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Accommodating Oversize/Overweight Vehicles at Roundabouts

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16 **Abstract**

Safety and traffic operational benefits of roundabouts for the typical vehicle fleet (automobiles and small trucks) have been well documented. Although roundabouts have been in widespread use in other countries for many years, their general use in the United States began only in the recent past. 1990 is generally accepted as the year the first ***modern*** roundabouts were built in the United States (US), but their use is growing. Roundabouts can offer several advantages over signalized and stop-controlled intersection alternatives, including better overall safety performance, lower delays, shorter queues, better management of speed, and opportunities for community enhancement features. However, potential use of roundabouts with all their benefits may be greatly diminished if they cannot accommodate oversize/overweight vehicles (OSOW). Accommodating OSOW at roundabouts is the central issue and the need for this research. Note that the acronym OSOW has been used in this report as a universal term, generally understood to mean a permitted vehicle. OSOWs impact pavement structure, roadway geometrics, and traffic operations. These issues are discussed in the report. OSOWs are a reality for American industry and often critical for certain industries. A better understanding and sharing of current practices is essential for states that permit such movement, and the industry which must rely on state highways and a permit to deliver large loads. Thus, the main objectives of this report are to compile current practice and research by various states and countries related to the effects OSOW have on roundabout location, design, and accommodation. Second, the research will attempt to fill in information gaps with respect to roundabout design and operations for this class of vehicles. A literature review uncovered no published reports on OSOW accommodation per se; however, much information on the advantages of having designated truck and OSOW networks is analyzed and reported. The authors make an argument that states should consider conducting a study to develop a freight network, which includes segments where OSOW need to be accommodated, in accordance with state and federal commerce laws and policies and the state's economy. The study should include determining all motor vehicles whose size and turning movements are critical to developing routes on which all segments will accommodate these vehicle. To obtain information on the state-of-the –art of OSOW accommodation, the authors turned to personal contacts, unpublished material, case studies and surveys. Examples of accommodating OSOW in general, and various turning movements, found in the literature, surveys, and personal contacts are provided in the report as examples of ideas and concepts that could be considered, and possibly adapted to the needs of a specific site. Several examples from England, France, and Germany, and other countries, were also found and are presented. Also, cutting edge research and a state's recent policy on accommodating low, ground clearance vehicles that could "hang up" are presented. Four surveys were developed, executed and analyzed: a general survey on permitted vehicles to the 50 states; a second survey to the 50 states on specific roundabout issues, a survey to regional managers of the Specialized Carriers and Rigging Association (SC&RA), and a survey developed and conducted in partnership with the American Transportation Research Institute (ATRI) and sent to their membership. The complete analysis and some actual answers are contained in the report and its appendices. From all surveys and contacts made during the course of this investigation, based on the most mentioned concern, the authors conclude that vertical ground clearance in general, and curbs in particular, are a major problem for large trucks and OSOW and definitely need to be mitigated whenever OSOW need to be accommodated. The authors conclude that ground clearance is an issue that has not been given as much attention as it deserves and must be addressed. The authors further conclude that three inches should be considered as a maximum height of splitter islands, truck aprons and curbs. Many other issues uncovered by the surveys are presented and discussed in the report. Numerous ideas are presented and design strategies are illustrated. Simulations of seven OSOW check vehicles, from a Wisconsin vehicle library, were run on many hypothetical, and some actual, roundabout scenarios. The authors emphasize that the ideas and concepts shown and illustrated are just that, i.e., ideas and concepts. No attempt has been made or was ever intended that this report should be a design guide; however, the authors believe it contains a wealth of ideas that designers and states should consider. The authors primary conclusion from conducting great numbers of vehicle path simulations is that, given the knowledge of what OSOW need to be accommodated, and their turning characteristics, any knowledgeable designer can do it, provided that right of way is available. It is up to the state to determine the economic benefits or dis-benefits of doing so. A final section of the report presents guidelines developed by Wisconsin DOT to check and avoid low, ground clearance vehicles ("low boys") from scraping bottom while traversing roundabouts ("hang ups"), believed to be one of the first such studies in the USA. The authors present over three pages of other conclusions and recommendations, based on the literature reviewed, four surveys, examples of OSOW accommodation obtained from personal contacts, numerous OSOW simulations on various roundabout scenarios, the seven OSOW check vehicles used, and the low ground clearance concern that was the number one reported concern of the trucking industry.

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Final Report

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A Report on Research Sponsored by

THE KANSAS DEPARTMENT OF TRANSPORTATION
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and

KANSAS STATE UNIVERSITY TRANSPORTATION CENTER
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PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

NOTICE

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Abstract

Safety and traffic operational benefits of roundabouts for the typical vehicle fleet (automobiles and small trucks) have been well documented. Although roundabouts have been in widespread use in other countries for many years, their general use in the United States began only in the recent past. 1990 is generally accepted as the year the first ***modern*** roundabouts were built in the United States (US), but their use is growing. Roundabouts can offer several advantages over signalized and stop-controlled intersection alternatives, including better overall safety performance, lower delays, shorter queues, better management of speed, and opportunities for community enhancement features. However, potential use of roundabouts with all their benefits may be greatly diminished if they cannot accommodate oversize/overweight vehicles (OSOW). Accommodating OSOW at roundabouts is the central issue and the need for this research. Note that the acronym OSOW has been used in this report as a universal term, generally understood to mean a permitted vehicle. OSOWs impact pavement structure, roadway geometrics, and traffic operations. These issues are discussed in the report. OSOWs are a reality for American industry and often critical for certain industries. A better understanding and sharing of current practices is essential for states that permit such movement, and the industry which must rely on state highways and a permit to deliver large loads. Thus, the main objectives of this report are to compile current practice and research by various states and countries related to the effects OSOW have on roundabout location, design, and accommodation. Second, the research will attempt to fill in information gaps with respect to roundabout design and operations for this class of vehicles. A literature review uncovered no published reports on OSOW accommodation per se; however, much information on the advantages of having designated truck and OSOW networks is analyzed and reported. The authors make an argument that states should consider conducting a study to develop a freight network, which includes segments where OSOW need to be accommodated, in accordance with state and federal commerce laws and policies and the state's economy. The study should include determining all motor vehicles whose size and turning movements are critical to developing routes on which all segments will accommodate these vehicle. To obtain information on the state-of-the –art of OSOW accommodation, the authors turned to personal contacts, unpublished material, case studies and surveys. Examples of

accommodating OSOW in general, and various turning movements, found in the literature, surveys, and personal contacts are provided in the report as examples of ideas and concepts that could be considered, and possibly adapted to the needs of a specific site. Several examples from England, France, and Germany, and other countries, were also found and are presented. Also, cutting edge research and a state's recent policy on accommodating low, ground clearance vehicles that could "hang up" are presented. Four surveys were developed, executed and analyzed: a general survey on permitted vehicles to the 50 states; a second survey to the 50 states on specific roundabout issues, a survey to regional managers of the Specialized Carriers and Rigging Association (SC&RA), and a survey developed and conducted in partnership with the American Transportation Research Institute (ATRI) and sent to their membership. The complete analysis and some actual answers are contained in the report and its appendices. From all surveys and contacts made during the course of this investigation, based on the most mentioned concern, the authors conclude that vertical ground clearance in general, and curbs in particular, are a major problem for large trucks and OSOW and definitely need to be mitigated whenever OSOW need to be accommodated. The authors conclude that ground clearance is an issue that has not been given as much attention as it deserves and must be addressed. The authors further conclude that three inches should be considered as a maximum height of splitter islands, truck aprons and curbs. Many other issues uncovered by the surveys are presented and discussed in the report. Numerous ideas are presented and design strategies are illustrated. Simulations of seven OSOW check vehicles, from a Wisconsin vehicle library, were run on many hypothetical, and some actual, roundabout scenarios. The authors emphasize that the ideas and concepts shown and illustrated are just that, i.e., ideas and concepts. No attempt has been made or was ever intended that this report should be a design guide; however, the authors believe it contains a wealth of ideas that designers and states should consider. The authors primary conclusion from conducting great numbers of vehicle path simulations is that, given the knowledge of what OSOW need to be accommodated, and their turning characteristics, any knowledgeable designer can do it, provided that right of way is available. It is up to the state to determine the economic benefits or dis-benefits of doing so. A final section of the report presents guidelines developed by Wisconsin DOT to check and avoid low, ground clearance vehicles ("low boys") from scraping bottom while traversing roundabouts ("hang ups"), believed to be one of the first such studies in the USA. The authors present over three pages of other conclusions and recommendations, based on the literature reviewed, four surveys, examples of OSOW accommodation obtained from personal contacts, numerous OSOW simulations on various roundabout scenarios, the seven OSOW check vehicles used, and the low ground clearance concern that was the number one reported concern of the trucking industry.

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Putting this report together has been a long dusty road made possible, and in general, interesting, and in some cases even enjoyable, by the assistance of several people who were involved in the conduct of the research, comments via phone, e-mail, internet meetings, commenting on pieces of early drafts, and particularly supplying material for the examples of accommodating oversize overweight vehicles (OSOW) at roundabouts, presented in chapter 5.

First the authors would like to acknowledge Steve King, road design squad leader for the Kansas DOT (KDOT) for his patience, understanding and advice on moving the project forward. Also very helpful and encouraging were the members of the project advisory committee who showed interest in meetings and offered material and advice by e-mail. All advisory committee members are listed in Appendix A of the report.

In particular, the authors would like to acknowledge Pat Fleming, Wisconsin DOT, for sending a great deal of important material directly related to the objectives of this study, not the least of which was the WisDOT library of 7 Check vehicles, developed by Mark Lenters, Ourston Roundabout Engineering, used extensively for examples and illustrations in Chapter 6, Peter Lynch with the University of Wisconsin's freight laboratory, who has conducted truck and OSOW studies for Wisconsin and Minnesota, who also supplied considerable insight and material related to this study; Rich Crossler-Laird, Oregon DOT, whose communications with the authors provided them with considerable insight into issues with roundabouts and OSOW in the state of Oregon and also, Brian Walsh, Washington State DOT, shared many thoughts and examples of removable signs.

Chapter 5, which is perhaps the heart of this study, would not have been possible without the considerable material made available directly to the authors via e-mail, discussions, or pointing out relevant material, by roundabout designers with knowledge expertise and experience in designing roundabouts in general, and in accommodating OSOW at roundabouts in particular. Thus, the authors would like to acknowledge Mark Lenters, Ourston Roundabout Engineering; Phil Weber, Ourston Roundabout Engineering, Canada; Scott Ritchie, Roundabout and Traffic Engineering; Wes Butch, DLZ National; Josh Stratka, Strand Associates; Kelli Owen, Reid Middleton; Mark Johnson, MTJ; Howard McCulloch, NYSDOT; Clive Sawyers, Consultant, United Kingdom; Andrew O'Brien, Consultant, Australia; L.G.H. (Bertus) Fortuijn, Consultant, Netherlands; and Dr. Werner Brilon, Professor, Germany.

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Also, several photos used for illustrations were available through KDOT personnel or KDOT photo services. Other photo credits are referenced throughout the report.

The states of Kansas, Connecticut, Iowa, Mississippi, Ohio, Oregon, Washington and Wisconsin acknowledged for their financial support, as well as the Federal Highway Administration. Also, the authors wish to thank the non-state sponsors: Kansas State University, University Transportation Center, Mid-American Transportation Center and Transoft Solutions, Inc., particularly Daniel Shihundu and Steven Chan, for their advice and help running software.

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Chapter 1: Background and Introduction

1.1 Background

Funding for this project comes from the following five sources:

- K-TRAN Project KSU-10-1 (KDOT—Kansas DOT)
- Transportation Pooled Fund Project TPF-5(220) with KDOT as lead state
- Mid-America Transportation Center-University of Nebraska-Lincoln (MATC)
- Kansas State University Transportation Center (KSUTC)
- Transoft Solutions, Inc.

The following state DOT study partners also participated in transportation pooled fund project TPF-5(220):

- Connecticut Department of Transportation
- Iowa Department of Transportation
- Kansas Department of Transportation
- Mississippi Department of Transportation
- Ohio Department of Transportation
- Oregon Department of Transportation
- Washington State Department of Transportation
- Wisconsin Department of Transportation

A list of advisory committee members may be found in Appendix A.

1.2 Interim Report

In October 2011, an interim report was written and presented to the advisory committee. (Russell, Landman, Godavarthy 2011). The scope of the interim report is outlined below. The interim report was to satisfy task five, and covered tasks one through four of the contract proposal. (Specific project tasks can be found in Appendix A.1. This final report builds on and expands the tasks covered in the interim report, and completes the discussion and conclusions for the remaining tasks.

1.3 Project Overview and Tasks

The project overview, objectives and tasks are presented below, paraphrased from the project contract, with some editing.

1.3.1 Project General Statement

Safety and traffic operational benefits of roundabouts for the typical vehicle fleet (automobiles and small trucks) have been well documented. Although roundabouts have been in widespread use in other countries for many years, their general use in the United States began only in the recent past. 1990 is generally accepted as the year the first ***modern*** roundabouts were built in the USA, but their use is growing. Roundabouts can offer several advantages over signalized and stop-controlled intersection alternatives, including better overall safety performance, lower delays, shorter queues, better management of speed, and opportunities for community enhancement features. In some cases, roundabouts can avoid or delay the need for expensive widening of an intersection approach that would be necessary for signalization.

However, potential use of roundabouts with all their benefits may be greatly diminished if they cannot accommodate oversize/overweight vehicles (OSOW). Accommodating OSOW at roundabouts is the central issue and the need for this research.

Note: In the beginning of this project, the term "superload" was used to designate large vehicles generally needing a permit to be allowed on a state's highways. As the project progressed, it was determined that "superload" meant different things to different states; therefore, the acronym OSOW has been used as a more universal term, generally understood to mean a permitted vehicle.

The design vehicle for a roundabout, as in any design, should be the largest vehicle reasonably anticipated for normal use. However, OSOW use the roadway by special permit and travel on a random basis. Further, their physical characteristics may greatly exceed the dimensions given for design vehicles in "*A Policy on Geometric Design of Highways and Streets*" (AASHTO, 2004). Although not specifically stated in the proposal for this project, there is an underlying question of policy regarding which roundabouts in a state need to accommodate OSOW.

OSOWs impact pavement structure, roadway geometrics, and traffic operations. OSOWs are a reality for American industry and often critical for certain industries. In Kansas these vehicles average 122 feet long, 12 feet 9 inches wide and almost 15 feet high, and with an average weight of 218,000 pounds (Personal communication, Jim Brewer, Engineering Manager-State road Office, Kansas Department of Transportation). In addition, many of the trailers have low ground clearance above the roadway surface. Kansas has experienced a significant increase in the number of these loads moving through the state. In 1999 there were 433 total loads that grew to 6,402 total loads in 2007. It is believed this situation is similar in many other states. A better understanding and sharing of current practices is essential for states that permit such movement, and the industry which must rely on state highways and a permit to deliver large loads.

Most USA roundabouts are intentionally designed to operate at slower speeds, by using narrow curb to curb widths and tight-turning radii. However, if the design geometrics are too restrictive, roundabout use by OSOWs may be difficult or even impossible. Therefore, the central issue is how to accommodate OSOWs where appropriate without sacrificing the integrity, i.e., safety and operational efficiency, of the roundabout. Typical OSOWs are routed around roadway restrictions such as certain bridges, narrow roadways, etc. However, with the popularity of roundabouts and the benefits they provide, such routing is becoming more difficult and could inhibit roundabout growth.

1.4 Research Objective

This research project is necessary to compile current practice and research by various states and countries related to the effects OSOW have on roundabout location, design, and accommodation. Second, the research will attempt to fill in information gaps with respect to roundabout design and operations for these classes of vehicles. Currently there is little information available for accommodating the OSOW vehicle classes in roundabout design.

Chapter 2: Formal Literature Review

2.1 General

Very little has been written in the available published literature on OSOW accommodation. The authors feel an important approach of maintaining the safety, operational and environmental benefits of modern roundabouts for all motorists, and not inhibiting roundabout growth, is to do the best planning and design possible for all large trucks. Good planning and design for all large trucks on key state routes should make it easier to accommodate OSOW as needed on segments of those routes. Further, the authors believe consideration should be given by all states to develop freight routes and include OSOW segments of these routes. A few states have done this and the approach by Wisconsin is documented in this report. Also, other literature is reviewed dealing with freight routing in general, as well as OSOW routing.

2.2 Review of Completed Study Reports

2.2.1 OSOW Safety Study

The American Association of State Highway and Transportation Officials (AASHTO) published a study report to synthesize the safety implications of oversize/overweight commercial vehicles (AASHTO, 2009). This project followed an international technology scanning tour conducted by the U.S. Federal Highway Administration (FHWA), AASHTO, and the National Cooperative Highway Research Program (NCHRP).

The primary objective of this project was to identify known relationships between commercial vehicle safety and causal factors (vehicle type, weight, length, speed, load, driver, etc.,) so that certain modifications can be suggested for commercial vehicle enforcement and permitting practices. Thus, investments and expenditures on size and weight enforcement can be justified for improving safety. The secondary objective was to identify research needed to guide future safety and enforcement enhancements.

A general trend was identified that crash rates decrease but crash severity increases as commercial vehicles become larger and heavier. However, scientific measures of reliability of this trend are not identified. No existing truck crash data sets contain sufficient data for a scientific analysis of specific contributions of size and weight to crash causation or severity.

Researchers need much more information to interpret the role of size or weight in OSOW crashes. Some studies in Canada have indicated that the largest vehicles, longer combination vehicles (LCV), have lower crash rates (all severities) than other trucks and all vehicles as a group (Honefanger 2009). According to Honefanger (2009) another study in Canada (not identified in the Honefanger executive summary) found that large truck performance measures (static roll stability, off tracking, etc.) are highly correlated to large truck crash rates. Controlling truck safety through performance thresholds might offer an alternative way to enhance large truck safety programs in the USA (Honefanger, Jeff G, 2009, executive summary).

Recommendations addressed by the Canadian study team (not identified in the Honefanger executive summary) for additional data and for enhanced awareness of the complexity of heavy truck crashes were reported in the Honefanger report as follows:

- Make data available, if possible online, from weigh stations, weigh-in-motion (WIM), and virtual WIMs, especially when weight and dimensional data can be attributed to specific vehicles that are later involved in traffic crashes. This data can add significant scientific merit to truck safety studies. The weight data can also be used for state and federal planning and enforcement activities.
- Expand the number of WIM and virtual WIM stations to provide more data at relatively small incremental costs compared to alternative labor-intensive methods to collect the same data.
- Expand the "Truck Involvement in Fatal Accidents" and "Large Truck Crash Causation" databases. They are prepared by supplementing crash data with specific information about the configuration of each involved truck, driver information, citation information, load information, and much more. It seems realistic to use weight databases to expand these files for individual truck crashes.
- Conduct a regional study of OSOW vehicles.
- Inventory states with categorical exclusions to Truck Size and Weights that allow very heavy commercial vehicles, to see if any of them have comprehensive records of crashes of OSOW vehicles.

- Examine load and weight distributions of commercial vehicles involved in collisions to find the relationship among weight and factors like braking capacity and handling characteristics, which could provide a breakthrough in commercial vehicle safety knowledge.
- Conduct an intensive project to gather significant, high-quality data to analyze OSOW commercial vehicle crashes, including follow-up crash site investigations to collect truck-specific data using a crack team of experts.
- Where needed, provide specialized training to troopers, police officers, and other involved personnel to help them determine the cause or contributing causes of heavy truck crashes. This can affect type and amount of data they collect.
- Encourage Federal Highway Administration and Federal Motor Carrier Safety Administration to continue to work together to develop and administer policies and programs that address the big picture of roadway safety, of which heavy truck safety is an important element" (Honefanger 2009).

2.2.2 Design Measure and OSOW Issues

A study was conducted by Gingrich and Waddell (2008) of Ourston Roundabout Engineering Inc., Ourston Roundabouts, Canada. It discusses various issues and a design measure related to trucks and oversize vehicles at roundabouts, and describes treatments used when the truck percentages are high, and the trade-offs in terms of safety and speed control when using these techniques.

An optimal roundabout design is that design which accommodates a larger portion of road users. Therefore, frequencies of use by various users are considered for an optimal roundabout.

Accommodating larger vehicles at roundabouts is not a new practical challenge. Many practical measures have been developed to accommodate larger trucks at roundabouts and include fully traversable center islands (similar to mini-roundabouts), widened entry and exit lanes, right-turn bypass lanes, partially traversable central islands (truck apron), gated pass-throughs, lane striping, and others. Each of these methods carry design trade-offs in terms of safety and speed control of cars and small trucks, and each should be considered for site-specific conditions.

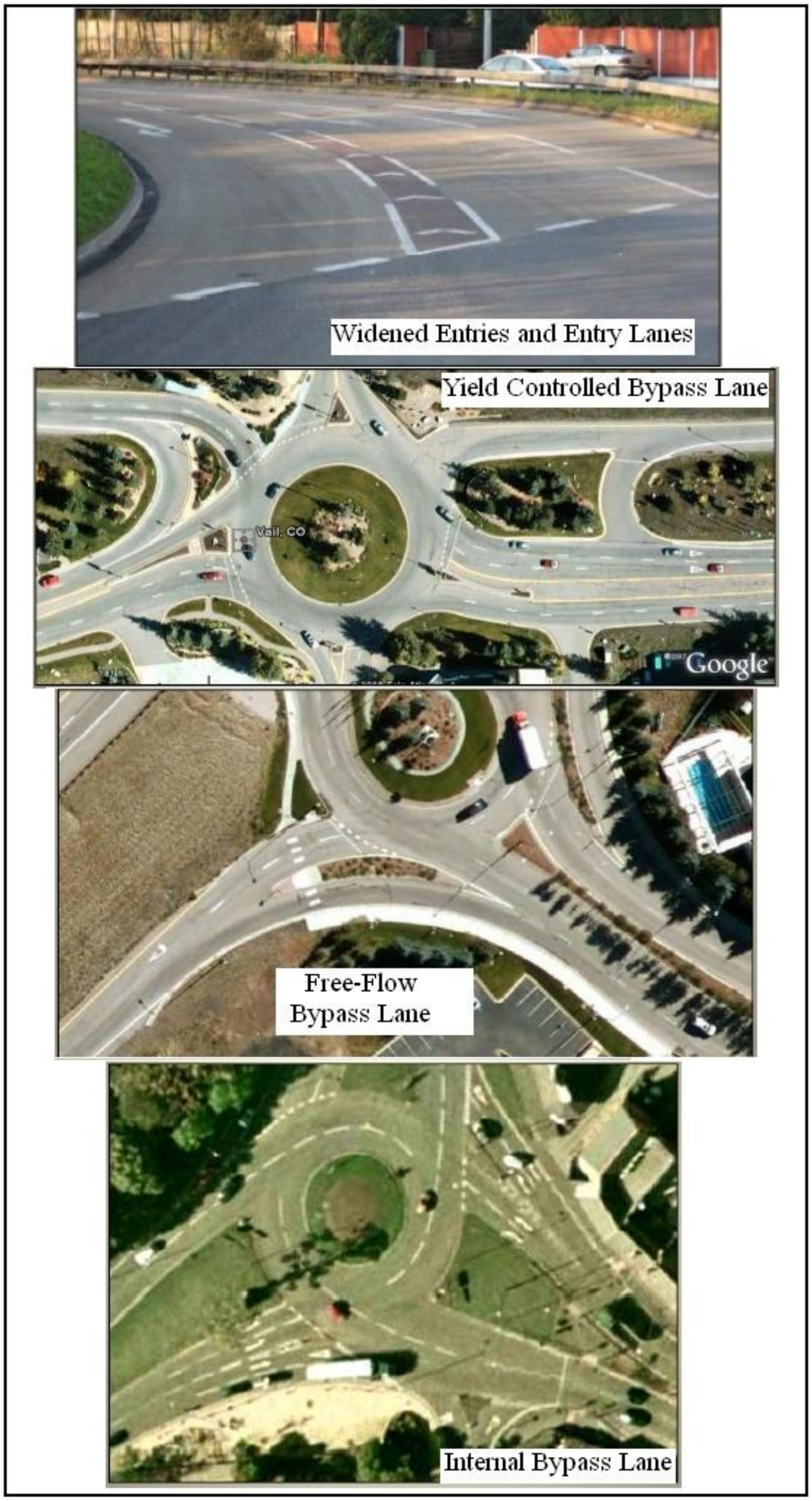
Truck aprons are designed to provide maneuvering space for large vehicles in a roundabout, while still providing deflection for smaller vehicles. They should be capable of being mounted by semi trailers, but unattractive to cars. However, an apron may not be necessary if speed control and truck maneuvering space can be provided without an apron. A fully raised splitter island provides an effective lateral deflection when compared to aprons. Sometimes, the height and slope of the apron can create under-clearance and stability problems for trucks. (Authors' comment: Although it seems the previous suggestion of not having aprons may be okay for normal, large vehicles, e.g., using AASHTO WB -67 truck criteria for design, it seems it might be counterproductive if it is necessary for OSOW of very complex dimensions to traverse the roundabout, particularly to make a left turn).

2.2.3 Truck Apron Study

A truck apron field study (not OSOW) was conducted at I-17/Happy Valley Road, Phoenix in July 2007. Peak hour apron use by semis and large single-unit trucks was observed. Data showed that out of 624 trucks observed, 77% did not use the apron. Among the trucks that did use the apron, most (67%) used it because a car was in the adjacent lane. It was also observed that when a car and truck were side by side, the smaller vehicle usually accelerated ahead of the truck or applied brakes to get behind the truck (Gingrich and Waddell 2008).

2.2.4 Truck Turn Study

Truck right turns can be accommodated at larger roundabouts by different means, such as use of an adjacent lane, providing widened entries and entry lanes, providing right-turn bypass lanes, free-flow bypass lane, yield-controlled bypass lane, and an internal bypass lane. Figure 2.1 shows pictures of treatments used to accommodate truck right turns.



(Source: Gingrich and Waddell, 2008)

FIGURE 2.1
Treatments for Accommodating Truck Right Turns

2.2.5 Wisconsin Multi-lane Truck Study

A draft report prepared for the Wisconsin DOT (WisDOT) presents a synthesis of current design practices used to accommodate trucks at multilane roundabouts (MLRs) (Joint Roundabout Truck Study 2011). Although it is emphasized this is not a study of OSOW, the writers of this report believe that an understanding of good design for typical large trucks, i.e., AASHTO design vehicles, that travel on all of their highways and are not of such characteristics as to require a permit, will help in understanding the OSOW problem and perhaps be the basis of some solutions. It stands to reason that required changes to a roundabout to accommodate OSOW should be much easier to make if the basic designs create no problems for the typical large truck. One caveat the authors of the WisDOT report point out is that as a result of a relatively small sample size, many conclusions are based on current trends and general observations. (Joint Roundabout Truck Study 2011)

The authors of the WisDOT report point out the three prevailing methods of MLR design in the United States: 1. allow trucks to encroach into an adjacent lane as they approach and traverse the intersection; 2. accommodate trucks in lanes as they approach, but allow them to encroach into adjacent lanes as they traverse the intersection; and 3. accommodate trucks in lanes as they approach and traverse the intersection. This led the WisDOT joint roundabout truck study to classify the roundabouts studied into three groups based on whether they were designed to accommodate trucks in lanes on the approaches and/or circulating or whether trucks encroached into adjacent lanes. The three categories (See Figure 2.2 for pictures of the three cases) are described in the joint roundabout truck study as quoted below:

> Case 1 – Case 1roundabouts are designed such that trucks encroach into adjacent lanes while entering, circulating, and exiting a roundabout."
>
> 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."
>
> Case 3 – Case 3 roundabouts are designed such that trucks can stay within their lanes as they intersect, 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 utilize a truck apron on the central island to stay in the 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" (Joint Roundabout Truck Study 2011).

A survey indicated that truck percentages were the primary reason for a designer choosing a case type. Roundabouts at intersections with higher truck volumes were often designed as case 2 or case 3, and roundabouts located at intersections with lower truck lines were often designed as case 1. Ranges of the truck percentages given were case 1, 5.0% to 5.5%; case 2; 9.00% to 11.0% and case 3, 5.4% to 18.60%." (Joint Roundabout Truck Study 2011)

Reported advantages of case 1 roundabouts, with the design focusing primarily on passenger car accommodations, are that they allow for smaller and tighter geometry. In some situations this results in a smaller diameter roundabout and significant ROW cost savings. It also allows for the most design flexibility and radial designs to fit tight right-of-way situations." (Joint Roundabout Truck Study 2011)

Reported advantages of case 2 roundabouts are that they allow trucks to stay in lane within the entry. This provides improved traffic operations, increased safety, and less curb maintenance than case 1 roundabouts. The draft report also mentions some disadvantages: generally designers cannot use the radial design method and often require additional curve lengths to accommodate the trucks well. Also, they are slightly more complex to design, may require more striping maintenance, and may have a larger footprint. (Joint Roundabout Truck study 2011)

Reported advantages of case 3 roundabouts are that it allows trucks to stay in their 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 design treatments and higher percentages of trucks. (Joint Roundabout Truck Study, 2011)

FIGURE 2.2
From Slides Courtesy of Phil Weber, Ourston Roundabout Engineering, Canada

The study observed that design characteristics of case 2 roundabouts are as follows: (Joint Roundabout Truck Study 2011)

- widely varying entry radii ranging from 63 to 138 feet
- wider entry widths with typical ranges from 32 to 34 feet
- effective flare implemented between curb faces
- generally longer effective entry radii with varying lengths left ("effective radii" are those with sufficient lengths to affect driver paths/assist with deflection prior to crosswalk and yield line,)
- varying inscribed circular diameters within typical FHWA ranges

The study observed design characteristics of case 3 roundabouts as follows:

- generally larger entry radii ranging from 120 to 130 feet
- wide entry widths with typical ranges from 32 to 34 feet

- inside circulating lane widths of 14 to 17 feet and outside widths of 17 to 19 feet
- effective flare implemented
- larger entry radii of roughly 100 feet or more
- inscribed circular diameters with typical ranges presented in the FHWA roundabout guide Exhibit 6 – 19 (120 feet is minimum recommended diameter for WB – 65 trucks)

This study (Joint Roundabout Truck Study 2011) also distributed questionnaires to the Wisconsin Motor Carriers Association and Minnesota Trucking Association to determine their potential concerns about navigating multilane roundabouts. Only a few of the responses will be mentioned here. The majority of respondents indicated their drivers are not confused by pavement markings or truck aprons while circulating and exiting the roundabout. However, many respondents indicated confusion because they were not provided adequate signing or advance warning to indicate whether trucks must stay in lane, use the truck apron, or off-track into the adjacent lane. Several also indicated that other drivers (presumably passenger car drivers) occasionally enter the roundabout from the wrong lane or encroach on trucks that are attempting to use both lanes. Several respondents commented that using the truck apron may cause safety issues such as load shifting or tire damage. Several respondents suggested a sign that states “trucks use both lanes” or “do not pass trucks in roundabout.”

2.2.6 Freight Planning and OSOW

There is very little published information on oversize/overweight vehicles (OSOW) freight planning. There are a number of references on freight planning in general, some of which will be reviewed here. Good OSOW routing should also document routes where OSOW cannot be accommodated, e.g. a bridge too narrow or with an unacceptable load rating, or other obstacle that cannot be remedied for economic, legal, or policy reasons.

FHWA is interested in having states develop statewide freight plans. Although they do not specifically state anything about OSOW, the authors believe OSOW should be considered as an integral part of any state's freight network planning.

The FHWA Office of Freight Management and Operations, as stated on their website (http://ops.fhwa.dot.gov/freight/infrastructure/index.htm), is responsible for promoting investment in cost-effective infrastructure for the efficient movement of freight. They provide technical advice to others of the FHWA and its partners and oversight of four programs authorized by the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users, commonly known as SAFETEA -LU. Their website lists the freight network and major freight programs, and provides links to them.

There are approximately 200,000 miles of highways which are designated for conventional combination vehicles, of which 26,000 miles are major freight corridors. These corridors are explained in detail in "Freight Story 2008" and will not be reviewed here. Truck routes generally follow the National Network established by Congress in 1982 as explained in Figure 2.3. (Freight Story 2008)

The National Network

The National Network was authorized by the Surface Transportation Assistance Act of 1982 (P.L. 97-424) and specified in the U.S. Code of Federal Regulations (23 CFR 658) to require states to allow conventional combinations on "the Interstate System and those portions of the Federal-aid Primary System ... serving to link principal cities and densely developed portions of the States ... [on] high volume route[s] utilized extensively by large vehicles for interstate commerce ... [which do] not have any unusual characteristics causing current or anticipated safety problems." Conventional combinations are tractors with one semitrailer up to 48 feet in length or with one 28-foot semitrailer and one 28-foot trailer, and can be up to 102 inches wide.

The National Network differs in extent and purpose from the National Highway System (NHS), which was created more than a decade later by the National Highway System Designation Act of 1995 (P.L. 104-59). Both are about the same length, roughly 200,000 miles, but the National Network includes approximately 65,000 miles of highways beyond the NHS, and the NHS includes about 50,000 miles of highways that are not on the National Network. The National Network supports interstate commerce by regulating the size of trucks, while the NHS supports interstate commerce by focusing federal investments.

The National Network has not changed significantly in a quarter century. It is modified only if segments are added to the Interstate highway system or if states petition to have a segment beyond the Interstate highway system added or deleted. Petitions for modifications have not been received in years, even though the geography of interstate commerce has changed significantly with the growth of smaller communities into principal cities and the emergence of new, densely developed areas. Consistency between the National Network and freight-related portions of the more recent NHS is not required.

The definition of conventional combinations is also unchanged, even though 48-feet is no longer the maximum length of a single trailer in the majority of states. Single 53-foot trailers are allowed in 25 states without special permits and in an additional 3 states subject to limits on distance of kingpin to rearmost axle.

(Source: http://www.ops.fhwa.dot.gov/freight/freight_analysis/freight_story/major.htm)

FIGURE 2.3
The U.S. National Network

2.2.6.1 FHWA Statewide Freight Plan Template

FHWA has published a manual, “Statewide Freight Plan Template,” which will be reviewed here (Keenan and Quinn 2011).

The FHWA publication lists several reasons why statewide freight planning is important (Keenan and Quinn June 2011):

- increasing globalization and a corresponding economic (national, state, and local) dependence on expanding supply chains and transportation reliability (water, air, rail, highway, and pipeline)
- recognition by business leaders at all levels that efficient freight transportation is a key factor in economic (national, state, and local) competitiveness and vitality
- heightened awareness from both private and public sectors that investment from both are needed, if not required, to meet increasing freight transportation demands
- increasing demands for transportation among both passenger and freight interests creating stress on the transportation system, resulting in congestion and bottlenecks in key locations detrimental to productivity

The FHWA report covers all modes of freight transportation. The report discusses modal infrastructure and points out it is important to focus on major commodities for each mode, how they are transported, infrastructure, current issues within each mode, and important connections between each mode. As stated in the report:

“The decisions on routes, modes, time of day, etc. are often very different in terms of who makes the decision, why the decisions are made, where the decisions are made and when they are made”. (Keenan and Quinn 2011).

The highway section covers the National Highway System (NHS), the National Network, state routes and local routes. These all should be considered in statewide freight and OSOW route planning.

2.2.6.2 Key Points of the FHWA "Template"

Following in this section are some key points from the "Statewide Freight Plan Template" (Keenan and Quinn 2011), which will be referred to below as the "template."

Statewide freight planning needs to address aspects of safety, security, economic development, mobility, and environmental impacts. There should be "outreach" to increase awareness of freight issues to increase public and private understanding, and strengthen partnerships and coordination with other transportation agencies, other government organizations, private industry, and the public. Public outreach is well understood and practiced by states on all projects. Engaging the private sector may be a new experience for some. Private industry stakeholders, which provide nearly all of the freight service nationally, statewide, and locally, are a valuable resource and source of needed data. They can help identify regional, statewide, and multijurisdictional challenges to moving freight.

The template lists the following cross section of freight stakeholders that should be included: (Keenan and Quinn 2011)

- shippers
- carriers
- terminal operators
- economic development agencies
- seaport and airport authorities
- state and local governments and other public agencies
- receivers (stores, industry, etc.)
- distribution centers/warehousing representatives
- commercial and industrial developers

The template also lists the following activities that may be required: (Keenan and Quinn 2011)

- conducting focus groups with private sector stakeholders
- conducting interviews with private sector stakeholders
- holding conferences/meetings/workshops with private sector stakeholders

- implementing a freight advisory council
- exchanging data
- implementing the plan (ask them to help make it a reality)

The template makes a point that state freight characteristics should be studied. This should include major characteristics of a state's freight system and include who needs to be involved with freight movement into and out of the state. As stated in the template, this will provide *"---an overview of State economic structure and then present supply chains that are required by key industry sectors. This will lay the groundwork for tying the global, national, regional and intrastate freight flows and connections back to the economic activity within the State."* (Keenan and Quinn 2011)

- The template discusses the role that freight movements play in maintaining the vitality of a state's economy. It provides the following list of economic trends and forecasts that will affect freight: population
- employment by industry
- income
- imports and exports
- industrial production forecast
- total taxable sales
- inflation rate (Keenan and Quinn , June 2011)

In addition they stated that regional plans, with respect to economic growth and development, will also affect freight transportation demand. A "Guidebook for Forecasting Freight Transportation Demand" (NCHRP 388) should be a helpful resource.

The template discusses regional freight systems. Information is needed on primary destinations of interstate freight originating in the state, and origins and destinations of interstate freight coming into the state. The amount of freight by commodity, amount of freight by value, and analysis of the importance of adequate highway access should be documented. Key freight corridors should be identified within regions, and information on characteristics of routes such as primary interstates or alternates available, should be documented.

There are many sources of information on interstate freight characteristics. Some provide data on total freight movement between states and regions. The most comprehensive source of information is the national commodity of flow survey (CFS), a good resource to assist in developing state and regional plans. It has a quick response freight manual (QRFM) in the second edition.

In addition to interstate freight, i.e. goods into, through and out of the state, intrastate freight must also be considered. Interstate freight is generally defined as trade and associated freight movement that originates and ends within the state. As stated in the template, *"It is important to understand the intrastate freight context in terms of major intrastate movements fully within the state and how the states facilities fit within the surrounding freight networks" (Keenan and Quinn 2011).*

Key statistics to identify interest rate priority corridors include the following:

- inbound/outbound destinations by weight/volume/value
- inbound/outbound origins
- vehicle miles traveled (VMT)/vehicle hours traveled VHT) (Keenan and Quinn 2008)

The template goes on to provide guidelines to determine freight characteristics and needs for a state's major industry groups, which forms the basis of demand and freight transportation and thus the needs within a state. It may be obtained by conducting interviews with key freight stakeholders in the state.

Industry information should include the following information:

- business sectors and locations
- manufacturing versus service industry, etc.
- requirements for each industry (Keenan and Quinn 2008)

Other things the template points out that should not be overlooked are terminals, warehousing/distribution centers, and support facilities. As defined by the template: *"Warehouses and distribution centers are primarily used for the receipt, temporary storage, possible modification/customization and distribution of the goods that are on a route from production sites to where they are consumed"* (Keenan and Quinn 2008).

There are many concerns in regard to intermodal facilities and their multimodal linkages, principal commodity flows, and infrastructure. The major concerns are as follows:

- safety
- security
- congestion management
- land use, and
- environmental considerations (Keenan and Quinn 2008)

The FHWA has a website that lists National Highway System Intermodal Connectors by state, at http://www.fhwa.dot.gov/planning/nhs/intermodalconnectors/index.html.

- The template presents several examples of programs and partnership agreements that should be considered with the private sector, federal agencies, other state agencies, MPOs, and local agencies. In regard to highways, it would be beneficial to forge partnerships with private sector freight carriers, shippers, and industry, as well as local governments, to work toward the goal of improving the freight transportation system including infrastructure, services, and business practice (Keenan and Quinn 2008).

The template discusses the desirability of developing performance objectives and measures. The following is quoted from the template:

- "Establishing freight transportation performance objectives relative to system performance will provide a focus of action for a state DOT with respect to freight transportation. Performance measures should be implemented so a state can be determined if they are achieving their objectives and to quantify and assess the effects of current and future initiatives on system performance objectives to help determine the impact of investment choices. Performance measures can also serve as indicators of economic health and traffic congestion" (Keenan and Quinn 2008).

2.2.7 Western Minnesota Freight Network

The FHWA has mentioned three locations in the United States as examples of good freight planning by a state. These are Minnesota (MN), New Jersey (NJ) and Southern California (SCA). Minnesota has included OSOW in their plan and part of the Minnesota report, including the OSOW part, will be summarized below (Wilbur Smith Associates 2009). The others may be studied on their respective websites by anyone interested.

2.2.7.1 The Minnesota Plan Background: Network Limitations

The highway networks in Western Minnesota are comprised of federal, state, county, city, or township roadways, designated differently according to their intended purpose, and governed differently regarding truck size and weight.

2.2.7.2 Federal Truck Size and Weight Limits

As pointed out in the Western Minnesota report (Wilbur Smith Associates 2009), at the federal level Congress and the Federal Highway Administration (FHWA) have defined a primary network from a policy standpoint for encouraging interstate commerce and heavy truck travel. The National Network of Highways includes (1) the Interstate Highway System and (2) other highways designated by the states in response to the Surface Transportation Assistance Act (STAA) of 1982. The National Network, sometimes referred to as the national truck network, consists of highways submitted to FHWA as being capable of safely handling larger commercial motor vehicles.

The criteria provided to states for guidance in designating National Network routes is found in Chapter 23 of the Code of Federal Regulations (CFR), Section 658.9:

1. The route is a geometrically typical component of the Federal-Aid Primary System, serving to link principal cities and densely developed portions of the States.
2. The route is a high-volume route utilized extensively by large vehicles for interstate commerce.
3. The route does not have any restrictions precluding use by conventional combination vehicles.
4. The route has adequate geometrics to support safe operations, considering sight distance, severity and length of grades, pavement width, horizontal curvature, shoulder width, bridge clearances and load limits, traffic volumes and vehicle mix, and intersection geometry.
5. The route consists of lanes designed to be a width of 12 feet or more or is otherwise consistent with highway safety.
6. The route does not have any unusual characteristics causing current or anticipated safety problems.
7. For those states where state law provides that STAA authorized vehicles may use all or most of the Federal-Aid Primary System, the National Network is no more restrictive than such law. The appendix contains a narrative summary of the National Network in those states. (Wilbur Smith Associates 2009)

As stated in the Minnesota (Wilbur Smith Associates 2009) there are 4904 miles of roads that are part of the national network. This is supplemented by Minnesota's Twin Trailer Network, which is a system of other trunk and local highways on which semi tractor-trailers can operate. Table 2.1 summarizes the federal size limits that apply to national network highways.

