | | | X | | | | | X | truck left used hatched out area, moved to outer lane 2/3 into circulation |
| Lien & Thopmson | EB raw_4 | 3 | 2:50 | X | | | | X | | | | truck left waited for gap and used truck apron |
| Lien & Thopmson | SB SANY0002 | 3 | 15:38 | X | | | | X | | | | truck right turn |
| STH 53 & Old Town Hall | SB 06_19 | | 0:06:58 | | | X | | | | X | | truck through, may have slightly used truck apron |
| STH 53 & Old Town Hall | SB 06_19 | | 0:10:42 | | | | X | | | | X | truck U-turn, stradled lane hatching |
| STH 53 & Old Town Hall | SB 06_19 | | 0:12:32 | | | | X | | | | X | truck through from outside lane, switched to inside on circ. roadway, back to outside on exit |
| STH 53 & Old Town Hall | SB 06_19 | | 0:13:20 | | | | X | | | | X | truck through from outside lane, crossed over on entry and through circ roadway |
| STH 53 & Old Town Hall | SB 06_19 | | 0:27:14 | | | X | | | | X | | truck U-turn, used truck apron |
| STH 53 & Old Town Hall | SB 06_19 | | 0:33:15 | | | X | | | | | X | truck through from outside lane crossed while |
| STH 53 & Old Town Hall | SB 06_19 | | 0:51:10 | | | X | | | | | X | truck through |
| STH 53 & Old Town Hall | SB 06_19 | | 0:57:21 | | | | X | | | | X | truck through |
| STH 53 & Old Town Hall | SB 06_28 | | 0:11:08 | | | | X | | | | X | truck left, encroached on adjacent lanes |
| STH 53 & Old Town Hall | SB 06_28 | | 0:13:20 | X | | | | X | | | | truck through from inside lane, appears to clip truck apron |
| STH 53 & Old Town Hall | SB 06_28 | | 0:18:31 | | | X | | | | | X | truck right |
| STH 53 & Old Town Hall | SB 06_28 | | 0:30:40 | | | | X | | | | X | truck left used apron |
| STH 53 & Old Town Hall | SB 06_28 | | 0:51:15 | | | X | | | | | X | truck through from outside lane drifted into inside lane while circulating |
| STH 53 & Old Town Hall | SB 06_28 | | 0:51:44 | | | X | | | | | X | truck through from outside lane drifted into inside lane while circulating |
| STH 53 & Old Town Hall | SB 06_36 | | 0:17:55 | | | X | | | | X | | truck left used truck apron |
| STH 53 & Old Town Hall | SB 06_36 | | 0:20:28 | | X | | | X | | | | truck right encroached on inside lane while entering with vehicle following |
| STH 53 & Old Town Hall | SB 06_40 | | 0:35:36 | | | X | | | | | X | truck through from outside lane drifted into inside lane while circulating |

# Joint Roundabout Truck Study

## Report For Phase 3: Design Guidelines

June 2012

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## Table of Contents

## List of Tables

## List of Figures

# 1.0 Introduction

This document presents recommended guidelines for accommodating legal-sized trucks at roundabouts on state trunk highways, with an emphasis on two lane multilane roundabouts. A study team consisting of staff from the Wisconsin Department of Transportation (WisDOT), Minnesota Department of Transportation (MnDOT) and their consultants developed the information presented in this document.

The purpose of this document is to provide design guidance for accommodating legal-sized trucks at roundabouts, to identify criteria for using various design techniques, and to describe specific design methods. It is intended that the guidelines in this document could ultimately be incorporated into the WisDOT and MnDOT roundabout design guides. Potential recommendations for when to use specific design techniques are presented in this document. However WisDOT and MnDOT will ultimately decide at a later date which requirements to implement considering specific conditions within the respective states. The guidance in this document can be considered in the interim until information is included in the respective states' guides. Although not addressed directly by this report, it is also important that roundabout designs consider accommodation of Oversize/Overweight (OS/OW) vehicles. Designers should refer to separate state-specific guidance regarding this issue, especially for specific design measures to accommodate these vehicles (Note: Kansas State University and the Transportation Research Board are currently studying accommodation of OS/OW vehicles at roundabouts. Once completed, information from that study may be incorporated into WisDOT and MnDOT guidance).

This report summarizes the third phase of a larger study sponsored by WisDOT and MnDOT. The overall goal of the entire study is to research and recommend design techniques for accommodating trucks at multilane roundabouts. Phase 1 of the study was a synthesis of current design practice regarding how trucks have been accommodated at constructed multilane roundabouts. Eighteen constructed roundabouts were studied in Phase 1, and three main design philosophies (or "Cases" as noted below) were identified. Although Phase 1 was not a statistically rigorous analysis, it did provide useful insight into design techniques and operations/safety for different design techniques, and it resulted in recommendations for areas of further research. Phase 2 included additional data collection for the 18 roundabouts studied in Phase 1. The results of Phases 1 and 2 are summarized in a separate report. The third phase, summarized in this report, presents design guidelines for accommodating trucks at roundabouts. The fourth and final phase of the study entails preparation of a summary document that presents conclusions from the entire study.

The findings from the Phase 1 and Phase 2 research influenced the guidance presented in this report. Other factors which played a notable role in influencing this report were the collective experience of the project team, input/peer review from outside roundabout designers, policy direction from MnDOT and WisDOT, and direction from a Technical Advisory Committee (TAC) (made up of representatives from local government agencies, the trucking industry, MnDOT, WisDOT, and the University of Wisconsin TOPS Lab). The study team has collectively worked on designs for more than 700 roundabouts, 100 of which are Case 2 or 3 roundabouts (Case 2 and 3 are defined below). In total, approximately 300 of these roundabouts have been constructed, with about 30 of these being Case 2 or 3 roundabouts. The guidance in this document is collectively influenced by all of these factors.

As with other roundabout design guidance, designers should keep in mind that this document provides general direction that applies in most situations. In addition, the content of this document is not intended to be used as rigid standards that apply in all situations. Instead, a designer must exercise sound judgment as to whether a particular situation could warrant departure from direction in this document. Critical independent analysis should be applied when selecting a roundabout case type for each situation in order to provide an appropriate design.

## 1.1 Definitions

The following definitions are used within this document. Please note that roundabout case type definitions apply to multilane roundabouts only and do not apply to single lane roundabouts.

**Truck** – Defined as a WB 62 for MnDOT and a WB 65 for WisDOT, a legal-sized tractor-semitrailer combination truck with one kingpin connection between the trailer and tractor. A design truck typically has five axles and a wheelbase of 62 or 65 feet (distance between first and last axles). Swept paths for trucks are often drawn with a CAD program to depict the combination turn, the relationship between the tractor/trailer angle and the steering angle, and the difference between the front outside tractor tire/trailer overhang and the path of the inside trailer tire. Note that the term "trucks" as used in this document does not include all types of trucks, but only includes design vehicle trucks - WB 62 in Minnesota and WB 65 in Wisconsin. Also note that most traffic count data typically includes multiple sizes/designations of vehicles in the "truck" category which is different than the designations used in this document. Designers should refer to the American Association for State Highway Transportation Officials (AASHTO) manual *A Policy On Geometric Design of Highways and Streets* for the specific dimensions and illustrations of design vehicles.

**Case 1 Roundabout** -Case 1 roundabouts are designed such that trucks encroach into adjacent lanes while entering, circulating and exiting a roundabout. Some Case 1 roundabouts have two lanes on the approaches, exits, and circulating road without transitions to one lane approaching or exiting (i.e., there are two travel lanes in each direction on the road away from the roundabout). In other situations, Case 1 roundabouts have a single approaching lane upstream that widens to a two lane entry. In these types of designs, if the transition length from one to two lanes is relatively short (i.e., 100 feet or less), it will preclude a passenger vehicle from driving adjacent to a truck through the approach and entry. In these situations, a truck must use both lanes on approach and occupies the entire entry as it proceeds into the intersection. Another common design for Case 1 roundabouts is a single approaching lane upstream with a longer, more gradual transition, resulting in two approaching lanes for 200 feet or more from the roundabout. Please refer to the report for Phase 1 for an example graphic showing a Case 1 roundabout.

**Case 2 Roundabout** – Case 2 roundabouts are designed such that trucks enter the roundabout without encroaching into adjacent lanes, but may encroach into adjacent lanes when circulating and exiting the roundabout. Many Case 2 roundabouts have a painted "gore" area between lanes on the approaches, but this characteristic is not always present. Please refer to the report for Phase 1 for an example graphic showing a Case 2 roundabout.

**Case 3 Roundabout** – Case 3 roundabouts are designed such that trucks can stay within their lane as they enter, circulate, and exit the roundabout (i.e., no encroachment). Often, Case 3 roundabouts have a painted "gore" area between lanes on the approaches, but this characteristic is not always present. Typically, Case 3 roundabouts require a truck using the inside circulating lane to utilize a truck apron on the central island to stay in lane, but this is not always the case. Often the outside circulating lane is wider than the inside lane to allow trucks to stay in lane. Case 3 roundabouts typically are designed to allow trucks to stay in lane for through and left turn movements, while right turning trucks may occupy multiple lanes within a roundabout exit. With few Case 3 roundabouts implemented to date, these typically require significantly more designer skill than other case types to ensure proper operations, geometrics, speeds, and safety. Please refer to the report for Phase 1 for an example graphic showing a Case 3 roundabout.

**Width Transition** – Sometimes called a taper, the width transition is the distance over which an approach widens from the upstream width (i.e., cross section of roadway away from the roundabout) to the roundabout approach entry width. The length of the width transition is typically determined based on design vehicle swept paths, design speeds, the type of approach alignment, and capacity and queuing needs. Width transitions can entail adding full lanes, but often involve only minor widening of one to four feet at the entry. In some situations, width transitions are not needed if the upstream roadway has sufficient width.

**Controlling Radius** - On the right side of an entry, the controlling radius is the curb radius which has the greatest influence on a driver's path, speed, and entry alignment. For entries with compound radii on the right side curbline, the controlling radius is not necessarily the same as the smallest curb radius, though it may be in some situations. Similarly, the controlling radius may be different from the "entry radius" that is one parameter considered in British roundabout capacity models based on LR942[a]. The controlling radius typically has sufficient length to control vehicle speed while still allowing for maximum maneuverability. It is not typically short, tight, or abrupt as this hinders navigation and can create entry path overlap issues. The controlling radius is not the same as the R1 radius. Specifically, the controlling radius is a physical curbline radius, while the R1 radius is located along the fastest vehicle travel path and is not a physical curbline radius.

**Approach Roadway Curvature** – Approach roadway curvature describes horizontal curves in the alignment of an approaching roadway as it nears (typically within 1000 feet of) the roundabout ICD. Often times, an offset left alignment is used to accommodate trucks in lane. For Case 2 and Case 3 roundabouts, approach roadway curvature is gradual so that trucks can stay in lane. For more details on approach roadway curvature, please see NCHRP 672, section 6.3.2.

## 1.2 Tradeoffs and Relationships to Other Design Considerations

There will be tradeoffs when developing a design to accommodate trucks at any specific roundabout. One of the most common tradeoffs occurs when a designer considers whether to implement a larger diameter roundabout since this can have implications for right-of-way (ROW) impacts and cost. While designs which keep trucks in lane on entries and while circulating may have better safety performance than designs that allow trucks to encroach on adjacent lanes, further statistically rigorous study is needed to confirm whether this perceived benefit is fully validated in all circumstances. In some situations, this potential safety benefit may justify

[a] The Traffic Capacity of Roundabouts by G. West and R.M. Kimber (TRL LR942, 1980)

increased ROW impacts and construction costs, depending on the size and volume of trucks using an intersection.

Investigations conducted during Phase 1 of this project indicated that there was not an obvious relationship between driver speeds and trucks not being accommodated in lane. This is because design techniques commonly implemented to accommodate trucks (including wider entries, larger radii, gradual/sweeping approach curvature, and sometimes larger ICD) can be implemented in many different combinations and geometric configurations. Sometimes these configurations can increase speeds, but other combinations can result in lower speed regimes. By following commonly accepted design guidance (found in the Federal Highway Administration, WisDOT, and MnDOT roundabout guides), all critical design parameters (R1 speed control, entry angle, etc.) can be maintained in accordance with applicable guidance for designs which accommodate trucks. Therefore, accommodating trucks in lane can be accomplished without sacrificing operations or safety. Additional research in the future may identify specific design tradeoffs in this area, but at the present time, it does not appear that designing to accommodate trucks needs to result in higher speeds, safety concerns, or operational concerns.

### 1.3 Relationship to Established Design Guidance

These guidelines supplement information provided in the Federal Highway Administration (FHWA) Roundabout Guide (NCHRP 672), the WisDOT Roundabout Guide (Facilities Development Manual Chapter 11), and the MnDOT Design Guidelines for Modern Roundabouts (Road Design Manual Chapter 12). Some of the specific treatments for keeping trucks in lane are discussed in these existing guidelines, but this document provides additional specific criteria and discusses tradeoffs between different design strategies.

## 2.0 Single Lane Roundabouts

Single lane roundabouts were not evaluated as part of Phase 1 of the study. All information included in this section is based on the collective experience of the project team, direction from the TAC, and policy direction from MnDOT and WisDOT.

### 2.1 Geometric Design Guidance

Design techniques for standard single lane roundabouts can be found in established design guidance documents from the FHWA, WisDOT, and MnDOT. When designing a single lane roundabout, it is assumed that designers will judiciously implement applicable guidance from these manuals to ensure the applicable design standards and performance requirements are met. An iterative design process is typically used to verify compliance with the requirements described in these guides (speed control, geometrics, accommodation of design vehicle, sight distance, etc.), which are the highest priority objectives of roundabout design. The design methods for accommodating trucks described in this report are in addition to these higher priority requirements.

Where possible, a gradual, sweeping entry design in which trucks are not forced to navigate a tight curve at the entries is recommended. This entry design method will help accommodate right-turning trucks, which is typically the most difficult movement to accommodate at single lane roundabouts. Single lane roundabouts that are designed to accommodate trucks typically use an entry radius of 75 feet or larger, while entry radii of 100 feet or larger are common. In some cases smaller entry radii may be used. Additionally, entries and exits are typically designed to be 18 to 22 feet wide from curb face to curb face to accommodate trucks but may need to be wider in some situations to account for skewed intersections or Oversize/Overweight (OS/OW) vehicles. Accommodating trucks can often lead to entry angles on the low end of the recommended 16-30 degree range.

One design method occasionally used at wide single lane entries (wider than approximately 18 feet curb face to curb face) is to pavement mark an entry along the splitter island with hatched striping to reduce width. Observations indicate that trucks will use these hatched areas when entering a roundabout. This technique will require additional pavement marking maintenance. This approach may result in a lower overall cost than significant adjustments to geometry that can be otherwise required to accommodate trucks in some situations. An example of this technique is shown in **Figure 1** below.

At single lane roundabouts, the circulatory roadway is typically about 20 to 24 feet wide from curb face to curb face. Previous general guidance that the circulatory roadway width should be 1.0 to 1.2 times the widest entry width may not be applicable since single lane roundabout entry widths are determined to accommodate trucks. For locations with minimal truck traffic, a design can be provided that requires trucks to utilize truck aprons for through movements rather than providing a wider circulatory roadway.

**Figure 1 - Single Lane Roundabout with Pavement Markings to Reduce Entry Width**

Image Source: Otsego County Road Commission

In some situations where ROW is a serious constraint and other design changes are not practical, designers can reduce the width of splitter islands at the entries and/or exits to better accommodate turning trucks. This concept can be combined with the pavement markings described above.

Single lane roundabout ICDs often range from 120 feet to 150 feet. Providing an ICD that is in the higher end of this range (i.e., 140 to 150 feet) is typically beneficial if ROW is available. This diameter range can readily accommodate all truck movements while still meeting other design requirements. Selection of the ICD size is dependent on the constraints at each intersection location, the alignment of the approaching roadways, and the selected design vehicle.

## 3.0 Multilane Roundabouts

### 3.1 Criteria for Applying Specific Design Approaches

General geometric design techniques for multilane roundabouts can be found in established design guidance documents from the FHWA, WisDOT, and MnDOT. An iterative design process is typically used to verify compliance with the design performance measures described in these guides (speed control, geometrics, accommodation of design vehicle, sight distance, etc.), which are the highest priority objectives of roundabout design. The design methods for accommodating trucks described in this report are in addition to these higher priority requirements.

Every site has different constraints and challenges; therefore the designer must decide how to optimally accommodate trucks at each specific location and should not indiscriminately apply a particular design approach (i.e., Case 1, Case 2, Case 3). The decision about which design approach to use should be made early in the project development process (typically before the design is advanced to 20% complete stage). When making this determination, designers should consider a variety of factors, such as:

- Context
- Availability of ROW
- Cost implications
- Bike/pedestrian impacts
- Magnitude of local stakeholder concern about safety implications of truck encroachment
- Effect encroaching trucks would have on peak hour capacity and quality of service
- Need for regular maintenance of infrastructure
- Number of trucks projected in the design year traffic forecast
- Commercial uses that may dictate higher percentages of trucks
- Whether the intersection is likely to carry Oversize/Overweight (OS/OW) vehicles.