TABLE 2.1
National Network Commercial Vehicle Size Standards

Dimension	Regulatory Standard
Overall vehicle length	No federal length limit is imposed on most truck tractor-semitrailers operation on the National Network. Exception: On the National Network, combination vehicles (truck tractor plus semitrailer or trailer) designed and used specifically to carry automobiles or boats in specially designed racks may not exceed a maximum overall vehicle length of 65 feet, or 75 feet, depending on the type of connection between the tractor and trailer.
Trailer length	Federal law provides that no state may impose a length limitation of less than 48 feet (or longer if provided for by grandfather rights) on a semitrailer operating in any truck tractor-semitrailer combination on the National Network. (Note: A state may permit longer trailers to operate on its National Network highways.) Similarly, federal law provides that no state may impose a length limitation of less than 28 feet on a semitrailer or trailer operating in a truck tractor-semitrailer-trailer (twin-trailer) combination on the National Network.
Vehicle width	On the National Network, no state may impose a width limitation of more or less than 102 inches. Safety devices (e.g., mirrors, handholds) necessary for the safe and efficient operation of motor vehicles may not be included in the calculation of width.
Vehicle height	No federal vehicle height limit is imposed. State standards range from 13.6 feet to 14.6 feet.

(Source: Wilbur Smith Associates 2009)

It should be noted that while federal law imposes a gross vehicle weight limit on Interstate highways of 80,000 pounds, this does not apply to other parts of the NN. However, many states like Minnesota use the federal bridge formula to govern gross vehicle weight on non-Interstate highways (Wilbur Smith Associates 2009).

As stated in the MN report,

> Existing designated transportation networks were used as a basis to designate the new Minnesota truck network. The routes were selected because of their designation for existing truck use and for the specific purpose each serves in the overall transportation network. The networks include:

- Interstate/National Highway System/Strategic Highway Network
- National Network and Minnesota Twin Trailer Network
- Interregional Corridor (IRC) System
- 10-Ton Roadways
- Local Roadways (less than 10 tons)

- Minnesota Tiered Roadway Network (Designated State Trunk Network)”. (Wilbur Smith Associates 2009)

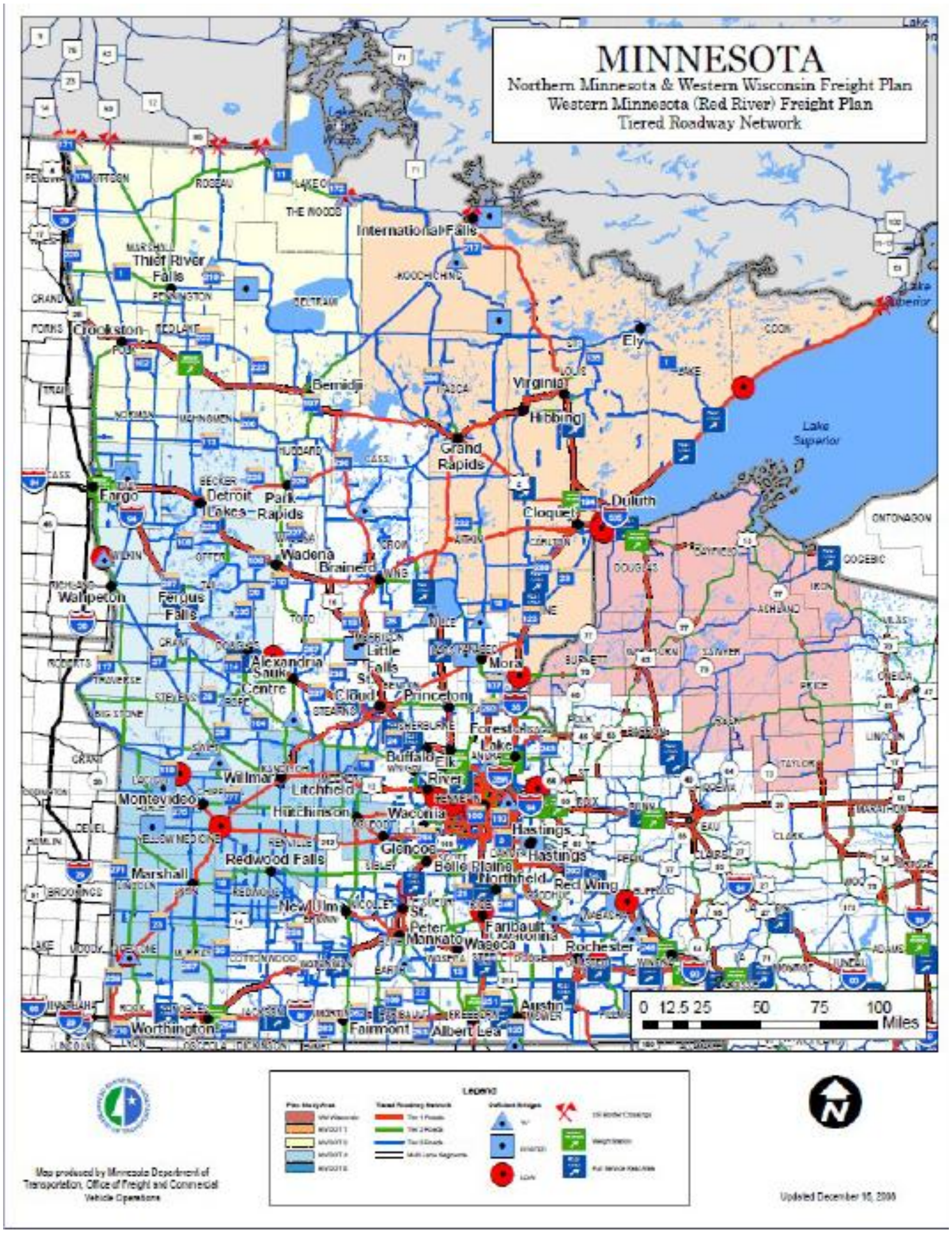
The roadway networks for the Western MN region are shown in Figure 2.4.

One of the things the consultant that conducted the Minnesota study was asked to study in detail was super-haul, truck corridors, i.e. he was asked to conduct an analysis documenting the best roads for heavy freight movements.

2.2.7.3 Minnesota Permitting of OSOW

Minnesota DOT (MnDOT) provides permitting oversized, overweight loads on trunk highways throughout the state. The report states the purpose of identifying super corridor routes was to acknowledge that certain routes are currently being used to move OSOW loads, and when designating improvements for these rounds, engineers should propose solutions that do not interfere with its super corridor function. Main parameters that must be addressed are weight, width, length and height.

The Wilbur Smith Associates (2009) report, points out that the two most restrictive parameters are weight and height, which are typically limited by bridges. As part of developing super corridor routes, they identified superload corridors that can accommodate a load with a 14 foot height limit, a 10 foot width limit, a 110 foot length limit and an 80,000 pound weight limit. They maintain that these corridors, in combination with portions of an Expanded Envelope Corridors, cover approximately 80% of the OSOW loads in Minnesota.



(Source: Wilbur Smith Associates 2009)

FIGURE 2.4
Tiered Roadway Network for Northern MN/WI and Western MN

The (Wilbur Smith Associates 2009) report stated that expanded envelope corridors are routes that can accommodate much larger loads than super corridors. Expanded envelope corridors are routes that can accommodate any permitted vehicle that is 16 feet high, 16 feet wide and 130 feet long with a weight of 235,000 pounds. Special considerations are sections of corridors having constraints or special considerations, such as requiring an escort, and may include roads with narrow shoulders or bridge restrictions which could require use of some local roads that may require special consideration. The report goes on to recommend that whenever possible, no roundabouts should be constructed along the identified expanded envelope routes, and counties/city should provide adequate notice of at least two weeks before a road closes along portions of the routes.

One of the things the consultants that conducted the Minnesota study (Wilbur Smith Associates 2009) was asked to study in detail were super haul truck corridors i.e. they were asked to conduct an analysis documenting the best roads for heavy freight movements. This is explained in more detail below.

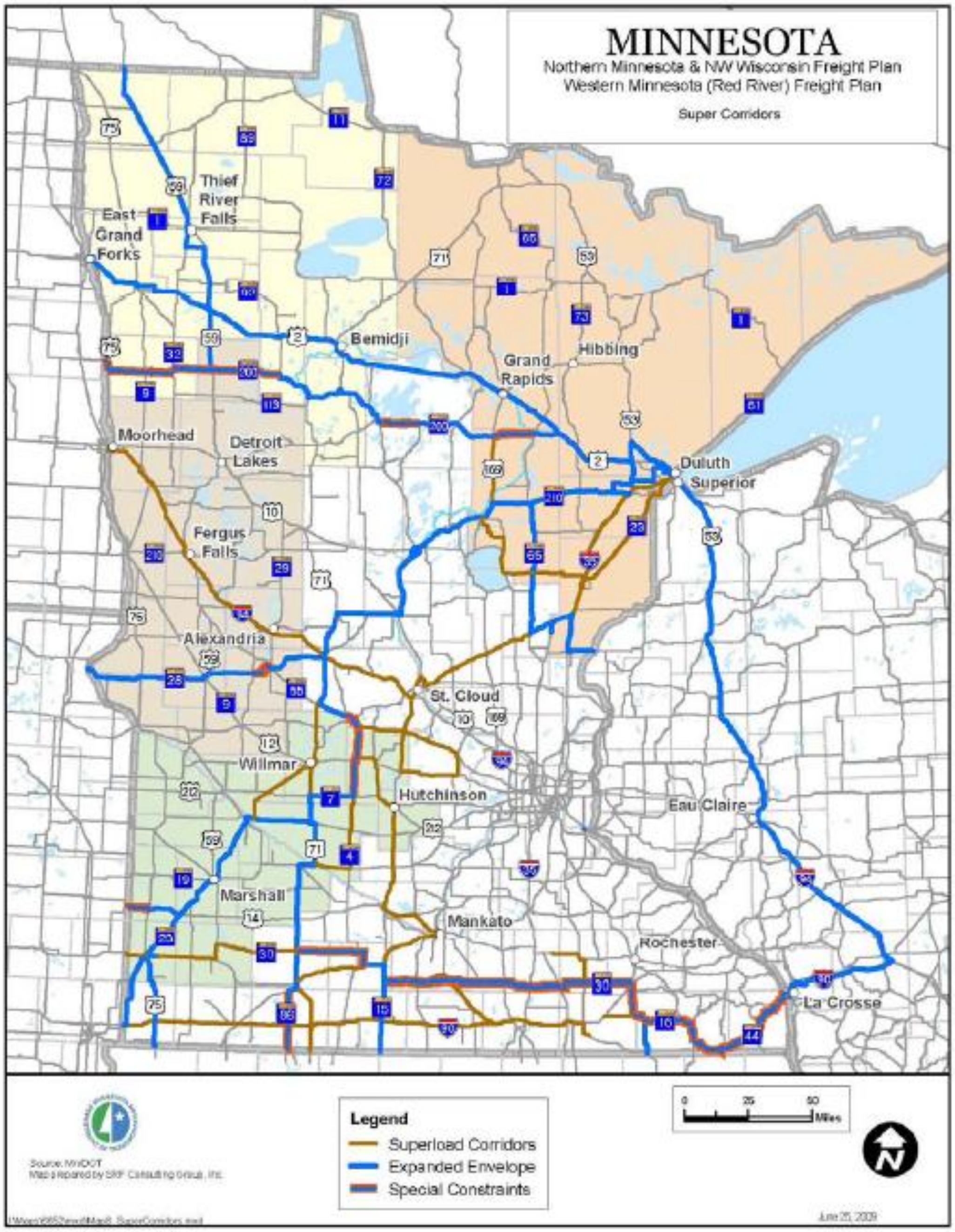
2.2.7.4 Minnesota Super Corridor Route Map

A super corridor route map was developed which is reflective of routes that can support a variety of oversize overweight loads. The Wilbur Smith Associates (2009) report goes on to recommend that when planning improvements and/or changes on any of these roads the district staff should preserve the ability to accommodate the OSOW load's characteristics and/or improve upon them when feasible. The Super Haul map is shown in Figure 2.5.

The Wilbur Smith Associates (2009) report made a number of recommendations for super haul truck permit corridors in two highway districts and Minnesota that the study had shown would be handling an increasing number of OSOW and needed a high – clearance route. These recommendations were in addition to designated commercial commodity corridors to improve regular truck operations and are presented below as an example of what any state may need to consider.

> The Smith report recommendations:
> As a starting point MnDOT may wish to publish web-based maps for specialized carriers who routinely transport over-size loads, to increase efficiency and improve route planning when moving super-haul loads. The route information mapped by this study can serve as a starting point for this purpose, as carriers could better plan movements by understanding "Super Corridors" based on routinely used routes for permitted loads. Freight shippers can also use the map to

effectively plan out a route that allows them to best transport over-size loads to a specified destination. The Superload Corridors and Expanded Envelope Corridors allow large freight shipments to be transported north-south and east-west to/from the Duluth-Superior ports, as well as throughout Minnesota. Another step in support of the "Super Haul Corridor" concept would be the creation of a scheduling procedure for road closures along the Super Corridor routes and create a policy to limit roundabouts on these corridors. For example, roundabouts could be prohibited on Superload or Expanded Envelope Corridors, and counties/cities could provide MnDOT Office of Freight at least two weeks' notice if a roadway along the corridor will be closed. This will help improve over-size freight movements along these routes by effectively rerouting these loads around a closure. In addition, when planning future improvements along Super Corridors, District staff should make every effort to try and preserve the ability to accommodate characteristics associated with each route and/or improve upon them, if feasible (Wilbur Smith Associates 2009).



(Source: Wilbur Smith Associates 2009)

FIGURE 2.5
Proposed Super-Haul Corridors in Minnesota

2.2.7.5 Regional Size and Weight Uniformity

As with other states, there is a lack of uniformity regarding truck size and weight at Minnesota's borders. The Wilbur Smith Associates (2009) report makes the following recommendations:

- Seek truck size and weight harmony on the routes with the most flexibility,
- Consider size and weight reciprocity agreements with neighboring states, and
- Join a regional permitting compact.

According to the Smith report (2009) no regional permit compact exists in the Midwestern United States. North Dakota participates in a regional compact developed by the Western Association of State Highway and Transportation Officials (WASHTO). Some limits established by WASHTO include: (Wilbur Smith Associates 2009)

Weight

- 600 pounds per inch of tire width.
- 21,500 pounds per axle.
- 43,000 pounds per tandem axle.
- 53,000 pounds per tridem (wheelbase more than 8 feet and less than 13 feet).
- 160,000 pounds gross weight

Length

- 110 feet overall. The agreement does not authorize permits for a semi-trailer longer than 53 feet to carry more than one item, or for any unladen semi-trailer longer than 53 feet used in a truck-tractor and semi-trailer combination.
- Movement of unladen vehicles must comply with the limitations of the jurisdiction being traveled through (i.e. loading jeep and/or booster onto trailer when semi-trailer exceeds 62 feet in Oregon).

Width: 14 feet

Height: 14 feet

The reader is referred to the Smith report for additional details (Wilbur Smith Associates 2009).

2.2.8 Kansas Statewide Truck Study

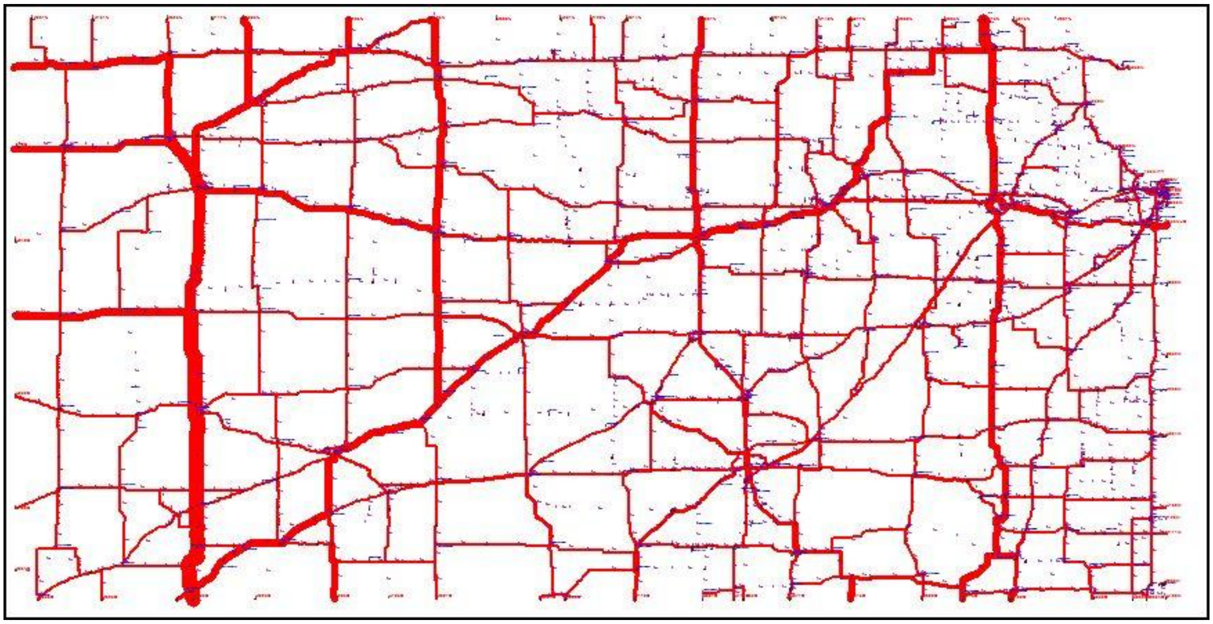
In the Kansas statewide truck study (Landman et al. 2010) a traffic assignment network was prepared that included from one to approximately eight zones per county and a station for each state highway connection at the state line. The speeds used in this network were computed by KDOT staff from the CANSYS database as a weighted average of the speeds of the control sections that made up the link. For example, if there were 10 miles from the county line to the edge of town with a speed limit of 65 mph, 0.5 mile on the edge of town with a 45 mph speed limit and 0.1 miles within the city limits of 20 mph. The weighted average speed would be something less than a link that contained only a control section with a speed limit of 65 mph. This network is being used to evaluate the effect of roundabouts on the movement of OSOW loads for this study and for determining corridors that are available for OSOW loads throughout the State System.

A number of modifications were made to the network for another, previous study to address weight, height and geometric restrictions that an OSOW load may encounter (Russell and Landman 2012). This study, Optimizing the Analysis of Routing Oversize/Overweight [OSOW] Loads to Provide Efficient Freight Corridors (Optimizing Routes Study) will be reviewed here, as it also relates to the need to accommodate OSOW on selected routes and intersections in Kansas, including roundabouts, and to illustrate the use of available planning software for OSOW routing purposes.

For the Optimizing Routes Study (Russell and Landman 2012), KDOT staff provided the load ratings for every bridge on the State System. These were appended to the network. If there were more than one bridge in a link, the lowest rating was appended into that link. Before the network was loaded with OSOW trips, an internal program was executed to adjust the speeds on the network. If it was decided to use 200,000-pound (200 K) loads as a limit, every link with an appended rating of less than 200 K was given and additional time of 100 minutes. The 100 minute adjustment was an arbitrary number to divert the load to other links but not prevent the load from reaching its destination, if all possible paths contained bridges with load ratings of less than 200 K. Since the 200 K loading was an arbitrary limit the researchers used for the study, a comparison was also made with 150,000-pound (150 K) loads. It was found that there was considerably more flexibility for loads under 150 K than for those between 150 and 200 K.

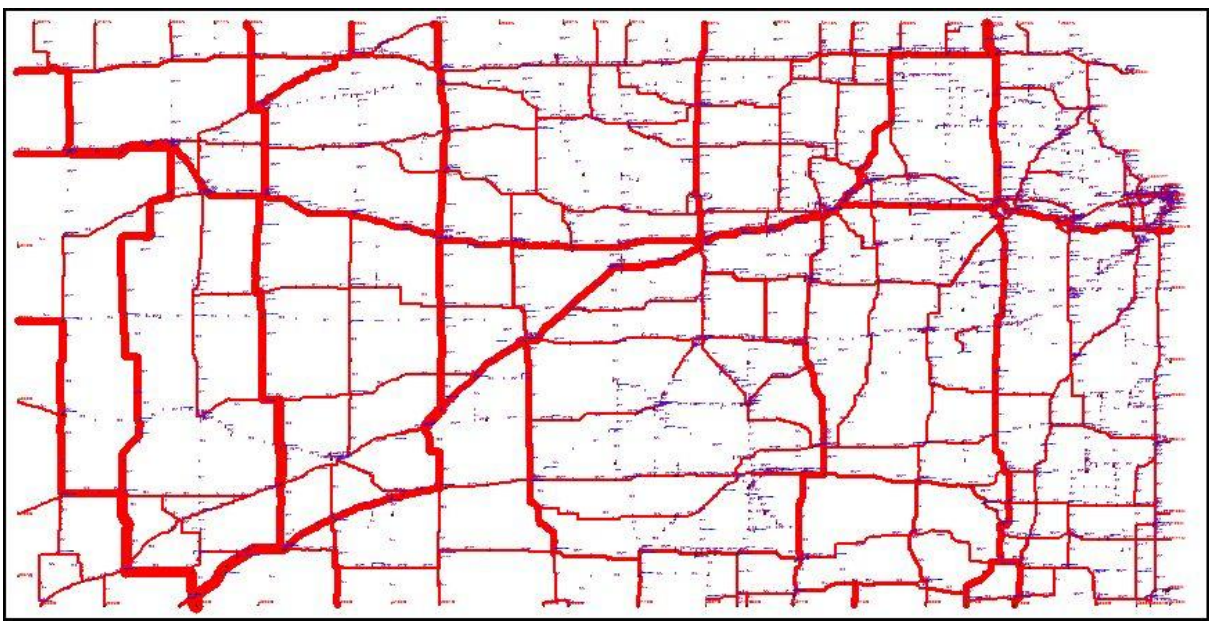
When providing information to the Kansas Trucking Connection (KTC) portal for them to prepare an individual permit, KDOT's Bridge Evaluation Squad checks every bridge of the proposed route and every axle of the individual truck proposed for carrying the load. The combination of axle weight and axle spacing is compared to the each bridge. Based on the bridge data provided by KDOT staff, and adapting QRSII software, analyses were performed using various assumed OSOW weights with the following results (Russell and Landman 2012).

The following two figures, Figure 2.6 and 2.7, show the 2010 loads that exceed 150,000 pounds assigned to the State Highway System. The paths in Figure 2.6 were determined by the weighted average speed limit with no other restrictions. The weighted average speed was provided by KDOT staff and was based on the rural speed limit, the reduced speed limit on the fringe of cities and the speed limit on the connecting links within cities. The attractiveness of a route was affected by the number of cities along the route. Figure 2.7 depicts the routes that were used for the same loads when links of the system were restricted by bridge ratings that were less than 150,000 pounds. There were many route changes across the state but the most significant one was the diversion away from US-83 by a restriction near Garden City.



(Source: Russell and Landman 2012)

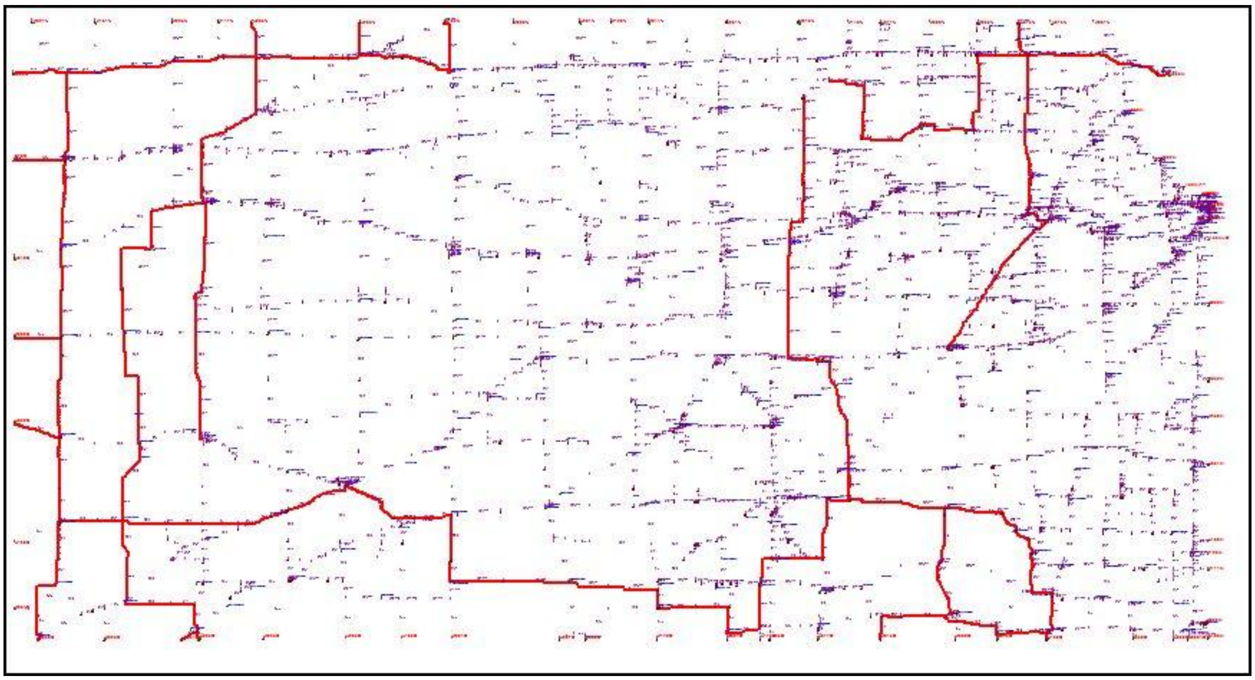
FIGURE 2.6
Loads Using Fastest Route, No Restrictions



(Source: Russell and Landman 2012)

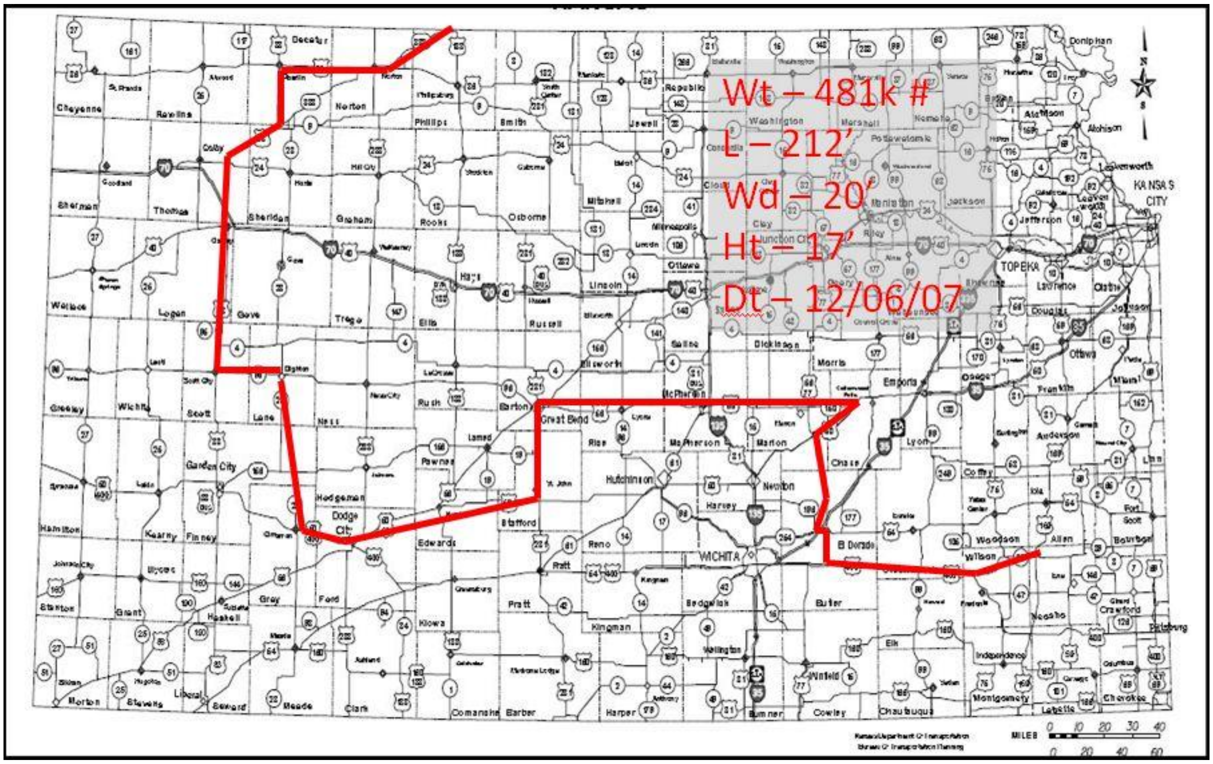
FIGURE 2.7
Loads Using Only Routes with Bridge Rating > 150,000 Pounds

Figure 2.8 shows the path of loads of 300,000 pounds or greater loaded on paths that allowed loads of that weight. Either, there were no bridges along these routes or they had a bridge rating equal to or greater than 300,000 pounds. These were extremely heavy loads and there were very few of them. Most (15 loads) came out of Oklahoma and traveled though the state, with the most coming into the state on US-83 and leaving into Colorado or Nebraska. The economic impact of those few loads that began or ended within Kansas is unknown



(Source: Russell and Landman 2012)

FIGURE 2.8
Loads Equal to or Greater than 300,000 Pounds



(Source: Russell and Landman 2012)

FIGURE 2.9
Permitted Route for Very Large Load

The Optimizing Routes Study also looked at some routes shown on some actual individual permits found in the KDOT data. One example will be presented here: (Russell and Landman 2012):

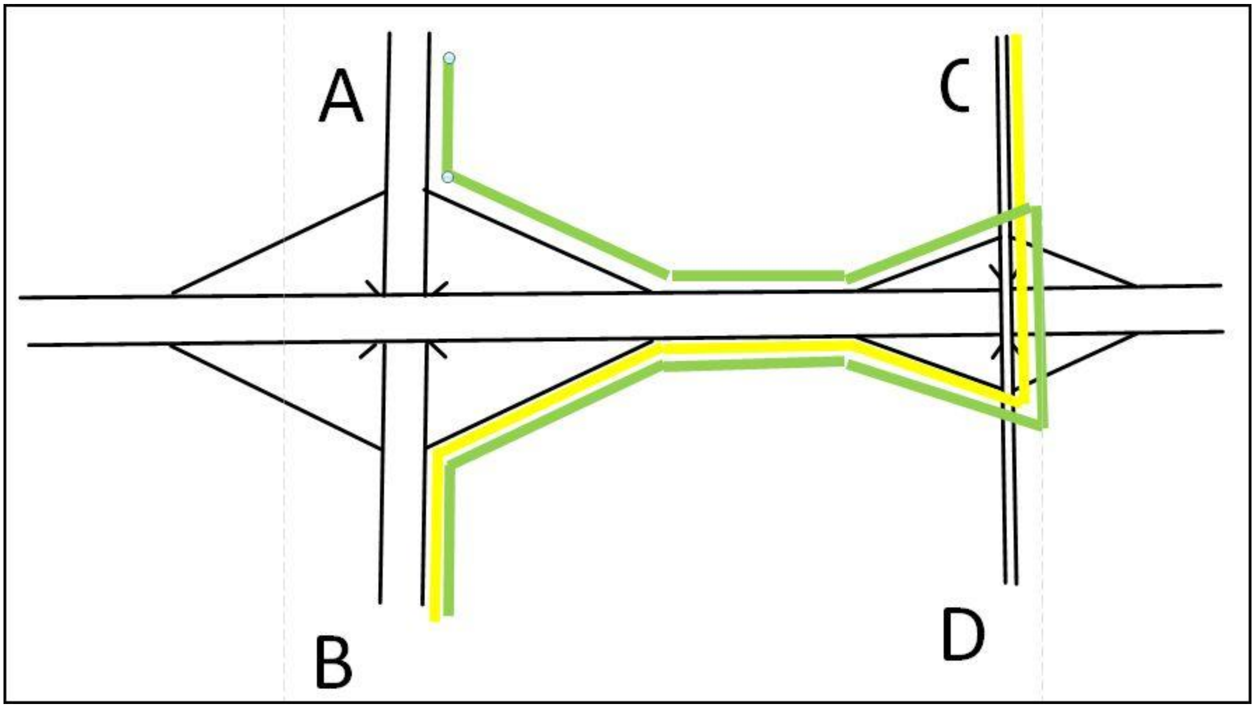
The load depicted in Figure 2.9 is a load, weighing 481,000 pounds, 212 feet in length, 20 feet wide and 17 feet high. Note the very circuitous route that must be taken to get from southeast Kansas to Nebraska.

In the Optimizing Routes study, an adjustment was also made for bridge height. Most of the height restrictions occur along freeway routes, such as the Interstate System and an occasional railroad grade crossing. One of the comments made by representatives of the trucking firms hauling OSOW loads in Kansas is that it is difficult to cross I-70 north and south. Examination of the bridge clearances showed that the Interstate System goes over the major non-Interstate routes and under the more local routes. In other words, the grades for the major non-Interstate routes were maintained and a pair of bridges was built to carry the Interstate traffic over the roads and the clearance provided was usually less than 15 feet. For more minor routes and local roads, the cross road is carried over the Interstate and clearance crossing the Interstate was no issue. When there are bridges at the intersection of two highways (i.e., interchanges), the vertical clearance was added to the intersection node and an additional code was included in indicate which road crossed over the other. (1 for cross road over and 2 for mainline over).

A representative of a trucking firm that hauls many of the wind generator components indicated that 15’6” is required and 15’10” is desirable. To determine the effect of a vertical clearance of less than 15.5 feet, an additional 100 minutes was added to the through movement of the cross traffic. Special codes were necessary to not penalize the through movement on the Interstate. Additionally, special coding was necessary to prevent left turns off the Interstate when the movement had to go under the separation which had less vertical clearance than needed.

A third adjustment was made for a restriction to prevent turns for one route to another. It was conceived at the beginning that this would be the principal part of the research since there was a perception that roundabouts were the biggest barrier to the movement of OSOW loads. This adjustment was the most difficult to analyze. First, whether a load can maneuver through a roundabout or make a corner turn depends a great deal of the ability of the driver. Second, many of the firms now have steerable rear axles to assist in turning, and third, there is so much variability in the geometrics of the locations. For example, the placement or lack of curbs; placement of signs, including overhead sign structures; location of guardrails; center islands, etc, all can affect the ability of OSOW trucks to negotiate intersections.

Based on initial assignments of truck trips to the State traffic assignment network, it was discovered that, over height loads could cross the Interstate by using a pair of interchanges. The following sketch (Figure 2.10) shows several alternatives that may allow over height trucks to cross the Interstate even though they cannot cross directly.



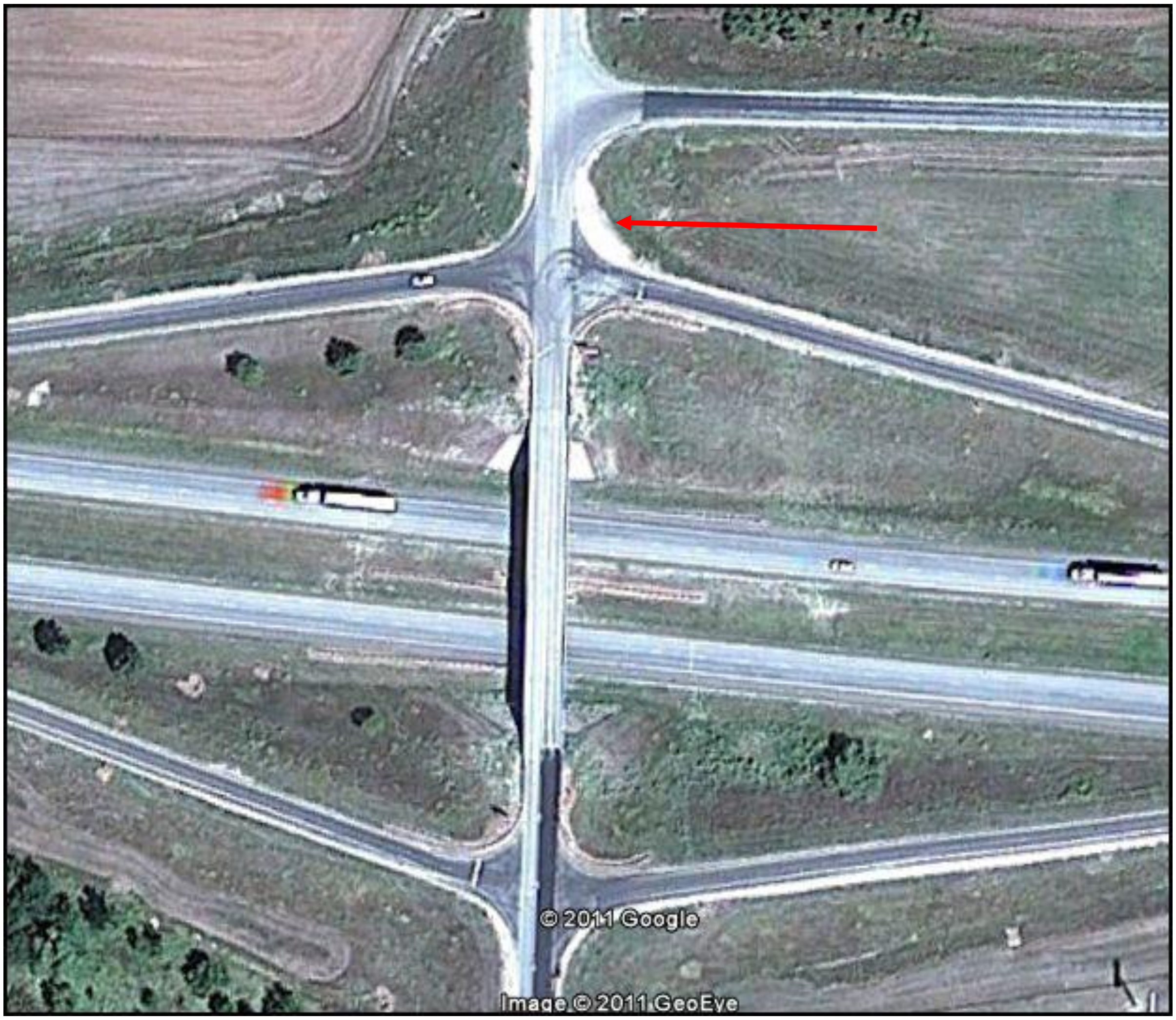
(Source: Russell and Landman 2012)

FIGURE 2.10
East-West Freeway Route with Two North and South Routes Crossing the Freeway

Figure 2.10 depicts an east-west freeway route with two north and south routes crossing the freeway. Route AB is a major route the crosses under the freeway and Route CD is a minor route that crosses over the freeway. This configuration is a typical result of BPR/FHWA design policy at the time the Interstate was built. It is assumed that the vertical clearance is less than an over height load that wants to move from south of the freeway to a destination north of the freeway.

One alternative is to follow the route depicted in yellow, with several assumptions: 1. the load can make the turns on and off of the freeway at the diamond interchanges, and 2. there are no restrictions on Route C to prevent the load from reaching its destination. The second alternative is to essentially make a U-turn at the interchanges on Route CD and return to exit onto Route A. Again, this assumes that the load can make the turns on and off of the freeway.

There are examples of modifications made to intersections in order to accommodate OSOW loads. One is the west-bound off ramp at the west junction of I-70 and K-14. The authors believe that the Google photo, Figure 2.11, shows fill that was added to the end of the off ramp so that trucks carrying wind generator blades could be delivered to a wind farm just north of the interchange. Details of the westbound off ramp are shown in Figure 2.12.



(Source: Google Search)

FIGURE 2.11
I-70 K-14 West Interchange

(Source: Google Search)

FIGURE 2.12
I-70 and Westbound Off-Ramp at West Junction of K-14

The authors of the study (Russell and Landman 2012) believe that additional study is desirable to determine how restrictions of all types could be eliminated or managed to allow access to all parts of the state and for more efficient movement across the state for OSOW loads. While the initial assumption of the authors of the study was that roundabouts were the primary restriction, others were identified. Further research should be pursued to reduce the restrictions of the various intersection types as well as develop criteria to assure that areas are not isolated by restrictive intersection design, including roundabouts.

Finally, the authors of this pooled fund study believe that one must consider the policy of the law enforcement agencies. Some movements can often be made if the OSOW loads are allowed to cross the center line to use the ramp in the opposite direction of normal travel or go around a roundabout in the opposite direction. The authors further believe that legislation may need to be considered to lessen or remove liability for crashes if recommended practices are undertaken. Finally, the authors believe that KDOT or other highway agencies may be able to temporarily modify elements of the highway system as necessary, if the transporting company or the company owning the load is willing to pay for the modification.

2.3 Design Considerations

2.3.1 Excerpts from the FHWA Roundabout Guide, Second Edition (NCHRP 672 2011)

2.3.1.1 Authors Comment

No attempt is being made in this report to reproduce the entire roundabouts: An Informational Guide – Second Edition, (NCHRP 672 TRB 2011) which will be referred to in this section as “the guide”. In material below some sections of the guide that deal directly with issues relevant to this study, and should enhance understanding and good practice, are presented. The interested reader should refer to the relevant sections directly from NCHRP 672, available online. Figure numbers – exhibits in the guide- and section numbers from the guide are retained as in the guide. References made to section numbers are as they appear in the guide.

The guide’s discussion of design vehicle below in the guide, section 3.5.4.1 is particularly relative to this study. The guide recommends involving all stakeholders, which the authors of this report interpret to include a study of area industry and their needs for specific OSOW shipments that need to be accommodated. It points out larger roundabouts sometimes need to be designed for larger trucks (WB-67) or to accommodate OSOW while attempting to maintain deflection for smaller vehicles. It states that space requirements may make it impossible and require OSOW to be rerouted. It points out that in rural areas, farm vehicles or equipment may be the design vehicle.

2.3.2 Section 3.5.4.1 from the Guide; Design Vehicle

This section is reproduced in part because it contains detailed material the authors of this report consider directly relevant to this study and key to later discussions (NCHRP 672 2011).