The recommendations in this section are based upon the collective experience of the study team (including the TAC), with the results of Phase 1 of the study as only one factor considered in developing the recommendations.

Unless doing so would result in a significant impact to ROW or would be prohibitively expensive, designers should initially consider using a Case 3 design for two-lane roundabouts on state trunk highways. If a Case 3 design is not feasible due to cost, ROW impacts, or other compelling and substantive concerns, then designers should consider a Case 2 design where space is available and pedestrian accommodations are not compromised. Typically, Case 1 designs should be implemented only where Case 3 or Case 2 designs are not feasible. Where Case 1 designs are implemented at locations having flared approaches from one to two lanes, consideration should be given to using a short (approximately 100 feet) flare which allows a truck to split both lanes on approach and occupy the entire entry as it proceeds into the intersection.

Assuming cost and ROW impacts are deemed reasonable, two-lane Case 3 or Case 2 roundabouts should be considered for potential implementation at locations with multilane approaches on arterial routes, near industrial/warehouse districts, and near truck stops. Additionally, Case 3 and Case 2 designs are often a particularly good application at interchange ramps since truck numbers are typically high compared to other intersections. Additional consideration to implementing a Case 3 or Case 2 design should be given where OS/OW vehicles may travel through an intersection or where an OS/OW route exists. In these locations, Case 3 or Case 2 designs may be beneficial because these designs tend to accommodate OS/OW vehicles more easily than Case 1 designs. Designers should refer to separate state-specific guidance regarding this issue, especially for specific design measures to accommodate these vehicles.

This document does not identify thresholds for implementing specific design case types based on traffic volumes, truck percentages, truck volumes or other factors. However, it is recommended that WisDOT and MnDOT would consider developing such thresholds in their respective states. If thresholds are developed, these should focus upon the overall context of the intersection and allow for balancing of potential negative impacts against the benefits of accommodating trucks in lane (while also considering the impacts and benefits of alternative intersection control such as traffic signals). Consideration should be given to the total traffic volume serviced by the intersection, truck volumes, and truck percentages. Additionally, the factors noted in the preceding three paragraphs could be considered when establishing thresholds.

The lists below present (in no particular order) general statements about potential advantages and disadvantages of the various design cases, based on observations from the Phase 1 study and the opinions of the study team.

## Case 3 Roundabout Design Characteristics

**Advantages**

- Phase 1 survey indicates this design is preferred by truck drivers and the trucking industry
- Safety benefits at entries and in circulatory roadway due to no truck encroachment
- Less damage to curbs (less maintenance)
- Trucks can maneuver more freely at entries and in circulatory roadway
- May have greater public acceptance
- May have greater entry capacity / less delay
- Can be used in urban or rural environments
- Better operations in circulating roadway
- No truck/trailer encroachment required for turning movements, more lateral clearance

**Disadvantages**

- Fewer approach alignment design methods can be used
- May require slightly more ROW / larger geometry
- Potentially higher cost in some situations
- May require more pavement marking maintenance (relative to Case 1)
- Slightly higher circulating speeds and worse lane discipline possible
- Requires greater designer and contractor skill
- Poor design could result in more crashes

## Case 2 Roundabout Design Characteristics

**Advantages**

- Phase 1 survey indicates this entry design is preferred over Case 1 by truck drivers
- Safety benefits at entries due to no truck encroachment
- Less damage to curbs (less maintenance)
- Trucks can maneuver more freely at entries
- May have greater public acceptance
- May have greater entry capacity / less delay
- Can be used in urban or rural environments

**Disadvantages**

- Fewer approach alignment design methods can be used
- May require slightly more ROW / larger geometry
- Potentially higher cost in some situations
- May require more pavement marking maintenance (relative to Case 1)
- Slightly higher circulating speeds and worse lane discipline possible
- Requires greater designer and contractor skill
- Possibly lower safety in circulatory roadway due to truck encroachment (more research needed to verify)
- Poor design could result in more crashes

**Case 1 Roundabout Design Characteristics**

| **Advantages** | **Disadvantages** |
|---|---|
| • Wide variety of approach alignment design methods can be used<br>• More likely to fit into tight ROW locations, including built up urban environments<br>• Potentially lower costs in some situations<br>• Less pavement marking maintenance<br>• Requires less designer and contractor skill | • May result in increased delays due to trucks occupying both lanes on entries and while circulating<br>• Trucks may track over outside curbs resulting in damage and maintenance costs<br>• May result in additional truck/car crashes (more research needed to verify)<br>• Outside curb truck aprons sometimes considered |

Video observations made during Phase 2 of this study suggest that some Case 2 designs may accommodate design trucks (i.e., WB 62 or WB 65) in lane when they circulate and exit the roundabout. Based on the experience of the study team, swept path drawing software (such as AutoTrack and AutoTurn) sometimes produces conservative results (i.e., a wider swept path than reality), and therefore Case 2 designs based on the output of these software packages may provide enough extra width for trucks to stay in lane as they circulate and exit. It is not recommended, however, to implement a lower case design relying solely on these observations.

The next three sections below provide design guidance for the three specific cases. Based on the general approach described above (i.e., implement a Case 3 design where feasible at intersections with notable truck usage, followed by a Case 2 where ROW is available and pedestrian accommodations are not compromised, and then Case 1), the same order is followed below (Case 3 presented first followed by Case 2 and Case 1).

Typical design parameters for two-lane roundabouts, discussed in the following three report sections, are listed in **Table 1** below. Please note that Table 1 does not include information for several primary design principles such as speed control, path overlap, and sight distance. Guidance for these parameters can be found in the FHWA, WisDOT, and MnDOT roundabout guides.

**Table 1. Typical Design Parameters for Two-Lane Roundabouts***

| Item | Case 1 | Case 2 | Case 3 |
|---|---|---|---|
| **Inscribed Circle Diameter[a]** | 150' to 190' | 160' to 210' | 180' to 220' |
| **Inner Circulatory Lane Width[b]** | 11' to 13' | 11' to 13' | 13' to 15' |
| **Outer Circulatory Lane Width[b]** | 13' to 15' | 13' to 15' | 15' to 18' |
| **Approach Gore Widths** | Not used | 2' to 6' | 2' to 6' |
| **Entry Width[a]** | 28' to 32' | 32' to 34' | 32' to 34' |
| **Entry Radius** | 65' or greater | 65' or greater | 65' or greater |
| **Controlling Radius** | 65' or greater | 65' or greater,<br>100' to 130' typical | 65' or greater,<br>100' to 130' typical |
| **Controlling Radius Length** | No max, typically 70' or less | No max, typically 80' + | No max, typically 80' + |
| **Entry Angle** | 16 to 30 degrees | 16 to 30 degrees | 16 to 30 degrees |
| **Length of Two Full Lanes for Lane Add[c]** | Low V/C – Short length<br>Medium V/C – Medium length<br>High V/C – Long length | Low V/C – Short length<br>Medium V/C – Medium length<br>High V/C – Long length | Low V/C – Short length<br>Medium V/C – Medium length<br>High V/C – Long length |
| **Exit Widths[a]** | 28' to 32' | 28' to 32' | 28' to 32'<br>(where large radius or tangential exit used) |

* - Based on site conditions, ROW constraints, specific design vehicle, and other factors, designers may choose to implement geometrics outside these recommended ranges; however the overall design should comply with FHWA and WisDOT or MnDOT guidance documents

a - Measurements are from face of curb to face of curb (includes 2' gutter pans on each side)

b - Measurements are from edge gutter flange line to lane line

c - In addition to the segment with two full lanes, a taper following FDM guidance is needed to transition from one to two lanes

## 3.2 Geometric Design Guidance for Case 3 Roundabouts

When preparing a Case 3 design, it is imperative to involve a design expert who is fully knowledgeable of the applicable design features, how they impact roundabout performance with regard to non-truck drivers, and performance trade-offs. For Case 3 two-lane roundabouts, the conventional approach to design described in established guidance documents from the FHWA, WisDOT, and MnDOT should be followed. Once the primary objectives from these guides have been met (speed control, sight distance, adequate space for a design vehicle), the designer will typically revise the design iteratively to allow trucks to stay in lane at the entry and circulating road while still maintaining the primary design principles (i.e., speed control, sight distance, adequate space for a design vehicle). Although there are some specific design characteristics which are unique to Case 3 roundabouts, the overall approach, methods, and iterative design process remain the same as multilane roundabouts in general.

See **Table 1** above for a summary of typical geometric parameters at Case 3 roundabouts. Overall, Case 3 roundabouts embody similar geometric characteristics as Case 1 and 2 roundabouts. However, there are specific geometric elements where Case 3 roundabouts differ from Case 1 and 2 designs. Case 3 roundabouts:

1. Often have slightly wider entries (typically 2 to 6 feet wider) than a comparable Case 1 roundabout at the same location. For example, a Case 1 roundabout may have an entry width of 28 to 32 feet (including gutter pan width) wherein a typical Case 3 roundabout could increase the entry width to about 32 to 34 feet (including gutter pan width and striped gore area) to allow trucks to stay in lane in entry. **Figure 2** shows a typical Case 3 entry.
2. Usually have longer curve lengths than Case 1 roundabouts on the approach geometry and within the entries. Offset left alignments (i.e., alignment directed to the left of the center of the ICD) are generally preferred where possible.
3. Should avoid tight radii curves (generally defined as smaller than 80 to 90 feet, but highly dependent upon many site specific factors) and closely spaced curves (less than 100 feet of separation) in opposite directions (these elements are sometimes used for Case 1 designs). Instead, larger, longer radii with straight tangent sections between curves are common at Case 3 roundabouts, resulting in gradual sweeping curvature which makes it easier for trucks to stay in lane. Optimal entry radii values will vary based on the ICD, approach alignment, and entry design method. Typically, an urban Case 3 design may have a controlling curb radius value of 100 feet or greater, while a larger rural Case 3 design may range as high as 130 feet or more (note: per definition above, controlling radius is not the same as the R1 radius). Regardless of the actual values (which are site specific), the designer still must maintain other design requirements such as appropriate fast path speeds, while still accommodating for trucks in-lane. Considerable designer skill is typically needed to accomplish these competing objectives.

Case 3 roundabouts typically should not use a radial design method unless unusual circumstances are present and other methods are substantially problematic (A radial design is one that has roadway centerline(s) for the applicable leg(s) going through the center point of the roundabout – i.e., the center of the inscribed circle. This typically results in symmetrical entry and exit geometry on the applicable leg and straight approach alignments without deflection prior to the entry radius. Often, entries can become offset to the right of center with short and tight curb radii to keep speeds low. See section 6.3.2 and Exhibit 6-10 of NCHRP Report 672 for more details regarding this topic). In situations where a radial design is used on a two lane approach, it would typically be implemented with a relatively large ICD of 220 feet or greater.

**Figure 2 - Case 3 Roundabout Entry**

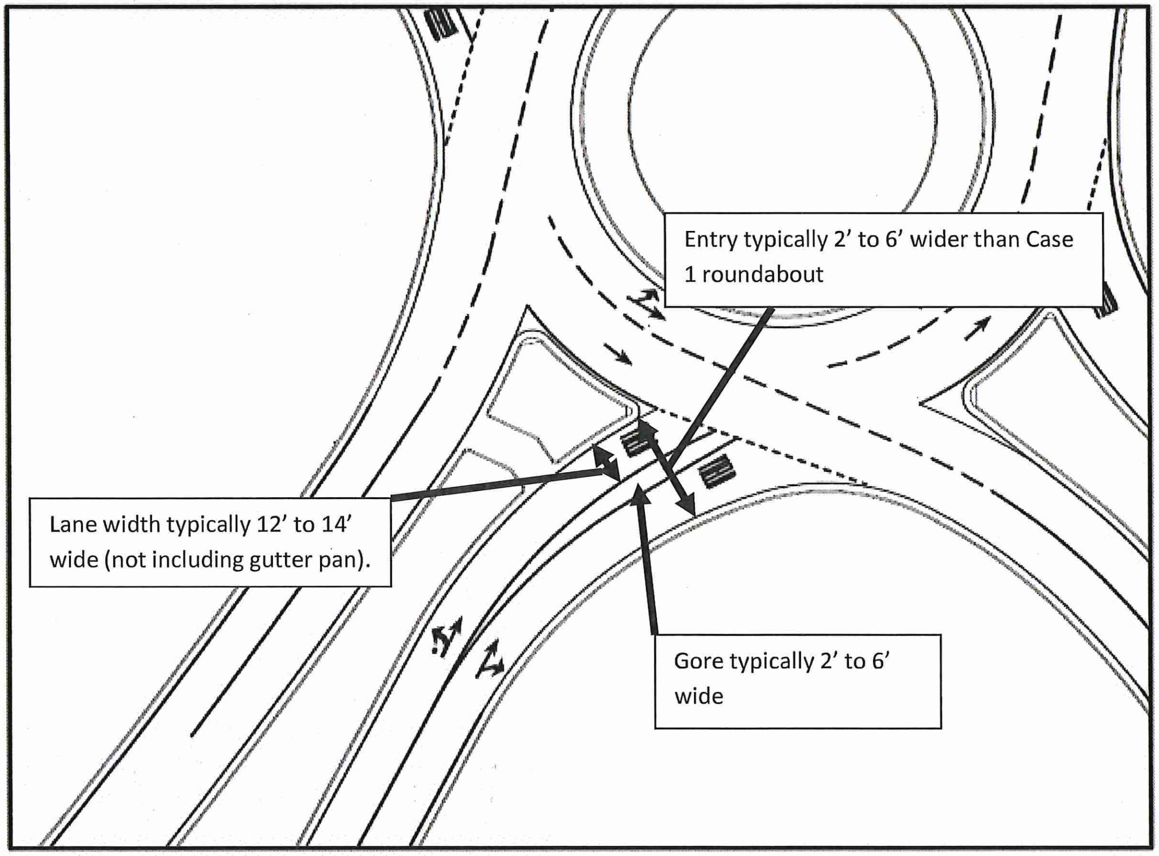


Image Source: Wisconsin Department of Transportation

Case 3 roundabout ICDs can vary widely depending upon the characteristics/constraints of each specific location and designer knowledge. In general terms Case 3 diameters for dual lane entries on a state trunk highway can range from as small as approximately 180 feet up to as large as 220 feet or more (the range observed at two roundabouts under Phase 1 of this study was approximately 190 to 220 feet). If space and site constraints permit, a diameter within the higher end of the typical two-lane roundabout range (200 to 220 feet) is recommended to allow entry radii, flare, entry widths, and path overlap to be optimized for trucks and speeds. Although it may be easier to design a Case 3 roundabout toward the higher end of this size range, it is possible under some conditions to be in the lower end of the range and still have trucks stay in lane.

As with any design, smaller ICDs and tighter geometry do not necessarily result in slower approach, circulating and exiting speeds since there are many other factors in the overall geometric design which affect speeds. Likewise, larger geometry does not necessarily result in faster entry speeds (R1 speeds). Hence, speeds are not necessarily the result of ICD size, but more on the combination of all geometric design parameters on approaches and at the entries and exits. Regardless, designers must maintain appropriate fastest path entry speeds (around 25 mph maximum) and speed differentials between entering and circulating traffic (10-15 mph), as well as providing a design that safely accommodates bicycles and pedestrians. A higher level of designer experience is typically needed to achieve a Case 3 roundabout that meets speed requirements at entries and is consistent with applicable geometric design guidelines.

The designer should ensure a Case 3 roundabout has the following design characteristics:

- Use of width transitions. With Case 3 roundabouts relatively long width transitions may be needed to allow trucks to use more roadway width to stay in lane. Designers should ensure that the total length of the combination of the taper and the second full lane width utilized accommodates the design truck as well as queuing and capacity needs. Not including the gore area between entry lanes, the lanes should typically have continual tapers between the normal width upstream location and the entry [See WisDOT Roundabout Guide (FDM 11-26-30.5.21) and the MnDOT Roundabout Guide (MnDOT Road Design Manual 12-4.05.09)], and at no point should lane widths become narrower over this distance. The design of the gore areas may require variable widths, including narrowing toward the entry as needed.
- A slightly wider (typically 2 to 6 feet wider, though there may be exceptions to this range in some situations) entry width than usually provided at Case 1 roundabouts. The designer should keep the entry width as narrow as possible while still allowing trucks to stay in lane. Total two-lane entry width should typically not exceed 34 feet (from curb face to curb face, including gore area) unless special circumstances are present due to the interaction of factors that affect an entry design. Depending on the design vehicle, approach alignment, controlling radius, total entry width, gore width, etc., lane widths (usable painted lane not including 2-foot gutter pan width or gore area) at the entry would typically vary from 12 to 14 feet. There may be exceptions to this range, especially if gore striping is not used, thus resulting in wider lanes.
- The relationship between width transitions, entry widths, lane widths, and gore widths should be carefully considered by the designer when determining how to optimally serve trucks and passenger vehicles. As a general principle, widths should be minimized while still accommodating the design truck.
- Sufficiently long controlling radius along curb line. Controlling curb radius length can vary over a large range depending upon ICD, approach alignment relative to ICD location, approach design type (tangential, offset left), and alignment and location of the adjacent downstream exit. The controlling curb radius length value is highly dependent upon site specific factors and can often range from 50 to 150 feet. The controlling radius should have sufficient length (not radius value) to provide deflection while allowing for maximum truck maneuverability. It should not be short, tight, or abrupt as this hinders a truck's navigational and turning capabilities and can create entry path overlap issues.
- Typically, a Case 3 design would have a controlling radius value of 65 feet or greater, while a more common range is 100 to 130 feet.
- Steep vertical break over should be avoided at roundabout entries, as this may result in "low boy" trucks bottoming out. The WisDOT current maximum grade break over between travel lanes is 5 percent.