> 3.5.4.1 (3-27) Appropriate design vehicle consideration will depend on road classification, input from jurisdictions and/or road authorities, and the surrounding environment. On larger statewide facilities, such as interstate freeway ramps or intersections with state highway facilities, it may be necessary to accommodate large WB-67 trucks or even oversized vehicles (superloads). Smaller design vehicles may often be chosen at local street intersections. The size of the design vehicle often has a direct effect on the size of the inscribed circle diameter required. In general, larger roundabouts are often used to accommodate large vehicles while maintaining low speeds for passenger vehicles. In some cases, land constraints also dictate the need for approach re-alignment to

> adequately accommodate large semi-trailer combinations while achieving appropriate deflection for small vehicles. In particular, at locations where a WB-67 is anticipated to be the design vehicle, a larger inscribed circle diameter should be planned for when estimating the space requirements of the roundabout. Design vehicles alone should not dictate roundabout designs or specific dimensions. It is often beneficial to engage local stakeholders to ensure that the proper design is developed. In the case of larger vehicles, it may be appropriate to choose another route entirely, negating the need to design the roundabout to accommodate these vehicles. In rural locations, a farm vehicle may be the most appropriate design vehicle and require special attention.

2.3.3 The Guide Section 6.4.7 on Truck Aprons

Section 6.4.7 of The Guide provides more guidelines for determining a design vehicle. It would be wasteful to use OSOW as a design vehicle; however using a larger design vehicle such as WB – 67 particularly on state highways, would make it easier to accommodate OSOW. It stresses the tradeoff between accommodating large vehicles and maintaining deflection and low speeds for small vehicles so as not to compromise roundabout safety from higher speeds. It points out that space requirements might not be adequate for the larger design vehicles and a truck apron would be a necessity. Truck apron design will be discussed in a following section.

Truck aprons provided additional space for large vehicles while maintaining a smaller radius for small vehicles. The guide also points out that manufacturing areas may need to accommodate OSOW and makes a very good point that these special vehicles should be brought into the design process very early. The authors of this report believe also that potential shippers input should also be considered early in the design process.

The guide also points out that providing for OSOW type vehicles may be directional. For example, only one movement direction, such as straight through, may be all that is required for accommodating OSOW on a specific roundabout. This could result in a smaller roundabout. If it is a straight through movement, the authors of this report believe a through road, or stabilized central island should be considered. These options are covered in Chapter 5.

Where OSOW movements need to be accommodated, special modifications may need to be made to various roundabout features such as a wider truck apron and other features that are discussed, in examples shown, in Chapter 5 of this report. The off tracking of these vehicles needs be considered. The guide shows the results of off tracking in Exhibit 6 – 19. Other examples are shown by the authors of this report in chapter 5.

Exhibit 6-19
Vehicle Over-Tracking from Inadequate Entry and Exit Design

(a) Entry over-tracking (b) Exit over-tracking

(Source: NCHRP 672 2011)

FIGURE 2.13
Exhibit 6-19 from the Roundabout Guide, 2nd Ed.

The guide does point out that for locations with a high volume of traffic, special considerations may be given to the size of a roundabout which accommodates large vehicles, such as a WB 67, without requiring a large truck apron. The state of Kansas has a number of roundabouts at intersections of state highways that accommodate high truck volumes very well. The Guide uses one of these, Florence Kansas, as the example shown as Exhibit 6 – 20 of the guide. This is shown below in Figure 2.14.

Florence, Kansas

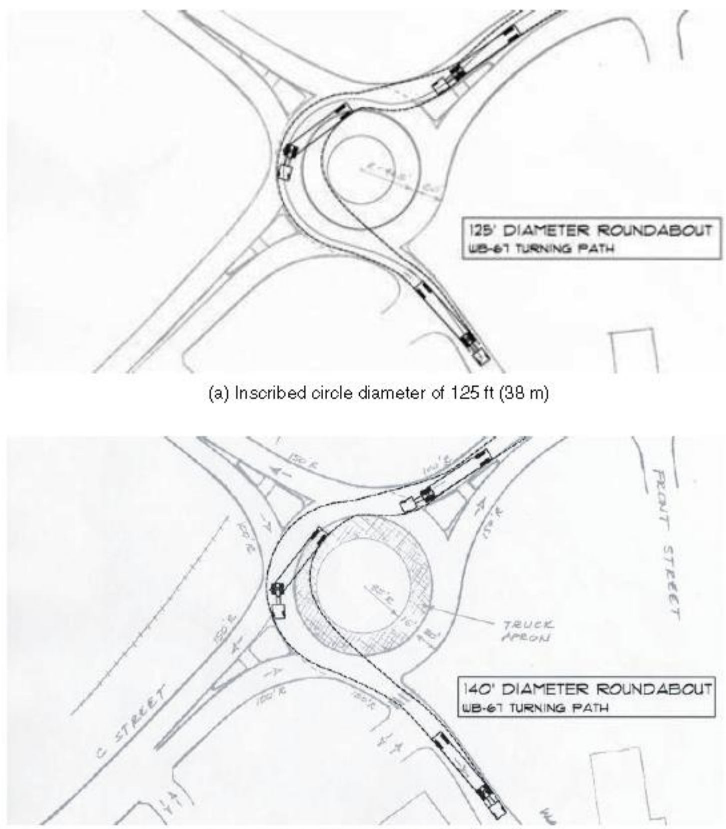
Exhibit 6-20
Roundabout with High Volume of Heavy Vehicles

(Source: NCHRP 672 2011)

FIGURE 2.14
Exhibit 6-20 from the Roundabout Guide, 2nd Ed.

Section 6.4.7.1 of The guide points out that the truck apron should be designed such they are traversable to trucks but discourage passenger vehicles from using them. It states they should generally be 3 to 15 foot wide and have a cross slope of 1% to 2% away from the center island. Further, to discourage use by passenger vehicles, the guide states that the outer edge should be raised approximately 2 to 3 inches above the travel way and be of a different material than the traveled way. **The authors of this report believe this guidance of "—2 to 3 inches above the traveled way—" may be one of the most important in the guide.** The authors have more discussion on this in Chapter 5. Another consideration is that the apron does not cause load shifting. It is further pointed out and illustrated in Exhibit, 6 – 21 in the guide, that wide truck aprons may be needed to accommodate a left turn movement. This exhibit is shown below as a Figure 2.15.

Exhibit 6-21
Comparison of Swept Paths for a WB-67 Design Vehicle at Various Diameters



(a) Inscribed circle diameter of 125 ft (38 m)

(b) Inscribed circle diameter of 140 ft (43 m)

(Source: NCHRP 672 2011)

FIGURE 2.15
Exhibit 6.21 from the Roundabout Guide, 2nd Ed.

The guide also points out that in a single lane roundabout the right turn movement of large vehicles may be the controlling movement. This may require increasing the corner radius or providing a wider entry area striped out for smaller vehicles, or an outside truck apron provided. The guide states that wide entry areas and external truck aprons are generally undesirable but may be necessary. The guide suggests alternatives such as: “include realigning the approaches to be more perpendicular, providing an offset-left alignment on the entry to improve the radius for truck turning, increasing the inscribed circle diameter, or providing a right-turn bypass”. The authors of this report will present some additional information and examples in chapter 5 of this report regarding these options for accommodating OSOW turning movements.

2.3.3.1 Kansas Roundabout Example

On their website, The Kansas Department of Transportation has the following for large trucks: (http://www.ksdot.org/roundabouts/trucks.asp) which is quoted below. The sentence emphasized by the authors of this report because they believe it is good general advice, if not policy and/or law.

> Roundabouts on the state highway system are generally designed to accommodate large vehicles. When large trucks with wide turning needs are expected to use the intersection, the roundabout will have a truck apron with a low curb around the center island. It might be colored red or some other color to set it off from the island. The apron allows truck drivers to roll the trailer’s rear wheels over the low curb as they drive through the roundabout. The low curb discourages other drivers from using the apron, helping to keep their speeds slow and consistent.
>
> If you’re a truck driver, stay close to the left side of the entry as you approach the roundabout. As you pass through the roundabout, your trailer tires may roll over the truck apron. As you exit, stay close to the left side of the exit.
>
> **At a multilane roundabout, you may need to occupy the entire circular roadway to make the turn.** [emphasis added by the authors of this report]. Signal your intention in advance and claim both lanes when you approach the roundabout *http://www.ksdot.org/roundabouts/trucks.asp* (last accessed 9-23-2012).

An analysis of states’ policies and laws is beyond the scope of this study; however, from material uncovered during the course of this study , it is believed that policy and laws in this regard are unclear in some states. More detailed discussion of these issues are contained in section 2.7 below.

2.3.4 The Guide on Multilane Design Vehicle Considerations (NCHRP 672 2011)

In regard to the multilane design vehicle considerations, section 6.5.7 of the guide points out that the percentage of trucks and lane utilization is an important consideration, for example, when initially deciding whether the design will allow the design vehicle to stay in its lane or to use two lanes. If the design vehicle needs to be accommodated within its own lane, a larger inscribed circle diameter and entry radius may be required. The other technique may be to have a wider outside lane to accommodate the truck and lane and a narrower inside lane assuming a truck on the inside lane will make use of a truck apron. The authors of this report will present additional material below, including a review of a study that was done to recommend designs for large vehicles staying in their lane, or not staying in their lane.

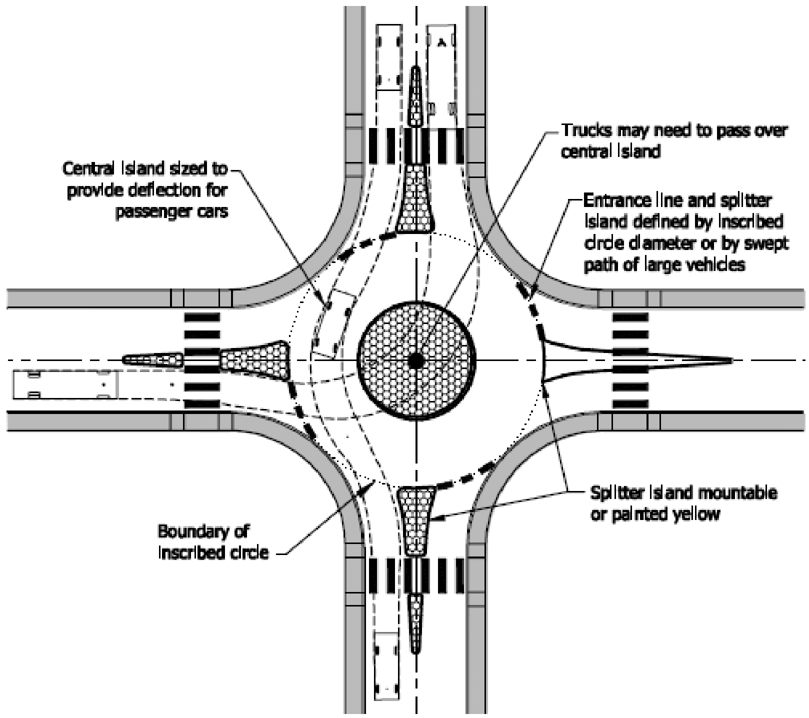
2.3.5 The Guide on Mini Roundabouts (NCHRP 672 2011)

In section 6.6, the guide discusses mini roundabouts. Upon first thought, it may be inconceivable to imagine OSOW using a mini roundabout. However, the authors believe that the "mini roundabout concept", where OSOW could go straight over the center island of a regular roundabout when necessary, should be considered. The authors believe this could be done with a traversable central island by having it all truck apron, all pavement or stabilized turf. This will be discussed further and examples will be presented in Chapter 5. To acquaint the reader with mini roundabouts, section 6.6 of the guide provides good information explaining the characteristics and general guidelines of mini roundabouts.

> **6.6 MINI-ROUNDABOUTS** A mini-roundabout is an intersection design form that can be used in place of stop control or signalization at physically constrained intersections to help improve safety and reduce delays. Typically characterized by a small diameter and traversable islands, mini-roundabouts are best suited to environments where speeds are already low and environmental constraints would preclude the use of a larger roundabout with a raised central island. Exhibit 6-38 presents the characteristics of a mini-roundabout. Mini-roundabouts operate in the same manner as larger roundabouts, with yield control on all entries and

counterclockwise circulation around a central island. Due to the small footprint, large vehicles are typically required to travel over the fully traversable central island, as shown in Exhibit 6-38 (Figure 2.16 below).

Exhibit 6-38
Basic Characteristics of a Mini-Roundabout



(Source: NCHRP 672 2011)

FIGURE 2.16
Exhibit 6-38 from the Guide

The following are general guidelines for the types of splitter islands under various site conditions:

Consider a raised island if:

– All design vehicles can navigate the roundabout without tracking over the splitter island area,

– Sufficient space is available to provide an island with a minimum area of 50 ft^2 (4.6 m^2), and/or

– Pedestrians are present at the intersection with regular frequency.

Consider a traversable island if:

– Some design vehicles must travel over the splitter island area and truck volumes are minor, and

– Sufficient space is available to provide an island with a minimum area of 50 ft^2 (4.6 m^2).

Consider a flush (painted) island if:

– Vehicles are expected to travel over the splitter island area with relative frequency to navigate the intersection,

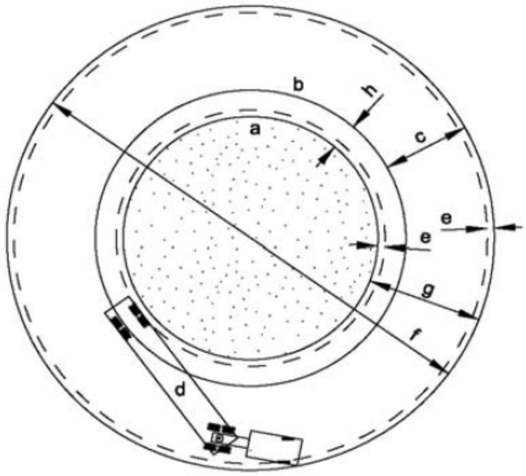
– An island with a minimum area of 50 ft^2 (4.6 m^2) cannot be achieved, and

– Intersection has slow vehicle speeds

2.4 Wisconsin Truck Apron Guidance

Truck apron widths are not provided in the typical design parameters published by WisDOT or Mn/DOT. However, these agencies recommend that AutoTurn software be used to determine the width of the apron, and WisDOT unofficially recommends a 12-foot minimum apron be used. In addition, WisDOT provides guidance on truck apron sizing. (Chapter 11-26-50.2 of WisDOT's *Facilities Development Manual* (FDM)) provides the relationship between typical circulatory turning widths for normal roundabouts to be used as guidance to size truck aprons on roundabouts.

Typical Circulatory Turning Widths for Normal Roundabouts



Legend

a Raised vertical curb face at central island.
b Low profile mountable curb at apron.
c Remaining circulatory roadway width is 1.0 - 1.2 times the maximum entry width.
d Design vehicle.
e 2 feet clearance from wheels based on desirable 'c' values.
f Inscribed circle diameter (ICD).
g Width between curbs (face to face).
h To obtain a circulatory roadway width for single lane roundabouts that allows a bus not to need the truck apron, determine 'g' for a truck then subtract 'g' for the bus to obtain the truck apron width (h).

Circulatory Turning Widths (g) for Normal Roundabouts (feet)				
Inscribed Circle Diameter (ft)	Design Vehicles (d)			
	CITY - BUS	Wb-50 Truck	Wb-65 Truck	Wb-67 Truck
100	20.0	32.5	N/A	N/A
110	19.0	30.0	N/A	N/A
120	18.5	27.5	39.0	42.0
130	18.0	26.0	36.0	38.0
140	17.5	24.5	33.5	35.5
150	17.0	23.5	31.5	33.0
160	17.0	23.0	30.0	31.5
170	16.5	22.0	28.5	30.0
180	16.5	21.5	27.5	28.5
190	16.0	21.0	26.5	27.5
200	16.0	20.5	25.5	26.5
210	16.0	20.0	24.5	26.0

The values provided in this figure are for general guidance. They are not intended to be strict standards that ensure good design.
(Source: WisDOT FDM)

FIGURE 2.17
Guidance from WisDOT on Turning Widths and Truck Apron Size

2.5 Survey of the Trucking Industry from a Joint WisDOT/MnDOT Study

The report describes the survey as follows: (Joint Roundabout Truck Study 2011)

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-six responses were received from managers, trainers, and safety officers at trucking industry companies representing approximately 225 truck drivers (Joint Roundabout Truck Study).

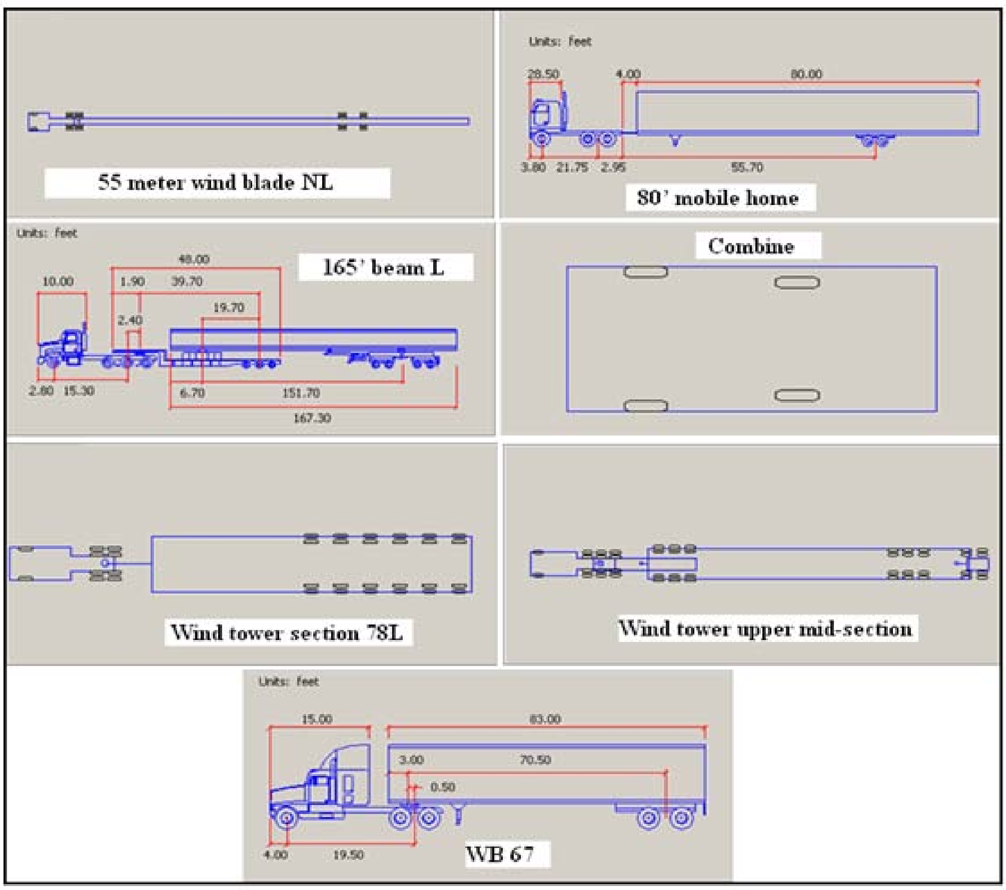
Only the responses believed relevant to this study will be presented here: (Joint Roundabout Truck Study 2011)

> 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 helpful 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.

2.6 An Overview of Wisconsin's Freight Network

The following section is based on conversations and emails with Peter Lynch and Pat Fleming in regard to their statewide truck routing network (Lynch and Fleming 2012):

A policy study was done with pooled funds from Minnesota and Wisconsin. They worked with Lynch to build a statewide freight network. This network was a general highway freight network and not specifically related to roundabouts. There were other studies done for Wisconsin DOT that did study the network to determine where OSOW are needed to be accommodated on roundabouts within the state. Every truck route has to be designed for a WB-67 vehicle (shown in Figure 2.18). On the OSOW portions of the freight network, six check vehicles as shown in Figure 2.18, must be accommodated.



(Source: Email from Patrick Fleming, Wisconsin DOT; from study by Mark Lenters)

FIGURE 2.18
OSOW Check Vehicles from the Wisconsin DOT Vehicle Library

2.6.1 Wisconsin Permits and Route Descriptions

Wisconsin requires the following five types of permits described below in 2.5.1.1 through 2.5.1.5 (Peter Lynch 2012):

2.6.1.1 Multiuse Permits

These are permits carriers can obtain per Vehicle Identification Number (VIN) and are within a defined envelope size and weight as prescribed in law for a given commodity type (mobile homes, construction equipment, mobile cranes, raw forest, etc.) and use is unlimited up to a year and carriers does not have to submit a route to the state before departure.

2.6.1.2 Transactional Permits (Tier 1)

These are single trip permits that are completely handled by the online permit routing system from Bentley (pretty much the same vehicle size as the multiuse permit vehicles).

2.6.1.3 Specific Permits – Single Trip (Tier 2)

These are the loads that often require bridge weight (wtg) and/or geometric (length, width, or wtg) reviews (bridge beams, wind industry, large tanks, cranes in some cases). Clearance is first determined in the routing system. This is what the OSOW FN was designated to handle. OSOW Routes (7 'check' vehicles) are referenced on this network and design guidance has been adopted in the state's Facilities Development Manual. (**Note that this is for all intersection and interchange designs and not just roundabouts.)**

2.6.1.4 Mega Load (Tier 3)

For the real big and heavy stuff. No specific routes are preserved for them beyond the OSOW freight network (OSOW FN). No check vehicle is referenced for this class of OSOW truck either. These vehicles have cutting edge technology and capabilities and in some cases that are not as constrained in turning movements as OSOW Tier 2. For example, they may have hydraulic lifts and multiple points of articulation.

2.6.1.5 Long Truck Routes

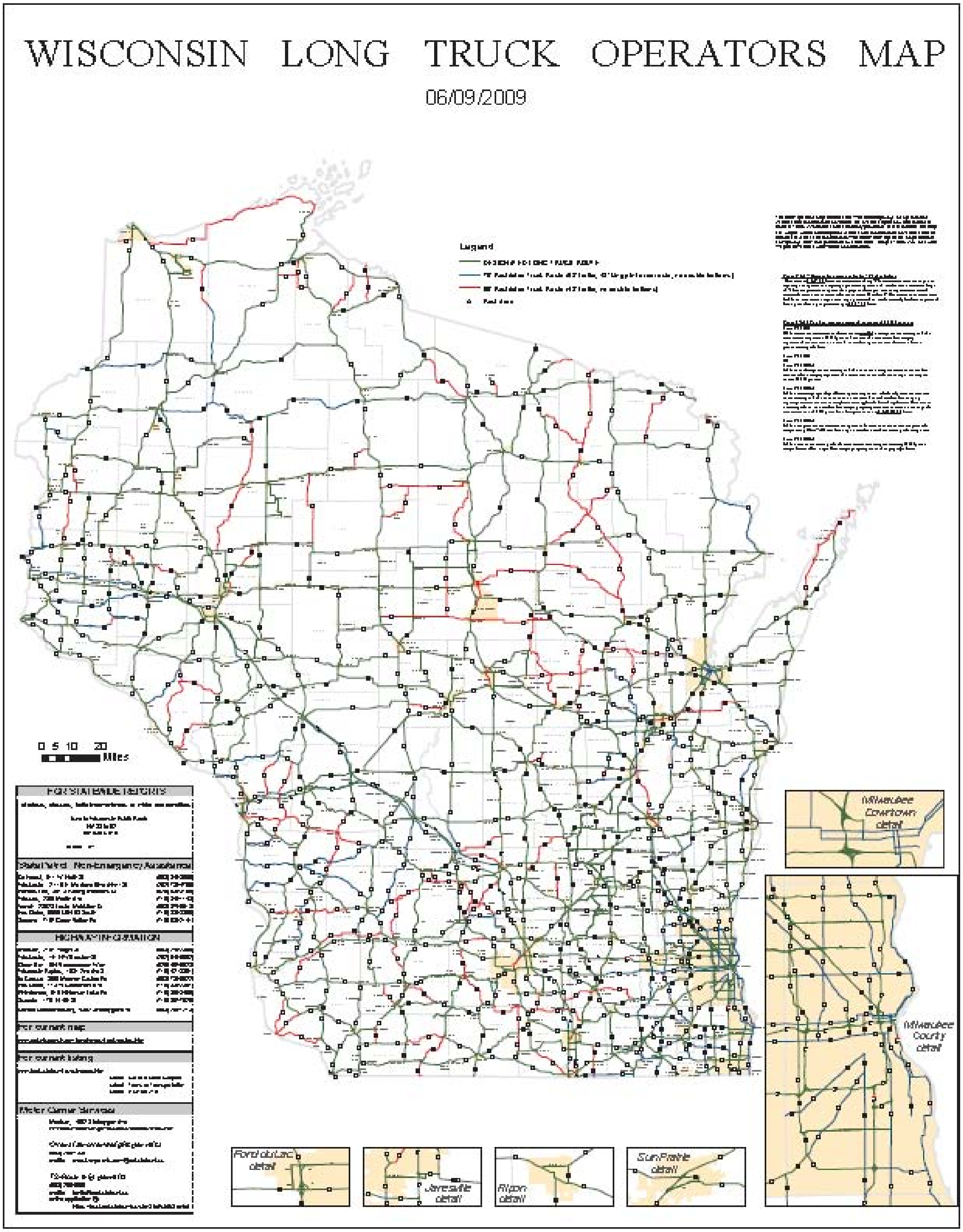
WB-67 Long, ‘check vehicle’ on the 7 OSOW vehicle reference sheet (Figure 2.18).

2.6.2 OSOW Freight Network Summary

A subset of roads in the WisDOT freight network including interstates on the state highway network that are ideal, or would be ideal with some improvements, for OSOW transport vehicles (Tier 1 and Tier 2) that have logical connections with neighboring states’ OSOW routes as well as between WisDOT’s five regions. It is comprised of optimal routes, historically used, with the goal to consolidate OSOW traffic of similar size and dimensions as opposed to letting them use the whole state system and multiple routes.

2.6.3 Wisconsin Long Truck Operators’ Map

These long trucks are 53 foot long, tractor trailers with sleeper cabs, or what some call your standard semi trucks. (sometimes called “18-wheelers”). This is a larger network than the OSOW freight network but not the whole state system. See figure 2.19 below. Due to some geometric limitations, some routes are limited to 65’ (Red) where others are 75’ (Blue) while others have no set limit (Green)



(Source: link on the state network, http://www.dot.wisconsin.gov/travel/maps/docs/truck-routes.pdf 2012)

FIGURE 2.19
Wisconsin Long Truck Operators Map

2.7 Legal Issues Overview

An in depth analysis of legal issues is beyond the scope of this study; however, the authors believe that they are very important in accommodating OSOW and should be studied. An overview of the gaps that need to be studied in routing large trucks and OSOW can be summarized in a proposed synthesis study sent to NCHRP by the TRB Roundabout Committee and supported by KDOT. (Russell 2012) Whether or not this synthesis is funded and a nationwide study conducted, the authors believe a study by each state would be beneficial. The synthesis is reproduced below in section 2.6.1.

2.7.1 Gaps in Legal Knowledge Relating to OSOW

The Influence of State and Local Laws on Roundabout Operations (Russell 2012)

There appears to be a significant degree of inconsistency between states and among municipalities concerning statutes, ordinances, policies and procedures that affect the operations of roundabouts. This can have a profound impact on the movement of freight, in particular, due to routine and widespread movement across political boundaries – the essence of interstate and intrastate commerce. As roundabouts are continuing to become more popular across the United States, it is likely that these inconsistencies will become more problematic in the absence of a national effort to understand the related dynamics and begin to craft a general consensus going forward.

One very specific example of these inconsistencies involves how vehicles are expected to behave on approach to and circulating through a roundabout. At some locations, a roundabout may have been designed to allow for larger vehicles (i.e,. multiple-unit trucks) to encroach into adjacent lanes, or to use a traversable apron (if provided), while at other locations those same vehicles may be expected to maintain lane discipline. The size of the roundabout is directly influenced by decisions regarding encroachment. However, size also influences the speed of vehicles through the roundabout, which in turn can negatively affect safety performance. Designers are challenged to strike a balance with respect to size, speed, safety and accommodation of various user characteristics.

Not explicitly understood by most designers is how the enforcement and education influences should be brought to bear on design decisions. Variation among states, and possibly within states at municipal levels, will foster uncertainty and confusion. The oversize/overweight (OSOW) community is at greater risk of being affected by these inconsistencies, since some degree of encroachment is usually necessary when negotiating an intersection. Legal problems can be encountered depending on permit policies and procedures, such as whether police or non-police escorts are usually required, and how traffic control is handled. Furthermore, in the case of an incident/crash, how the responding law enforcement agency assigns fault may or may not be another matter altogether. At least one state's trucking association (Oregon) has lobbied for a change in state statute so that encroachment by a truck is not considered a moving violation, which had been resulting in large monetary awards to plaintiffs in court cases when involving a crash where the truck had been "at fault" and liable for damages based on lane encroachment.

A synthesis of existing roundabout-related statutes, ordinances, policies and procedures is needed in order to begin to address inconsistency in practice. This would include examining how police assign fault in the case of a crash. Also valuable would be an assessment of driver manuals (including commercial driver literature) and state vehicle codes, and examples of commercial driver training/curriculum that speak to roundabout operation. A synthesis that captures these issues will provide valuable and timely information to road agencies working to address these issues, and will ultimately serve as a basis for future efforts toward national consistency.

2.7.2 Laws Regarding Large Truck and OSOW Routing Issues in Oregon

Section 2.7.2 was developed with information from Rich Crossler-Laird, Oregon DOT (ODOT). The state of Oregon, and truckers and their associations in Oregon, have been trying to work out differences between the State DOT and the trucking industry in regard to roundabouts. Opposition by various road user groups led to a state representative proposing a law with severe limitations on the use of roundabouts. The state of Oregon put a moratorium on building roundabouts until the issue could be worked out. As stated in the Bend Bulletin, October 25, 2011:

> ODOT halted its support of roundabouts on state highways this year after the freight industry raised concerns about the difficulties they pose for large trucks.
>
> "We're taking a time-out on roundabouts on state highways," said ODOT spokesman Peter Murphy, noting that ODOT won't reconsider its position until the completion of a two-year study examining the effects of roundabouts on freight movement.

The above information illustrates that freight routing is an important issue that must be dealt with and should be considered by all states. Oregon may be unique in that the trucking associations have strong influence on state highway design as discussed below.

Legislation was introduced in the Oregon Legislature around the year 2000 and passed into law ORS 366.212, which formed a Freight Mobility Advisory Committee, This legislation provides for an advisory committee for multimodal freight interaction and of which highway trucking is a key factor between the modes. Following this legislation, the ODOT Motor Carrier Group created a subcommittee - the Motor Carrier Transportation Advisory Committee (MCTAC) dealing specifically with truck/freight mobility.

Then in 2004 a bill was introduced and passed in the Oregon Legislature, referred to as the "reduction of vehicle – carrying capacity", ORS 366.215l. The final definition of "vehicle carrying capacity" followed the freight haulers definition of "the hole in the air" concept necessary for a truck to traverse a section of highway. ORS 366.215(2) states: "Except as provided in subsection (3) of this section, the commission may not permanently reduce the vehicle carrying capacity of an identified freight route when altering, relocating, changing or realigning a state highway unless safety or access considerations require the reduction." For the Oregon DOT to change the "the hole in the air" concept on an identified freight route, they have to have the freight communities agreement, or lacking that, apply to the Oregon Transportation Commission for a decision. An identified freight route is now interpreted as not only the Oregon Highway Plan Freight Route designation, but in addition, any nationally recognized truck route, e.g. NHS routes.

The ODOT Highway Mobility Operations Manual provides more detailed information. One paragraph from this manual illustrates the policy of dealing with the trucking industry:

> NOTIFICATIONS AND APPROPRIATE FOLLOW-UP (ODOT Highway Mobility Operations Manual, p 10) "The Motor Carrier Transportation Division (MCTD) is the primary contact to engage industry stakeholders for all of ODOT's maintenance, construction, and engineering activities. The MCTD Freight Mobility Coordinator needs to be involved in all communications with industry stakeholders. When contacting local industry stakeholders, the MCTD Freight Mobility Coordinator must be included. Local contact with the trucking industry absent MCTD involvement does not satisfy the project communication requirements addressed in this manual. The audience of potentially impacted freight stakeholders extends well beyond known familiar local users of the road system. MCTD tracks and relays information to all industry stakeholders within the United States and Canada that are authorized to use Oregon's state highway system. (ODOT Highway Mobility Operations Manual)

In regard to the impasse regarding roundabouts on the Oregon state highways, a freight/roundabouts steering committee was formed to work out whatever differences there are in building roundabouts on Oregon state highways. They are working toward a process of inclusion of freight representatives that has their input into creating roundabout design criteria in general and then having review capacity at specific locations when the design occurs (Crossler-Laird 2012).

2.7.2.1 Issues and Concerns from MCTAC

The issues and concerns of MCTAC are repeated below: (Crossler-Laird 2012)

Issue 1 - Mix of Cars, Trucks, Bikes, Buses, and Pedestrians

- Each Location has a Different User Mix
- Each User has a Different Optimum Design
- Each Location has Different Site Constraints
- Designs must Balance Safety and Operations
- Unbalanced Designs Create Problems: Crashes, Injuries, Delays, Environmental Impact

Issue 2 - Truck accommodations/Oversize Loads – (separate from design for trucks)

- Oversize loads – gates?
- Gates in center of roundabouts
- Single lane roundabouts not a problem
- Multi-lane roundabouts cannot accommodate large loads

Issue 3 - Design for Trucks (design vehicles)

- Need wider lanes
- Aprons lower, curb height less
- Under-clearance for lowboy
- Truck stability

- Wider entry and exit, less effective deflection
- Longer cabs on WB67's
- Fitting a commercial vehicle around a roundabout while staying in only one lane.
- Design appropriate truck aprons; designing wider entry and exit points to the roundabout; signage.
- Roundabouts are not truck friendly, create numerous of problems for drivers.
- No.1 priority should be a design solution that truck from interacting with cars – avoid the possibility to start with
- Dual lane roundabouts: when they make them large enough to accommodate trucks, they don't seem to handle traffic as well.

Issue 4 - Legal issues-

- Trucks using both lanes
- Legal issues when there is a crash
- Overtracking (taking more than your lane as you travel the roundabout). Law enforcement not determining fault for accidents in Roundabouts, and trucks losing in court.
- Signage about not driving beside trucks while they maneuver through the roundabout; Bill, law change, or education, how is the average person going to know the law has changed?

Issue 5 - Safety of Roundabouts & Issue 6 -Operations

- Pedestrian crossings may lead to more rear-end collisions
- Don't roundabouts slow the overall movement of freight because they force you to go slower?

Issue 7 - Design Software - AutoTurn

- Does it accurately reflect truck turning?

Issue 8 - Other Design Issues

- Good, clear visibility across and around the roundabout.
- Signage and lighting (pole & arm height) limits as you approach.
- Vertical poles (which may be in the way of a trailer sweep).
- Pedestrian islands.
- Having landscaping within or the height of any landscaping/artwork within the center
- Lack of sign standards for roundabouts, drivers don't know what's legal.
- Lack of design standards for roundabouts

Issue 9 – Planning and Policy

- Long-term planning. Industry wants to be involved to help indentify future possible conflicts with freight mobility.
- Roundabouts may be ok in residential situations
- Roundabouts should not be put on interstate ramp terminals
- Roundabouts should not be put on state highways
- Roundabout should not be put on primary highways

2.7.2.2 Update on Lane law for Trucks

A law was passed in the Oregon legislative session in 2011. It is now illegal to pass or drive beside a truck in a multi-lane roundabout in Oregon. Oregon is still determining appropriate signs and implementation (Crossler-Laird 2012).

Chapter 3: States' Surveys

3.1 General Comments on States' Surveys

At the first meeting of the project advisory committee, a decision was made to send out a general survey to all 50 states. The consensus was that the survey should not stress roundabouts, but be more general. It was felt that if the survey clearly emphasized roundabouts only those few states with roundabouts on state highways would respond. After the first survey, which would determine which states had roundabout concerns, a second survey specifically directed towards roundabouts would be designed and executed. In hindsight, it may have been more expedient and/or efficient to go directly into a survey specifically directed at roundabouts. However, the first survey did provide some beneficial information, and taken together, both had valuable information for OSOW concerns.

A summary of the two surveys sent to states will be presented in this report in this chapter. Key points will be included in the summary. Where more detailed responses from respondents may be relevant, they are referred to in the text, and more complete response(s) are contained in the appendices.

3.2 Survey 1 Summary

The first OSOW survey was conducted through AASHTO member contacts from 50 U.S. states. The objective of the first survey was to find the permits that are required for different states to transport OSOW loads and to determine the bottlenecks for OSOW on their roads. A Zoomerang survey was used to electronically distribute the survey to the AASHTO officials. A total of 41 U.S States responded. Of those who responded, 37 states responded to the complete survey as prepared and four states responded to a follow-up survey to get their contact information for survey two, planned for a later stage. Among the 37 states that responded to the survey, most were online responses, while a few of the states sent paper responses. Results from the survey are summarized below.

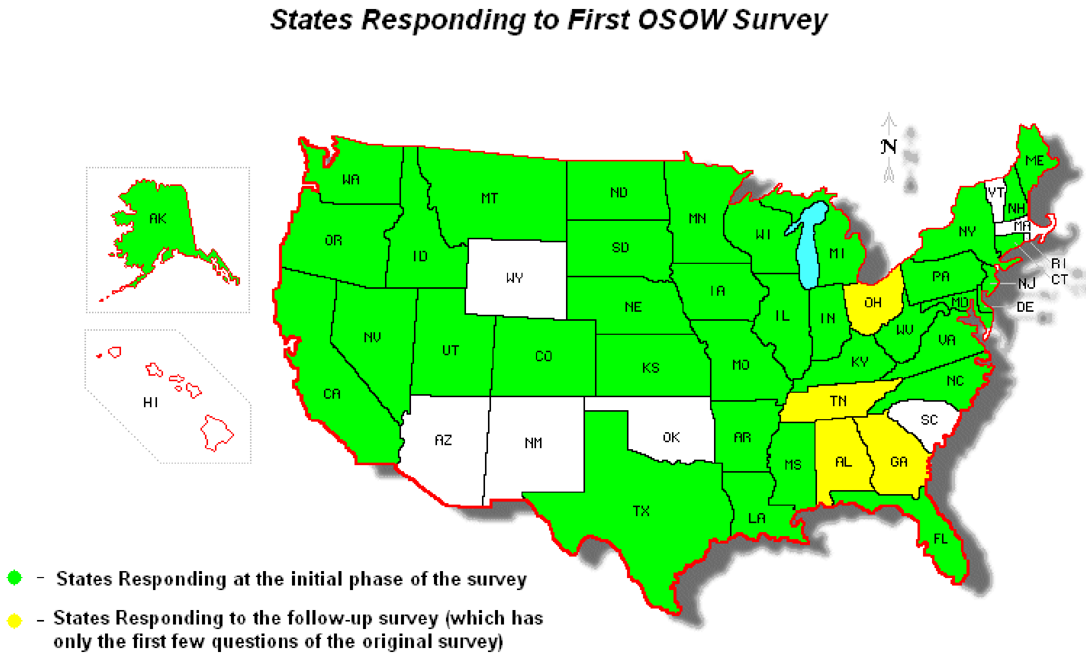


FIGURE 3.1
States that Responded to the First Survey

Thirty-one (31) responding states had a category for different types of oversize/overweight (OSOW) loads. Five States did not have a category. Those five states were Alaska, Arkansas, California, Maine, and South Dakota. Appendix B shows how the category for different types of OSOW loads is defined.

Thirty-five (35) U.S responding states require a permit for transporters to use the state's highway system for loads that exceed state statutes. Among them, 31 states require a permit by state statute. North Dakota and North Carolina require a permit by both state statute and DOT Policy. Maryland requires a permit by state statute, and also regulations are contained in the Code of Maryland Regulations. **Montana and Nebraska don't require a permit.**

In regard to questions about fee schedules, industry served, and typical load types, number, of OSOW vehicles on highways in an average year, and peak periods for a certain type or types of load, the respondents' answers were so diversified as to defy a concise readable summary. Thus, the reader interested in this information is directed to the appropriate appendices as set forth in the following paragraph.

Fee schedule for permits is summarized in Appendix C. Data on industries served and typical load type for each Industry is summarized in Appendix D. Data on types and number of OSOW vehicles on highway in an average year is summarized in Appendix E. Peak period for a certain type or types of load is summarized in Appendix F.

In regard to typical route restrictions, height, length, and weight of OSOW are the most common. Data on states' height, length, and weight restrictions is summarized in Appendix G.

Table 3.1 shows the design vehicle states typically use on their state highway system. Twenty-eight (28) of the responding states did not have a typical design vehicle to aid in determining needed roadway geometry for OSOW vehicles. Eight (8) states have a typical design vehicle to aid in determining needed roadway geometry for OSOW vehicles.

Twenty-five (25) US states responded that they have designated truck routes. Twelve (12) states did not have designated truck routes. These were Arkansas, Colorado, Connecticut, Florida, Iowa, Kansas, Montana, Nebraska, Utah, Washington, and West Virginia. Nine (9) states had designated OSOW routes. They were California, Colorado, Maryland, Missouri, Nebraska, North Dakota, Ohio, Texas, and Wisconsin.

Thirty-five (35) states had route restrictions. Montana and Alaska don't have route restrictions. Appendix H shows states having route restrictions and their details. Additional information on truck and OSOW routes and restrictions is provided in Appendix I.

In regard to the question, "Are any of these restrictions a problem for your OSOW loads?" the following is a summary of the reported restrictions with the percentage of respondents reporting the restriction as a known problem to OSOW. Table 3.2 gives restrictions by states.