**Figure 3** highlights key design features for the approaches at a Case 3 roundabout.

At Case 3 roundabouts, the outside circulating lane is typically wider than the inside lane (different circulating lane widths are also used at some Case 1 and Case 2 roundabouts). At Case

3 roundabouts, the outside circulating lane is often in the range of 15 to 18 feet (from edge of outer curb gutter flange line to lane line) and the inside lane ranges from 13 to 15 feet (from edge of central island gutter flange to lane line). When traversing the inside lane, a truck's tractor will stay in the travel lane, and the trailer can off-track onto the central island truck apron.

Case 3 roundabouts usually include relatively large or flat exit radii which allow trucks to depart from the circulating road with minimal curvature to the right, thus allowing them to stay in lane more easily.

Case 3 two lane roundabouts may have larger ICD's in some situations where a double left turn is required based on traffic turning patterns. This type of design may be quite complex.

**Figure 3 - Case 3 Roundabout Design Characteristics**

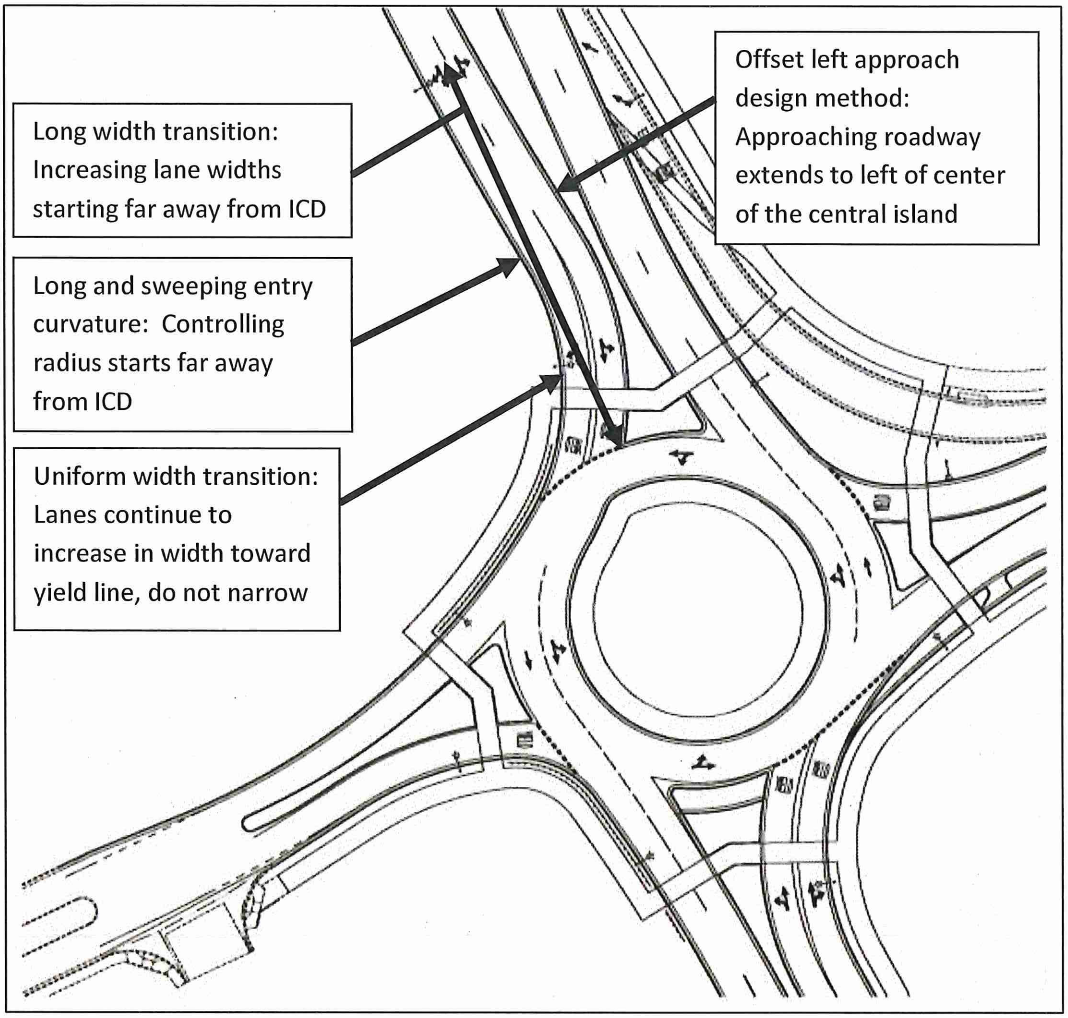


Image Source: Roundabouts & Traffic Engineering (RTE)

**Figure 4** illustrates typical distinguishing design features for a Case 3 roundabout and shows a truck staying in lane in the entry, circulating, and exiting the roundabout.

**Figure 4 - Case 3 Roundabout Characteristics and Truck Path**

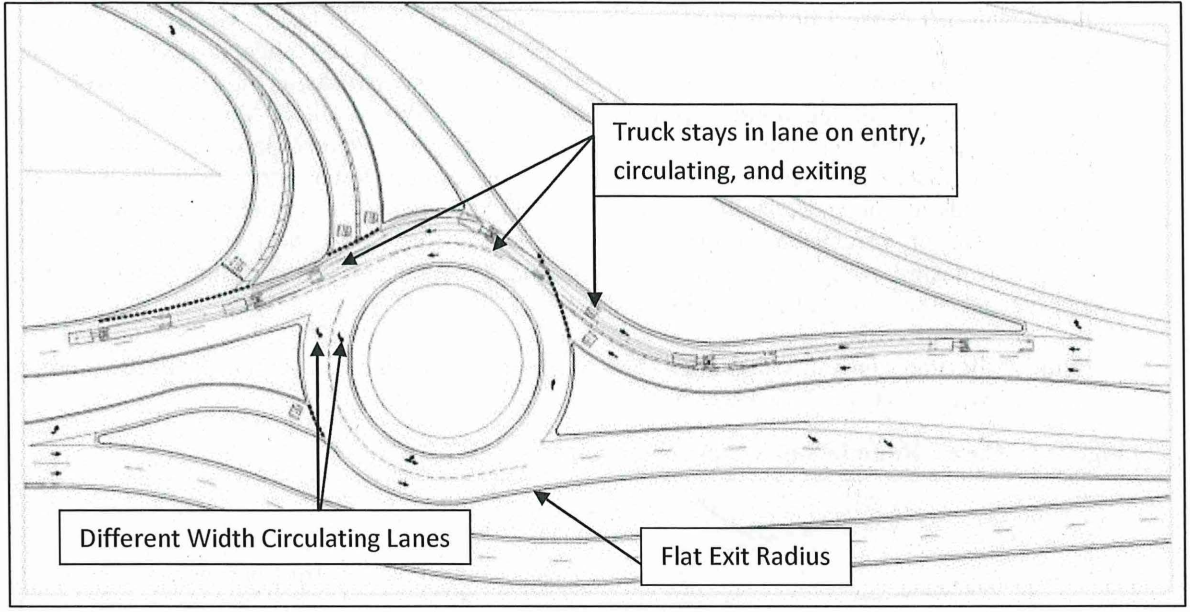


Image Source: Roundabouts & Traffic Engineering (RTE)

## 3.3 Geometric Design Guidance for Case 2 Roundabouts

For Case 2 two-lane roundabouts, the conventional approach to design described in established guidance documents from the FHWA, WisDOT, and MnDOT should be followed. Once the primary objectives from these guides have been met (speed control, sight distance, adequate space for a design vehicle), the designer will typically revise the design iteratively to allow trucks to stay in lane at the entry while still maintaining the primary design principles (i.e., speed control, sight distance, adequate space for a design vehicle). Although there are some specific design characteristics which are unique to Case 2 roundabouts, the overall approach, methods, and iterative design process remain the same as multilane roundabouts in general.