- bridges 100%
- overhead structures 89.2 %
- signs and signals 70.3%
- intersections 64.9 %
- interchanges 56.8%
- rail-highway grade crossings 48.6%
- utilities 48.6%

- overhead wires 40.5%
- **roundabouts 35.1%**
- curbs 18.9%
- raised channelization 18.9%

TABLE 3.1
Design Vehicle for State Highway System

State	Design Vehicle for State Highway System
Illinois	Tractor Trailer Combo
Washington	WB-67
Indiana	HS20-44, HL-93, Toll Road Loadings, Michigan Train Trucks
NJ	WB50
NH	HS-20
Minnesota	WB62
Florida	HL93
Mississippi	WB67
Montana	WB-67
Alaska	WB-67
Nebraska	W-40
Maine	WB-67
Connecticut	HS20
South Dakota	HS25
Louisiana	WB 67
Kansas	WB-67
Texas	WB-65
Missouri	Semi truck and trailer combination
Pennsylvania	Penn DOT modifies the LRFD HL-93 vehicle to a PHL-93 vehicle.
Virginia	WB-67
North Dakota	WB-67
California	AASHTO P-13 Truck
Arkansas	WB-67
Wisconsin	WB-65

TABLE 3.2
Number of States Having Various Restrictions as a Problem for OSOW Loads

Restriction	**Restriction a problem for OSOW loads**
Bridges	37 States
Overhead structures	33 States
Signs and signals	26 States
Intersection	24 States
Interchanges	21 States
Rail- highway grade crossings	18 States
Utilities	18 States
Overhead wires	15 States
Roundabouts	13 States
Curbs	7 States
Raised channelization	7 States

Some of those solutions to the restrictions provided by the respondents are as follows:

- Utilize automated routing and analysis system to ensure none of the items listed above in Table 3.2 are involved in a specific route of an oversize vehicle.
- Reroute the vehicle/load to a highway that will accommodate the load.
- Raise overhead wires on rare occasions for “jumper” bridges.
- Stop use of fixed cross arms for signal lights or have them able to swing out for high loads.
- Require all utility lines to be higher.
- Design roundabouts to accommodate longer loads, at least on major routes.
- Design intersections with more shoulder for better turning radius.

The states that replied that roundabouts are a known problem were Connecticut, Idaho, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, New York, Nevada, Ohio, Virginia, and Wisconsin.

Additional suggested solutions can be found in Appendix J.

The respondents were asked to provide a score of 1, 2, or 3 for each restriction, where 1=common, 2=occasional, and 3=uncommon. The results are summarized in the following figures.

Figure 3.2 summarizes results of this question. States having 'roundabout' as a restriction are further categorized in Figure 3.3 in the form of a map.

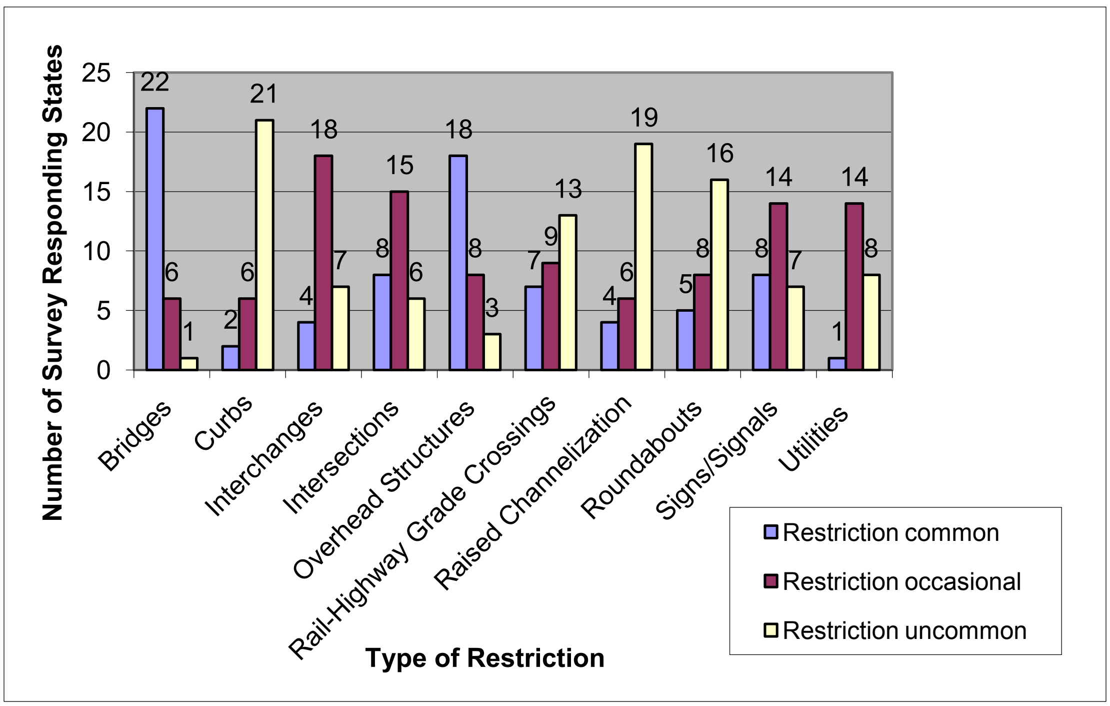


FIGURE 3.2
Common, Occasional, and Uncommon Categorization of a Restriction for OSOW Loads

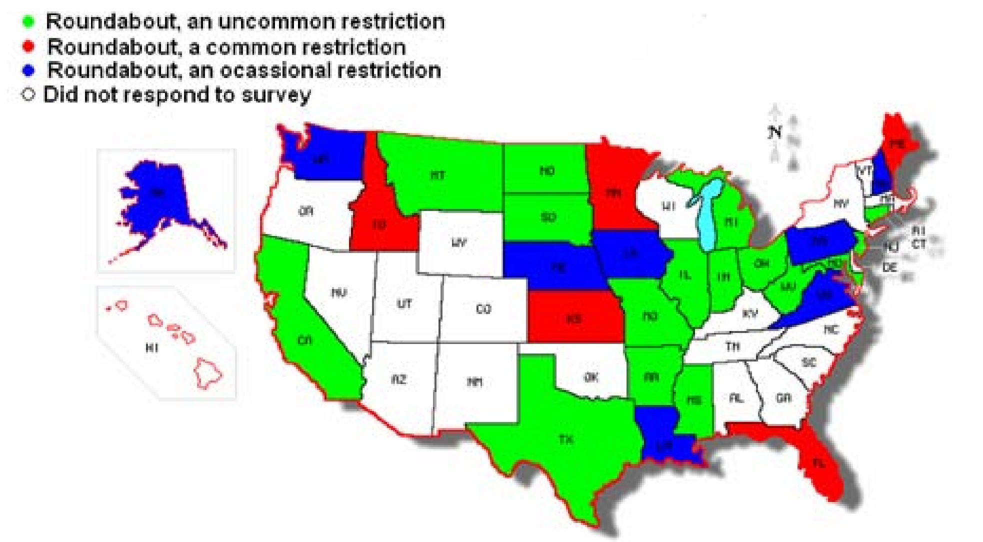


FIGURE 3.3
States Having 'Roundabout' as a Restriction

Figure 3.4 below illustrates different restrictions respondents reported as little or no problem to OSOW loads.

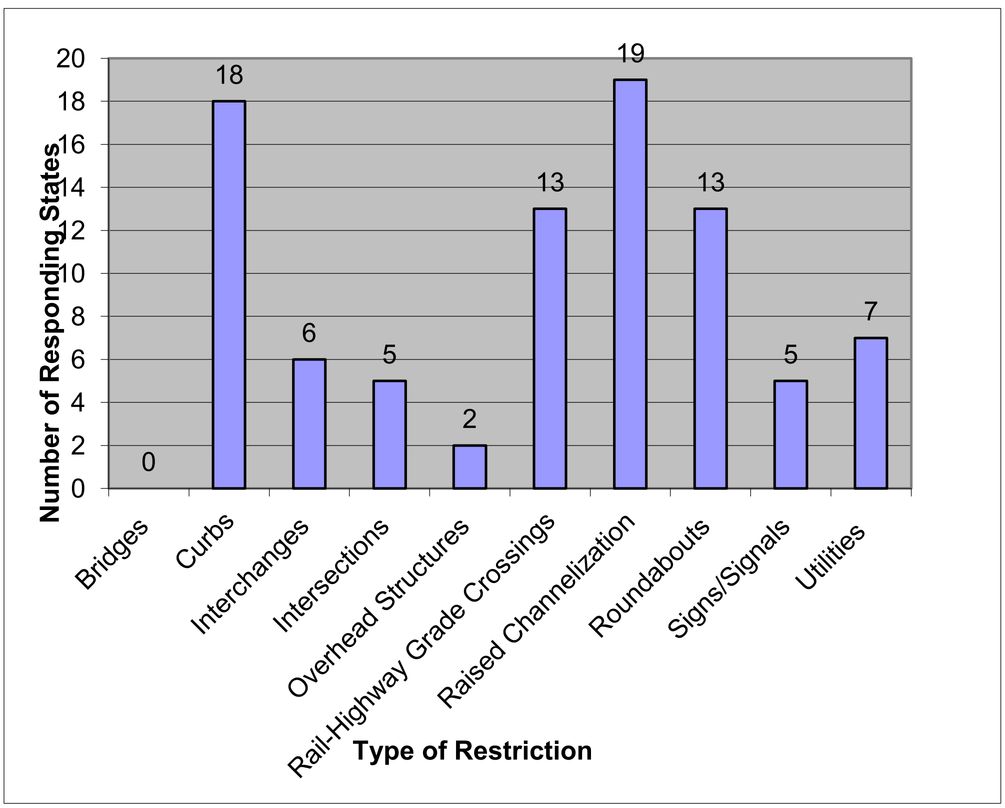


FIGURE 3.4
Restrictions of Little or No Problem to OSOW Loads

For certain extreme loads, a route survey could be done by a company to physically measure clearances and pre-clear an anticipated route before the move. Thirty-one (31) states require route surveys. Among these states, 26 have the transporter be responsible for their route surveys.

Fourteen (14) responding states use routing software and 23 states don't use routing software. Table 3.3 shows routing software used by different states.

TABLE 3.3
Routing Software Used

State	Routing Software Used
Illinois	ArcGIS Navteq
New Jersey	Bentley SUPERLOAD
Minnesota	Bentley Systems Inc product called RouteBuilder
West Virginia	WVPASS/Superload from Bentley Systems
Florida	In-house developed software
Nebraska	Superload for bridge analysis and Bentley Systems for routing
Michigan	MiPARS (Bentley product)
Texas	TxPROS (Texas Permitting and Routing Optimization System) by ProMiles Software Development Corporation.
Pennsylvania	AMPL and XPRESS-MP
Virginia	ARS Routing Software
California	AutoTurn's latest version
Arkansas	ARPARS developed by Bentley Systems
Missouri	Bentley
Wisconsin	Developed by C.W. Bielfuss, purchased by current vendor Bentley Systems, Inc.

3.3 Survey 2 Summary

A second survey was conducted with all 50 U.S. states to obtain further detailed information regarding their roundabouts and their issues with OSOW loads. KSU's AXIO online survey was used to distribute the prepared survey to AASHTO officials from all 50 states. A

100% survey response rate was obtained in this second survey from several follow-up e-mails and telephone calls to State officials. Results from the second survey are summarized below.

The section/department of the person who responded to the survey for each state is summarized in Appendix K.

Alabama, Hawaii, Idaho, North Dakota, Oklahoma, Texas, Utah, and West Virginia reported they do not have modern roundabouts (built after 1990) on state highways. The remaining states have modern roundabouts on state highways. Figure 3.5 shows a U.S. map with states having modern roundabouts.

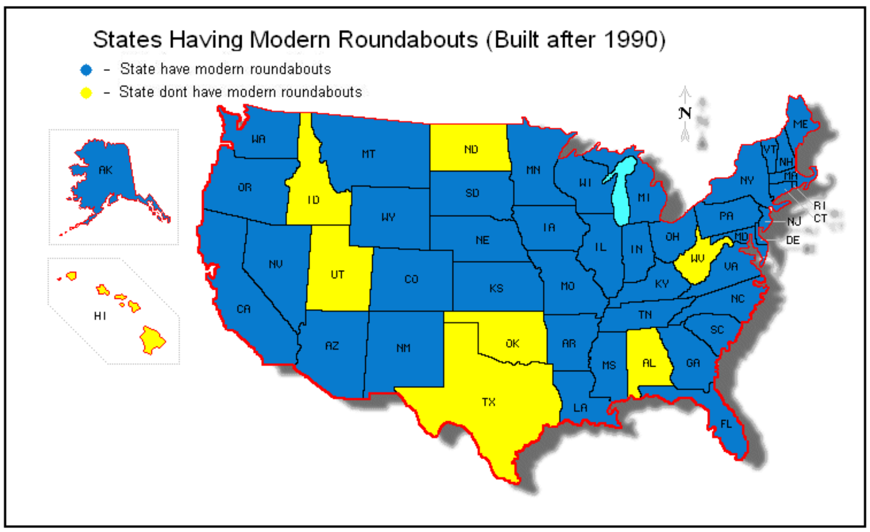


FIGURE 3.5
States Having Modern Roundabouts

Among all the states with modern roundabouts, Delaware, Nebraska, and Rhode Island reported they do not have modern roundabouts on non-state roadways. Figure 3.6 shows states having and not having modern roundabouts on non-state roadways.

Figure 3.7 shows the approximate number of modern roundabouts as reported by respondents. If a state is missing, it is because the respondent for that state left it blank.

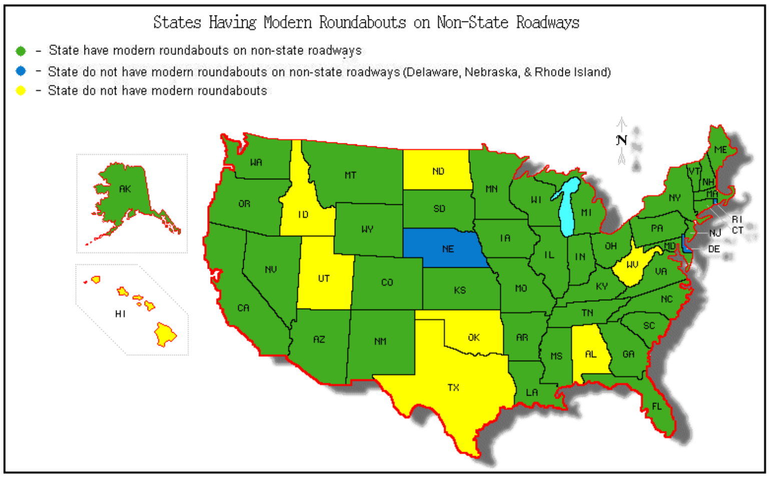


FIGURE 3.6
States Having Modern Roundabouts on Non-State Roadways

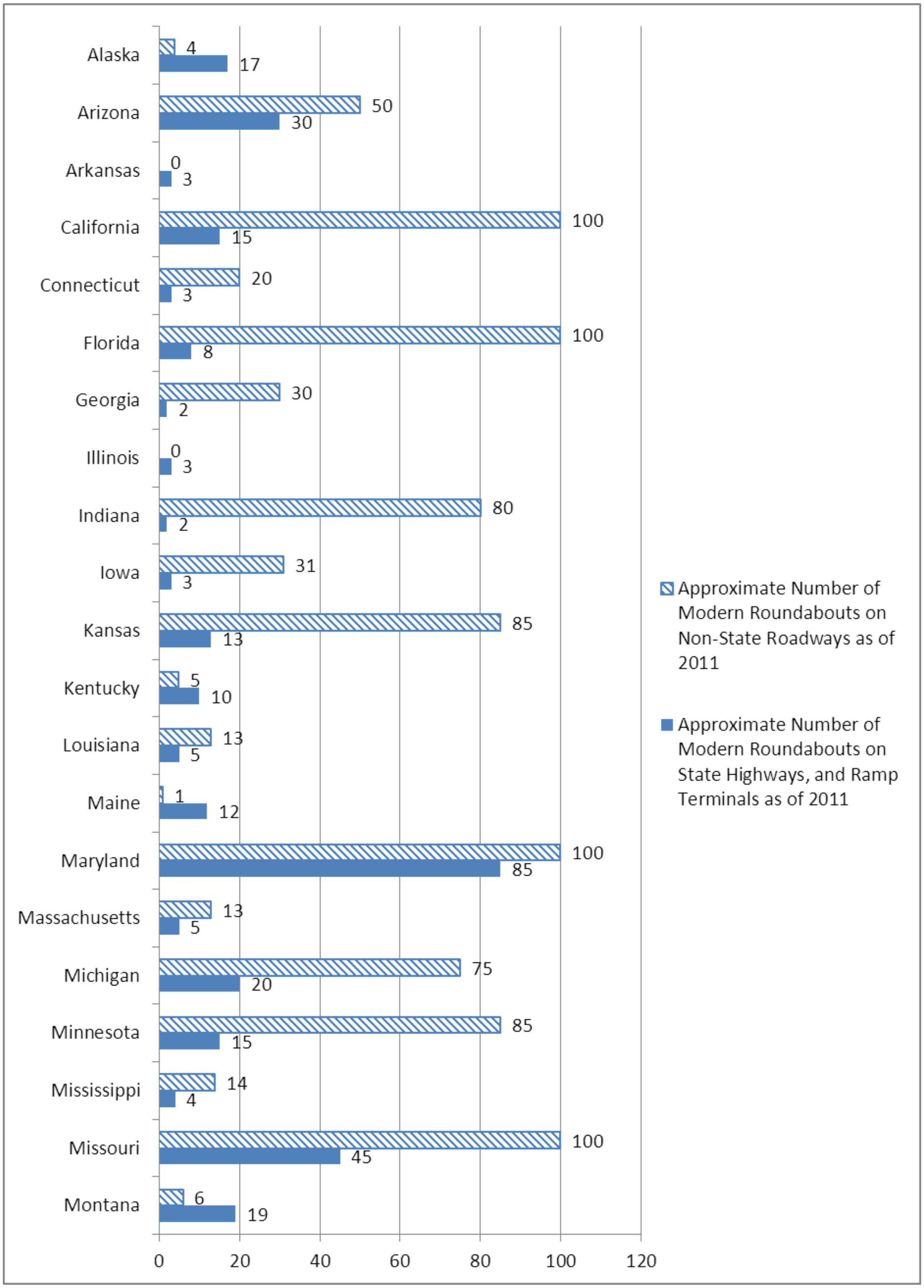


FIGURE 3.7
Approximate Number of Roundabouts (as Reported by Respondents)

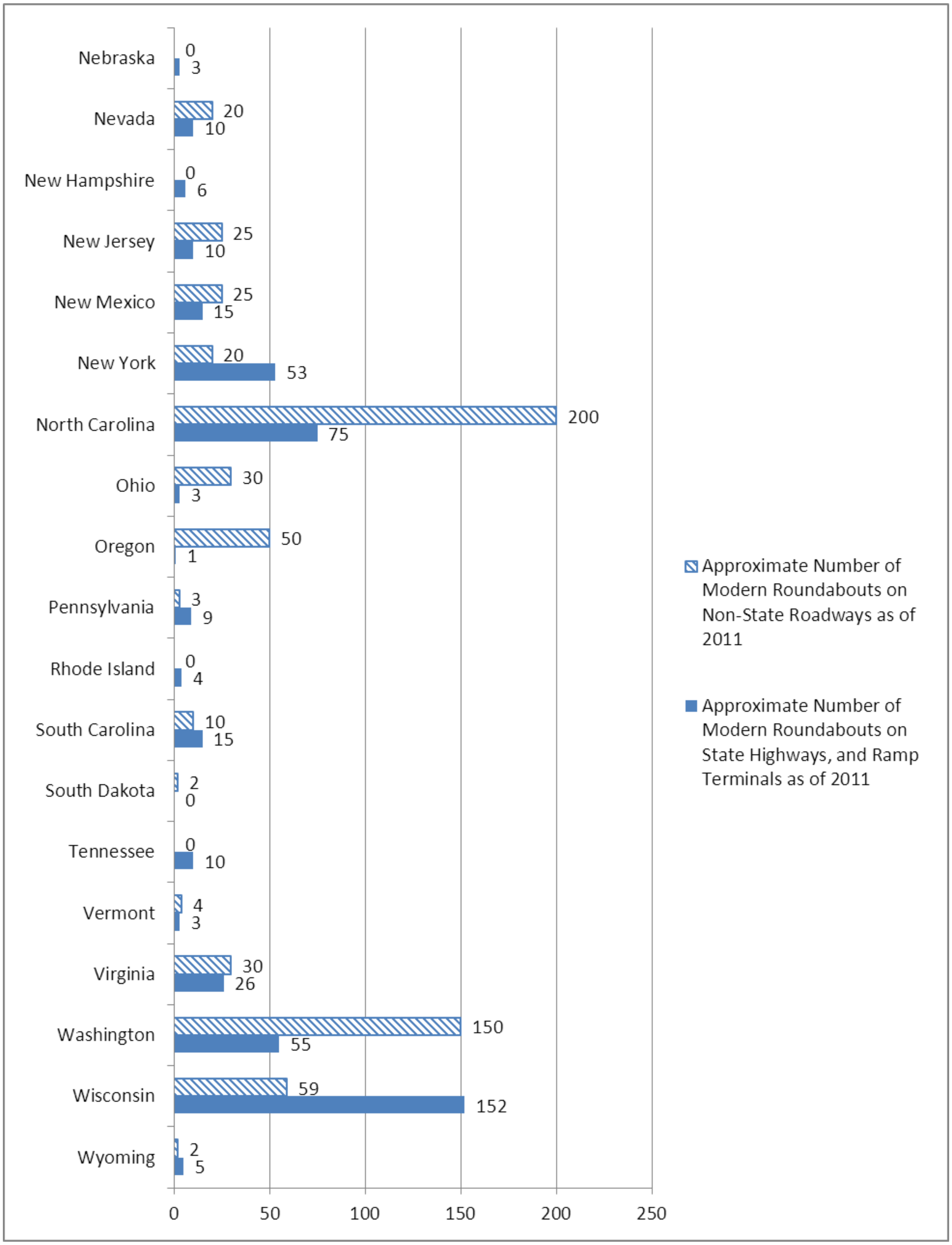


FIGURE 3.7, Continued
Approximate Number of Roundabouts (as Reported by Respondents)

One of the most informative questions on survey two was question seven in which respondents were asked, "Have you heard any concerns about your roundabouts from companies that deal with a vehicle requiring a permit?" Answers that are considered to have information pertinent to this study are paraphrased below. Detailed responses can be found in Appendix L.

- concerns about long trailers 53 feet plus and long doubles 100 to 120 feet
- trucks required to stay in lanes in the approaches
- lowboy vehicle built to limit vertical roundabout clearance to approximately 3 inches
- no identifying of a roadway network based on geometric design limitations
- concern about roundabouts with tight radii; also clearance issues
- concern about long loads
- issues with oversize loads riding up on the exterior curb; also clearance issues
- issue with high-profile curb on truck apron
- concerned with too narrow lanes
- concerned that drivers do not understand truck aprons are designed to be mounted by tractor-trailer combination vehicles,
- concerns over placement of signs and landscaping
- concern over misinformation used by lobbyists to reduce or eliminate roundabouts on state highways
- concerns about objects in the center island
- concern about two or more roundabouts built too close together – 300 feet suggested
- concern about farming and emergency response vehicles

It is interesting to note the most mentioned concern was clearance, which was mentioned six times – seven if the concern over the outside curb was mentioned. Long loads were mentioned three times. The state of Washington indicated they have all sorts of problems with standard intersections but have not had any issues with roundabouts. (Note: only 13 states did and only five said it was common.) This is similar to our list of general problems with OSOW that ranked roundabouts 9th out of 11 “bottlenecks” or problem locations for roundabouts - see Figures 3.2 and 3.3.

However, Washington responded with the following suggestions, which are consistent with more detailed suggestions and examples presented in Chapter 5:

- mountable curbing
- removable signage
- addressing stationary landscape features
- larger radius design to accommodate longer vehicles

All are good suggestions that would tend to help mitigate states’ concerns listed above.

A related question was number 17 which asked, “Have you heard of any problems with OSOW vehicles navigating roundabouts?” In hindsight, this question probably should have been combined with the question asking for state DOT concerns. However, some insight comes from this question. The problems with roundabouts are paraphrased below:

- Alaska’s response was very informative. They said meetings with the trucking company led to better design templates and larger diameter roundabouts overall; also, in heavy trucking areas, full use of individual lanes and truck aprons. However, they reported that OSOW will have to straddle multilane approaches and multilanes in some restricted areas.
- One state reported the permits department gave a permit, which allowed OSOW through a roundabout not designed to accommodate a large vehicle. (It was noted in another part of the survey that there should probably be better coordination between the permitting departments and the design sections in some states.) However, other states reported they did coordinate with the OSOW permit section to determine vehicle sizes and geometric requirements on permitted routes.
- Getting long loads through roundabouts has required removal of permanent signing, special law enforcement action, and rerouting of some trucks.
- One state reported placement of a roundabout eliminated its use for OSOW transport.

- Oregon reported some specific problems which are worth quoting; however, they will be quoted in a paragraph below along with some other material received from Oregon.
- Washington reported a unique problem with a roundabout in a local agency where the local agencies did not want OSOW going through the location because they did not want their landscaping injured. A meeting was held and education presented on the types of OSOW loads that could use the roundabout without destroying the landscaping.

It seems to the researchers of this project that the above comments lead to an understanding that communication is very important. This includes internal communication between permitting sections and designers, between designers and trucking associations, and also between states and local agencies where local agency roundabouts might be important on some OSOW permitted routes.

Another question with potential good relevance to this study is question 11: “Do you know of any studies in your state or have any information or insight into how OSOW vehicles or trucking associations accept roundabouts in your state?” The Wisconsin/Minnesota study, which we are following up on, appeared to be the most relevant. Although not specifically directed toward OSOW. It is notable also that they have developed a freight network. It seems to the researchers of this study that perhaps all states could benefit from a freight network in general and perhaps some study of developing OSOW routes.

The state of Oregon has some issues which could possibly affect the growth of roundabouts not only in Oregon but elsewhere should trucking associations and their lobbyists prevail in their opposition to roundabouts. Although the bill introduced in the state legislature has been tabled, legislation was introduced to severely restrict or eliminate roundabouts on state highways in Oregon. It was reported on the survey that Oregon officials are currently meeting with OTA (Oregon Trucking Association) representatives and so far have had a positive response once people understand the specifics of roundabouts, (and I assume their benefits).

The following is a quote from the nine responses to question 17 – problems with OSOW vehicles navigating roundabouts:

> We have had some minor issues with the only roundabout on the state highway system in Oregon. It is a multi-lane, so not as much problem for OSOW. From what we have heard, most of the problems have been on roundabouts on city streets. We hear they are too small. Unfortunately, due to misunderstanding about roundabouts, the freight haulers assume we would build the small diameter roundabouts on state highways. We are working to educate the industry. There have been a few cases where heavy haulers had to rebuild curbs/landscaping, but much of the complaints seem to be more anecdotal in nature with few specifics. One state Senator has "heard" from constituents that large horse trailer suspensions are being damaged by curbs in roundabouts and horses are stepping on themselves when the trailer must drive over the curb. We are trying to address the misinformation about roundabouts that seems to be prevalent in the general public and promote the positives about roundabouts.

Washington reported that one roundabout project in particular had an overwhelming opposition from a local trucking company and a 130-foot articulated load was used as the design vehicle and the central island was designed to be mountable. Again, as indicated above in other survey question responses and comments, clearances and mountable curbs appear to be one of the most, if not the most, reported concerns in OSOW transport through roundabouts.

Wisconsin responded that mega high (16'+) and wide (16'+) and long (225'+) and/or heavy (350K+) vehicles on occasion, needed to be rerouted. However, they stated that most of the OSOW fleet can get through either in the direction of traffic or counterflow, depending on the roundabout design and year built. They do suggest that removable signs, wide truck aprons, and tapered or custom center islands are modifications that make roundabouts friendlier for OSOW. (Again, their suggestions correspond to concerns and problems in other states that have been reported on the second survey, i.e. low vertical clearance, lack of obstructions in the center island, and placement for removal of signs are important potential countermeasures.)

Maine mitigated similar problems to ones mentioned in the paragraph above (vertical and horizontal clearance) by providing an overlay at a roundabout which reduced the truck apron curb height from 4 inches to 3 inches. They also modified the geometry to remove the vertical exterior curb and replaced it with a sloped, mountable curb.

Iowa put a vehicle-length restriction on a roundabout where previously a vehicle too large for the roundabout had gotten stuck.

Note: Determining states' laws is beyond the scope of the current project; however, the issue of putting restrictions on certain intersections and/or routes should be more thoroughly researched. No state should be required to make every intersection in the state accommodating to OSOW; however, what is acceptable, what is practical, and what does not interfere with interstate commerce? Another policy issue which may be of concern is whether states are responsible for intersections of roundabouts off the state system yet on OSOW permitted routes. Along these lines, Minnesota responded that an OSOW truck caused damage to the landscaping and curb of one roundabout which the permits section staff was unaware of on the routes, and they are developing methods to assist the permits staff to be aware of roundabout locations.

North Carolina responded that they feel there is a problem with truck drivers who refuse to utilize the apron and try to navigate the circular lanes and stay away from the apron. They have heard that drivers are afraid of loads shifting when using the aprons. They have modified their curbing around the apron so it is not an abrupt change in elevation. Their latest roundabout has experienced issues with trucks not using the apron and damaging outside curbs, etc.

This situation at North Carolina goes along with the need for education being mentioned more than once in the survey responses. Although this is beyond the scope of the pooled fund project, it seems there should be more research on the real overturning potential of some types of loads – which may not be an issue with OSOW-type carriers – and optimum cross slopes of truck aprons and circulating roadways.

For the reader desiring more details and exact language of the respondents, these details can be found in various appendices to this report. Appendix L summarizes detailed concerns about roundabouts from companies that deal with vehicles requiring a permit, i.e. oversize/overweight vehicles. Appendix M summarizes the state's contacts with OSOW companies or organizations in the state.

Input of OSOW companies/organizations that deal with these OSOW vehicles in highway design include the following:

- curb height and shape of curbs
- lack of OSOW companies' input; only sought for project meetings, special design meetings, and during public hearings

- rolled curbs and understanding OSOW routes in Washington state to promote the right conversations on projects, including central island landscaping

Appendix N summarizes OSOW companies/organizations that deal with OSOW input into highway design, particularly roundabout design.

Appendix O summarizes information about how OSOW vehicles or trucking associations accept roundabouts in each state.

Fifteen (15) states (Alaska, Arizona, California, Iowa, Kansas, Maine, Montana, Nebraska, Nevada, New York, Oregon, South Carolina, Tennessee, Washington, and Wisconsin) responded that they interact with OSOW vehicle or trucking associations on designs such as roundabouts. Each state's response is as follows:

- **Alaska:** Interact through plan reviews and direct communications
- **Arizona:** If a community is knowledgeable of OSOW vehicles in the area, our roundabout consultant has met with local trucking companies to accommodate their design vehicle requirements.
- **California:** When an origination or destination of OSOW tracks is identified, we solicit input. Also, when the roundabout will be on a permit load route, the associations are solicited for comment.
- **Kansas:** We interact with the companies in the immediate area.
- **Montana:** Trucking companies and private hauling companies have provided input at public meetings. We take their comments into consideration and ensure that we accommodate their vehicles as appropriate.
- **Nebraska:** If they provide comment at the public meetings
- **Nevada:** We take OSOW issues into account when we design our roundabouts.
- **Oregon:** Design staff meets as needed with the Motor Carrier Technical Advisory Committee, Oregon Trucking Association, and our own state Motor Carrier Permitting folks to discuss/evaluate operations and design needs.
- **South Carolina:** On an individual project basis, our public involvement process allows interaction between DOT and shareholders. During the public involvement

process, shareholders provide feedback and/or concerns related to the proposed design.

- **Tennessee:** Have interacted with trucking associations on several issues including safety and truck parking areas but have not addressed design or placement of roundabouts.
- **Washington:** The interaction has been heightened because of the perception of roundabouts; however, OSOW is also an issue with standard intersections with traffic signal poles, illumination poles, and fixed signs as well as straight-faced curbs and building encroachments. Roundabouts have in a large degree developed this conversation within the agency as well as the heavy haulers.
- **Wisconsin:** WisDOT Freight Operations Section developed an inventory of seven OSOW check vehicles and continues to support the design community. Industry assisted WisDOT in development of the OSOW Freight Network (FN). This network includes interstate and non-interstate facilities. WisDOT and industry worked together to conduct an OSOW test drive a model roundabout temporarily laid out in the parking lot at Miller Park, the Milwaukee Brewers Stadium.

Appendix P summarizes state interaction with OSOW vehicle or trucking associations on designs such as roundabouts.

Nineteen (19) states replied that their section which plans and designs roundabouts will coordinate with their section that does permit routing. These 19 states are Alaska, Arizona, California, Colorado, Connecticut, Florida, Georgia, Kansas, Kentucky, Michigan, Montana, Nebraska, Nevada, New Hampshire, New York, Oregon, Pennsylvania, Washington, and Wisconsin. Twenty-three (23) states replied that their section which plans and designs roundabouts does not coordinate with their section that does permit routing. These 23 states include Arkansas, Delaware, Illinois, Indiana, Iowa, Louisiana, Maine, Maryland, Massachusetts, Minnesota, Mississippi, Missouri, New Jersey, New Mexico, North Carolina, Ohio, Rhode Island, South Carolina, South Dakota, Tennessee, Vermont, Virginia, and Wyoming.

Thirty (30) states replied they have roundabouts on state or non-state routes on which OSOW vehicles might be routed. They are Alaska, Arizona, Arkansas, California, Colorado, Connecticut, Georgia, Illinois, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Oregon, Pennsylvania, South Carolina, Washington, Wisconsin, and Wyoming. Nine (9) states replied they do not have roundabouts on state or non-state routes on which OSOW vehicles might be routed. They are Delaware, Florida, Indiana, Louisiana, Montana, Ohio, Rhode Island, South Dakota, Tennessee, and Virginia.

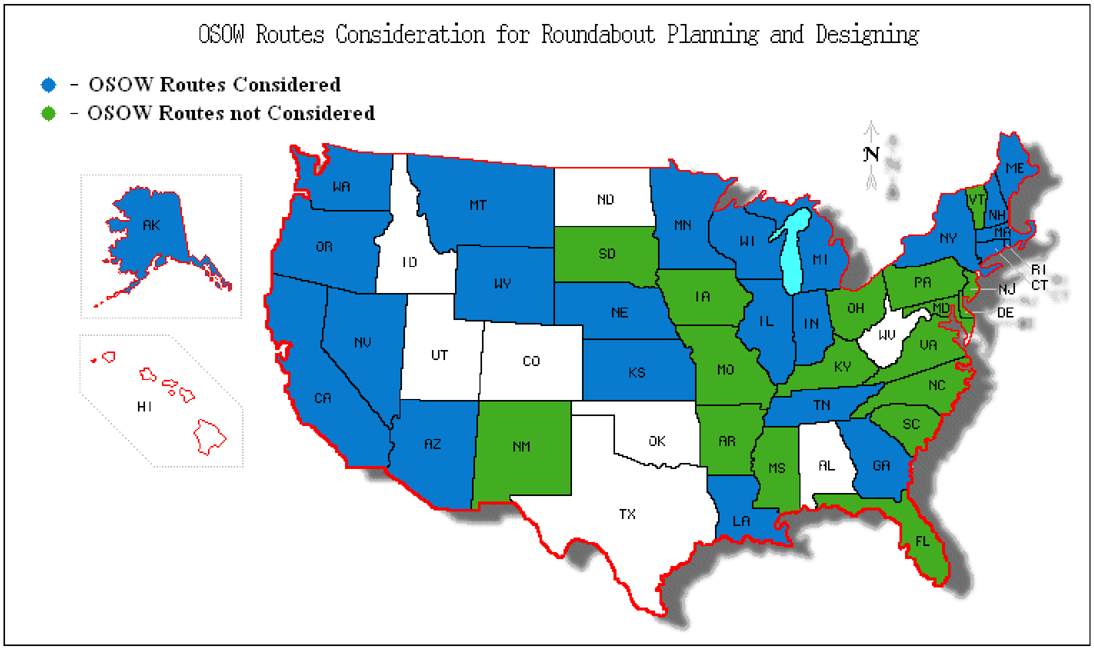


FIGURE 3.8
OSOW Routes Consideration for Roundabout Planning and Designing

Twenty-four (24) states take OSOW routes into consideration when planning or designing a roundabout. Seventeen (17) states do not take OSOW routes into consideration when planning or designing a roundabout. Figure 3.8 summarizes this information with a U.S. map. More details can be found in Appendix Q.

Figure 3.9 shows states having and not having roundabouts in agricultural areas. More detailed information can be found in Appendix R.

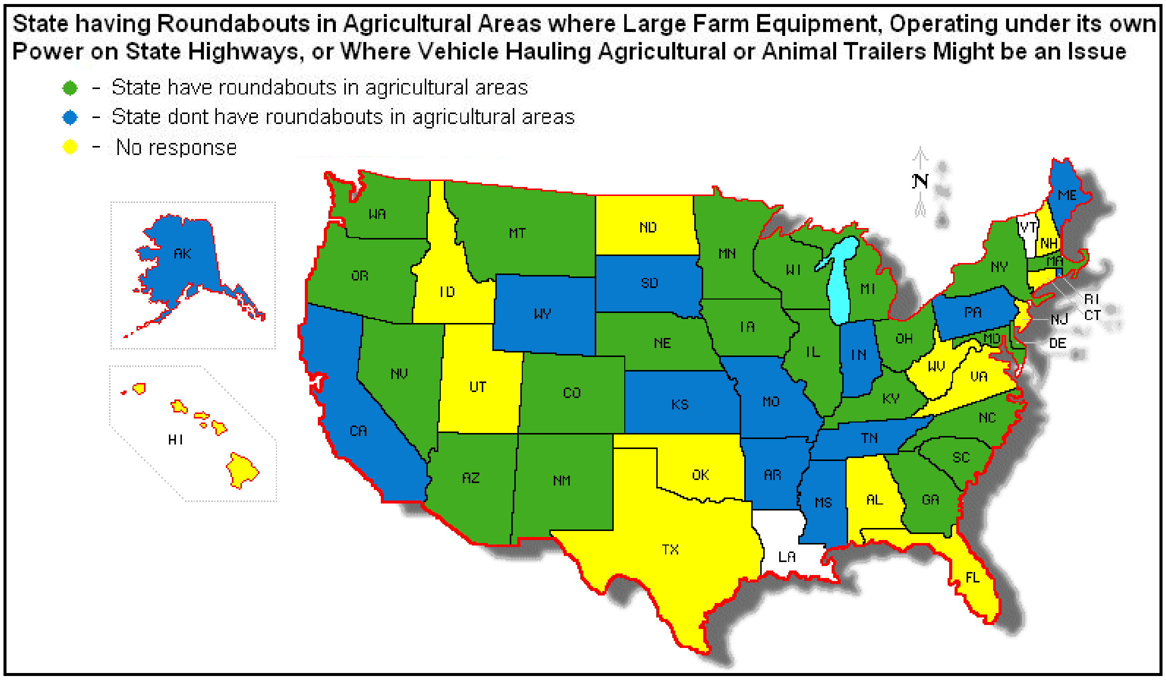


FIGURE 3.9
States Having Roundabouts in Agricultural Areas

Fifteen (15) states replied that their roundabout designs are done in-house and twenty-three (23) states replied they outsource to a consultant. The states were asked what design manual they used for roundabout design. For those interested in this information, it can be found in Appendix S.

Figure 3.10 summarizes states that have responded that they have a roundabout design in their state to address the concerns with OSOW or agricultural equipment or animal trailers. Summary of these states responses follow:

- **Alaska:** All 13 of them to differing extents O'Malley Road and C Street Interchange was the premier design standard set primarily and specifically for OSOW loads > 120' in the field, with subsequent designs using smaller diameters of 165' plus for multilane (2 Ln), but not too small for most trucks.
- **California:** Most are not on OSOW or farm routes. At least three were designed with OSOW considerations

- **Kansas:** We have discussed bypasses, gated central islands, modified splitter islands and driving the wrong way through a roundabout.
- **Nebraska:** We developed some simulations of OSOW loads moving through a roundabout and modified geometry to accommodate the loads. Project was placed in the inactive status after cost outpaced the benefit.
- **Nevada:** Nevada routinely has these types of equipment using our roads and occasionally encountering roundabouts. Therefore, OSOW concerns are considered during the design.
- **New York:** Roundabout in Greenwich, N.Y., was designed to accommodate a 16' x 80' modular home trailer.
- **South Carolina:** Most of our modern roundabout designs incorporate truck aprons, which allow extremely large wheel base vehicles to maneuver through the intersection.
- **Washington:** One WSDOT ramp terminal, a 130' long articulated load was modeled to try and placate a local trucking company and tear drop designs were made completely mountable (central island as well). As a sidenote, there have been numerous examples of roundabout projects where the trucking company was in favor of roundabouts for their safety and operational advantages over standard intersections.
- **Wisconsin:** WisDOT has several roundabouts that have unique design features intended to accommodate OSOW loads.

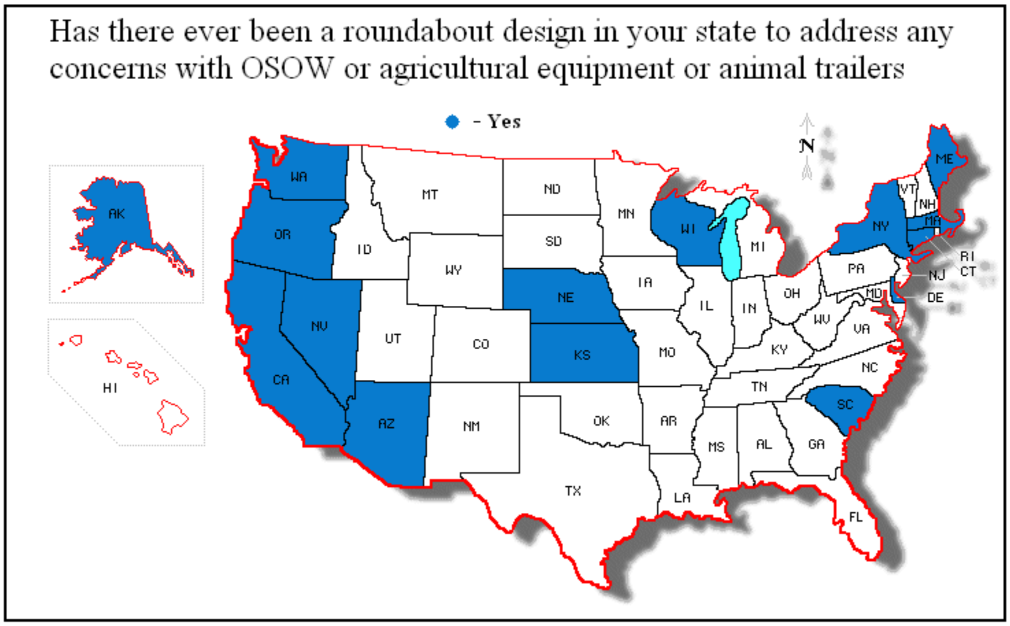


FIGURE 3.10
States Responding to Having a Roundabout Design in Their State to Address Concerns with OSOW or Agricultural Equipment or Animal Trailers

Chapter 4: Industry Surveys

4.1 Survey 3

The first Industry Survey (labeled project number 3) was limited to the Specialized Carriers & Rigging Association (SC&RA).

4.2 Background for Survey 3

A decision was made that the study should get information on roundabout concerns directly from OSOW haulers. A survey was developed and sent out to a number of trucking firms that were selected arbitrarily from the Internet. The Internet has a number of locations where OSOW haulers and firms that haul OSOW loads and/or provide escort services advertise. After picking about 30 off of these lists, telephone calls were made to ask if they would answer the survey and most said "yes". However, after sending the survey out, there was no response. Not a single one of the firms responded, even after some follow-up calls were made.

4.3 Answers to Survey 3

There was only one good source of information obtained to the questions of survey three. An officer with the SC&RA was very cooperative (Ball 2011). He informed the researchers in an upcoming national meeting with 13 of his regional managers, he would discuss the survey with them. The survey answers sent in response were a composite of answers by him and the 13 regional managers of SC&RA. Survey 3 answers are presented below (indicated as "Response") as sent to the researchers. In some cases, the respondents provided comments (indicated as "Comments"). The responses and comments are presented with only minor, light editing for clarity and sometimes paraphrased, with care taken not to change the meaning of any answers or comments. Any, material; added by the authors is in brackets, i.e., "[ ]".

After each question, the authors have provided comments regarding their opinion regarding the answer insofar as its relationship to finding viable solutions to mitigating problems that hinder accommodating OSOW at roundabouts (indicated as "Authors/researchers comment" and presented in italics). The questions, responses, comments (by respondents), and in some cases, authors/researchers comments, follow.

Question 1: **Provide the organization and type**: Specialized Carriers & Rigging Association (SC&RA) and the type of responding organization was given as "truck permit policy committee."

Question 2: **Are roundabouts any more of a problem compared with intersections?** Response: Yes. Comments: The design to move cars or legal-size trucks does not take into account permitted loads which exceed these dimensions. The cargo is essentially material transporting equipment, energy, mining, and manufacturing products of a non-visible nature. **Problem designs will incorporate curbs, statutes, flowers, signs, etc**. (emphasis by respondents)

Authors/researchers comment: Based on all surveys conducted on this study, curbs, and associated vertical ground clearance and tire wear, were mentioned many times. It is clear that curbs are a major problem.

Question 3: **Do you have unique problems with roundabouts, and if so, please explain**. Response: Yes. Comments: The design does not take into account permit loads which exceed normal parameters of lengths, widths and weights. The extra design for beautification hampers the use of the full radius of the roadway. Signs, statues and brickwork all look great but cannot withstand the dimensions of the permit loads. Roadway becomes one-dimensional for light traffic and not a safe and usable route for OSOW.

Authors/researchers comment: Ornament, statues, walls, etc. in and around a roundabouts can really enhance beauty; however, some may not be compatible with clearance needs of OSOW. In Chapters 5 and 6 this is discussed more and illustrate.

Question 4: If answer to question 2 and/or 3 is "yes," what possible solutions do you think might mitigate their [roundabouts] problems without compromising their safety benefits to passenger vehicles, or requiring excessive right-of-way and costs? Response: The cost is a product of poor design. What is the cost of not being able to deliver a generator or a transformer to the electrical plant? What is the cost of blocking access to a refinery because of a roundabout design? If needed, roundabouts should be designed such that multiple units can use it, i.e. permit loads as well as car [small vehicle] traffic. Widen the access; do not establish barriers or designs so that the only usable portion is the paved lanes. Design curbs that can be traversed so that turning is enhanced.

Authors/researchers comment: Although beyond the scope of this project, the authors believe that states should conduct studies to determine the economic benefits to the state or regions within the state, of various industries requiring OSOW, as a basis for a cost-benefit analysis of developing OSOW routes. This discussion is expanded elsewhere in the report. It is interesting that once again, curb design is mentioned as a problem or concern.

Question 5: Specifically, what is your experience with OSOW loads as they negotiate a roundabout: a. on the approach, b. in the circulating roadway, and c. on the departure? Response: a. the approach – no problem, b. the circulating roadway – serious problem exists, and 3. the departure – serious problem exists. Discussion and/or comments on question five are contained in question 6 below.

Question 6: If you checked 1 and/or 2 on question 5, what specific experience lead you to do so? Response: From experience with multiple loads throughout the U.S. where roundabouts are used, every company has a story about a design issue in moving OSOW loads. Many times the obstacle can be overcome with basic ingenuity. States route around these areas and that has increased routing miles, and delivery delays.

Authors/researchers comment: Although not doubting the above concerns, according to survey 2, other obstacles such as bridges, the wires and other barriers to OSOW were rated higher, i.e., roundabouts were rated 9th of 11 reported obstacles in survey number 1.

Question 7: How beneficial would it be if loads could go straight through the roundabout, considering that a removable barrier would have to be in place to prevent other vehicles from doing so, or the pathway would have to be offset so the entrance would line up with the left approach where the driver would have to move to the left lane of the approach – which is illegal in many states? Response: That would be good if the space would accommodate the size. Routine loads on 53-foot trailers, 8'6" wide, are one thing, but could it handle dimensional loads 15 to 18 feet wide? With permit loads is not illegal to move over to the left lane as pilot cars and/or police escorts control safety. Depending on exact size and escort car procedures, traffic is interrupted anyway.

Authors/researchers comment: The authors believe that roads through some roundabouts could have merit and should be considered. This is done at a lot of roundabouts in Europe. Examples and more discussion are included in chapter 5.

Question 8: **Do you feel there is a need for you to provide more input on roundabout design, and if so, what topics?** Response: Design engineers need to look at a broader use of user groups, and not just cars [small vehicles] and legal loads.

Authors/researchers comment: Planners and designers should attempt to find out the OSOW needs of industry and haulers in their area or state, and involve all stakeholders in determining needs to be considered in any planned roundabout on key routes. This is even stated in the Roundabout guide: "Design vehicles alone should not dictate roundabout designs or specific dimensions. It is often beneficial to engage local stakeholders to ensure that the proper design is developed" (NCHRP 672).

Question 9: What are your views on the concerns below? Could you add to the list of concerns? The list of concerns, taken from the second survey are as follows:

1. Lowboy (low clearance) vehicles have problems with curbs more than 3 inches in height.
2. There are issues with OSOW riding up on the curb on the exterior of the roundabout.
3. OSOW vehicles don't like hauling their long loads through roundabouts with tight radii.
4. Fixed objects within the center of the roundabout cause problems.
5. Slopes of circular roadway and/truck aprons cause risk of overturning.
6. Drivers not understand what the truck apron is for and need education.

Response: All these [above] are concerns. Simply stated, they cause a major disruption of the flow of traffic, and permit loads cannot properly negotiate the circle. Some radii are so tight that even the steerable dollies' load is too long to negotiate a turn when faced with obstacles, signs, statutes, curbs, and flowers.

Authors/researchers comment: It was hoped more would be provided on each of the concerns in the list, particularly some discussion of their thoughts on problems with curbs more *than 3 inches in height, and the respondent's "number" for a maximum height or at least some discussion of a maximum height.* ***However, they did reiterate the problem with obstacles, signs, statutes, curbs, and flowers. Going back through all surveys, curbs are definitely a major concern or problem*** (emphasis by the authors).

Question 10: **What are your views on the mitigation examples below?** Could you comment on the usefulness of the suggested mitigation strategies? Here respondents were asked to comment on some suggested mitigation strategies for large trucks (based on another state study) and it would they benefit OSOW? The list presented in the survey is as follows:

1. Wide truck aprons (12 feet or more) with a minimum slope and mountable curb
2. Custom center island to address known left turns
3. Tapered center island to support through movements
4. Paved area behind curb (right side for off-tracking)
5. Installing removable signs of setbacks for permanent fixtures (light poles)
6. Allow trucks to cross over the median (stamped, depressed, or corrugated) before entering the roundabout , in a counter flow direction, to make a left turn in the opposing lane and then cross back over after the turn
7. Right-turn lanes (sometimes gated).

Response: All have merit but real examples and review of existing loads should be examined. Go out and observe a bridge beam or generator being moved, and evaluate the turn radius. The European designs have made some interesting adjustments to roundabouts and while not perfect, they do in fact offer some alternatives. Each of these listed strategies offers some mitigation but none by themselves offer the solution. It is a combination of these, plus a capability to expand the roadway (if needed) depending on the size of the load.

Authors/researchers comment: The authors agree with this response. That respondents believe all strategies have merit is encouraging. Some European designs will be discussed further in chapter 5.

Question 11: In Kansas, the highest priority is given to bridge loading. Do you make adjustments to routes if their routing contains an intersection you are unable to negotiate, and do you report the adjustment? Response: Yes. Comments: No comments were given.

Question 12: How do you handle the case where a state indicates a route leaving the state, and it puts you on a route in which you cannot continue into the next stage? Response: States require you to do a route survey, so it is basically your fault! Many times this requires a significant deviation. Depending on the size of the permitted load, a 100-mile trip may in fact take a carrier 200 or more miles. Routing for bridge issues, turn issues and width and height issues are a constant and daily issue.

Authors/researchers comment: The response to this question indicates what has been pointed out in other sections of this report roundabouts are not the only issue with OSOW routing. That is not to say roundabouts do not have issues that should be addressed. However, the authors believe shippers/drivers of OSOW should understand that it is usually easier to have a roundabout accommodate their movement than to rebuild a bridge. In the latter case, a bridge (and some other non-roundabout features) may more likely cause long detours.

Question 13: Do you use your own escort or do you use a certain lightness court service? Response: Certified escort service.

Question 14: If you use a certified escort service, does it provide traffic control when traffic is interrupted? Or, are police required and who pays? Response: Police are required. Comments: It depends on the state. Many states do not allow civilians to direct traffic and only law enforcement can do so. Carriers use both.

Question 15: Do you remove and replace stop signs, and so forth and replaced them after passing? Response: Yes. Comments: The issue depends a lot on the size of the load. Bucket trucks can be needed to lift wires, lights, and so forth. Instances have happened where signs, lights, and other stationary objects have been removed, then replaced. All of this is part of the permit and contract. Bonds are required in many places to ensure compliance.

Question 16: Do you pay the government agency to replace signs or fix damage fixtures? Response: Yes. Comments: Carriers in the OSOW field do pay for all services.

Question 17: Are there places where you are permitted to hold traffic and travel in the wrong direction to continue towards your destination? Response: Yes. Comments: Yes, and for some movements that are mega-loads, the interstate is shut down to allow passage. This is a very well-coordinated and drastic measure but it does happen. Bridges sometimes are closed for traffic as the load has to be centered.

Authors/researchers comment: The above response and comments appear to apply to other than roundabout situations. There is no reason a roundabout design that anticipates some OSOW movement could not do the same if necessary; however, the possibility of a specific OSOW and the potential for accommodation should be known in the planning and design phase of a roundabout, or possibly, when developing an OSOW freight route.

Question 18: Do you suggest routes to provide information to the permitting agency about restrictions that you cannot negotiate on a given route? Response: Yes. Comment: This is usually a result of a route survey done prior to the move.

Question 19: **What are your views on typical states' permitting and routing policies and procedures?** Response: Progress has been made over the past several years but uniform progress is a constant challenge. Border states have such varying policies, regulations, and requirements that it is a maze. The AASHTO regional organizations [**Northeastern Association of State Transportation Officials (NASTO) Region 1; Southeastern Association of State Highway and Transportation Officials (SASHTO) – Region 2;** ;**Mid America Association of State Transportation Officials (MAASTO) – Region 3; and** .**Western Association of State Highway and Transportation Officials (WASHTO) – Region 4]** are an absolute necessity to partner with industry to constantly review procedures and look for ways to be more uniform.

Authors/researchers comment: This issue is essentially beyond the scope of this study; however, some discussion of this was covered in the review of literature in chapter 2. Also, the authors have started another research project funded by KDOT that will study some of these issues.

Question 20: Question 20 only asked for contact information.

4.4 An Additional Industry Survey

Although the response from the SC&RA was greatly appreciated and known to be from knowledgeable, OSOW haulers, a broader based respondent pool was sought. Based on the "zero" response the researchers were able to get on their own from surveying industry, a new approach was taken. Several communications with the American Trucking Research Institute (ATR I) led to a partnering agreement whereby they would send out a survey to their membership. The survey, project survey 4, is explained and the responses summarized in the following section.

4.5 Summary of Survey 4: Background

For Survey 4 to trucking firms, the Kansas State University (KSU) researchers partnered with the American Transportation Research Institute (ATRI). As agreed with ATRI, they added several questions of interest to them but not necessarily important to the project, although they may have some benefit as to what types of trucks are on US highways. The final survey had 47 questions. Several iterations were edited and agreed to and the final version (see Appendix T) was distributed. KSU's, AXIO online survey was used for ATRI to distribute a link from the prepared survey to ATRI members. A total of 60 responses were returned and the results from these responses are summarized below.

Of the 60 responses, it was a disappointment that only 18 of the respondents answered that they use OSOW permits, i.e., from the survey answer to a question asking if they use permits for loads 37 of the respondents answered "no" and therefore, the authors assume do not haul OSOW loads *(the basic definition of OSOW is a load requiring a permit, a legal requirement in most states)* and Five did not answer that question. Thus, several questions designed to specifically address OSOW haulers would not apply to them. For example, the question about the usefulness of a gated road through a roundabout would be meaningless to a non OSOW driver, or as one indicated in his answer, "It was a dumb question". Some other questions may have had more subtle problems due to the researchers having OSOW in mind when making up the questions while non OSOW drivers may have had a different interpretation of the point of the question. All surveys have this concern of the respondent being in the same mind set as the questioner.

4.6 Details of Presenting Respondents' Answers

In our summary tables and charts below, whenever the total number of responses for a particular question are not equal to the total number of returned responses or 100%, it has to be understood that a few of the respondents did not provide replies to that particular question.

Question 30 of survey 4 was designed to find out if the responding trucking agencies use OSOW permits. Only 18 respondents answered they were using vehicles requiring OSOW permits and 37 respondents replied that they do not use OSOW permits. In this case, the sum of the respondents using OSOW permits (18) and respondents not using OSOW permits (37) is 55 and it does not add up to 60. This situation means that Five respondents did not answer this particular question.

Each question was summarized in three different categories, i.e., one based on the total 60 respondents, one based on the 18 respondents who answered they use OSOW permits, and the third based on the 37 respondents who answered they do not use OSOW permits. However, a few questions (refer to questions 14 through 47 in Appendix T) in the survey were exclusively designed to be answered by OSOW haulers and therefore, only the 18 responses that mentioned using OSOW permits were considered in summarizing and analyzing these questions.

In some cases, the authors/researchers have added some comments as to their interpretation as to how the answer may relate to the main objective of this project accommodating OSOW at roundabouts. These are clearly indicated by being preceded by "Authors/researchers comments", and are in italics. Only light editing was done to the survey answers if it was felt necessary to enhance the meaning. Any words added by the authors, very few, are in brackets i.e., "[ ]".

4.7 Summary of Survey 4 Answers

Table 4.1 shows the summary of results for question 1: "Which sector of the trucking industry do you operate in?" As discussed above, this question has been analyzed for three categories of respondents: 1) all the 60 respondents, 2) respondents who use OSOW permits, and 3) respondents who do not use OSOW permits. It can be seen in Table 4.1 that 83.3% of the haulers using OSOW permits operate in the "For-hire" sector of trucking industry. For haulers not using OSOW permits, 67.6% of respondents operate in the "For-hire" sector. Table 4.1 gives more details of responses for the respondents' operations' in different sectors of trucking industry.

TABLE 4.1
Sector of Trucking Industry Being Operated

Sector of Trucking Industry being Operated	All Respondents *Responses (%)*	Respondents who use OSOW Permits *Responses (%)*	Respondents without OSOW Permits *Responses (%)*
For-hire	45 (75%)	15 (83.3%)	25 (67.6%)
Private Fleet	13 (21.7%)	2 (11.1%)	11 (29.7%)
Mail/Parcel	0	0	0
Other	2 (3.3%)	1 (5.6%)	1 (2.7%)

Table 4.2 summarizes results of Question 2: "Which carrier type best describes your company?" It can be summarized that most of the respondents who use OSOW permits use carrier type "Truckload" (38.9%) or "Specialized Flatbed" (38.9%). Table 4.2 shows more detailed responses. Figure 4.1 shows hazardous materials hauling by different categories of haulers.

TABLE 4.2
Carrier Type that Best Described the Company

Carrier type that best describes the Company	All Respondents *Responses (%)*	Respondents who use OSOW Permits *Responses (%)*	Respondents without OSOW Permits *Responses (%)*
Truckload	23 (38.3%)	7 (38.9%)	14 (37.8%)
Less-Than-Truckload	8 (13.3%)	1 (5.6%)	6 (16.2%)
Private Fleet/Shipper	8 (13.3%)	2 (11.1%)	6 (16.2%)
Specialized (Flatbed)	9 (15%)	7 (38.9%)	2 (5.4%)
Specialized (Tanker)	5 (8.3%)	0	4 (10.8%)
Express/Parcel	0	0	0
Other	5 (8.3%)	1 (5.6%)	4 (10.8%)

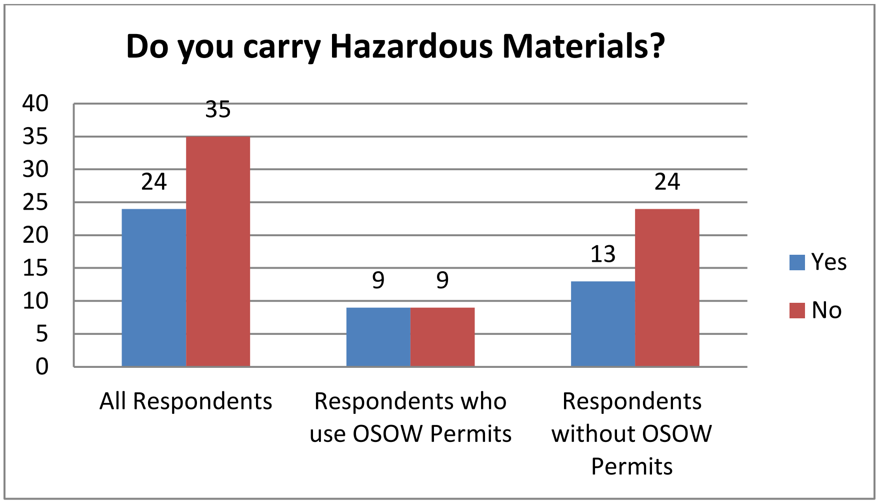


FIGURE 4.1
Hauling Hazardous Materials

Questions 4 to 10 were meant to ask each respondent the approximate number or percentages of different truck types they have for their operation. These responses were summarized only for the haulers who replied they use OSOW permits and are shown in Table 4.3 below. The responses were either the number of trucks or percentage of total trucks.

TABLE 4.3
Approximate Number of Trucks or Percent of Total Trucks for Different Vehicle Types (Based on 17 Responding OSOW Haulers)

Survey Respondent (OSOW Hauler)	Straight Trucks	5-Axle Tractor/ Semitrailer	6-Axle Tractor/ Semitrailer	Standard Double	Rocky Mountain Double	Turnpike Double	Triple Trailer
1	8	35	0	0	0	0	0
2	0	3	0	0	0	0	0
3	1	10	10	0	10	0	2
4	4	90	1	2	10	0	0
5	50	10	5	3	25	0	0
6	0	160	10	0	0	0	0
7	2%	50%	47%	0	0	0	0
8	0	0	0	0	1	0	0
9	0	6	0	0	6	0	0
10	0	90%	10%	0	0	0	0
11	12	7	2	0	0	0	0
12	0	2100	15	0	0	0	0
13	1	207	1	1	0	0	0
14	0	2	3	0	0	0	0
15	0%	100%	0	0	0	0	0
16	0	50%	30%	0	0	0	0
17	3	45	0	0	0	0	0

Table 4.4 summarizes results of Question 11: "What type of commodity do your drivers or contractors typically haul?" Most of the OSOW haulers haul either heavy machinery/equipment (33.3%) or general freight/truckload (22.2%). Some other commodities that were not mentioned in the survey options were oilfield equipment, production buildings, dry bulk commodities, coil steel, grain, and bulk liquids.

Table 4.5 summarizes results of Question 12: "What are the primary road types on which your trucks typically travel?" for different categories of vehicle.

TABLE 4.4
Type of Commodity Drivers or Contractors Typically Haul

Type of Commodity Drivers or Contractors Typically Haul	All Respondents *Responses (%)*	Respondents who use OSOW Permits *Responses (%)*	Respondents without OSOW Permits *Responses (%)*
Consumer/Retail Products	3 (5%)	0	3 (8.1%)
Household Goods	2 (3.3%)	0	2 (5.4%)
Truck/Auto Transport	1 (1.7%)	0	0
Modular/Mobile Homes	0	0	0
Heavy Machinery/Equipment	6 (10%)	6 (33.3%)	0
US Mail/Parcel	0	0	0
General Freight/Less-than-Truckload	1 (1.7%)	0	1 (2.7%)
Petroleum Products	7 (11.7%)	0	6 (16.2%)
Mine Ores	0	0	0
Forest Products/Building Materials	1 (1.7%)	1 (5.6%)	0
Agricultural Products/Livestock	4 (6.7%)	1 (5.6%)	3 (8.1%)
Processes Foods	3 (5%)	0	3 (8.1%)
General Freight/Truckload	14 (23.3%)	4 (22.2%)	8 (21.6%)
Other	17 (28.3%)	6 (33.3%)	11 (29.7%)

TABLE 4.5
Primary Road Types on Which Trucks Typically Haul

Primary Road Types on which Trucks Typically Haul	All Respondents [Yes (*% Yes)*]	Respondents who use OSOW Permits [Yes (% Yes)]	Respondents without OSOW Permits [Yes (% Yes)]
Urban Interstate, Highways and Freeways	47 (78.3%)	13 (72.2%)	31 (83.8%)
Urban Major Highways	37 (61.7%)	11 (61.1%)	24 (64.9%)
Urban Local Roads	38 (63.3%)	10 (55.6%)	26 (70.3%)
Rural Interstate, Highways and Freeways	51 (85%)	16 (88.9%)	32 (86.5%)
Rural Major Highways	41 (68.3%)	13 (72.2%)	27 (73%)
Rural Local Roads	39 (65%)	12 (66.7%)	26 (70.3%)

Figure 4.2 summarizes results of Question 14: "Are roundabouts any more of a problem compared with other intersections?" for different category of respondents. It can be observed that 16 OSOW haulers responded they felt roundabouts are a problem compared to other intersections. The comments from the OSOW haulers for this question were summarized in Table 4.6.

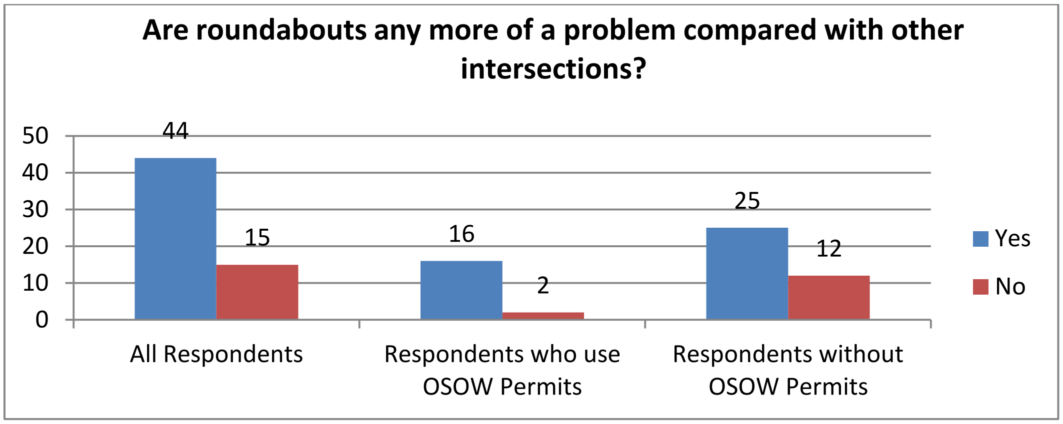


FIGURE 4.2
Summary of Question 14

Figure 4.3 summarizes results of Question 15: "Are roundabouts any more of a problem than other highway features which may be a concern to oversize/overweight loads such as narrow bridges, wires, curbs, ramps, and so forth?", for different categories of respondents. It can be observed that 83.3% of the OSOW haulers felt that roundabouts are more of a problem than other highway features, which may be a concern to oversize/overweight loads such as narrow bridges, wires, curbs, ramps, and so forth. Comments from the OSOW haulers for this question were summarized in Table 4.7.

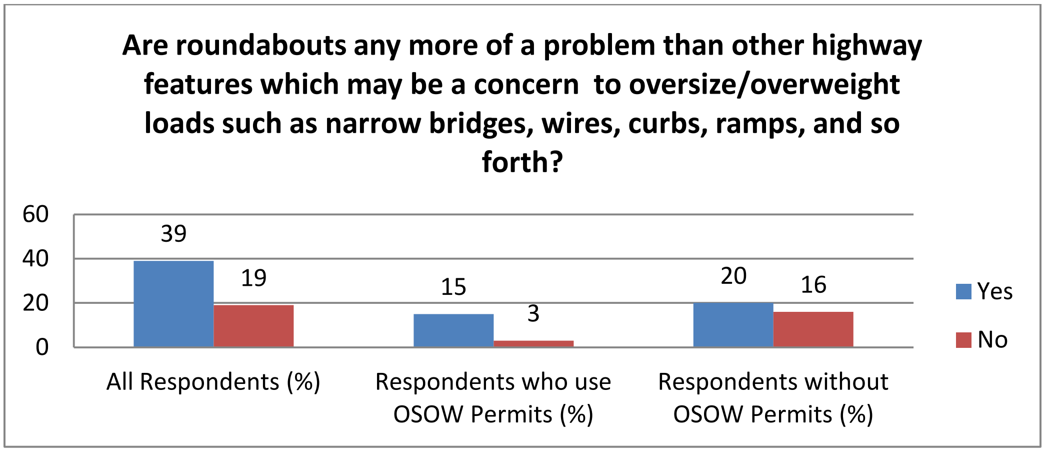


FIGURE 4.3
Summary of Question 15

TABLE 4.6
Comments for Question 14 from OSOW Haulers

Survey Respondent Number (OSOW Hauler)	Are roundabouts any more of a problem compared with other intersections?	Comments
1	Yes	To narrow a radius for trucks, especially if there is a curb in the middle, and also trailers track in the other lane if not built right
2	Yes	Clearance issues, liability issues, driver education challenges (not ours but the traveling public)
3	Yes	We have several roundabouts in town and they are a substantial problem for large trucks as vehicles encroach in adjacent lanes. If lanes are wider than the normal, they can be ok.
4	Yes	Depends on if they have round or square corners [curb radius?] - and the height of them
5	Yes	Here in Billings, MT, the roundabouts are very difficult to maneuver with the rocky mountain doubles.
6	Yes	Difficult to move oversize loads. Should never be in middle of major highways.
7	Yes	Double-drop trailers and 53-foot-spread axle trailers, as well as any stretch trailers have issues with roundabouts.
8	Yes	Too many drivers feel it is an automatic green light and no [do not] yield.
9	Yes	We haul many oversized loads and they are limiting the routes we can use.
10	Yes	Yes, the trailers drift into the second lane causing the potential for a collision.
11	Yes	The concept is posing an extreme threat to the movement of oversize cargoes and results in routing headaches and unnecessary out-of-route costs to our shippers. It is imperative that roundabouts not be allowed on state or federal highways.
12	No	Not if built right. Note that large trucks are not allowed on residential streets except for deliveries and moves.

Note: Only minor editing for grammar and spelling was performed for responses for clarification.

TABLE 4.7
Comments for Question 15 from OSOW Haulers

Survey Respondent Number (OSOW Hauler)	Are roundabouts any more of a problem than other highway features which may be a concern to oversize overweight loads such as narrow bridges, wires, curbs, ramps, and so forth?	Comments
1	Yes	The traveling public is interacting on three or four points as well as not truly educated on how to traverse a roundabout.
2	Yes	Yes, they can be a problem for heavy haul and car haulers due to height of trailer from ground.
3	Yes	States will not route you through them.
4	Yes	Yes, the width of the lanes do not compensate for articulating CMV or OW / OS [OSOW]load.
5	Yes	They are, and will continue to be a major operational and safety issue for O D [OSOW]carriers.
6	Yes	There are more and more of them and unlike narrow bridges, they are not as well documented for routing purposes.
7	No	If the road is for long vehicles, it needs a bigger radius.

Note: In table 4.6 and similar tables, only minor editing for grammar and spelling was performed for clarification in a few cases when felt necessary.

Authors'/researchers' comment: In question 14, it was almost unanimous that roundabouts are more of a problem than other types of intersections. In preliminary studies in Kansas, the researchers know of a number of intersections, particularly diamond interchanges, that are also a problem. The authors believe they are more of a problem than a well-designed roundabout. The authors are of the strong opinion the comment of the one dissenting "no," "not if built right," is most insightful. Likewise, in the answer to question 15, "Are roundabouts any more problem than other Highway features?", it was almost unanimously "yes." This is contrary to our second survey which listed 11 obstructions to OSOW, and roundabouts were 9th of 11. The authors believe roundabouts on specific routes can be built to accommodate OSOW if the specific need and characteristics of the vehicle are known. Survey two, which listed the 11 obstructions, listed bridges as number one. The authors believe it is more likely a state will *design or modify roundabouts to accommodate OSOW than they will to rebuild bridges for this purpose. Preliminary studies by the authors of Kansas Permitting and Routing Policy indicate bridges are the primary bottleneck to OSOW and the cause of lengthy detours on all OSOW routes.*

Table 4.8 summarizes results of Question 16: "Do you have any unique problems with roundabouts, and if so, please explain?" asked of respondents who use OSOW permits. Table 4.9 summarizes the responses for Question 17 for OSOW haulers, "If the answer to question 15 and/or 16 is "yes", what possible solutions do you think might mitigate the problem(s) without compromising their safety benefits to passenger vehicles, or requiring excessive right of way and cost?"

TABLE 4.8
Summary of Question 16 Responses from OSOW Haulers

Do you have any unique problems with roundabouts, and if so, please explain?	Comments
Yes	The traffic volumes in and around them make it hard for trucks to enter safely. It takes a long time especially in multilane roundabouts to have an opportunity to enter safely.
Yes	Clearance issues, sight distance, bike and pedestrian islands, size and radius.
Yes	Roundabouts are too small and the trucks can't stay in the proper lane and smaller traffic doesn't pay attention to signs saying trucks need both lanes. Poor or no directional signage for which lane to be in to get off of the roundabout where you want to and where that street or road goes.
Yes	Both construction and maintenance cost are high especially in snow country
Yes	Elevated and sloped curbs cause trailers to hang up on any turns more than 90degrees
Yes	Loads cannot get through them.
Yes	Yes, the trailer will track from lane 1 to lane 2 or the trailer will run up on the curb/island if lane 2 is being used.
Yes	Continued expansion of roundabouts will force O D cargoes [OSOW] to use only Interstates and inappropriate secondary routes and add needless costs and exposure to accidents. We can foresee tonnage being forced back onto the inefficient rails.
Yes	Typical roundabout design is too small in scale to accommodate large trucks effectively and doesn't provide enough time for larger vehicles to enter without impeding traffic

Note: Only minor editing for grammar and spelling was performed for responses for clarification. Any words in brackets [ ] were added by the authors.

Authors'/researchers' comment: The authors see little value toward the objective of accommodation with the range of comments to question 16. This could be an example of a case where the researchers had different expectations for answers in mind than the respondents. The one comment about clearance issues (assuming ground clearance) being a problem is definitely on target and is addressed in chapter 5. Also the comment about curbs causing "hang ups" is definitely a problem, also addressed in chapter 5. The issue of trucks and OSOW staying in their lanes and drivers of small vehicles not paying attention are issues beyond the scope of this project; however, they definitely need to be addressed through changes in laws and education, among other things.

TABLE 4.9
Summary of Question 17 Responses by OSOW Haulers

Survey Respondent (OSOW Hauler)	Q17: If the answer to question 15 and/or 16 is "yes";, what possible solutions do you think might mitigate the problem(s) without compromising their safety benefits to passenger vehicles, or requiring excessive right of way and cost?
1	Make them large enough to accommodate all vehicles including stretch trailers as well as over width and keep the entire roundabout at one level; do not raise the center with a curb
2	Do not build them on Interstate or State Highways, or intersections that connect said highways. Do not build a roundabout anywhere before the state, city and county governments have looked at their long term planning for regional projects both public and private. Did not put a cork in the bottle you want to build a ship in!
3	Increase the diameter of the roundabouts. Add directional signs well ahead of the roundabout. Improve public knowledge of the laws pertaining to roundabouts.
4	Roundabouts with rounded raised corners vs square [radii and curbs?] are much better. Roundabouts need to be at least 2 lanes wide. In KS on hwy 420 between Wichita and Joplin is an example of a bad one (square corners, single lane)
5	The concept of the roundabouts is good, however much more room is needed for trucks to safely utilize them.
6	It is nearly impossible to negotiate the roundabout with rocky mountain doubles without bumping the curb with either the outside steer tire or the rearmost inside tire of the rear trailer..... solution? Bigger/wider roundabouts Also, I have noticed that as my trucks SLOWLY navigate the circle, cars are likely to impatiently pull out in front of the trucks...... I have invited the Motor Carriers of Montana (Assn) to come to Billings and video my trucks as they navigate the roundabouts and would be happy to share the results.
7	Use standard [stop] light controlled intersections
8	Making roundabouts double lanes allows room to maneuver. We much prefer a [stop] lighted intersection because it has the room to make a big enough turn to accommodate the extra long or wide loads.
9	Lets have the 'so-called' Highway Engineers that design these roundabouts actually ride along, or better yet attempt to drive a class 8 TT [trailer truck ?] through the road hazards they have designed. They need “Real World Experience”. It cant be done sitting in a building.
10	I would like to see the ability to have blockages in the middle that a patrol could remove to travel through them if the radius was 135' or greater. Do not put them on state corridors so we do not limit commerce.
11	Make the lanes wider in the roundabouts.
12	Keep designs free of shrubs, curbs, rocks and signs, and anything that hinders the use of lowboys and other specialized equipment that is currently used to move today's O D [OSOW] cargo.
13	Wider lanes when requiring OSOW loads to follow traffic flow to right.

Note: Only minor editing for grammar and spelling was performed for responses for clarification. Any words in brackets [ ] were added by the authors.

Authors'/researchers' comment: The authors agree with a number of sentiments expressed in the respondents' comments in Table 4.9. When the respondents indicate larger roundabouts, they may be thinking of a much larger roundabout and the authors believe this is optimal, i.e. big enough and with wide enough lanes for a large vehicle (a WB-67 should be considered as design vehicle on all state highways) and to accommodate OSOW that need to use the roundabout. However, in order not to diminish the safety benefits to all users, it should be no bigger than necessary and maintain deflection for small vehicles, which is key to roundabouts safety. Definitely, the public and small vehicle drivers need better education and perhaps stiffer laws on operating safely around large trucks in roundabouts. FHWA has a "no zone" campaign to educate drivers on safe operations around large trucks, and most trucks have a sign on them somewhere warning drivers about the truck making wide turns at intersections. A roundabout is an intersection and the same cautions should apply to small vehicle drivers.. Likewise, no one should expect a large truck to stay in a lane in a standard, non-roundabout intersection, so it seems counterproductive for laws that can make large trucks liable for damages in a crash just for being out of their lane in a roundabout. (Studies of this issue are underway in Wisconsin and recently the law has been changed in Oregon.)

Table 4.10 summarizes the respondents' experience with different aspects of a roundabout for different category of haulers. Figure 4.4 summarizes the Question 20 responses from OSOW haulers: "How beneficial would it be if loads could go straight through a roundabout, if a removable barrier is in place to prevent other vehicles from doing so?". Figure 4.5 summarizes Question 21 for OSOW haulers: "How beneficial would it be if loads could go straight through a roundabout, if the pathway would be offset so the entrance would line up with the left approach (where the driver would have to move to the left lane on the approach)?"

TABLE 4.10
Respondents Experience with Different Aspects of a Roundabout

Feature of a Roundabout	Serious Problem Exists			Problem Exists but not so Serious			No Problem		
	All	OSOW	Non OSOW	All	OSOW	Non OSOW	All	OSOW	Non OSOW
The Approach	15	7	7	19	6	11	17	3	14
The Circulatory Roadway	26	12	12	18	4	13	7	0	7
The Departure	15	6	8	27	9	16	9	1	8

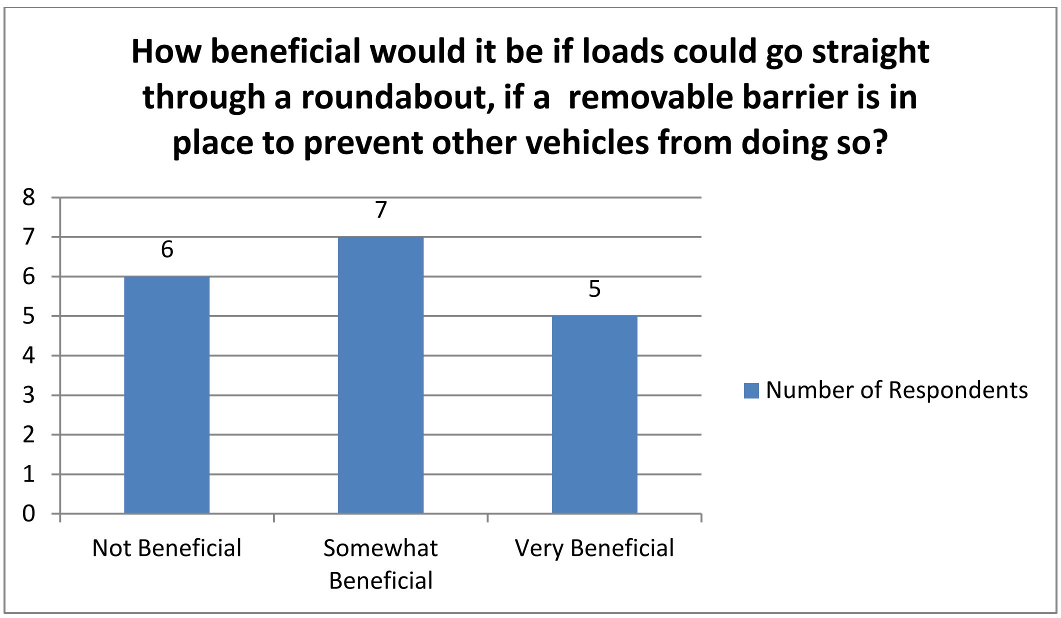


FIGURE 4.4
Summary of Question 20 Responses from OSOW Haulers

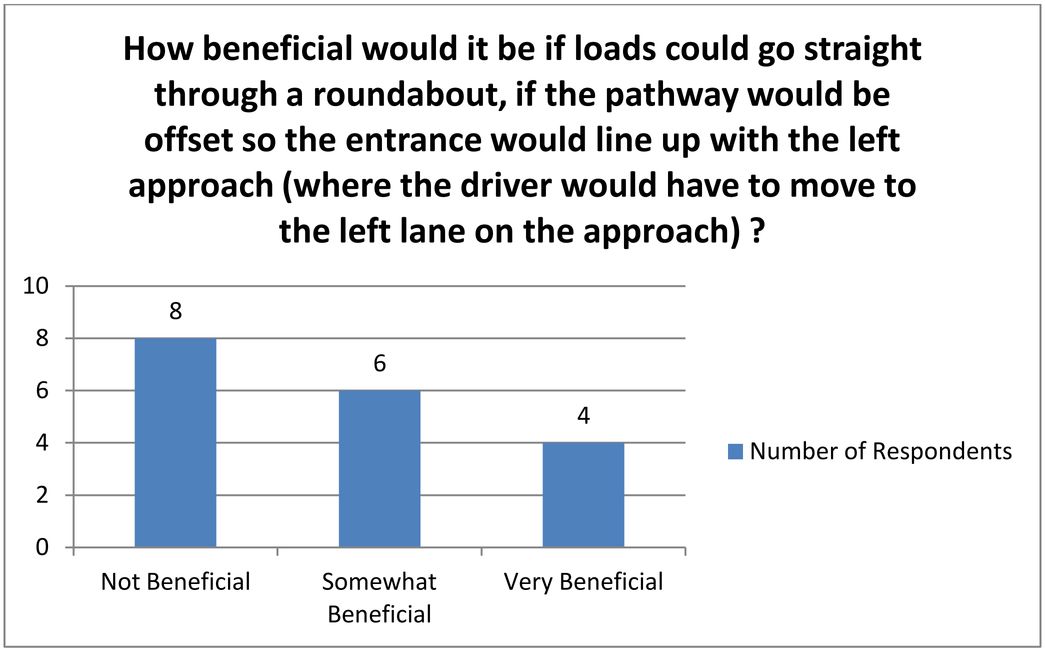


FIGURE 4.5
Summary of Question 21 Responses from OSOW Haulers

Authors'/researchers' comment: It is encouraging to note the majority of OSOW respondents answered that a road through the roundabout would be somewhat or very beneficial. This concept is widely used in Europe and the authors believe it should be given more consideration in the United States. Extensive discussion of this is included in chapter 5.

Table 4.11 summarizes responses for question 22 for OSOW haulers: "Do you feel there is a need for you to provide more input to roundabout designers, and if so, about what topics?" Tables 4.12-4.17 summarize the OSOW hauler respondents' views on different roundabout concerns identified from survey 2. Table 4.18 summarizes additional concerns other than the concerns that were asked in survey 4. Table 4.19 summarizes responses to Question 38: "Do you make adjustments to routes if their routing contains an intersection you are unable to negotiate, and do you report the adjustment?" for different categories of respondents. Figure 4.6 summarizes responses for Question 40: "Do you use your own escort or do you use a certified escort service?" for OSOW haulers.