Case 2 roundabouts are designed such that trucks stay within their lane as they enter the roundabout (often times utilizing painted “gore” areas on entries), but they will encroach into adjacent lanes as they circulate and exit the roundabout. Case 2 roundabouts have the same design characteristics at entries as Case 3 roundabouts described in the previous section. Generally speaking, tighter, shorter, and smaller geometry are not used with Case 2 designs. **Table 1** above includes a list of typical design parameters for Case 2 roundabouts. The main differentiating feature between Case 2 and Case 3 roundabouts is that Case 2 roundabouts employ narrower circulating lanes (inner lane approximately 2 feet narrower and outer lane 2-3 feet narrower) than Case 3 roundabouts.

Case 2 roundabout ICDs are typically 10-20 feet smaller than for Case 3 roundabouts. Case 2 roundabout ICDs can vary widely depending upon the characteristics/constraints of each specific location. In general terms Case 2 diameters for dual lane entries on a state trunk highway can range from as small as approximately 160 feet up to as large as 210 feet or more (the range observed during Phase 1 of this study was approximately 160 to 200 feet). Although it may be easier to design a Case 2 roundabout toward the higher end of this size range, it is possible under some conditions to be in the lower end of the range and still have trucks stay in lane. As with any design, smaller ICDs and tighter geometry do not necessarily result in slower approach and exiting speeds since there are many other factors in the overall geometric design which affect speeds. Likewise, larger geometry does not necessarily result in faster entry speeds (R1 speeds). Hence, speeds are not necessarily the result of ICD size, but more on the combination of all geometric design parameters at the entries and exits. Regardless, designers must maintain appropriate fastest path entry speeds (R1 - around 25 mph) and speed differentials between entering and circulating traffic (10-15 mph).

**Figure 5** illustrates how a design truck stays in lane in the outside lane with other traffic present on an approach at a Case 2 roundabout.

**Figure 5 - Case 2 Roundabout Truck Swept Path**

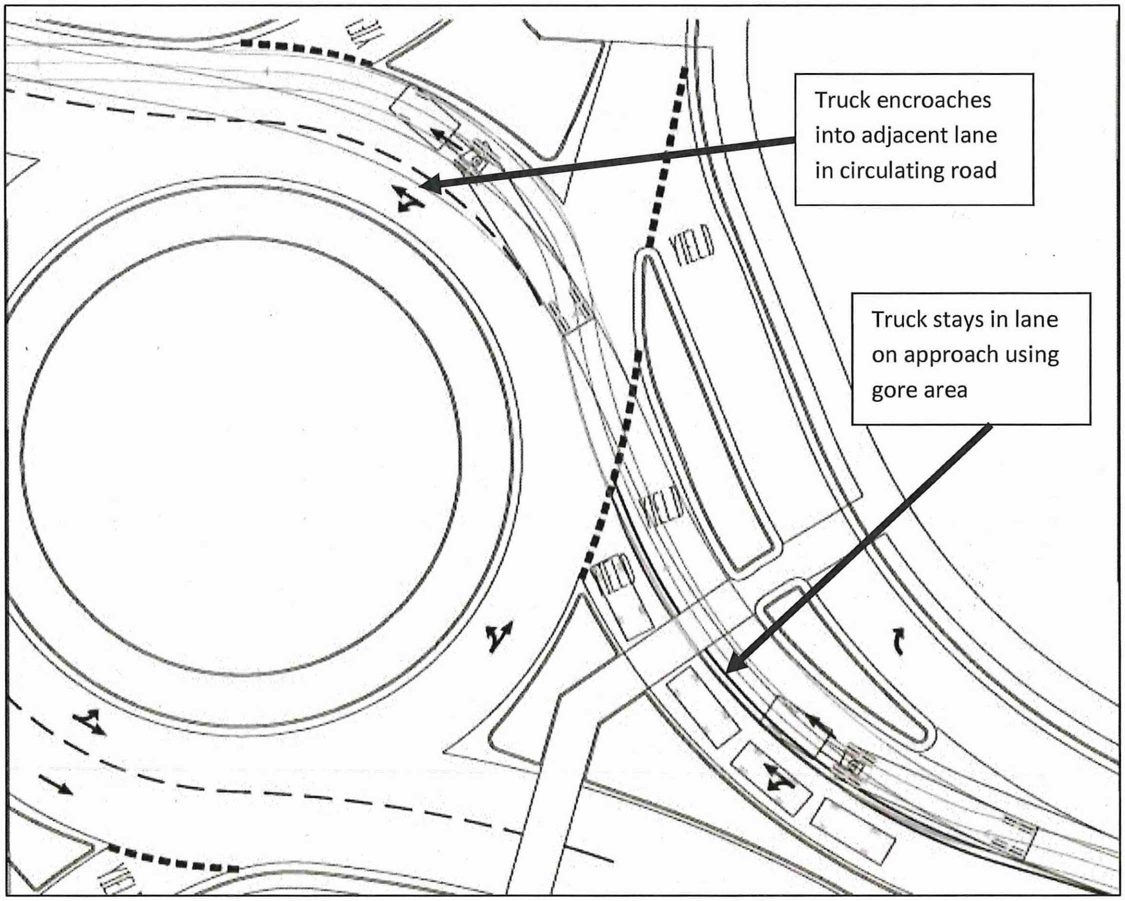


Image Source: Roundabouts & Traffic Engineering (RTE)

## 3.4 Geometric Design Guidance for Case 1 Roundabouts

For Case 1 roundabouts, the conventional iterative approach to design as described in established design guidance documents from the FHWA, WisDOT, and MnDOT should be followed. Designers following this established guidance for Case 1 roundabouts will be able to accommodate trucks within the roadway (curb face to curb face with a 2-foot buffer). See **Table 1** for a list of typical design parameters for Case 1 roundabouts.

Case 1 roundabouts are designed such that trucks encroach on adjacent lanes at the approaches and when circulating and exiting the roundabout. Generally an alignment offset left of center is preferred. Designers should consider implementing features that would result in a clear encroachment by trucks into adjacent lanes rather than a subtle encroachment (such an approach would typically include avoiding wide lanes, long sweeping curves, large ICD's, and large radii). Although research has not been performed in this area, it is believed if the likelihood of encroachment is more obvious to drivers, they may have more time to compensate and fewer crashes may result than with a design that has a more subtle encroachment.

Additionally, Case 1 designs can allow for the approaching roadways to have more tangential alignments with short, tighter entry radii (See **Figure 6** below).

**Figure 6 - Case 1 Roundabout with Tangential Approach on West Leg**

Note tangential (i.e., straight-on) approach on west leg. This approach does not utilize an offset left alignment.

Image Source: Google Maps

In some rare Case 1 design locations, implementing outside curb truck aprons (i.e., a sloped/mountable curb with a concrete/pavement area behind the curb) may be beneficial to repair and prevent rutting behind the entry radius curb, curb damage or damage to signs and landscaping from truck off tracking. The off tracking can happen when queues at the entries prevent trucks from utilizing both lanes to enter the roundabout thus requiring trucks to drive outside of the intended driving surface and over curbs. However, the implementation of outside truck aprons in new designs is discouraged due to potential concerns about pedestrian safety and optimal operations. For this reason, outside aprons should only be used when other design accommodations are not practical or feasible. When it is necessary to provide outside curb truck aprons, a high level of care should be taken to assure that this paved area is not mistaken for a pedestrian path or sidewalk to avoid truck/pedestrian conflicts. As such, designers should not typically consider outside truck aprons as a preferable option when sidewalks or multi-use paths are present. In the rare cases where outside aprons are implemented, the width of the apron is dependent on the design vehicle, the approach lane width, the circulatory roadway width, the ICD, and the angle between entries and exits. The width of this apron should be determined through the use of software that generates swept paths for trucks. **Figure 7** shows an example of outside curb aprons.