TABLE 4.11
Summary of Question 22 Responses from OSOW Haulers

Survey Respondent	Do you feel there is a need for you to provide more input to roundabout designers, and if so, about what topics?
1	Lane width
2	Wider turn radii, better signs, study traffic volumes to see if roundabout are even feasible.
3	I feel they have made up their minds and are trying to convince the rest of us there is no other solution
4	We are trying that approach in Montana right now on a roundabout being proposed at the entrance of a truck stop on highway 200 near Bonner. This really does not make sense right at the entrance to a truck stop where many over dimensional loads travel.
5	Yes I think it would be great to have more input
6	Calculating the types of traffic flow at any intersection and review the potential of future development in the area, ie. future road work or new industry construction.
7	The roundabout designer must be able to drive a tractor and 53' trailer around any circle he designed . He must do this during rush hour traffic. All look good on paper but once you start around in a long truck you find out quickly if it is any good or not. Most of the problem is where they locate the signs.
8	We would expect a higher level of fender bender accidents with autos hitting trucks/trailers compared to high speed accidents on traditional intersections especially in rural settings (such as the proposed roundabout north of Rochester on U S 63)
9	No

Note: Only minor editing for grammar and spelling was performed for responses for clarification.

Authors'/researchers' comment: The authors believe planners and designers should consider the needs of all stakeholders, including large trucks and necessary routes for OSOW, when designing a roundabout.

TABLE 4.12
Summary of Views on the Roundabout Concern "Low Boy (Low Clearance) Vehicles Have Problems with Curbs over 4 Inches in Height" from OSOW Haulers

Response No	Views on the roundabout concern: "Low boy"(low clearance) vehicles have problems with curbs over 4 inches in height'
1	Yes. No raised structures.
2	Curbs need to be mountable to prevent tire damage and load shift and never over 4' high.
3	Low boy trailers can't go through roundabouts with high curbs and tight turn radii.
4	There needs to be provisions to accommodate Lowboys - how does your equipment get there to build the homes and roads - lowboys bring it
5	Agree
6	I agree, could cause high centering and traffic jams
7	This is very true. The other issue not brought up much is the damage to trailer tires on the side wall as loaded trailers try to climb over the curb to circle the roundabout.
8	Very big concern, Equipment damage, frame rails, tires, suspension.
9	If ground clearance was the only issue I feel we could make accommodations around that.
10	Both lanes need to be used to prevent curbing, which causes the potential for accidents.
11	If they are wide enough this is not problem. There is no different [difference] with a low boy hitting a curb or having to drag the tire over the curb .
12	Why would a truck be on the curb? Poor driving skills.
13	We are opposed for exactly this reason.
14	Could create unexpected problems

Note: Only minor editing for grammar and spelling was performed for responses for clarification.

Authors'/researchers' comment: In all surveys and contacts made during the course of this investigation, it is clear that vertical ground clearance in general and curbs in particular are a major problem to large trucks and OSOW, and definitely need to be mitigated whenever OSOW need to be accommodated. There is no clear cut policy or consensus of maximum height of curbs and so forth; however, 4 inches appears to be a maximum. The authors believe 3 inches should be considered. It should be kept in mind that not all roundabouts and connecting roadways are built on a level plane, i.e. a flat surface. Vertical curvature of the entering and circulating lanes, combined with slope and crown roadway, and truck apron all contribute and have to be considered. The state of Wisconsin has studied this problem and developed some guidelines and *policies which will be discussed in chapter 5 of this report. One of the authors' conclusions from studying reading material for this project is that vertical elevation of curbs as well as curb design needs a lot more attention and study and it has been given. Respondents' answers in Table 4.13 further emphasize this point.*

TABLE 4.13
Summary of Views on the Roundabout Concern "There are Issues with OSOW Riding up on the Curb on the Exterior of the Roundabout" from OSOW Haulers

S.No	Views on the roundabout concern: 'There are issues with OSOW riding up on the curb on the exterior of the roundabout'
1	Concern
2	Tire wear, vehicle control, shock to components
3	Concern for causing tire failure with heavy loads hitting the curb with one tire.
4	Need provisions to get them thru
5	Have a lot of problems. Very poor engineering.
6	Our long vehicle with heavy weight messes up the curbs. We try to stay far enough away but sometimes curb the tires,
7	Agree
8	It's a problem
9	Oversize/overweight loads can hang up or potentially tip over on uneven surfaces. Roundabouts are considered an acute danger to most OSOW drivers.
10	Very big problem
11	I would be concerned of a load tipping over and breaking the pavement with heavy loads
12	Yes, the trailer could tip over from the change of center of gravity when the tires override the curb. A few inches can make all the difference. The same effect can occur from flat/low tire pressure.
13	All the curb should be tapered if this is a problem the circle is too small . If you don't have enough room for the correct size roundabout just don't build it
14	No issue with OW. [weight] Maybe OS [size] needs diverting.
15	That's why we object to any type of curb, rocks or shrubs
16	Requires greater right of way to avoid

Note: Only minor editing for grammar and spelling was performed for responses for clarification.

TABLE 4.14
Summary of Views on the Roundabout Concern "OSOW Vehicles Don't Like Hauling Their Long Loads through Roundabouts with Tight Radii" from OSOW Haulers

S.No	Views on the roundabout concern: 'OSOW vehicles don't like hauling their long loads through roundabouts with tight radii'
1	Concern
2	That In my opinion is a nonsense question. If you can't make radii you can't make it.
3	I agree. It is dangerous. It puts trucks at a safety disadvantage, even if the truck is not at fault, the resulting (DOT recordable accident) goes on their safety record.
4	It is not possible for long loads to get through some roundabouts. Over width loads have a problem with vehicles to the side of them as well as fixed objects in the center.
5	That's right [don't like]
6	They are not made to turn short radius that fast.
7	What more can I say to describe the difficulties?
8	At local meeting we were told truckers would avoid the roundabouts thus causing problems elsewhere.
9	Long loads cannot fit physically in a single loop roundabout as they cannot turn through the circle if they have more than the first 45 degree turn.
10	Very big problem
11	I would agree that it makes it very difficult and risk property damage and getting stuck in the intersection
12	At the correct 'slow' speed with enough room, and no one on either side of the CVM, it is not a concern or problem.
13	If they can't get through don't use that road . They don't need roundabouts at every intersection
14	The states, counties and municipalities regulate the routes of OD [OSOW] loads and in a perfect world we would have to be routed out of the way - or in the real world we would be faced with blocking traffic
15	Addressed in earlier opinion citing lane infringement / safety concerns

Note: Only minor editing for grammar and spelling was performed for responses for clarification. Any words in brackets [ ] were added by the authors.

Authors'/researchers' comment: As previously stated, radii should be sufficient to accommodate needed OSOW, but no longer than necessary in order to maintain adequate deflection and safety for small vehicles.

TABLE 4.15
Summary of Views on the Roundabout Concern "Fixed Objects within the Center of the Roundabout Cause Problems" from OSOW Hauler

S.No	What are your views on the roundabout concern: 'Fixed objects within the center of the roundabout cause problems'
1	[It is a]concern
2	With girder and bridge beam the load crosses the center of the roundabout.
3	Visibility of vehicles or people that might be entering the roundabout, correctly or in the wrong direct (which I have had happen to me) are not visible, thereby increasing the likelihood of an accident
4	Fixed objects with limited clearance to the roadway are a problem with tight turn radii.
5	Yes [a problem]
6	Agree [a problem]
7	Bad idea; it cuts down full vision
8	The fixed shrubs and other fixed objects will be damaged over time as longer vehicles cannot go through without the trailer getting into the center of the roundabout.
9	If they are engineered larger, a fixed center should not be an issue.
10	you cannot drive through with large loads
11	Dependent upon height, potential of blocked view or distraction.
12	No problem . It stops someone from just "flying" straight though
13	No concern
14	Right on! [meaning of response not clear]
15	Traffic control devices and curbs/islands would increase turning radius of larger vehicles creating lane infringement to the right. Monuments/Signs would obscure vision.

Note: Only minor editing for grammar and spelling was performed for responses for clarification. Any words in brackets [ ] were added by the authors.

Authors'/researchers' comment: Considerable discussion and illustrations contained in chapters 5 and 6, will stress the point that to accommodate many OSOW, there needs to be sufficient clear areas, which in some cases means little or no" hardware" in the central island like, flagpoles statues, etc. Also, there is a need in some areas for signs that can be easily removed for the passage of OSOW. Again, these concepts and illustrations are contained in chapters 5 and 6.

TABLE 4.16
Summary of Views on the Roundabout Concern "Slopes of Circular Roadway and/Truck Apron Cause Fear of Overturning" from OSOW Haulers

S.No	Views on the roundabout concern: 'Slopes of circular roadway and/truck apron cause fear of overturning'
1	[It is a] concern
2	Curbs need to be mountable to prevent tire damage and load shift and never over 4' high.
3	Depending on the slope and angle there is a substantial risk of overturning the vehicle as opposed to operating in a straight line.
4	I have not seen a roundabout design where that was a concern.
5	[It is a] minor issue
6	If the truck slows down, there should eliminate the chance of turning over
7	Agree [It is a concern]
8	I do not like when riding my motorcycle makes turning difficult especially when intersection full of sand or gravel [Not clear meaning for trucks]
9	The higher the slope the more likely for a turnover. A high center of gravity loads and the tractor turned enough for the king pin deck to tip there is nothing preventing the trailer from tipping.
10	Again, Design and engineering
11	It is a real concern
12	Yes, The angle of the slope could affect the center of balance of the load.
13	If you have that much slopes you should not build a roundabout
14	Roundabouts have no place in rural settings so speed should not be a factor.
15	Not a condition that we've experienced, slow and steady would have to be the rule.

Note: Only minor editing for grammar and spelling was performed for responses for clarification. Any words in brackets [ ] were added by the authors.

Authors'/researchers' comment. Roadway and truck apron slope and crown, or sloped circulating lanes are things that need more study. There are varying views on these roundabout *attributes and not everyone agrees on a best solution. As stated previously, Wisconsin has studied this issue and developed some guidelines and policy which will be presented in chapter 5.*

TABLE 4.17
Summary of Views on the Roundabout Concern "Drivers Do Not Understand What the Truck Apron Is for and Need Education" from OSOW Haulers

S.No	Views on the roundabout concern: 'Drivers do not understand what the truck apron is for and need education'
1	[It is a] concern
2	Name two states that roundabouts are mentioned in their driver's manual!
3	Most drivers do not know how to operate their car around trucks already; putting them in a tight, turning environment is not safe.
4	I addressed that earlier- it is a very serious problem.
5	we are just seeing more roundabouts. Fortunately we don't use them regularly.
6	Agree [Truck drivers do not understand apron use]
7	TRUE[Truck drivers do not understand apron use]
8	Drivers are trained not to drive on curbs and to swing wide for corners. Both of these rules are compromised when a trucks goes into a roundabout.
9	No need, [Use of truck apron] should be self explanatory.
10	I think the drivers understand that already. If it is paved my drivers use the space to maneuver already
11	The main concern should be to educate all drivers, not just the CVM operators.
12	Good luck. You will never get car to understand the amount of room it takes for a long truck. [Not clear how answer relates]
13	No comment
14	Drivers of large vehicles typically have a much better understanding of the space constraints created by road design and traffic patterns than drivers of smaller vehicles. [Not clear how answer relates]

Note: Only minor editing for grammar and spelling was performed for responses for clarification.

Authors'/researchers' comment: It is apparent in the answers in Table 4.17 that even truck drivers disagree on whether use of the truck apron is understood. As indicated in some *answers, and the authors agree, there definitely is a need for more extensive roundabout education to all drivers throughout the United States.*

TABLE 4.18
Responses to Question 29 from OSOW Haulers "Please Add Any Additional Concerns You Have about Roundabouts That Were Not Mentioned in Questions 23 to 28."

S.No	Please add any additional concerns you have about roundabouts that were not mentioned in Questions 23 to 28:
1	[Heavy] Traffic volumes through roundabouts during certain times of the day.
2	Poor place for motorcycles. More close calls at roundabouts than any other intersection I drive through [Motorcycles and trucks ?]
6 to 10 3	Cars have an issue with roundabouts especially if there is a truck already in the process of moving within the circle. The rule seems to be to cut off the truck before getting trapped behind it.
4	I would like to see federal guidelines on state routes allowing commerce
5	General public education needs to be addressed. The benefits of reducing the potential contact points between two vehicles from 32 to 8 becomes mute when the motoring public actions don't change.

Note: Only minor editing for grammar and spelling was performed for responses for clarification. Any words in brackets [ ] were added by the authors.

Authors'/researchers' comment: The comments in Table 4.18 are generally good and the authors generally agree with them.

TABLE 4.19
Summary of responses to question 38 "Do You Make Adjustments to Routes If the Routing Contains an Intersection You Are Unable to Negotiate, and Do You Report the Adjustment?"

Do you make adjustments to routes if the routing contains an intersection are unable to negotiate, and do you report the adjustment?	All Respondents *Responses (%)*	Respondents who Use OSOW Permits *Responses (%)*	Respondents without OSOW Permits *Responses (%)*
Make Adjustments	16 (26.7%)	13 (72.2%)	1 (2.7%)
Do Not Make Adjustments	1 (1.7%)	0	0
Report Adjustment	5 (8.3%)	5 (27.8%)	0
Do Not Report Adjustment	3 (5%)	2 (11.1%)	0

FIGURE 4.6
Summary of Question 40 for OSOW Haulers "Do You Use Your Own Escort, or Do You Use a Certified Escort Service?"

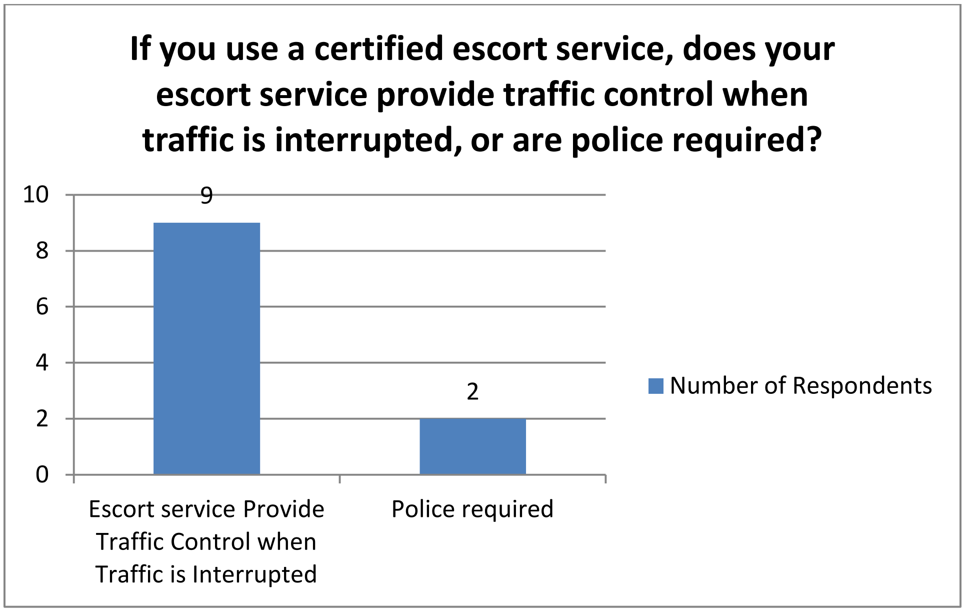


FIGURE 4.7
Summary of Question 41 for OSOW Haulers, "If You Use a Certified Escort Service, Does Your Escort Service Provide Traffic Control When Traffic Is Interrupted, or Are Police Required?"

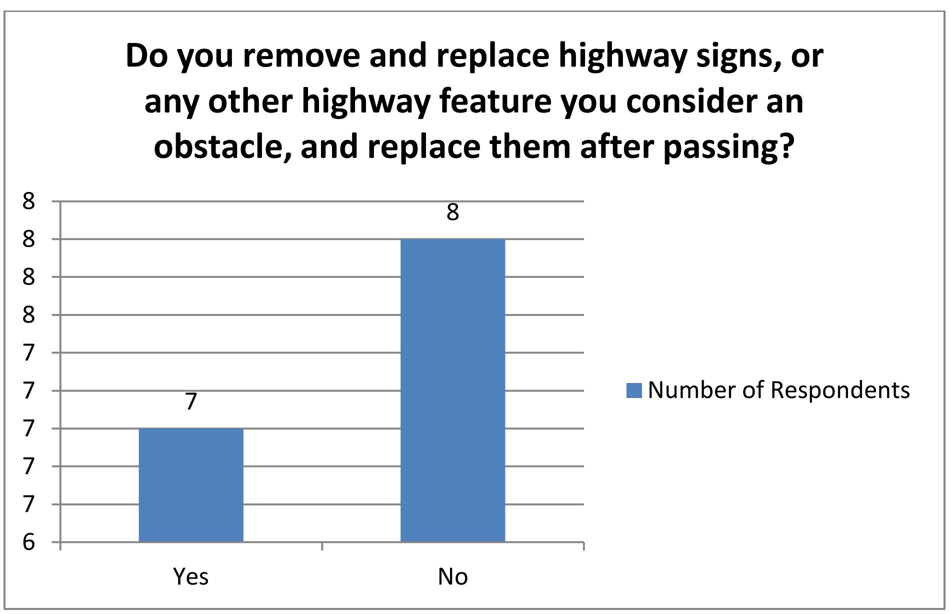


FIGURE 4.8
Summary of Responses to Question 43 from OSOW Haulers, "Do You Remove and Replace Highway Signs, or Any Other Highway Feature You Consider an Obstacle, and Replace Them after Passing?"

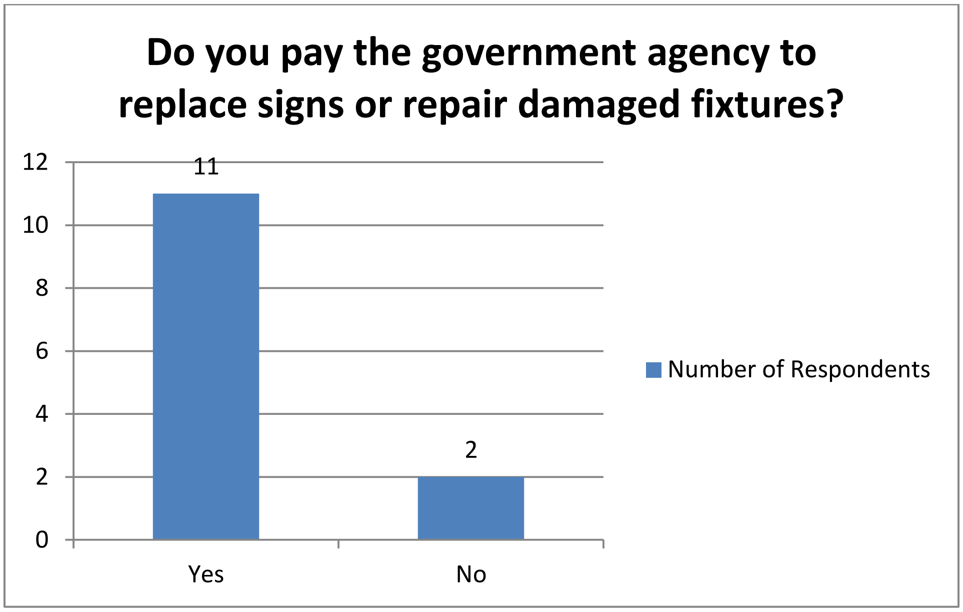


FIGURE 4.9
Summary of Responses to Question 44 for OSOW Haulers, "Do You Pay the Government Agency to Replace Signs or Repair Damaged Fixtures?"

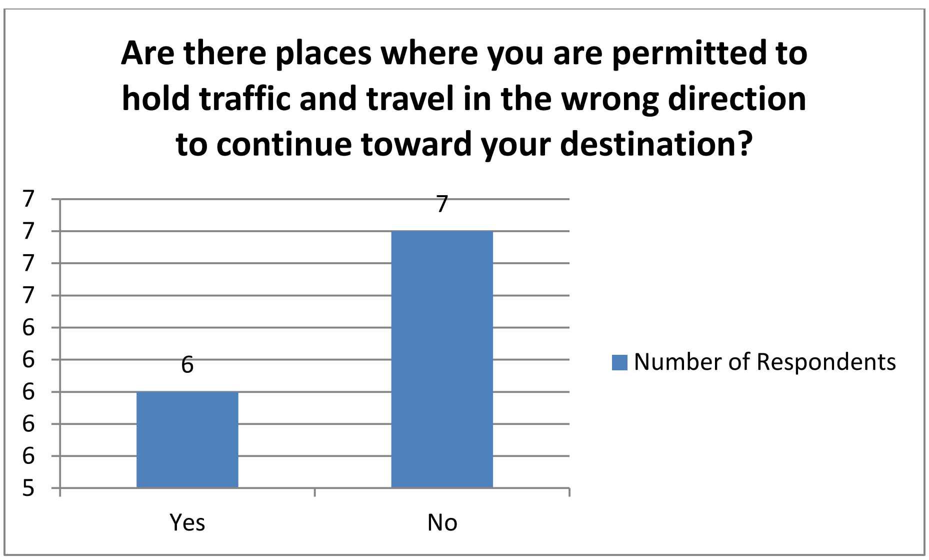


FIGURE 4.10
Summary of Responses to Question 45 for OSOW Haulers, "Are There Places Where You Are Permitted to Hold Traffic and Travel in the Wrong Direction to Continue toward Your Destination?"

Authors'/researchers' comment: Figures illustrating respondent answers in Figures 4.6 through 4.10 should be self-explanatory. These relate to the concept of accommodating OSOW *through roundabouts by counter flow. In some cases, this allows them to flow clockwise through part of the roundabout. This concept is discussed and illustrated in chapters 5 and 6.*

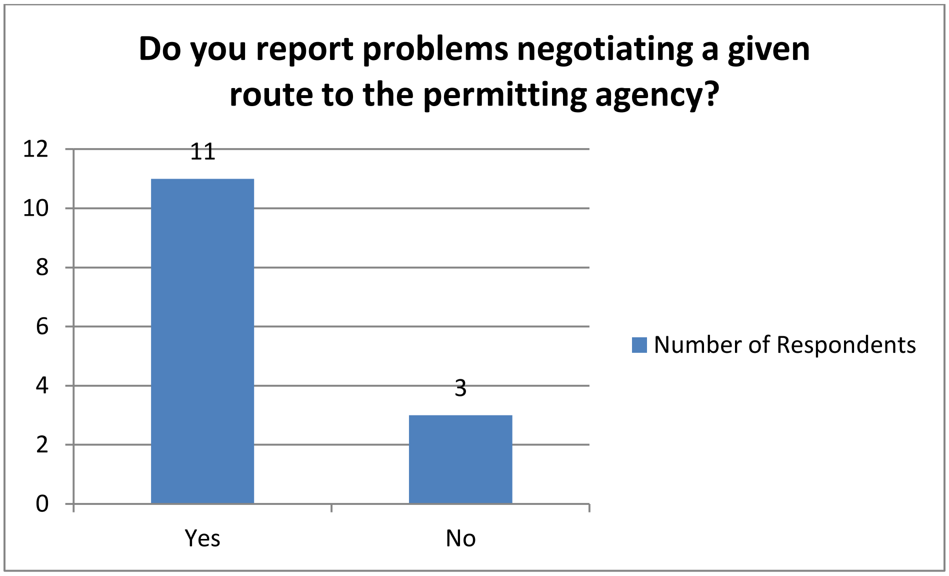


FIGURE 4.11
Summary of Question 46 for OSOW Haulers, "Do You Report Problems Negotiating a Given Route to the Permitting Agency?"

4.8 Authors' Concluding Comments on Survey 4

Although not as specifically directed, as much as hoped toward specific OSOW restrictions and their solutions, and lack of many constructive suggestions and due to the limited response of OSOW haulers and drivers, the authors feel the responses provide some additional insight. If not additional insight, at least it reinforced some of the "problems" uncovered by the authors throughout the literature review, other surveys and personal contact with designers experienced in accommodating OSOW. It is clear the majority of respondents, particularly non-OSOW respondents, do not like roundabouts. It is not clear, and one can only speculate, how representative this particular sample is of the hundreds or thousands of truck drivers throughout the United States. On one hand it could be the general feeling; on the other hand, it may be a small sample overrepresented by a biased group who saw an opportunity to vent their anger over some real or perceived problem they have had with a roundabout that possibly could have been better designed for heavy truck traffic and OSOW. The authors are of the firm opinion; however, for continued roundabout growth with its many benefits of safety, operational efficiency, environmental benefits, and others, the needs of all users need to be considered. Only a few roundabouts, inadequate for large trucks and unable to accommodate OSOW on necessary routes, could cause concern among influential members of the trucking industry and, should politicians get involved (as in Oregon), have negative consequences on roundabout growth and the thousands of lives they could save compared to other intersection traffic control. This obviously includes not only OSOW, but also heavy trucks in some cases.

Chapter 5: OSOW Turning Movements and Mitigation Strategy Examples

5.1 Overview of Chapter 5

The authors emphasize this report is not intended to be a design guide. The purpose of chapter 5 is to provide examples found in the literature, surveys, and personal contacts. The objective is to provide an example of ideas and concepts that could be considered. It would be wasteful for OSOW to be used as a design vehicle, as in most cases their need to be accommodated is infrequent. However, a roundabout designer should know the size, turning characteristics, and frequency of OSOW allowed on the route. This could be routine if all states had an OSOW freight network and check vehicles such as Wisconsin. This is discussed in more detail in sections that follow.

It is obvious from the surveys, particularly survey two, that categorizing characteristics of OSOW affected by current, common roundabout geometrics is relatively straight forward. Quite simply, the impedances to allow the free flow of OSOW make all desired movements through a typical roundabout, i.e. to enter on any given leg and exit on any other given leg, can be generalized in just two categories: 1. unobstructed, horizontal clearance in the OSOW's turning path; and 2. limited vertical clearance throughout the turning path of 3 inches or less. Some states and designers use 4 inches or less; and the authors are sure that roundabouts exist with vertical components greater than 4 inches. The authors believe 3 inches should be considered. This will be discussed in more detail in a later section.

Based on material gathered for this study, surveys, and interviews, an ideal theoretical solution would be as follows: a large, 150 feet to 200 feet, roundabout with an elevation no more than 3 inches above the roadway. It should be possible to accommodate OSOW at roundabouts with widened entries and exits, unobstructed central islands with large truck aprons, outer truck aprons, bypass lanes, and lanes through the center island, mountable curbs, no vertical obstructions on the splitter islands, and easily mountable curbs of 3 inches or less with signs, light poles, etc. outside of the turning paths and/or designed to be easily removed. The greater challenge is to design them in such a way to allow the splitter island curbs and central island to be retained to preserve deflection and the ability of the roundabout to control speeds, thus maintaining the safety benefits of roundabouts. Also, since speeds generally increase with roundabout size, they should be designed no larger than necessary in order to maintain their safety benefits.. Available right-of-way (ROW) and cost are also a consideration in keeping the size only as large as it needs to be.

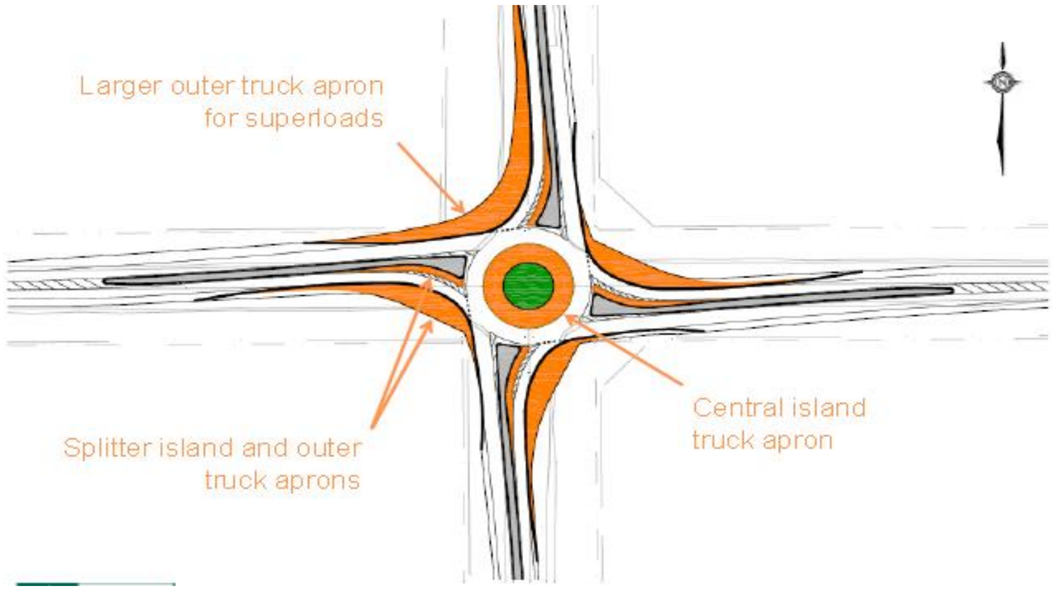
5.2 General Accommodation Ideas

In their response to survey two, Washington responded with these suggestions:

- Mountable curbing,
- Removable signage,
- Addressing stationary landscape features, and
- Larger radius design to accommodate longer vehicles.

In regard to the suggestions above, they are consistent with truckers concerns presented in the surveys, For example based on all surveys conducted on this study, curbs, and associated vertical ground clearance and tire wear, were mentioned many times. It is clear that curbs are considered a major problem. Likewise, common complaints in the surveys were related to not having enough horizontal clearance due to signs and stationary features being in the path. Several comments indicated a belief by truckers that roundabouts are too small, should be bigger, should have wider lanes, etc.

In a recent presentation at a tech conference in Canada, the following treatments were used in a case study roundabout design to accommodate OSOW (Weber 2011): a wide central island, truck apron, splitter island truck aprons, outer truck aprons, and a median pass through. Here again the concept is to provide a clear path free from mountable obstacles for the movement of the OSOW vehicle. The illustration below shows some of these principles. In chapter 6 of this report, there are several more illustrations of this type using OSOW check vehicles.



(Source: Phil Weber 2011)

FIGURE 5.1
Illustrating Truck Aprons for OSOW

5.3 Summary of OSOW Efforts in Wisconsin Related to Roundabout Designs (Lynch 2011)

The Wisconsin Department of Transportation (WisDOT) has established an OSOW freight network within the state, which is a subset for the larger, broader truck routes in the state. The network includes limited-access facilities such as interstates and expressways. The network has some impediments such as low bridges, weight restrictions, as well as interchange and intersection limitations (skewed intersections or left turns at diamond interchanges).

WisDOT is currently in the process of incorporating the OSOW freight network into planning and design manuals. The goal is to find a balance between the safety benefits without impeding freight movements. In short, if loads could get through before, the design needs to make sure it still can get through post construction without making huge intersections and exceeding acceptable budget limits. Most accommodation happens within the project limits right-of-way.

A remaining challenge is the left turn at interchanges for OSOW getting on or departing from the limited-access facility (typically diamond interchanges). Some mitigation examples deployed by WisDOT to date include the following:

1. Wide truck aprons (12 feet or more) with minimum slope and mountable curb,
2. Custom center island to address known left turns ,
3. Tapered center island to support through movements,
4. Paved area behind curb (right side for off-tracking),
5. Installing removable signs and set-backs for permanent fixtures (light poles),
6. Allowing trucks to cross over medians (stamped, depressed, or corrugated) in a counterflow direction before the roundabout to make a left turn in the opposing lane and then cross back over after the turn, and
7. Right-turn lanes (sometimes gated).

5.4 Kansas State Highway Roundabouts

Kansas has arguably been a leader of installing roundabouts at the intersections of high-speed state highways, i.e. most with at least 65 mph approaches. Figure 5.2 shows the roundabout near Paola, Kansas, which is typical of Kansas roundabouts on state highways. Although single lane, they are generally large with a flat unobstructed central island and work quite well on routes with very heavy truck volumes, some as high as 40 to 60%. Their mountable curbs and low vertical clearance should also accommodate many OSOW vehicles. Figure 5.3 shows a house being hauled through the roundabout. As pointed out in Chapter 2, the FHWA guide (2nd ed. 2011) points out that for locations with a high volume of truck traffic, special considerations may be given to the size of the roundabout to accommodate large vehicles, such as a WB 67, without requiring a large truck apron. The guide uses one of these in Florence, Kansas, as in the example shown as Exhibit 6 – 20 in the guide. The state of Kansas has a number of these at intersections of state highways with high truck volumes.

(Source: KDOT Photo)

FIGURE 5.2
Typical Kansas Roundabout at the Intersection of Two State Highways near Paola, Kansas

With open spaces on the central island, there's no reason to believe that most OSOW could not navigate the roundabouts. Signs would have to be moved and light poles might be a consideration for some movements of OSOW. This roundabout was part of a KSU study of 11 Kansas roundabouts and the conclusion was that both safety and operations were significantly improved for all vehicles.

Figure 5.3 shows a house that was moved through this particular roundabout north of Paola. Signs did have to be moved. A discussion of the benefits of removable signs where OSOW may need to be accommodated is included below and one is shown in figure 5.6.

(Source: KDOT photo)

FIGURE 5.3
Removing Signs to Allow a House to Pass through the Paola Roundabout

Figure 5.4 shows a wind generator tower section (one of the longest loads on Kansas highways approximately 135 –foot) traversing the roundabout at Florence, Kansas at the junction of two state highways. These relatively large roundabouts work well on Kansas highways with very heavy truck volumes (as high as 40%) and occasional OSOW. The only known problem with these roundabouts is shown in Figure 5.5. The truck aprons could possibly have been wider. However, it is felt that normal truck traffic would not have to go over the inside curb of the truck apron and this problem is perhaps driver carelessness. Section 5.4 presents a possible solution.

(Source: Steve Bass 2012)

FIGURE 5.4
Wind Generator Tower Section Section Going through Kansas Roundabout at Florence

(Source: KDOT Photo)

FIGURE 5.5
Truck Tracks Inside of Truck Apron and Center Island

In places where signs need to be removed, it would speed the process to have some system of sign or signs that could be easily removed. Figures 5.6 and 5.7 b show such a sign. There are likely to be other systems that would work well. It could be that additional research is needed on this subject to find a suitable system. All OSOW should be escorted, so having an escort remove the sign and replace it should be no serious obstacle as long as the sign could be quickly and easily removed and replaced.

(Source: Brain Walsh, Washington State DOT)

FIGURE 5.6
A Removable Sign on Roundabout Splitter Island

(Source: Brian Walsh, Washington State DOT)

FIGURE 5.7
Close-Up of Removable Base on Sign in Figure 5.5a

5.5 Use of Stabilized Soil

5.5.1 Off Tracking

Rutting problems caused by off-tracking could possibly be prevented by using a soil or turf stabilization system of suitable strength to sustain the prevailing truck loads over grass. Such a system is shown in Figure 5.8. Design details, load capabilities and cost are beyond the scope of this report but should be thoroughly checked out.

(Source: Bill Klingbeil, HR Green)

FIGURE 5.8
Cut-Away Illustration of a Turf Stabilization System Capable of Supporting Heavy Vehicles

5.5.2 Center Island Stabilization

The authors believe that in some cases consideration should be given to allowing OSOW to travel the straight through a roundabout on a paved road with suitable geometrics and load-bearing capacity. This could be by ordinary pavement design for the expected OSOW axle or wheel loads, or by a stabilized turf path. (Roads through roundabouts will be discussed and illustrated in another section of this report.)

This concept could be taken one step further and have a level central island which is all or mostly paved with a stabilized turf. The authors have seen roundabouts in Australia with a center island which is a round, level pad of concrete, one or two inches above the pavement. If no signs, light poles, etc. were in the way, or if they were designed to be removable, OSOW could go straight across. An example of this concept used in the United Kingdom is presented in Figure 5.9.

(Source: David Collett, Collett & Sons Ltd.)

FIGURE 5.9
An Example from the UK of a Turf-Stabilized Center Island

A stabilized turf system which allows OSOW making certain movements to go straight across the center island in the area circled by red.

The photo in Figure 5.9 was sent by the manager of an OSOW hauling company in the United Kingdom. He pointed out that local councils design removable road signs, chevron markings, and so forth from roundabout central islands on routes commonly used for heavy transport (OSOW) and he states that:

> In some cases, the council simply puts ‘grasscrete’ (see link for details of one type: http://www.grasscrete.com/docs/paving/grasscrete.html) straight through the RB [roundabout] so that the heavy transport don’t have to navigate around but simply run through. The fact that it is grasscrete means that the grass can grow and looks good, but can support heavy axle loads. Usually these are designed so that no street furniture has to be removed” (Collett 2011).

To provide some idea of the carrying capacity of grasscrete mentioned in the above e-mail, their website states that grasscrete has a load-bearing capacity of up to 40 tonnes [metric unit] or approximately 88,200 lbs. (one tonne equals approximately 2205 pounds) gross vehicle weight. (Grasscrete 2012) There is no information on how axle configuration or spacing might affect the capacity or wheel loading and the carrying capacity would have to be strengthened for some OSOW.

5.6 OSOW Accommodation of OSOW with Wide Aprons

The FHWA Roundabout Guide (NCHRP 672) points out that truck aprons should be designed such as they are traversable to trucks but discourage passenger vehicles from using them. They should generally be 3 to 15 feet wide and have a cross slope of 1% to 2% away from the center island. To discourage use by passenger vehicles, the guide states the outer edge should be raised approximately 2 to 3 inches above the traveled way and be of a different material than the traveled way.

The authors believe that wide truck aprons – or in some unique or special cases a central island that is essentially all truck apron as in Figure 5.10 can have benefits in accommodating OSOW. Figure 5.11 is another example of an advantage to a wide truck apron. This roundabout could almost be called a mini roundabout if the very small patch of landscaping in the center were solid apron and splitter islands removed. The writer of this report has spent many hours watching the operation of this roundabout and never witnessed a problem with small vehicles cutting across the apron. On one occasion a large fire truck was observed cutting across the roundabout. With the geometry and elevation of the apron about 2 inches, there is no reason any OSOW vehicle could not also cut across this roundabout.

(Source: Russell 2000)

FIGURE 5.10
Roundabout North of Baltimore - Almost All Truck Apron

(Source: Ritchie 2011)

FIGURE 5.11
Advantage of Wide Truck Apron in Arizona

Figure 5.12 shows a highway in an urban setting urban where an OSOW approaching the intersection would have a good chance of negotiating the intersection. Notice also, the external apron on the right.

(Source: Ourston Roundabout Engineering 2010)

FIGURE 5.12
GE Roundabout in Green Bay, Wisconsin, Modified for OSOW

Figure 5.13 shows a roundabout in a downtown area in Glen Falls, NY with a wide apron at the intersection of two state highways. It was designed for large trucks and not necessarily for OSOW. Although the authors did not check this location with any turning software, it is possible it could accommodate some OSOW on some movements.

(Source: Creighton Manning, in Russell et al., December 2011)

FIGURE 5.13
Five Leg Roundabout in the Heart of Downtown Glen Falls, NY

Figure 5.13a shows an OSOW taking a left turn at a roundabout with a wide truck apron in Grenwich, NY. In this case, the trailer is hauling a housing module 75’ long and 13’ wide. A video of this movement showed that the OSOW made the turn with no difficulty.

(Source: McCullough 2011)

FIGURE 5.13a
Long, Wide OSOW Making a Left Turn at Greenwich, NY Roundabout

In Australia, one author has seen highway intersections where the central island was a level pad of concrete, raised about two inches. An example in an urban location is shown in figure 5.14. Note that the splitter islands would also be traversable by a large truck and some OSOW. This concept would be the same as having a center island that is all truck apron, all pavement or stabilized soil, center island as shown in Figure 5.9 using “grasscrete” or with some system such as shown in Figure 5.8. Additional reasons for considering this concept are illustrated in Chapter 6.

(Source: Google Source: Andrew O’Brien, Consultant, Melbourne, AU)

FIGURE 5.14
Australian Roundabout with Low Concrete Central Island

Designs such as shown in Figures 5.15a and 5.15 b was specifically designed to accommodate specific local OSOW whose turning needs were field tested. These particular figures were captured from a video that showed a sizable OSOW making a U-turn in the roundabout with no problem. In Figure 5.15 – right - note the internal truck apron or bulb-out at the entry. The apron allows the OSOW to go over it, yet maintains deflection and speed control for other, smaller vehicles.

(Source Owen, Reid, Middleton 2011)

FIGURE 5.15a
A Roundabout Designed for a Specific, Local OSOW

(Source Owen, Reid, Middleton 2011)

FIGURE 5.15b
Entrance of Roundabout in 15a, Designed for a Specific, Local OSOW

As pointed out in section 3.5.4.1 of the roundabout guide (2-12) , large roundabouts designed for WB-67 (and possibly OSOW) with truck aprons, may be appropriate on state highways . The guide uses Kansas as an example and shows one of the Kansas roundabouts on on a high-speed highway in the guide Exhibit 3-20.

5.7 Apron Details

5.7.1 Relationship to Surveys

In all four surveys, particularly the survey is from industry, one thing that stood out as a "problem" was curbs. A number of respondents indicated concern over curbs and curb height. Although it was a disappointment to the authors that none of the respondents from industry would specify a maximum curb height, there were negative comments about having to ride up on curbs and also their effect on tire wear.

From the literature and personal contact with designers, the authors are of the opinion that many designers and states use a mountable curb and 4 inches as a maximum curb height. Studying the literature, analyzing the surveys and some personal contacts the authors believe that it would be better for both large trucks and OSOW if the maximum curb height was 3 inches. The authors also believe that 3 inches would be sufficient to properly direct all vehicle drivers and deter them from going off on truck aprons. The authors believe the latest roundabout guide should be strictly followed. As stated in the roundabout guide:

> To discourage use by passenger vehicles, the guide states that the outer edge should be raised approximately 2 to 3 inches above the travel way and be of a different material than they traveled way. (NCHRP 672 2011)

The roundabout guide also addresses the issue related to cross slope and vertical design of the truck apron. Section 6.8.7.4 of the roundabout guide covers truck aprons. It includes Exhibits 6-66 and 5-77, showing typical roundabout cross sections with a truck apron for crowned and non-crowned roadways. It also addresses vertical design concerns to check for lowboy type trailers

> The vertical clearance can be reviewed by drawing a chord across the apron in the positionwhere the trailer would sweep across. In some cases the warping of the profilealong the circulatory roadway can create high spots that could cause trailers to drag or scrape along the truck apron. (NCHRP 672 2011)

The roundabout guide goes on to point out that a variety of different curb shapes are used throughout the U.S. to meet the needs of individual state agency specifications. In Exhibit 6-78 the roundabout guide shows examples of sloping truck apron curb shapes used in the U.S.

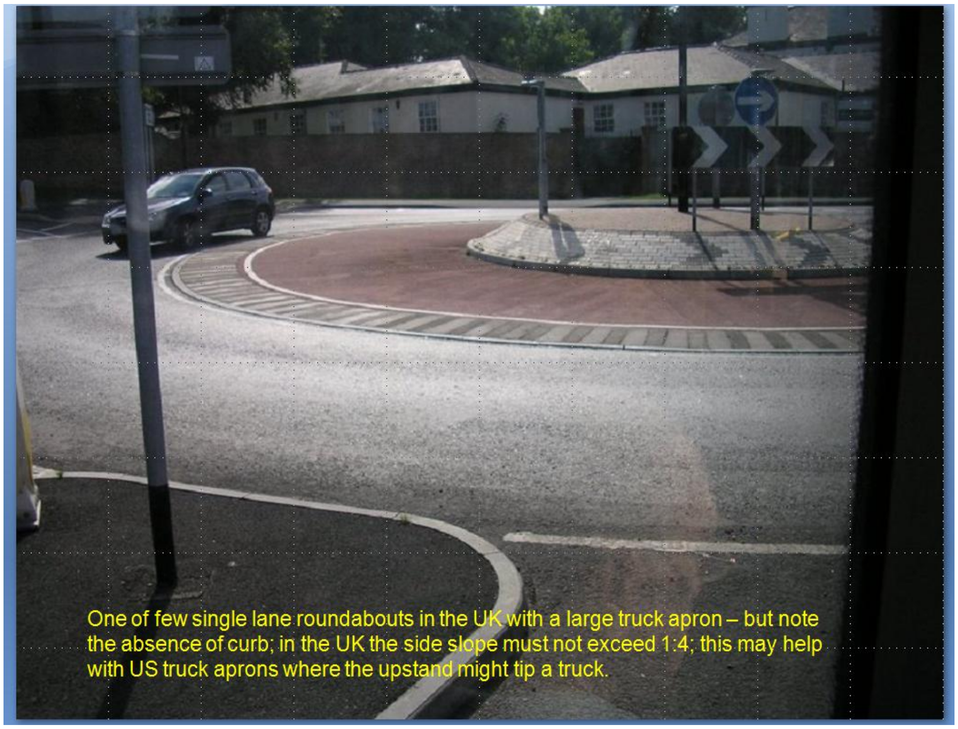
Oregon DOT is currently proposing, in their revised design manual, to only use their "low profile" mountable curb modified to 3 inch rise over a 12 inch run for roundabout aprons. Their regular low profile curb is 4 inch rise over 12 inch run. (Crossler-Laird 2012)

The state of Wisconsin has recently studied addressed the issue of lowboy vertical clearance and the results and added new sections to their design manuals. These are included below in this report in section 5.10.3, Wisconsin's Vertical Profile Guidelines.

One thing is certain in the authors' minds is that a great deal more attention needs to be paid to maximum height, and curb design in general. Some examples from Europe presented below should be considered. In general, examples from Europe appeared to have curbs on the truck aprons with lower heights than most in the United States and more easily mountable. One idea that deserves merit and some thought is the idea of discouraging drivers of smaller vehicles with rumble strips or rough surfaces rather than height.

5.7.2 A UK and European Examples

As shown in Figure out 5.16, the truck apron on the single Lane roundabout in the UK does not have a low curb, it has no curb. Notice via rumble strips around the edges the truck apron. This should deter drivers of small vehicles. Granted, there is no proof of this in the United States and some research on some trial applications might be of value. However, there is a roundabout in Junction City, KS which has a central island with rumble strips around to discourage drivers and no curb. No definite results are available at the time of this writing.



(Source: Clive Sawyers)

FIGURE 5.16
Low Truck Apron in the UK

In the Netherlands, it is recommended that the truck apron be separated from the circulating lanes by a rumble strip rising 7 cm (2. 8”) over the lateral dimension of 10 cm (3.9”). It is believed that this will prevent cars from using the apron will not present a major obstacle to trucks. (Fortuijn 2012) An example of an example of this is shown in figure of 5.17. The curb rise is approximately 2.8” (7cm) over a length of 3.9inches (10cm). The truck apron surface is cobblestone. Another example of cobblestone material used in an external truck apron is shown in figure 5.18. In this picture figure what is referred to as an “armpit”, in the US would be called an “outer truck apron” as illustrated in Figure 5.1 above.

10cm=3.94”   7cm=2.75”

(Source: Fortuijn 2012)

FIGURE 5.17
Cobblestone Truck Apron in Netherlands Showing Curb Height and Slopes

(Source: Fortuijn 2012)

FIGURE 5.18
Cobblestone External Truck Apron in the Netherlands

In Germany truck aprons appear to be similar. Figure 5.19 shows a large truck on a truck apron on a relatively small, single lane roundabout. Note the low curb and cobblestone type material on the truck apron. The authors believe this following the concept of low, mountable, cobblestone rumble strips and or rough surface materials similar to cobblestones could be used more to deter encroachment by drivers of small vehicles, rather than a higher curbs and the relatively smooth truck apron material used in the United States.

(Source: Werner Brilon)

FIGURE 5.19
Low Cobblestone Truck Apron in Germany

5.8 Roundabout Operational Issues

Figure 5.20 is a slide showing some roundabout operational problems. In our second survey, one problem mentioned was that truckers felt roundabouts were too close together. The distance of 300 feet apart was mentioned as a minimum by one respondent. Without data or known research, it seems that as long as the distance between the exit of one and the entrance to the next is greater than the longest "operational" length of an OSOW, i.e. giving it sufficient length to "straighten out," there should be no problem from two or more roundabouts in succession. There should probably be some research on this because roundabouts in corridors are becoming more common. However, this is beyond the scope of this particular project.

Figure 5.20 does show that vehicles have gone over the right side curb. The inset shows a solution to that, which is paving or an "outside truck apron," sometimes called a bulb-out or other names. However, in regard to terminology, an outside truck apron probably refers to one on the outside of the curb and a bulb-out to an apron on the entry leg side of the entry or exit (shown in Figure 5.20).

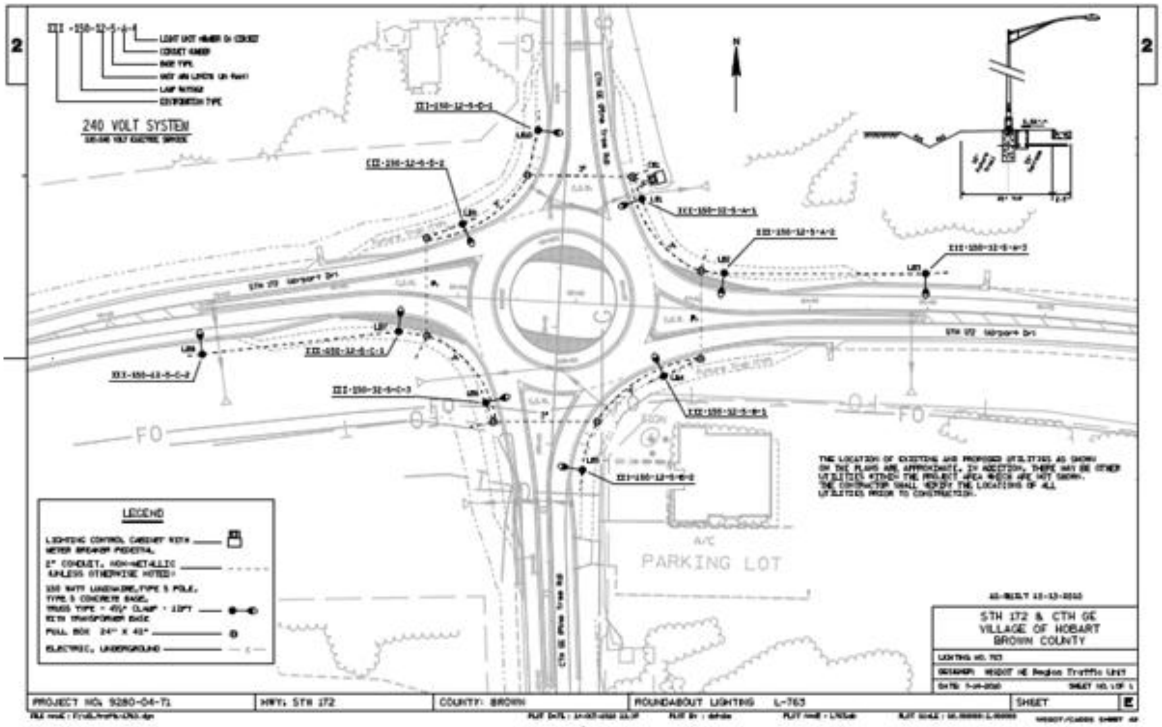
One thing to note in Figure 5.20 is the WisDOT sign. Some respondents in the survey indicated staying in lanes in a roundabout was a "problem." In some states it is law. Truckers worry, should there be a crash and they are out of their lane, they could be liable. This makes no sense to the authors of this report because no one expects large trucks to stay in their lane at a traditional intersection. FHWA has a safety campaign advising vehicle drivers to stay away from turning trucks at traditional intersections because of their wide turns, off-tracking, etc. The authors know of no logical reason why trucks should be required to stay in their lane in or through a roundabout.

In a case in a Midwestern city, brought to the researchers' attention, an OSOW was legally permitted on a route with a roundabout that appeared to be incompatible with accommodating the OSOW (Ball 2011). The vertical clearance was inadequate and the OSOW tore up some of the apron. The driver was ticketed for dangerous driving, supposedly for being out of his lane. The city billed the OSOW company for $40,000 for damage to the roundabout. The company intends to fight the charges and costs in court and it should be an interesting case.

(Source: Ritchie and Butch 2011)

FIGURE 5.20
Operational Issues of Some Roundabouts and Turning Movements

Figure 5.21 shows a modified, oblong central island and orientation, allowing extra paving or an apron to make room for the turning path of a designated OSOW movement for which this particular roundabout was designed. (Chapter 6 includes a number of similar illustrations developed by the authors.)



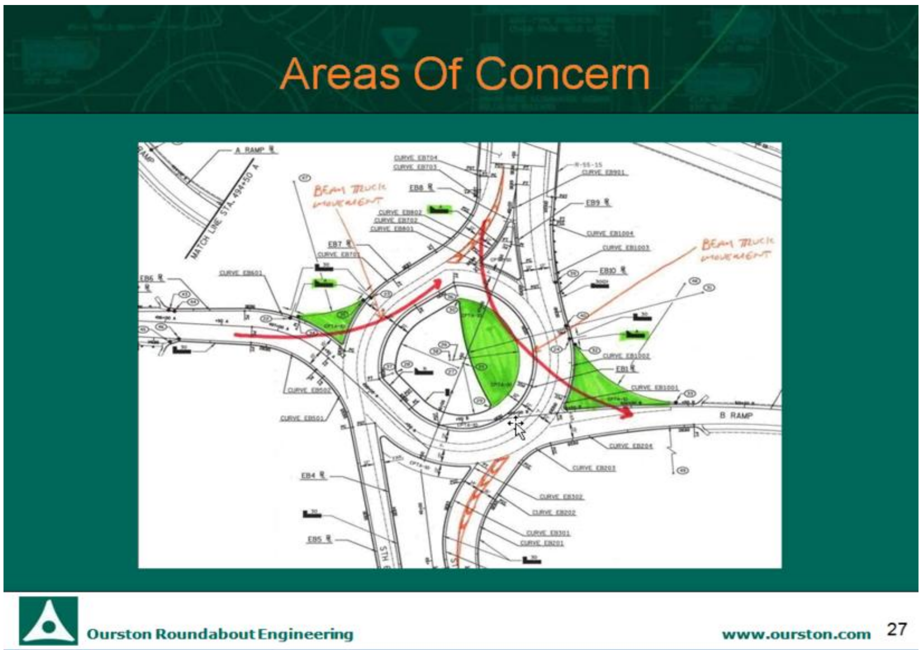
(Source: Ourston Roundabout Engineering)

FIGURE 5.21
Diagram Showing Narrowed Central Island and Additional Truck Apron Width for OSOW

5.8.1 Accommodating OSOW by Counter Flow

Also, as shown in Figure 5.22, if vertical clearance is limited in the intended paths, i.e. to 2 to 4 inches, and landscaping obstructions in the center island are kept to a minimum, there is no reason why OSOW cannot make almost unlimited paths if counter flow is needed and allowed. The green areas show where extra truck aprons (or possibly stabilization) would be necessary. Generally, in many cases, providing for counter flow in and through a roundabout allows sufficient accommodation for OSOW with a relatively smaller roundabout. (This concept is illustrated further in chapter 6.)

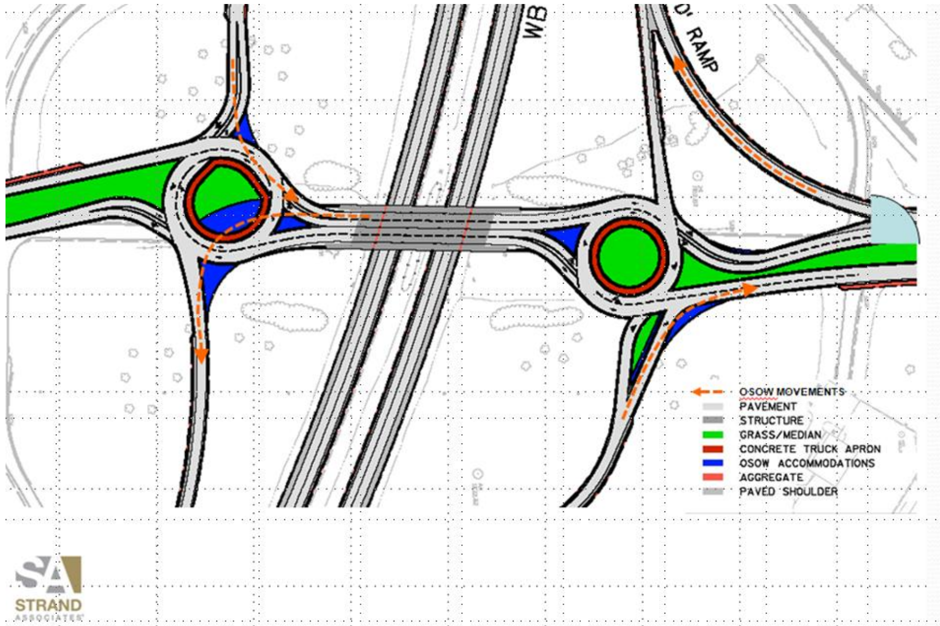
Of course, traffic control stopping other vehicles in the roundabout would be necessary. Although it is beyond the scope of this particular project, there needs to be a study of states' laws and/or policy in this regard. Anecdotally, the authors have heard conflicting information on whether it is illegal in some states for a truck to do this, i.e. go out of their lane or crossover a solid line to an adjacent.



(Source: Mark Lenters)

FIGURE 5.22
Slide Showing Schematic of Possible OSOW Turning Movements Through a Roundabout

Figure 5.23 shows a more complex double roundabout where accommodation is easily provided by allowing controversial movements. The extra truck aprons are shown in blue. Contraflow provides a simple solution for required OSOW movements to be accommodated, while keeping size and cost down (some illustrations of hypothetical comparisons are shown in chapter 6).



(Source: Josh Stratka)

FIGURE 5.23
Illustration of Accommodating OSOW at Roundabouts in an Interchange

The design concept illustrated in Figure 5.23, was a design for a Wisconsin interchange. The OSOW accommodation thought process is interesting:

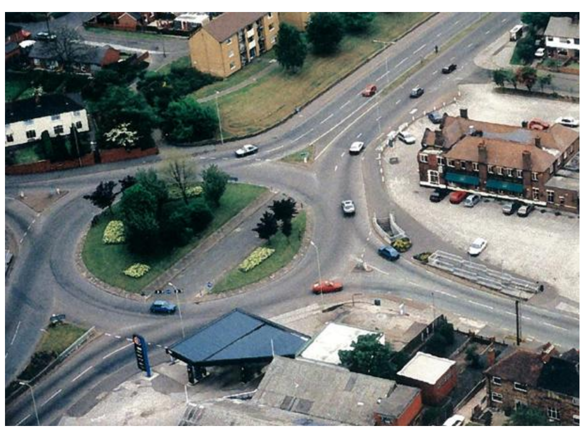
The Wisconsin IH 94/STH 65 interchange was designed with roundabout ramps at the WIS 65 overpass. Both IH 94 and WIS 65 were considered OSOW truck routes. The roundabouts were designed to accommodate an array of typical OSOW trucks. The design included a larger ICD (195’), six foot wide gored entries and additional circulatory roadway width. This interchange was also unique in that a concrete beam manufacture was located at the northeast corner of the interchange. This manufacture needed the ability to transport up to 165 foot concrete beams with a max haul truck length of 216 feet. To accommodate these trucking movements at these roundabouts the interchange included the following design details: (Josh Stratka)

1. Additional tracking pavement to both the central island and outer curb line locations

2. The creation of special truck turning templates in CADD turning software. The manufacture also tested the maneuverability of the design with a scaled model of the beam truck.
3. Located signage and lighting to avoid conflicts. Installed removable sign sleeves in the splitter islands and outside critical curb areas.
4. Installed mountable curbing for additional truck movements, where needed.
5. Paved island areas for truck tracking ability.
6. Set subtle grade changes throughout the roundabout intersections to minimize torque stress on the beams (Josh Stratka, Strand Associates).

5.8.2 Accommodating OSOW with Through Roads

Figure 5.24 shows a roundabout in the Netherlands with a road through the center to accommodate OSOW. Two caveats in regard to this design: 1. it only accommodates straight-through OSOW, and 2. the roadway through the center island needs to be barricaded so other vehicles cannot speed through the roundabout (Drivers in the Netherlands drive on the right as in the US).



(Source: K-State Roundabout sent by L.G.H. (Bertus) Fortuijn. 2012)

FIGURE 5.24
Roundabout Showing Straight-Through Path for Large Vehicles

It is possible to have a road through a roundabout for OSOW without having to barricade or gate it. For this concept, the OSOW needs to move to the opposite lane prior to entering to line up with an offset entrance to the road through the roundabout. Figure 5.25 shows a roundabout in the Netherlands where the roadway through the roundabout is offset such that a vehicle moves over to the left lane before entering the roundabout, and then the angled roadway leads to the correct lane as the vehicle exits the roundabout. This solves the problem of having to barricade the entrance to the roadway through the center island; however, this solution only accommodates OSOW going straight through the roundabout and requires traffic control. Since all OSOW in the US should be escorted, traffic control should be no problem.

(Source: K-State listserv, originally from L.G.H. (Bertus)

FIGURE 5.25
Roundabout Showing Offset Road through a Roundabout in the Netherlands

(Source: Fortuijn 2012)

FIGURE 5.26
Ground View Looking toward the Beginning of an Offset Road through a Roundabout

(Source: slides 2 and 6 from presentation by Fortuijn 2012)

FIGURE 5.27
An OSOW Going through a Small Roundabout in the Netherlands

Figures 5.28 through 5.30 show a typical small roundabout in Germany with a road for OSOW straight through on one movement.

(Source: Brilon)

FIGURE 5.28
Road Entrance of Straight through a German Roundabout

(Source: Brilon)

FIGURE 5.29
Road Exit of Straight through a German Roundabout

(Source: Brilon)

FIGURE 5.30
Road Close-Up of Road Straight through a German Roundabout

5.8.3 Further Comments on Accommodating OSOW Turns

5.8.3.1 General

The above material in this chapter has not specifically identified turns, except in section 5.6.1 Accommodating OSOW by Counterflow. The authors believe that the material in this section provides a powerful tool for any turning movement. In Chapter 6 of this report all possible movements, including counter flow movements are illustrated. It also should be kept in mind that wide aprons, or a low center island that is all apron, pavement or stabilized soil will accommodate almost all OSOW turns that can be made within the existing right-of-way.

5.8.3.2 OSOW Right Turns

Providing for OSOW right turn is perhaps the most straight forward. If a significant number of OSOW needs to be accommodated by a right turning movement, a special right turn lane or "slip lane" as it is sometimes called would probably be the most efficient, provided that right-of-way is available.

5.9 Temporary or Unique Situations

It has been stated previously in this report and by others and generally well accepted that it is economically wasteful for OSOW to be the typical design vehicle. However, should a specific OSOW be predictable and frequent in some area or on some routes, that would be an exception. This should be determined by area or statewide freight and OSOW study and planning. This section is about a unique, rare load of such magnitude that it would be wasteful of funds to provide permanent geometric accommodation.

In District 4 of KDOT, a 531,000 pound, 210.5 foot long, 19-foot high OSOW, a round abatement tower, as shown in Figure 5.31, needed to navigate the US-400 and K – 47 roundabout in Fredonia Kansas. This OSOW was situated on dollies with steerable axles.

(Source: KDOT)

FIGURE 5.31
531,000 Pound, 210.5 Foot Long, Round Abatement Tower Approaching the Roundabout at Fredonia, Kansas

This huge load was accommodated by placing a large mat of composite material on the East and West approaches to the single Lane roundabout enabling the OSOW to enter and exit the circulatory roadway with no damage to the concrete curbing in the medians. The process of placing the temporary mats is shown in Figures 5.31 and 5.32.

(Source: KDOT)

FIGURE 5.32
Two Photos (a-Left, b-Right) of Placing Temporary Mats to Accommodate the 531,000 Pound, 210.5 Foot Long, Round Abatement Tower at the Fredonia, Kansas, Roundabout

(Source: KDOT)

FIGURE 5.33
Photos Showing the 531,000 Pound, 210.5 Foot Long, Round Abatement Tower Successfully Exiting the Roundabout

The operation of getting this above OSOW through the roundabout, including preparations for his arrival and the restoration activities following its departure, began around 7 AM and continue this until about noon. The highway was closed to through traffic at Fredonia and traffic was detoured around the section.

This operation may seem to have been very slow and require a great deal of work. However, consider the alternative should this have been a bridge instead of a roundabout. Many bridges would not have allowed this OSOW to go over it, possibly requiring lengthy alternative routing. As pointed out by respondents in our first survey to states, (Chapter 3) bridges were rated as the number one obstruction to OSOW.

5.10 An OSOW Design Considerations

5.10.1 General Concerns

The authors believe that the roundabout designer should have access to information regarding needed OSOW routes. As indicated above in this report, the authors suggest that all states should consider developing OSOW routes that would accommodate the types of vehicles that are important to the economy of the state or area within the state. The freight and OSOW networks, and the check vehicles that all elements of the OSOW route must accommodate, that Wisconsin has developed, would be a good example to consider.

5.10.2 Uncommon OSOW

The case of very large, complex or unusual OSOW the designer may need other additional information. During the course of this study the authors found out that not all OSOW haulers are free with all the details of the components and turning movements of some of their vehicles, which in some cases seem to be considered proprietary information. As one large OSOW company officer told us: “I can give you the general turning outline of our common vehicles but not the details.” Perhaps not all of the turning space requirements of all vehicles are known even to the company. This same company officer sent us three pages of components that could be used to make up an OSOW vehicle to almost any kind of known load, and told us to think of these as “Legos” that can be put together almost any combination depending on what needs to be hauled. One possible solution is to get the vehicle in question and check out its turning requirements in a large enough parking lot. An example is shown below in Figure 5.34.

(Source: Stratka)

FIGURE 5.34
Turning Space Requirements of an OSOW Being Analyzed in a Parking Lot

An alternative would be to develop a scalable model of the OSOW be accommodated and use this for laying out dimensions and paper. Example of this is shown below in Figure 5.35.

(Source: Stratka)

FIGURE 5.35
Using the Model of an OSOW to Layout Needed Accommodating Space in a Roundabout

5.11 Vertical Considerations

5.11.1 General

As pointed out in discussions on the four surveys in chapters 3 and 4, a concern or complaint, much or more than any others, was vertical clearance of curbs. No consensus was found as to a maximum height although 3 inches has been suggested by a number of sources including the FHWA roundabout guide. The authors believe strongly that the overall vertical clearance and maximum heights need to be kept to 3 inches or less for splitter islands truck aprons and curbs, i.e. a minimum that will still discourage small vehicle drivers. The approach used in Europe – the UK, the Netherlands and Germany – relying more on rumble strips around the truck apron than the height. The authors believe they should be tried out and researched in the United States.

5.11.2 Vertical and Cross Section Considerations

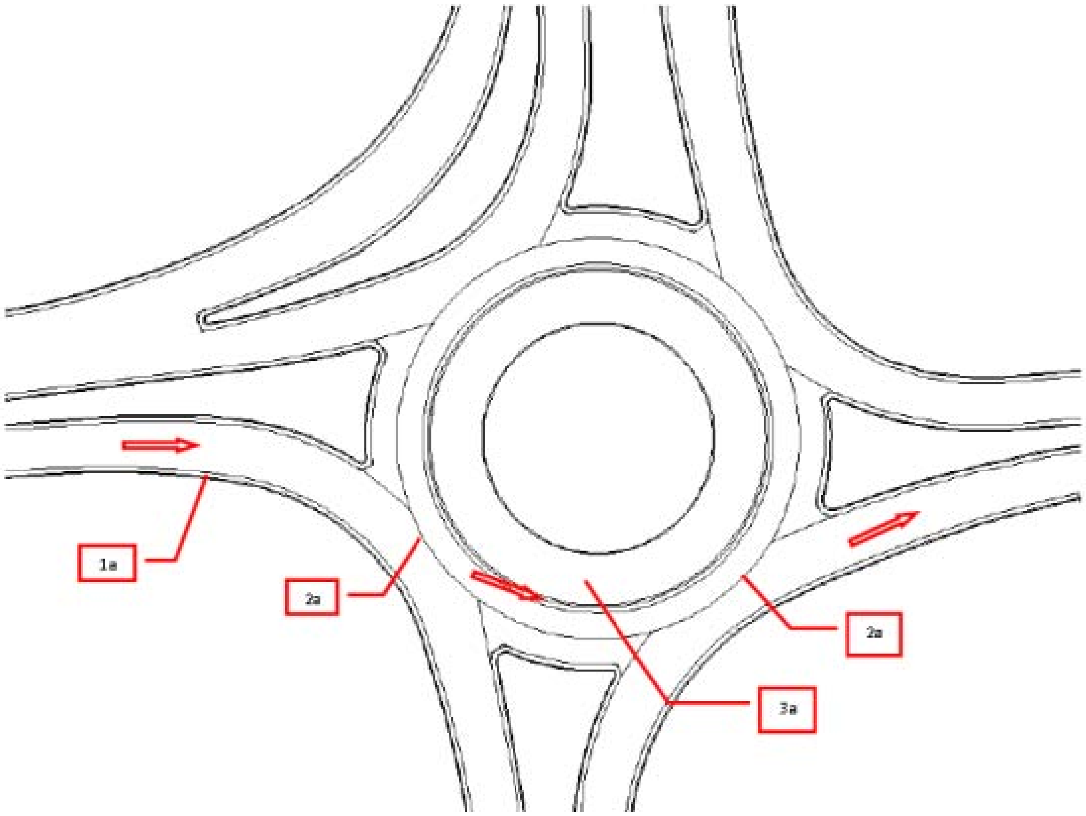
An in-depth study of vertical cross-section analysis and design is beyond the scope of this project. However as mentioned above it is a serious problem. ***One thing that needs to be understood is that the "hangup" problem identified for "lowboys" is not just the result of curb heights.*** This is only true if the entire roundabout were on a flat surface like a table. Even without curbs a low OSOW could get hung up on a vertical curve, or in some cases a highly crowned cross-section. This is an area in which there is need for more consideration, research and study. To the authors knowledge, this problem has been given the most serious attention by the state of Wisconsin and their solution is presented below in section 5.11.3.

5.11.3 Wisconsin's Vertical Profile Guidelines

As discussed above in chapter 2 of this report, the Wisconsin Department of Transportation (WisDOT) has developed a freight network and then OSOW network. On the OSOW network all elements had to accommodate seven check vehicles which had been developed to represent the range of OSOW that need to be accommodated on the OSOW network.

It was determined that they were still having "hangups" with lowboy vehicles, particularly low OSOW vehicles (OSOW low boys). They determined that the components that may have an impact on the ability to move OSOW lowboys through the roundabout had to do with truck apron width, truck apron slope, the curb and gutter design between the circulating roadway and the truck apron, possibly the roadway crown, or lack thereof, and the shape, or amount of warping the circulating roadway and the truck apron may have in the area where the low boy portion of the OSOW vehicle must clear the surface. (Pat Fleming, WisDOT, e-mail 02-28-2012)

On the WisDOT OSOW network, they experienced "touchdowns" (generally called "hangups" or bottoming out) at a couple roundabout locations. They decided to get out ahead of any further problems associated with OSOW lowboys. The problem areas were determined to be as shown in Figure 5.36 (Pat Fleming, WisDOT, e-mail, 05/03, 2012)



Notes for figure:

Typical ground clearance problem areas in roundabouts

1. Over-tracking at the entry curve/lowboy hitting the curb head
    a. Consider Curb and Gutter 4-inch Sloped Type G and a truck apron along the right side

2. Entry and exit rollover
    a. Consider flattening the circulatory roadway crown in these areas.
    b. Avoid steep profiles entering and exiting the roundabout

3. Truck Apron
    a. Consider flattening the truck apron slope
    b. See if the vehicle can track more on the circulatory roadway
        i. May need to consider 1a.
    c. Look at the circulatory roadway profile
        i. Keep it as flat/gentle as possible and still maintain drainage
        ii. Locate the crest away from the area of concern

(Source: Fleming 2012)

FIGURE 5.36
Roundabout Potential Hang-Up Areas as Determine by WisDOT

5.11.4 WisDOT Freight Network Guidelines for Roundabouts

The guidelines developed by WisDOT are presented here in their entirety because of the importance of this subject and the authors' believe that it is the most comprehensive treatment to date of the vertical clearance "problem", which the authors believe has not previously been studied or reported in detail.

5.11.4.1 The Following Guidelines As Developed and Distributed by WisDOT (Fleming 2012)

Preliminary Check for Low Vertical Clearance Conflicts for OSOW Freight Network Roundabouts

Purpose and intent is to help designers narrow down which roundabouts need this level of analysis.

Evaluating Roundabouts to be considered for AutoTurn Pro Analysis:

Is the roundabout located on the OSOW Freight Network, primary and secondary routes? (The location of the regional OSOW Freight Network maps are located at http://dotnet/dtid_bho/extranet/maps/docs/freightnetwork.pdf)

Yes: Continue to next step.

No: Analysis is not required but is recommended on routes that are known or anticipated to experience standard legal size lowboys.

Was the roundabout built in 2011, or programmed for construction in 2012 and after?

Yes: If it is located on the OSOW Freight Network, AutoTurn Pro is required to complete an analysis to determine if conflict points are present.

Clearance issue found?

If yes: Reconfigure the slopes within the conflict areas and check the surrounding area (i.e. approaches) for additional conflict points. If the truck is tracking outside of roundabout, reconfigure as necessary.

Roundabouts constructed in 2010 and prior years, it is not necessary at this time to analyze for OSOW lowboy clearance.

Design Guidance for Roundabouts:

WisDOT has provided the following roundabout design guidance for designing roundabouts in general but in particular those on the OSOW Freight Network.

WisDOT is a transport friendly state, and we should do what we can to provide accommodations not only for the standard large legal size trucks but also for the OSOW vehicles that use our highways.

1. Slope truck apron at 1% toward the roadway on all roundabouts (not 2% as in the past).

   The FDM is clear that the truck apron width should be a minimum of 12 feet wide on single lane, as well as, multilane roundabouts. Sometimes additional space is needed for trucks to off-track onto the truck apron that may exceed the 12 foot width.

2. Provide the pill shaped central island or other shape where appropriate to accommodate the anticipated OSOW turning maneuver. Discuss with the Regional Freight Network coordinator.

3. Roundabouts must have the recommended circulatory roadway crown installed, 2/3 inward and 1/3 outward on all roundabouts not just those on the OSOW Freight Network. See attached cross-section for clarification.

   WisDOT review of OSOW lowboys negotiating a roundabout use the extra height to help raise the lowboy bed.

   The location of the regional OSOW Freight Network maps are located at http://dotnet/dtid_bho/extranet/maps/docs/freightnetwork.pdf

4. Install a 4-inch type G/J curb & gutter on the outside of the approach where any large vehicles may over-track/off-track the curb.

5. Install a concrete pad (8-inch concrete thickness) behind the back of curb along the outside entrance area where off-tracking is anticipated. The slope of the pad should be a maximum of 1%. Evaluate the entrance for pedestrian crossings and placement of the concrete pad to prevent these areas from overlapping. The width of this pad will depend on the amount of off-tracking anticipated. The same 8-inch reddish colored concrete pad, without stamping the concrete, should be installed in the splitter islands where it is estimated that OSOW vehicles may drive to negotiate the roundabout.

The following items are a reminder for good roundabout design guidance.

Try to keep drainage structures away from the travel path of the possible OSOW vehicle wheel tracking.

The compaction levels under the 8-inch concrete pad along the back of curb near the entrance and in the splitter island areas (where needed) must be equal to the compaction levels under the roadway and truck apron.

With the wider 12 foot minimum truck apron that WisDOT now requires on single lane and multilane entries, it is rare that additional intersection sight distance is needed directly in back of the curb on the inside of the truck apron. If a central island landscape buffer area located adjacent to the back of the most inside curb and gutter is desired, avoid the use of hard surfaces that look like concrete sidewalk.

The FDM guidance is clear about the usage of a 2% cross slope maximum in the roadway area.

Avoid approach vertical break-over grades over 3% within 200 feet of the entry yield line location.

Provide a note to the construction engineer that the plans including vertical and horizontal shall not be adjusted in the field without the design engineer's approval.

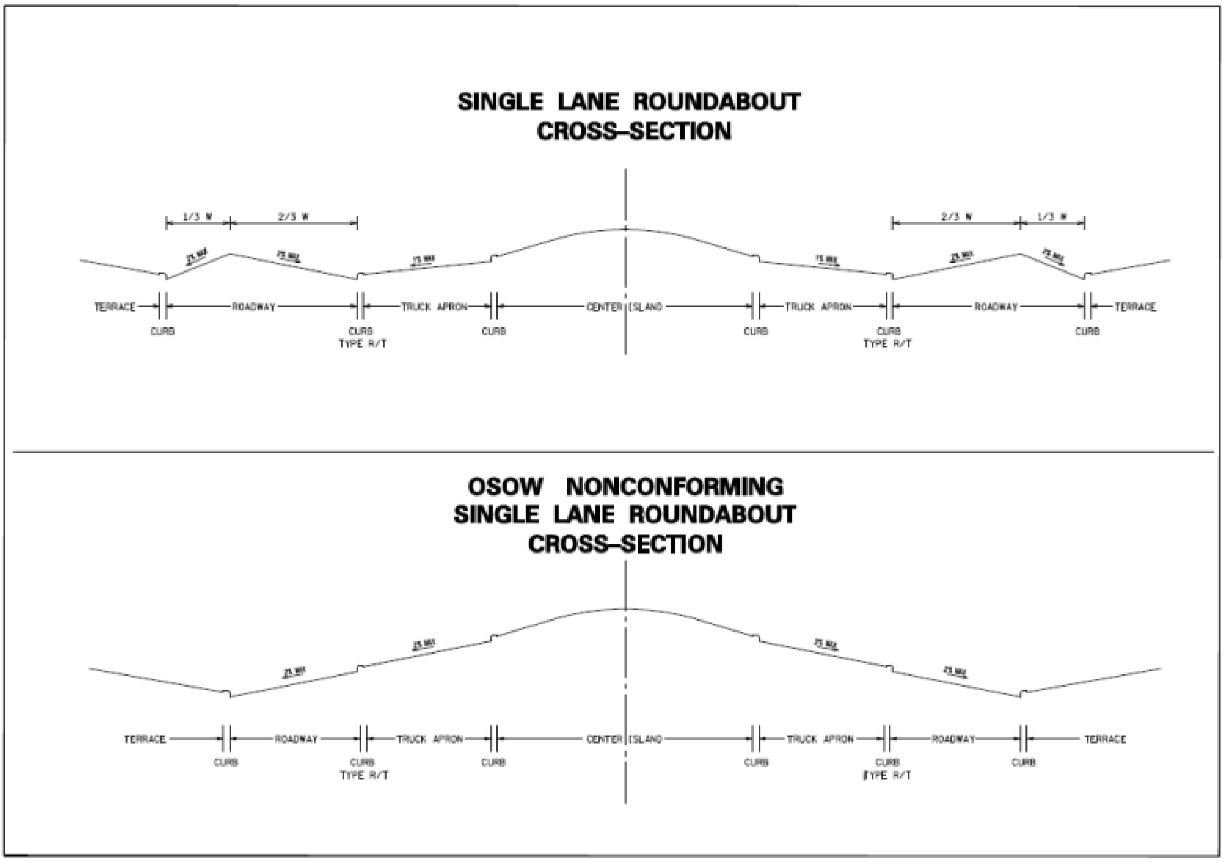
Refer to FDM 11-26-35 for guidance on removable signs at roundabouts.

For the roundabouts located on the OSOW FN, their grading plans should be verified with AutoTurn Pro for any conflict points. The tractor should be placed 100 feet back from the yield line.

5.11.4.2 Further Explanation (Pat Fleming, e-mail, 05-04-2012)

Probably the two most important issues are related to including the roadway crown and the truck 1% cross slope. Through our investigation we have found that a crowned circulatory roadway provides a number of benefits. Previous thinking was that it helped to reduce load shifting by providing a minimal amount of super elevation as truck negotiated the circular roadway. Another is the drainage so that water doesn't drain across the roadway and during freeze-thaw cycles cause roadway icing. The most current review and thinking is that the crown helps elevate the rear wheels of an OSOW vehicle which helps keep the lowboy bed off the pavement in the truck apron or roadway. We also see that if the gutter is a reject, or sloped outward rather than toward the truck apron that the 4 inch curb head and gutter slope stand up higher and is more likely to interfere with (hit or scrape) the front left corner of the lowboy bed as it crosses the curb/gutter. WisDOT uses a very tire friendly curb gutter design (Type R or T) that separates the circulatory roadway from the truck apron detail drawing [below in section 5.10.4.3].

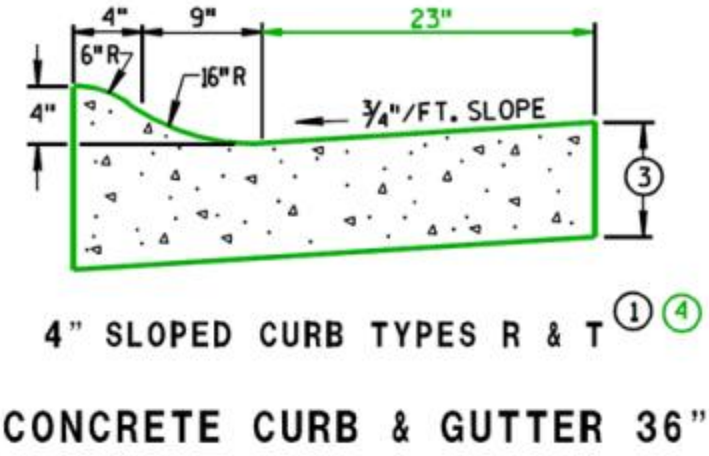
5.11.4.3 Detailed Drawing

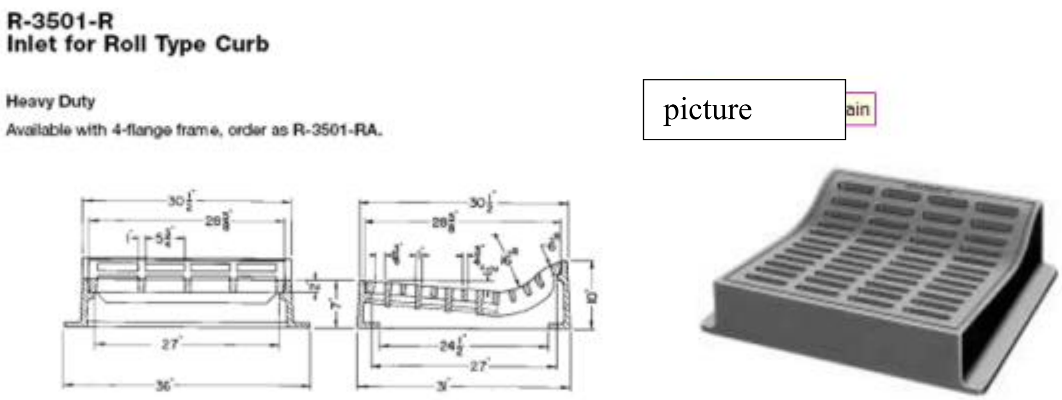


(Source: WisDOT Freight Network Guidelines for roundabouts)

Note: Non-conforming means that the lower design drawing does not conform to the OSOW design that WisDOT wants designed at all roundabouts on the OSOW Freight Network.

FIGURE 5.37
Detailed Drawing of Roundabout Cross-Section





(WisDOT Freight Network Guidelines for Roundabouts)

FIGURE 5.38
Details of the WisDOT Concrete Curb and Gutter

5.12 Additional OSOW Treatment, Concepts from Other Countries

The authors have had considerable input from the Netherlands, Germany and Australia. In addition to the ideas and concepts presented above, additional ones will be presented here.

5.12.1 The Netherlands

The following was provided by L.G.H. (Bertus) Fortuijn. 2012. He points out that their dilemma is similar to that. In the United States, i.e. keeping the width of roundabout lanes narrow to force small vehicle drivers to reduce speed whereas large trucks uses plenty of room to negotiate their roundabouts. Their solution is to include the following elements in the roundabout design: (L.G.H. (Bertus) Fortuijn. 2012)

- a 90° angle between approach leg and circulatory roadway,
- limited width of circulatory roadway,
- central apron offering additional width for large trucks using the inner Lane, and
- aprons in the "armpits" [external between roundabout legs].

The authors believe is most important point has to do with the construction detail of the apron (shown above in figure 5.17). The version shown in figure 5.17 is the version currently recommended for use in the Netherlands after others had proven to be unsuccessful. The apron around a central island should not be too steep and the slope should be less than that of the traveled way to reduce lateral acceleration forces it of heavy trucks. Further, it should be separated from the traveled way by a rumble strip rising 2.75 in (7 cm) over a lateral distance of 3.94 in (10 cm). This will prevent small vehicles from using the apron while not preventing presenting a major obstacle to trucks. These guidelines have been included in all Dutch roundabout guidelines between 1989 and 2012 (L.G.H. (Bertus) Fortuijn, e-mail, 2012)

5.12.2 Germany

The following was provided by Dr. R Werner Brilon, Germany takes no special precautions at normal roundabouts. The German design rules require large trucks can get through every roundabout in each direction. However, trucks are strictly regulated. The maximum size of a vehicle in Germany is 61.52 ft (18.75 m) long and 8.53 ft (2.6 m) wide. What is important for roundabouts is that each vehicle must be able to drive a full 360° circle on a ring with a 82 ft (25 m) outer diameter and 24.6 ft (7.5 m) width. There is no exception to these rules and the rules are within the German road traffic federal law. A vehicle which is allowed to travel with normal traffic is keeping size within these margins. These rules have also been adopted within the European Union and therefore trucks have no problem at the borders of the European Union countries.