**Figure 7 - Case 1 Roundabout with Outside Curb Truck Aprons**

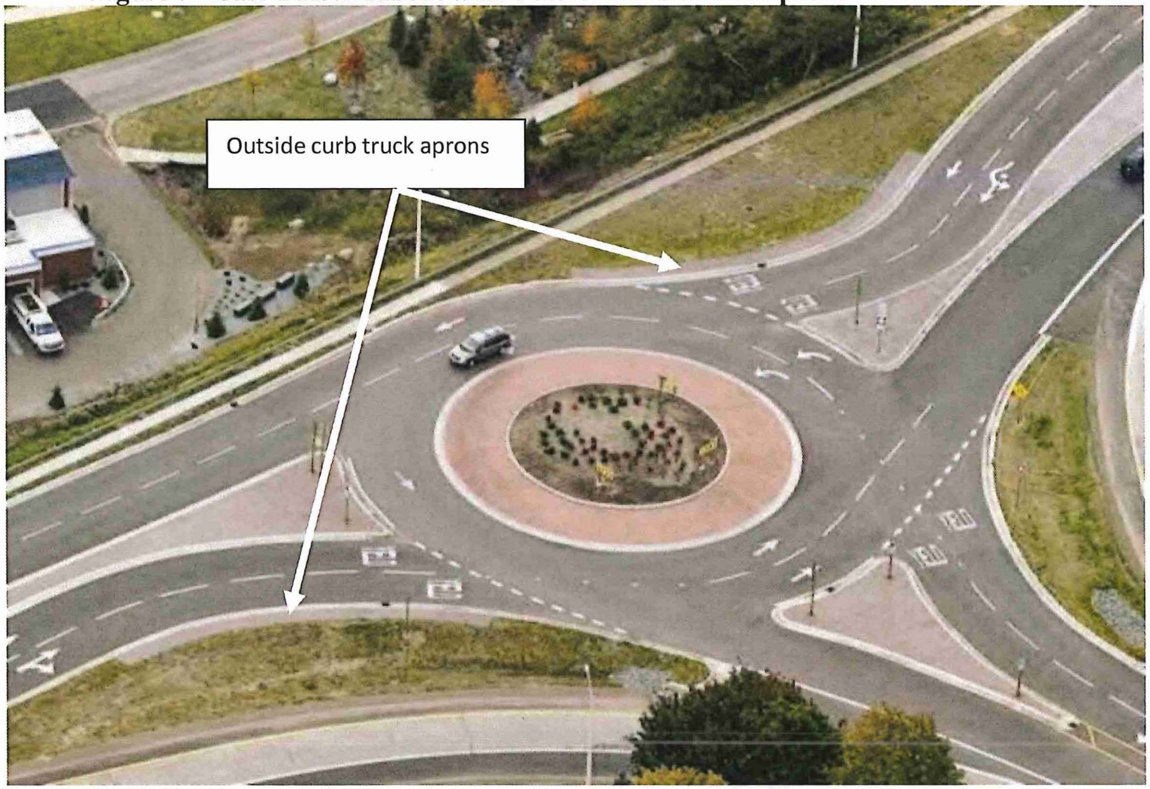


Image Source: Michigan Department of Transportation

## 3.5 Pavement Marking Recommendations

Designers should follow established guidance documents from the FHWA, WisDOT, and MnDOT when developing pavement marking plans for all three case types. At Case 2 and 3 roundabouts, particular attention should be paid to gore striping between lanes on entries and lane marking for the circulatory lane widths. For Case 2 and 3 roundabouts, the width of the gore area between lanes (if used) is usually between 2 and 6 feet. The most common striping method uses two solid lines without "fill" hatching. However, under some circumstances two solid lines with "v" shaped cross hatching may be used between the solid lines, depending on the specific agency's preferences. The hatching spacing and line widths should follow applicable Manual of Uniform Traffic Control Devices (MUTCD) or State Transportation Department guidance.

At all two lane roundabouts (Case1, Case 2 and Case 3) it is recommended that the inner circulatory lane be marked approximately 2 feet narrower than the outside circulating lane in order to maximize the likelihood of trucks staying in lane. **Figure 8** shows an example of pavement markings at a Case 2 or 3 roundabout.

**Figure 8 - Example Pavement Markings for Trucks at Multilane Roundabouts**

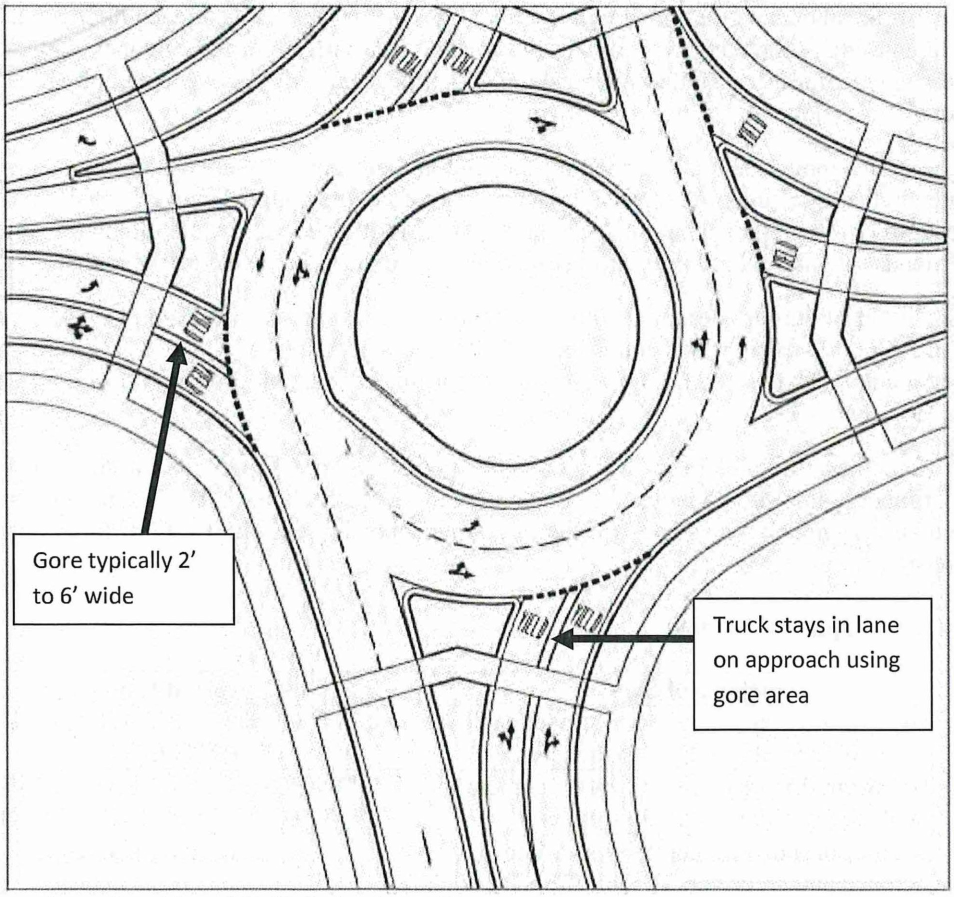


Image Source: Roundabouts & Traffic Engineering (RTE)

## 3.6 Signing

As a countermeasure for observed safety problems or where high truck volumes generate local concern, signage may be considered to improve truck safety and operations and to improve the interaction between trucks and other vehicles. These warning signs are optional and can be implemented at the discretion of Department policy, and many states have not found the need for these optional signs. These signs should be considered in addition to and not in lieu of other standard signage required at roundabouts. Additionally, designers should consult with their respective state's signing committee or comparable governing body to ensure agreement about the sign messages. Messages should be consistent with MUTCD requirements as well. Care should be exercised in the decision to implement these optional signs since two-lane roundabouts typically have a large number of signs. The benefits of the additional optional signs should be weighed against the potential negative side-effect of more signage (i.e., "sign overload/clutter" for motorists).

Responses from a trucking industry questionnaire (from a survey that was conducted during Phase 1 of this study) indicate that truck drivers would favor advance notice whether they will be expected to stay in lane or to use both lanes. The responses also indicated that signs would be helpful to let other motorists know how trucks may behave on approaches to roundabouts.

Case 1 roundabouts are designed with the intention that trucks will encroach upon adjacent lanes while entering, circulating and exiting the roundabout. Therefore, the optional signage for this case should inform trucks that encroaching on to adjacent lanes is expected and should inform other vehicles not to drive alongside trucks.

Case 2 roundabouts are designed with the intention that trucks will encroach upon adjacent lanes while circulating and exiting the roundabout. Therefore, the optional signage for this case should inform trucks that encroaching upon adjacent lanes is allowed only while circulating and exiting the roundabout and should inform other vehicles not to drive alongside trucks in that location.

Case 3 roundabouts are designed with the intention to accommodate trucks in lane while entering, circulating and exiting the roundabout (with the exception of double left turns at some roundabouts). Therefore, the optional signage for this case should inform trucks not to encroach upon adjacent lanes.

The guidelines to implement warning signs published in Chapter 2C of the MUTCD and Department policy should be used to implement these optional signs. **Table 2** below summarizes potential warning sign messages for the three roundabout cases. **Figure 9** illustrates examples of these signs.

**Table 2. Intent of Optional Signing**

| Case | Purpose of Sign | Suggested Language |
|---|---|---|
| 1 | To inform drivers that truck encroachment will occur throughout roundabout | CAUTION TRUCKS WILL OCCUPY BOTH LANES |
| 2 | To inform drivers that truck encroachment will occur while circulating and exiting | TRUCKS STAY IN LANE BEFORE ENTERING ROUNDABOUT |
| 3 | To inform drivers that trucks will not encroach and all drivers should stay in their lane throughout the roundabout | STAY IN LANE |

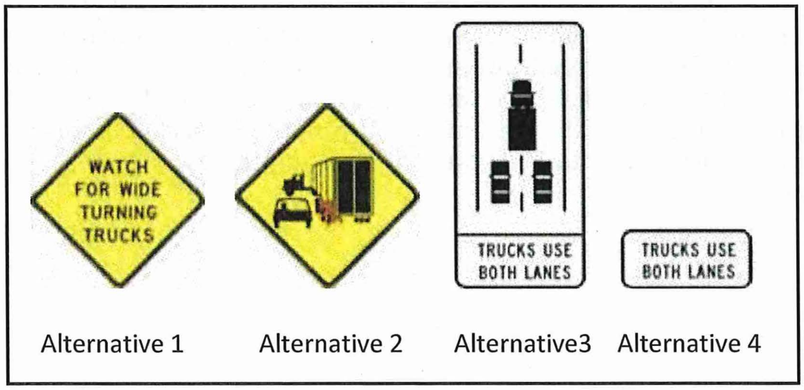
**Figure 9 - Optional Truck Signing Language**

Image Source: Short Elliot Hendrickson Inc.

The signs should be placed consistent with the guidelines provided in Table 2C-4 of the MUTCD and Department policy. These warning signs should ideally be located after regulatory lane assignment signs.

Final results from an in-progress United States Department of Transportation (DOT) study for signing indicating possible truck encroachment on roundabout approaches were not available at the time of this study. However, the signs shown in **Figure 10** are being considered as part of this study and may be included in the ultimate recommendations which are approved. It is possible that these signs may eventually be available for use at roundabouts in Wisconsin and Minnesota.

**Figure 10 - Signs Studied by U.S. DOT**



## 4.0 Special Considerations for Three Lane Roundabouts

Although Case 2 and Case 3 designs can be implemented at roundabouts with three lane entries, such a design is considerably more complex than at a roundabout with two lane entries. However, it is possible to accommodate trucks in lane at three lane roundabouts while still meeting applicable guidance for critical design parameters. There are additional considerations when preparing this type of design:

1. Designers should recognize that the required ICD may in some cases be larger than the ranges noted earlier in this document.
2. It may be more difficult to control approach speeds (R1) when entries become wider at three lane Case 2 and Case 3 designs.
3. At Case 3 locations, keeping trucks in lane in the circulating road can be challenging. However, since a three lane roundabout typically has a larger ICD, trucks will have larger circulating radii, thus helping them stay in lane.
4. At some three lane roundabouts, gore striping may not be needed in order to keep trucks in lane. This will depend upon the width of the lane in question as well as other factors such as the radius being negotiated and the overall approach/entry design. In order to make a determination whether gore striping is needed, an analysis of truck swept paths must be conducted (using a CAD software program) for each lane. Whether gore striping is needed between particular lanes can be determined from this analysis.

This situation is illustrated in **Figure 11** which shows a typical Case 2 design at a three lane roundabout.

## 5.0 Right Turn Bypass Lanes

Right turn bypass lanes can be applied to any design case and can provide considerable capacity improvement without compromising truck mobility when designed properly. Designers should follow established guidance documents from the FHWA, WisDOT, and MnDOT (the respective roundabout guides from these agencies) when designing right turn bypass lanes to accommodate trucks at multilane roundabouts. Following an iterative roundabout design process, the designer should model the swept path of the design vehicle using CAD software and ensure that there is a minimum two-foot clearance between the vehicle's tires and the face of curb. Where necessary, geometric adjustments should be made to accommodate the design vehicle. In some cases, designers may need to modify the design of bypass lanes to include larger radii and more gradual curvature. This applies to both types of right turn bypasses (free flowing and partial/yield controlled).

## Figure 11 - Case 2 Three Lane Roundabout

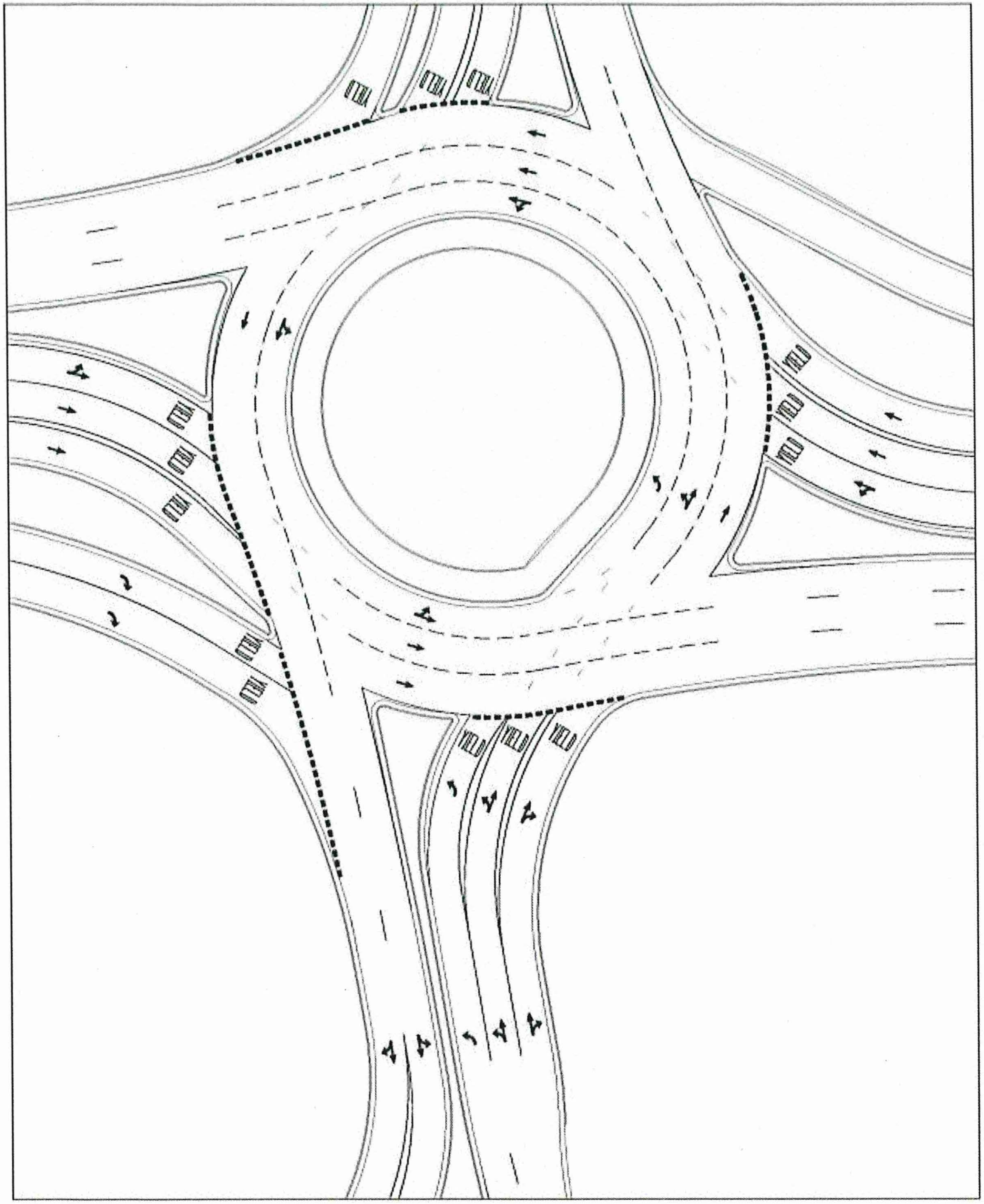


Image Source: Roundabouts & Traffic Engineering (RTE)