There are some exceptions will in regard to length. What has recently been started in Germany our experiments with "mega trucks" which can be up to 82 feet (25 m) long, for example, two articulated trailers or other similar configurations. However, these vehicles must be able to drive the 82 ft/24.6 ft (25 m/7.5 m) ring. These mega trucks are only permitted on unrestricted routes as an experiment.

Vehicles which do not fit into the normal margins as indicated above, have to apply for a special permission for each trip at government offices. The administration permits a trip without significant restrictions, like requiring police vehicles, time restrictions and so forth.

Only in cases that oversize trucks can be expected on a regular basis are specific roundabout solutions (accommodations) designed. The decision to do this is made as a result of cooperation between the state and the producer/hauler. **The question of cost is also regulated between them in each single case.** (emphasis added) An example of this is a factory producing large parts which need to go from the factory to a port every few weeks. One solution presented in the German guidelines since 2006 is a lane crossing the center island from left to right. (This is like the one shown in figure 5.25 from the Netherlands, and requires no gates because the entrance lines of with the left Lane where only OSOW are allowed to go). The advantage of this is that the OSOW can enter directly from the left lane, (assumed escorted with traffic control as in the US) but regular traffic entering from the right lane are not lined up with the entrance to the road. Also, landscaping is generally provided so that regular traffic does not see the entrance to the lane through the roundabout. They also build lanes directly through the center island in line with the right lane. In this case signs are necessary. An example of this is shown above in figure 5.28.

In Germany, as in other European countries, experiments are beginning to allow larger trucks up to 25 m long but with a maximum mass of 40 tons on specialized roads. These vehicles have to be equipped with steering equipment and several of the axles which allow them to turn within the standard circulating lanes, including truck apron, of the roundabout. In other words, they are required to be steerable to the extent that they fit within the standard roundabouts. Also, it is pointed out that the German highway code prohibits smaller vehicles from using a truck apron.

The appearance from the above that Germany controls the OSOW problem more by regulation than designing to accommodate any size that comes along. Australia regulates OSOW even more stringently as discussed below.

5.12.3 Australia

The following was provided by Andrew O'Brien (Consultant, Melbourne, AU). Under ROADS guidelines, "guide to road design" series, there are design vehicle for which roads must be designed. Typically, the largest is 19 m (62.3 ft) semi or a 25 m (82 ft) B- double. In Victoria, for unspecified over-dimensional loads, there is a check vehicle used that is a 23 m semi. It is typically used only at freeway interchanges and some major state highways.

If a user wants to use a larger vehicle, they must obtain a permit and demonstrate how the vehicle can negotiate a particular route if physical changes are needed, then that is on the user to fix. The cost is on the user, i.e., if alterations to the roadway or any roadway elements are necessary to accommodate a large vehicle the user pays the costs**.**

In sections of Australia there are a number of road trains, i.e. the tractor hauling several trailers. Where it is allowed, usually open rural areas, they are also a design vehicle; however, their use is highly restricted. For example a road train arriving in Perth Australia must enter a station on the outskirts and break the road train down to be within the B-double size.

5.13 European and Australia Summary

It is obvious that the three countries investigated, all with considerable roundabout design experience and expertise, have minimal problems accommodating large trucks at roundabouts mostly because they strictly regulate the truck size. Only in exceptional cases where there is need for a vehicle comparable to our OSOW, do they provide special accommodation. And in Australia, any costs of accommodation is paid for by the user. That is not to say that in the US we should follow these examples; however, it does seem to the authors that there need to be some limits, based on a cost-benefit analysis. The others believe it should apply to two areas: 1. Economic benefit to the state or area within the state versus the cost of accommodation, and 2. Costs to the shipper for transporting an item over highways versus constructing it at its location.

Chapter 6: Study and Examples Using Check Vehicles for Roundabout Design

6.1 General Approach to AutoTURN Simulations on TORUS-Generated Roundabouts

The authors are not advocating exclusive use of AutoTURN or TORUS software. These programs were used because they are sufficient and convenient to illustrate concepts the authors wanted to present, which are explained below. It is recognized there are other programs that could have been used.

6.1.1 Software Used

AutoTURN is computer-aided design (CAD) with vehicle-turn and swept-path analysis software used to evaluate standard designs or specialized vehicle maneuvers for all types of roadway, highway, and site design projects. It follows the AASHTO guidelines for turn radii, transition curves, super-elevation, and lateral friction.

TORUS is CAD-based software for designing modern roundabouts. TORUS software was used to generate the roundabouts in this chapter and run OSOW check vehicle simulations using AutoTURN on the TORUS-generated roundabouts to observe space requirements of these vehicles. This task was carried out by considering both a prototype single-lane roundabout and a prototype double-lane roundabout as examples.

6.1.2 Check Vehicles Used

The “check vehicles” used were developed for use in Wisconsin (Fleming, 2011). Wisconsin Department of Transportation (WisDOT) Freight Operations Section has compiled an inventory of seven OSOW check vehicles for designing the roundabouts for OSOW vehicles on OSOW routes . The seven check vehicles (shown in Figure 6.1) that were obtained from the WisDOT vehicle library are:

1. 55 meter wind blade NL (Vehicle Length (L)=209ft), .
2. 80’ mobile home (L=112.5ft),
3. 165’ beam L (L=201.10ft),
4. Combine (L=28.80ft; W=20 ft),

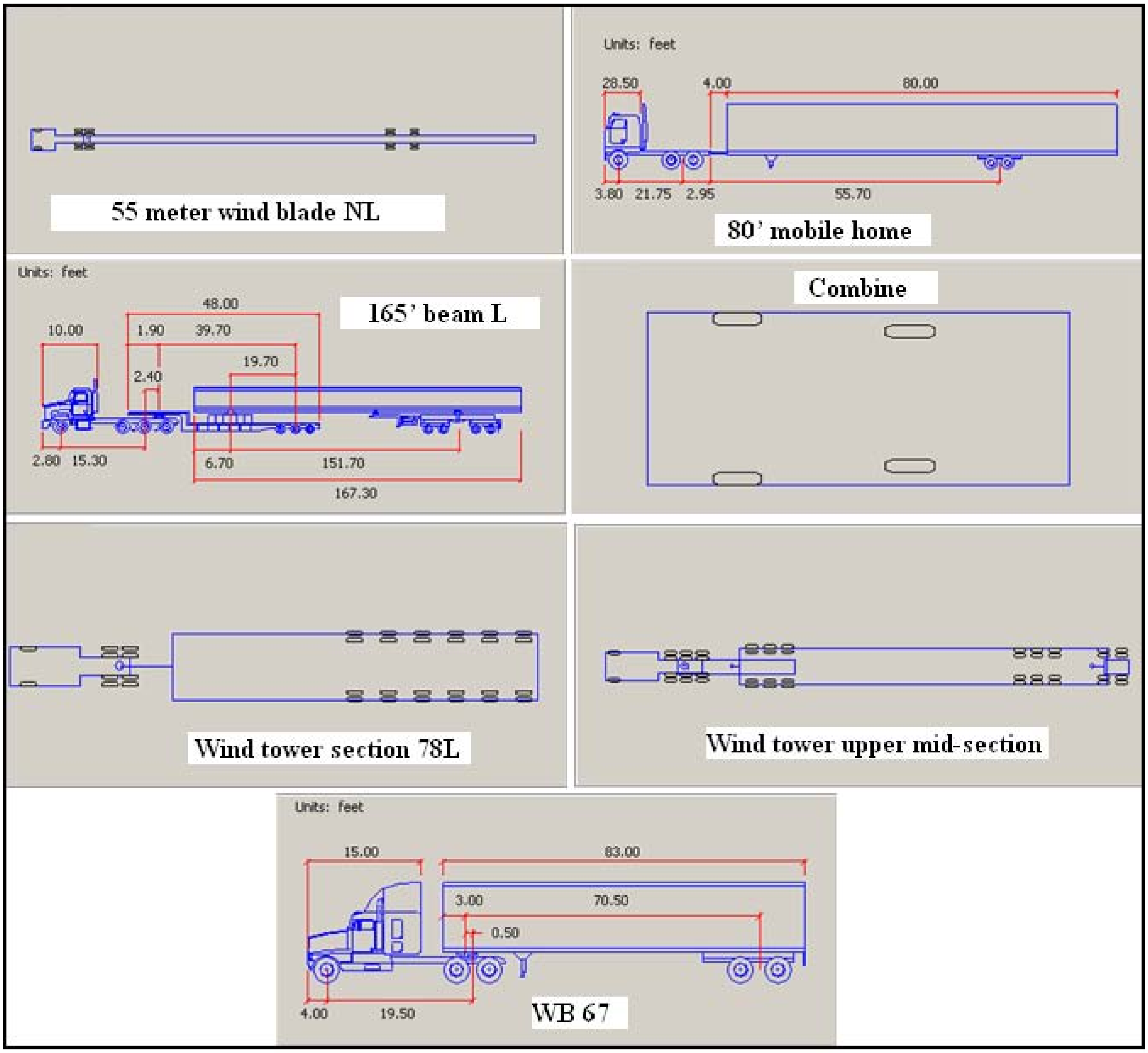
5. Wind tower section 78L (L=112.50ft),
6. Wind tower upper mid-section (L=148.80ft), and
7. WB-67(L=103ft)

Number 7, WB-67, an AASHTO-designated design vehicle, is not an OSOW. However, WisDOT uses this vehicle as a check vehicle on their statewide truck freight routes.

These seven OSOW check vehicles from the WisDOT vehicle library were used to perform the vehicle path simulations on the TORUS-generated roundabouts used in this study to illustrate concepts of accommodating OSOW. The authors stress the actual designs shown are meant to illustrate principles and not necessarily to recommend actual designs, which should be designed in the context of site-specific parameters. Also, these seven check vehicles, including six OSOW, were considered appropriate for Wisconsin. For other states, a study of key OSOW vehicles using "freight routes" and/or key industries needing OSOW shipments, may find they need a different or modified set of "check vehicles."

6.2 Single-Lane Roundabouts

To draw roundabouts using TORUS software, initially an inscribed circle diameter needs to be determined for a particular location. According to NCHRP 672 (2012), the inscribed circle diameter for a single-lane roundabout is in the range 130 to 180 ft. when the design vehicle is a WB 67. For roundabouts designed to illustrate OSOW accommodation concepts larger than the WB 67 vehicle, the upper limit of the inscribed circle diameter range (180 ft.) was selected. Basically, the approach was to use the WB-67 as the basic design (some roundabout designers believe this should be the design vehicle for all roundabouts on state highways) and then modify for OSOW check vehicles.



(Source: Pat Fleming, WisDOT)

FIGURE 6.1
OSOW Check Vehicles from the Wisconsin DOT Vehicle Library (Developed by Mark Lenters, Ourston Engineering)

The TORUS -generated, single-lane roundabout has a default designed, center island truck apron width of 10 ft. This truck apron width was not sufficient for the design vehicle (WB 67) to traverse a left turn (usually the most critical movement). Therefore, a central island truck apron width of 15 ft. was initially assumed to accommodate the left-turn movement of a WB 67. Each approach was designed in such a way that the approach has a 15-ft. (value selected arbitrarily), left offset to the center of the roundabout. Figure 6.2 shows the "basic" roundabout for this illustration, designed with TORUS software with the specifications mentioned above.

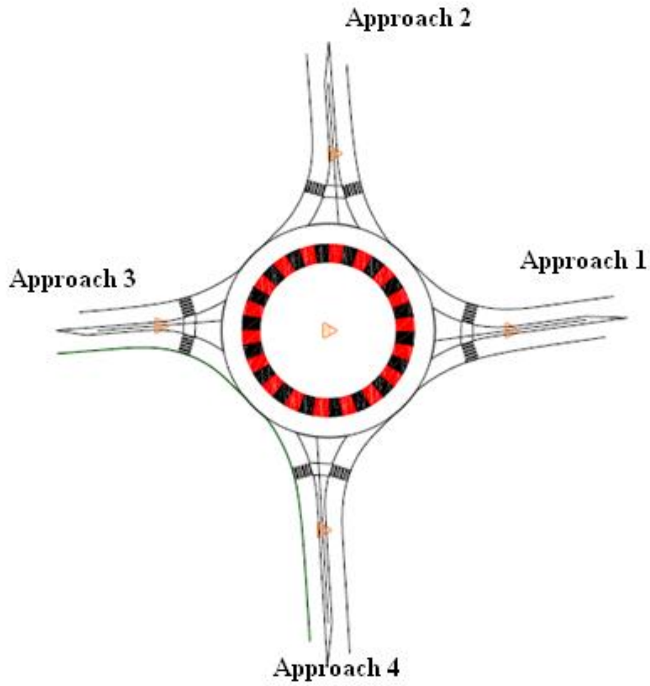


FIGURE 6.2
TORUS-Generated Single Lane Roundabout with180 Foot Inscribed Circle Diameter, 15 Foot Truck Apron, and 15 Foot Left Offset for Each Approach

TORUS uses the guidelines from "Roundabouts: An Informational Guide" (FHWA-RD-00-067) for designing its roundabouts. However, for this study the roundabout designs were based on the guidelines provided from the latest roundabout guide, NCHRP 672. As some design specifications from the latest roundabout guide were different from the initial version, the TORUS software indicate some errors while generating the roundabouts, which can be ignored.

It was assumed that OSOW trucks would be able to go over the splitter island at the approach and exit when necessary to safely traverse a roundabout. It was also assumed, for some scenarios, that drivers can enter from any lane and change into any lane at any point for the purpose of maneuvering through the roundabout. (The advantages or desirability of this maneuver, as well as allowing movement in a counter direction, is discussed in another section of this report.) Right-turn maneuvers, through maneuvers, and left-turn maneuvers of the seven check vehicles will be considered for checking and redesigning the geometry of the roundabout as necessary for the "critical" vehicle.

Figure 6.3 shows an example right-turn simulation of a "wind tower section 78L" traversing a right turn, i.e., enters from approach 3 and exits into approach 4. (This numbering system will be used on all four- leg roundabouts in this study.) From Figure 6.3, among the three red lines in a vehicle simulation, two red lines represent the front-tire paths of a vehicle and the center red line indicates the path of the vehicle traversed by the front portion of the vehicle. The green lines represent the rear-tire paths of the vehicle. The blue lines represent the vehicle body clearance, i.e., swept path. Similarly, all right-turn movements of the seven check vehicles for the four approaches were simulated and the roundabout was modified with a 15-foot external truck apron between each two consecutive legs. The external truck apron is colored in blue in Figure 6.4.

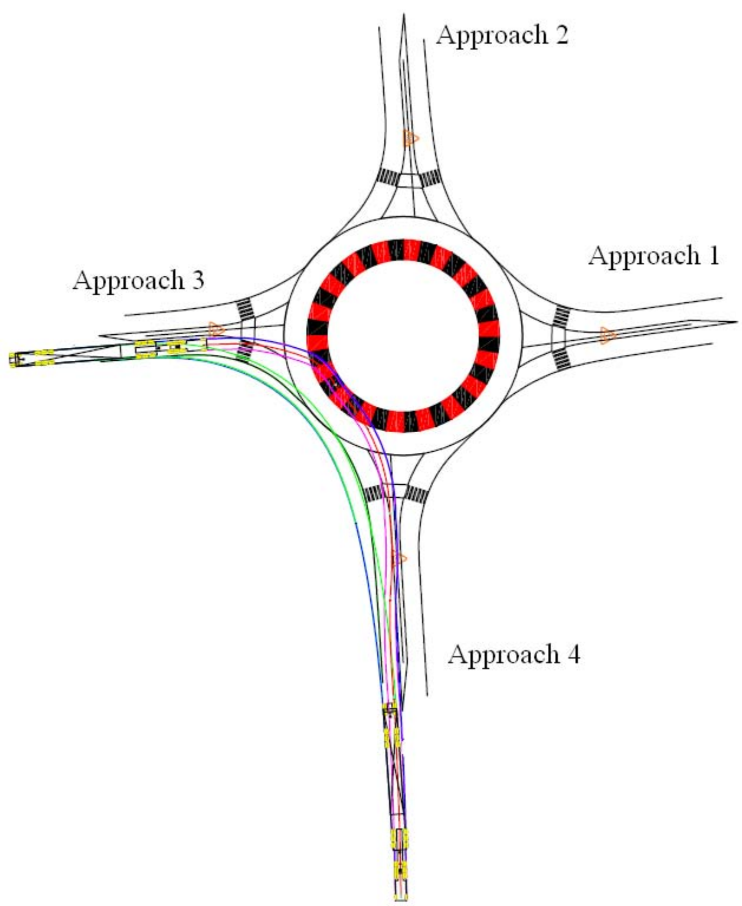


FIGURE 6.3
Right-Turn Maneuver of "Wind Tower Upper Midsection"

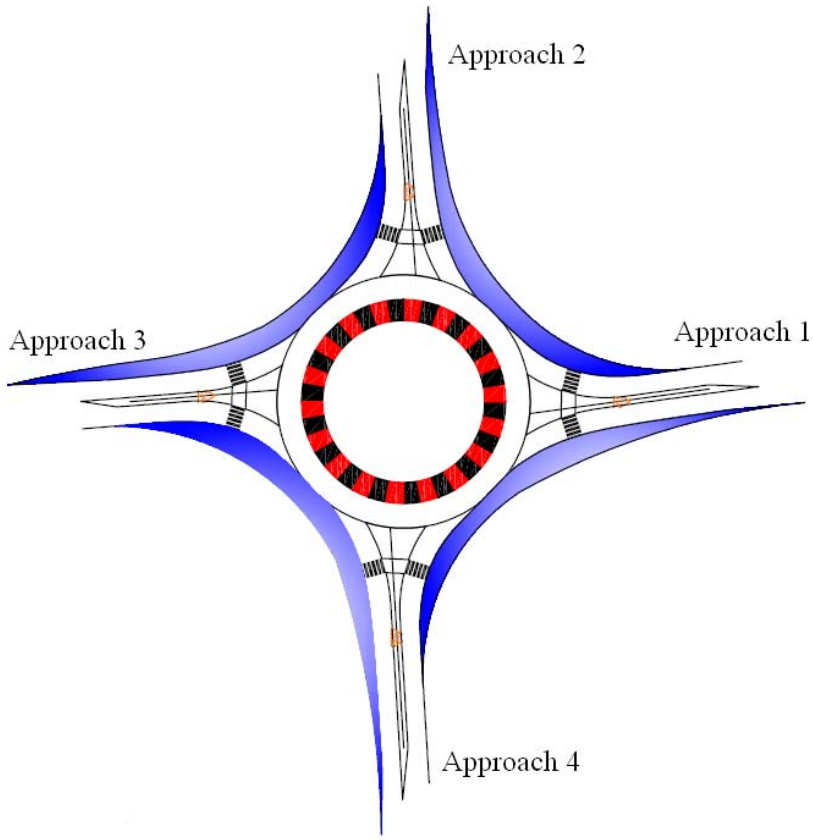


FIGURE 6.4
Roundabout Design with External Truck Apron for Accommodating Right-Turn Movements for All Check Vehicles

When OSOW vehicles are expected at a roundabout, such as in Figure 6.4, from two opposite approaches e.g., 1 and 3, the modified design of the center island is dictated by the critical OSOW movement. Among all possible simulations of the OSOW check vehicles, the simulations having comparatively more swept path (which dictate the center island truck apron width and shape, external truck apron width, and vehicle clearance area, based on their space requirements) were considered as OSOW *critical movements*. This is illustrated in Figure 6.5 and this scenario can be accommodated by an oval shape as shown in Figure 6.6. In this oval-shaped truck apron design for the roundabout, maximum size of truck apron width needed is 30 ft., and minimum width of the truck apron is 15 ft. However, if we assume that OSOW loads are entering from all four approaches, then the center island shape will need to be modified again to a circular shape with a center island truck apron width of 30 ft. as shown in Figure 6.7. For the above two cases, a 15-ft external truck apron should also be provided in between two consecutive legs of the roundabout as shown in blue in Figures 6.6 and 6.7.

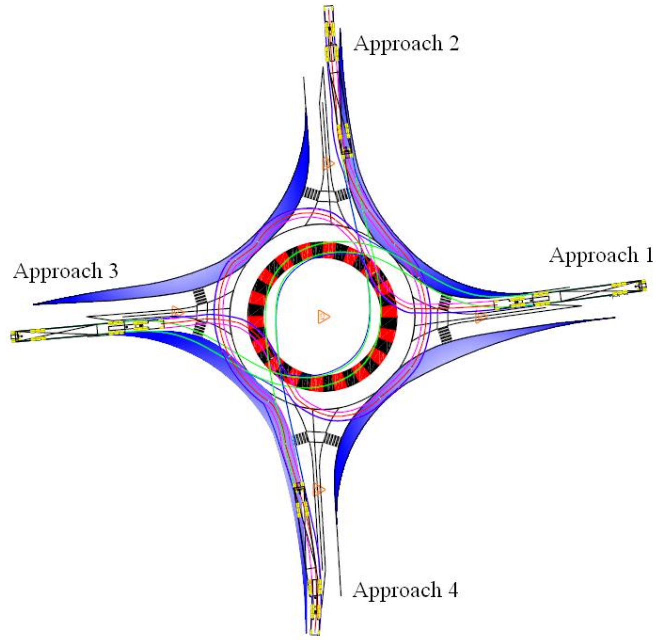


FIGURE 6.5
Critical OSOW Movement Which Dictates the Center Island Truck Apron Design

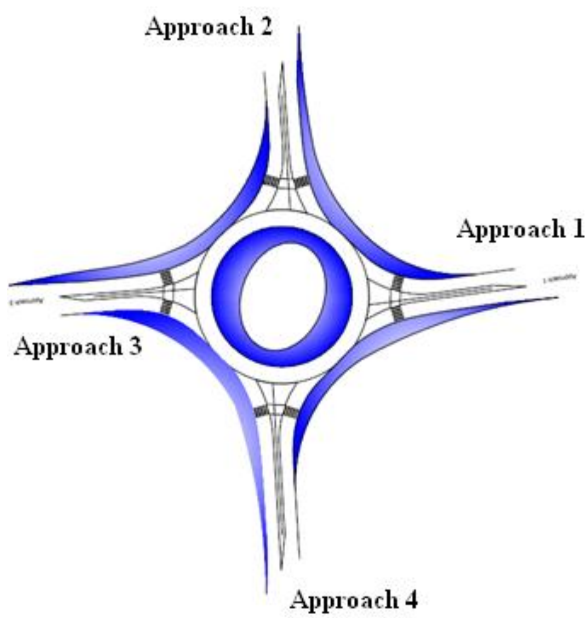


FIGURE 6.6
Final Design of a Roundabout When OSOW Vehicles Are Expected from Approach 1 and Approach 3

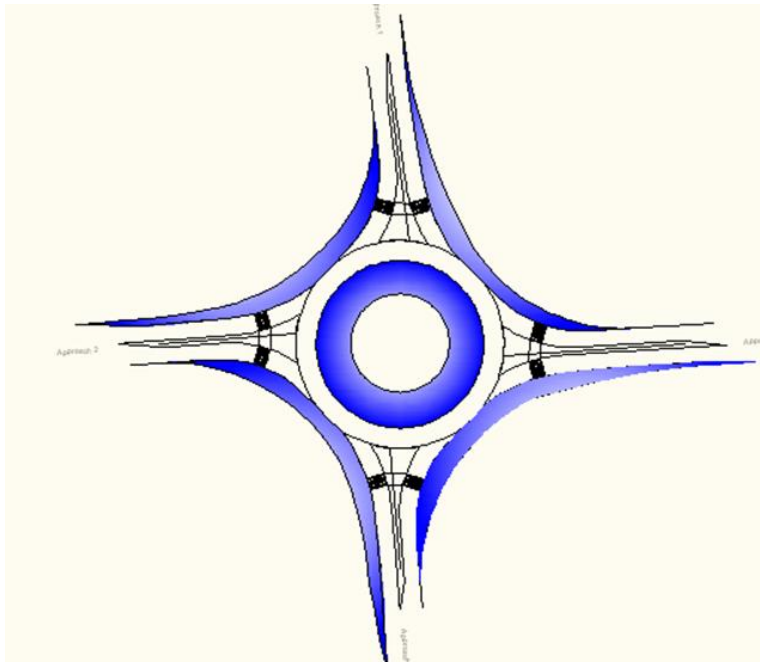


FIGURE 6.7
Final Design of a Roundabout When OSOW Vehicles Are Expected from All Approaches

There are some locations where we can expect the OSOW vehicles needing to enter the roundabout from two opposite directions and/or they might need only a through movement. In such cases, providing a special through movement through the center island would make it easier for OSOW vehicles to traverse through the roundabout. (Discussion and examples of this approach are contained in other sections of this report.) Figure 6.7 shows simulations of all OSOW check vehicles using the straight passage through the center island. The straight pass-through is designed to accommodate the through movements from approaches 1 and 3. Therefore, entry of the pass-through is made “left offset,” requiring the vehicles to mount over the splitter island to safely get into the offset to the left pass-through lane.

Figure 6.8 shows the design generated in the single-lane roundabout when only OSOW through movements are expected from approaches 1 and 3. Removable gates have to be provided for direct, straight-ahead through paths (no offset) so that only permitted OSOW trucks can legally have access to these paths and avoid regular traffic using them. In some cases, if the OSOW vehicle is permitted (state laws vary or are unclear, as discussed in other parts of this report) to move to the left on the approach and enter an offset through lane, a gate would not be required, as smaller vehicles would not be permitted to legally do so. Traffic control would be necessary; however, most if not all OSOW vehicles that could benefit from this concept would be escorted, and presumably have accompanying persons with authority to do so. Pictures of other examples of this concept, primarily from Europe where it is used frequently, are shown in chapter 5 of this report.

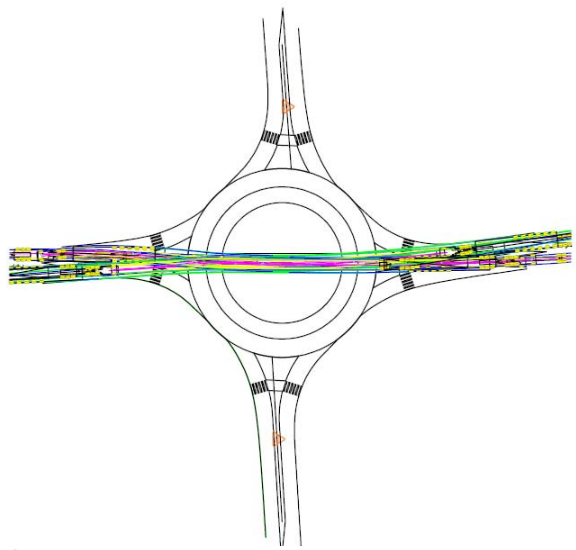


FIGURE 6.8
Simulations of All OSOW Check Vehicles Using the Straight Passage through the Center Island from Either a Right-Lane or Left-Lane Approach

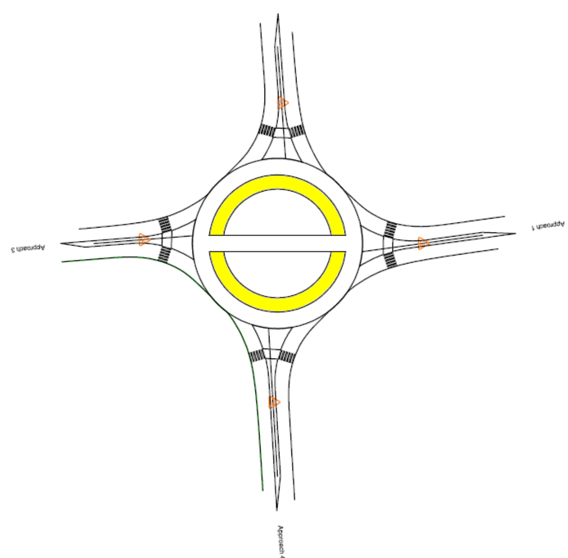


FIGURE 6.9
Redesigned Roundabout with Straight Passage through the Center Island (Assuming Trucks Are Able to Go over the Splitter Island)

6.3 Two-Lane Roundabouts

According to report NCHRP 672, the inscribed circle diameter for a two-lane roundabout is in the range 165 to 220 ft. when the design vehicle is WB 67. As the roundabout is designed to illustrate OSOW accommodation concepts larger than the WB 67 vehicle, the upper limit of the inscribed circle diameter range (220 ft.) was selected. Basically, the approach was to use the WB-67 as the basic design and then modify for OSOW check vehicles. It was assumed OSOW vehicles would ignore lanes and lane lines.

The TORUS-generated, basic, two-lane roundabout has a center island truck apron width of 20 ft., and this width was kept the same for this design of the two -lane roundabouts as it accommodates the left-turn movement of the design vehicle WB-67. Each approach was designed in such a way that it has a 40 ft., arbitrarily selected left offset to the center of the roundabout. Figure 6.10 shows the roundabout designed with TORUS software with the specifications mentioned above. It was assumed that OSOW trucks can go over the splitter island at both the approach and exit to safely traverse a roundabout. It was also assumed that drivers can enter from any approach lane and change into any lane at any point for the purpose of maneuvering the roundabout. Right-turn maneuvers, through maneuvers, and left-turn maneuvers of the seven check vehicles were considered for redesigning the geometry of the roundabout as necessary for the "critical" vehicle.

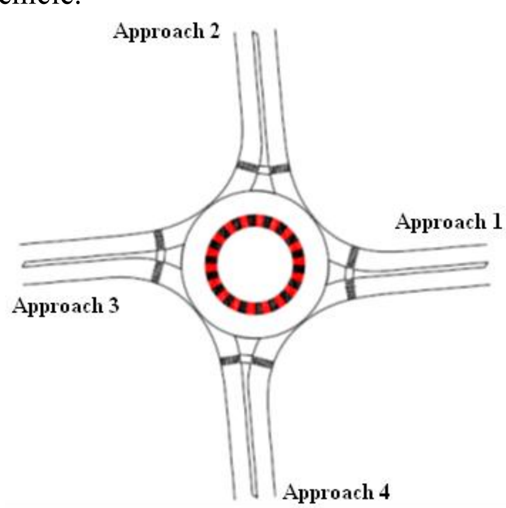


FIGURE 6.10
TORUS-Generated Two-Lane Roundabout with 220 Foot Inscribed Circle Diameter, 20 Foot Truck Apron, and 40 Foot Left Offset for Each Approach

Figure 6.11 shows an example right-turn simulation of a "165-ft. beam" entering from approach 3 and exiting into approach 4. Figure 6.12 shows an example left-turn simulation of a "55-meter wind blade" entering from approach 3 and exiting into approach 2.

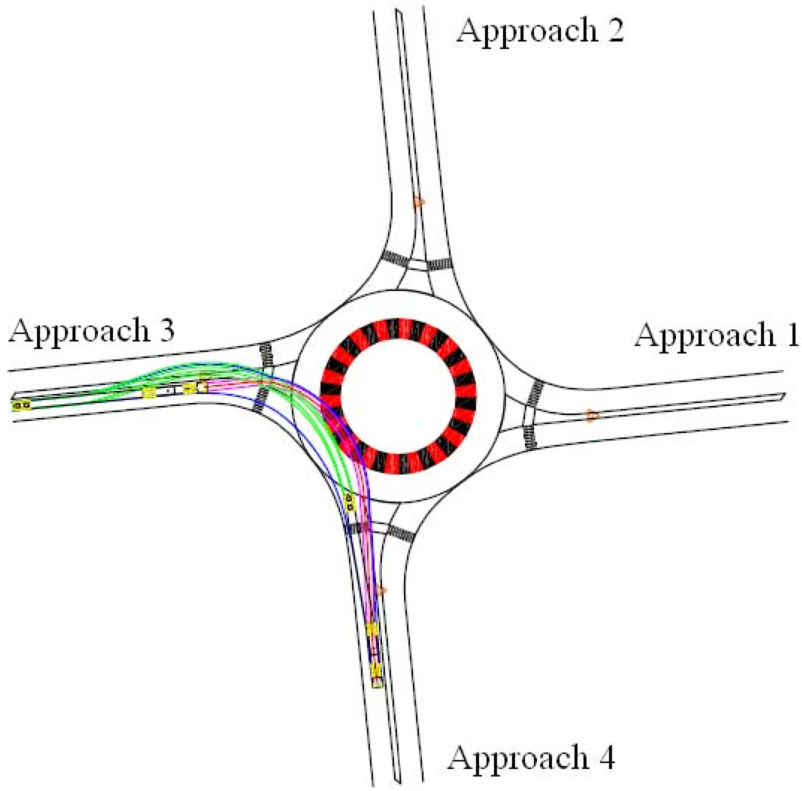


FIGURE 6.11
Right-Turn Maneuver of a "165 Foot Beam"

Some left-turn maneuvers of check vehicles, such as the "165-foot beam" and "wind tower upper mid-section," need extra space beyond the roundabout paved area to traverse the center island. For such critical moves, the other possible left-turn maneuver is by traveling the roundabout in the opposite direction without traversing the center island. Figure 6.13 shows the left-turn movement of "165-ft. beam" from approach 3 to 2 without traversing the center island. This concept may be more economical than other accommodating designs. In such cases, these OSOW loads are assumed to traverse left turns in opposite directions for effective utilization of roundabout paved areas. Traffic control would be necessary. (Examples of actual designs are shown in other sections of this report.)

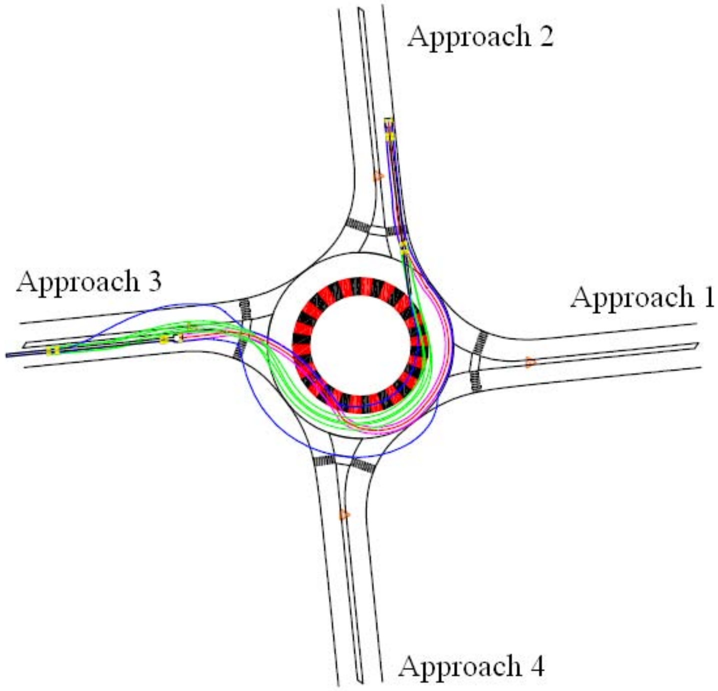


FIGURE 6.12
Left-Turn Maneuver of a "55 Meter Wind Blade"

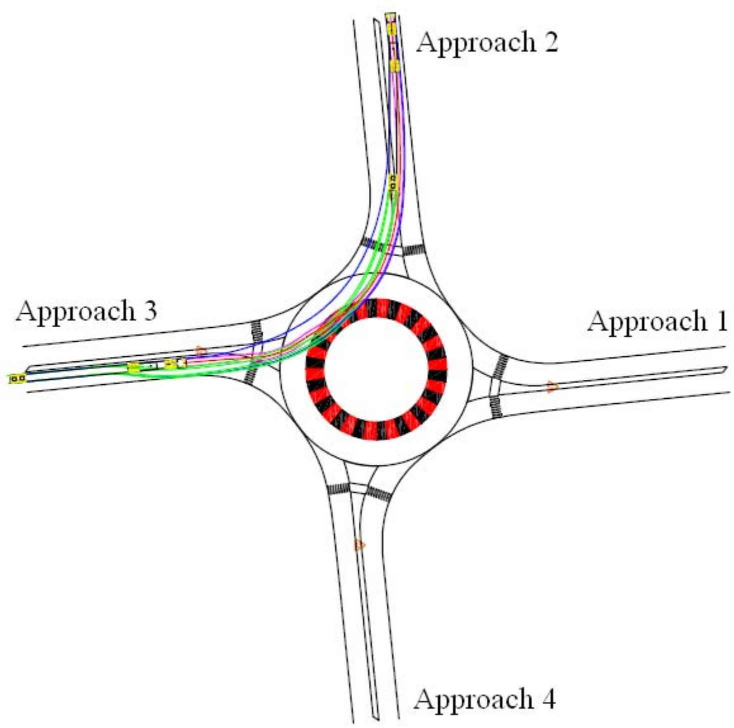


FIGURE 6.13
Left-Turn Maneuver of a 165 Foot Beam from Approach 3 to Approach 2 in Opposite Direction of Traffic without Traversing the Center Island

Figure 6.14 shows all critical movements (right turn, through movement, and left turn) which need more space entering from approach 3. As previously defined, critical movements are selected vehicle simulations among all possible simulations requiring comparatively more swept path space. It can be observed from Figure 6.14 that front-tire tracks and rear-tire tracks of all the critical movements are in the paved area of the designed roundabout. This situation is similar for the remaining three approaches as the roundabout is symmetrical. Therefore, it can be concluded there is no need of any extra paved area for this two-lane roundabout to accommodate various critical movements of OSOW vehicles entering from any of the four approaches. However, the roundabout should be designed with removable signs (and no permanent fixtures inside the swept path envelope) so that the OSOW vehicles do not knock them down while they traverse the roundabout. Figure 6.15 shows the OSOW wheel and load paths used to determine where the removable sign area, and no permanent obstruction area, should be, if the OSOW vehicles enter from all the four approaches. Figure 6.16 shows the template developed from figure 6.15, with the removable sign area in red, and no permanent obstruction area in orange. This "template" would apply if the OSOW check vehicles used entered from all the four approaches. The removable sign area in the body of the roundabout (shaded in orange) can be differentiated from the removable sign area outside the body of the roundabout (shaded in red).

Other templates could be constructed from a state specific check list, appropriate to the needs of OSOW accommodation in that state. The authors believe templates such as these could be valuable in the planning phase and/or preliminary design phase of considering roundabouts on a route.

Should there be only OSOW entering from approach 3, requiring all movements, figure 6.14 would apply.

If there should be OSOW vehicles entering from approaches 1 and approach 3, and needing only the through movement, a straight passage through the center island may be more expedient and economical and should be considered as in figure 6.6 and figure 6.18.Again, removable gates have to be provided for direct, straight-ahead through paths so that only permitted OSOW trucks can legally have access to these paths and avoid regular traffic using them. An offset left entrance would require the vehicle moving left on the approach, which would require more traffic control and state laws need to be checked.

Any set of necessary (to some given state) OSOW that needs to be transported in or through a state, and any combinations of movements, can be used to develop similar required needs and/or templates. In the appendix T for this section, many more examples/illustrations are shown.

Some real-world examples from Kansas are shown in the next section.

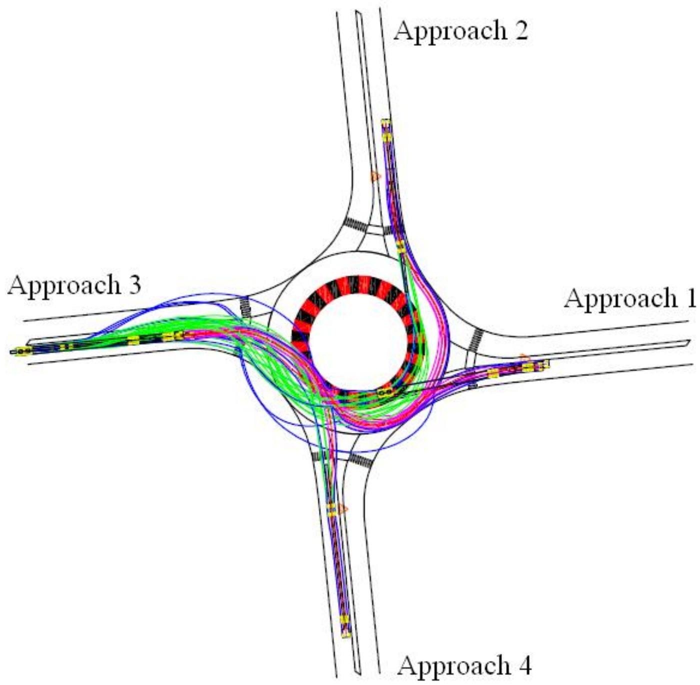


FIGURE 6.14
All Critical Check Vehicle Movements from Approach 3

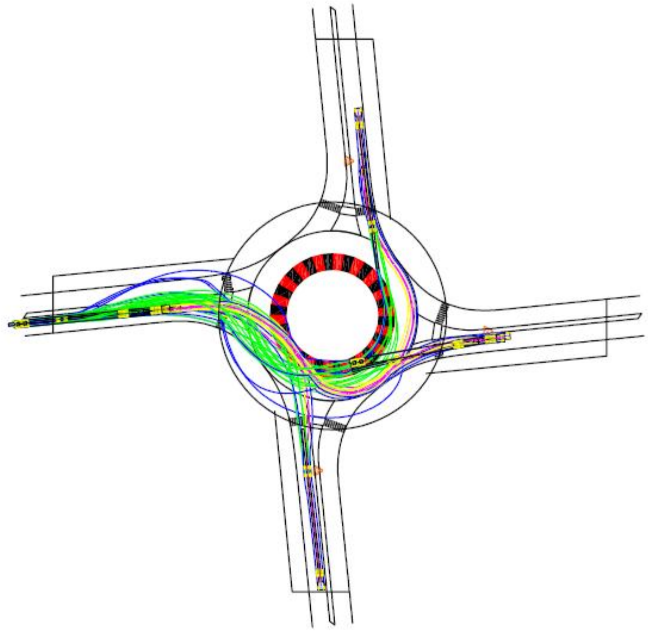


FIGURE 6.15
Removable Sign Area Developed Based on Critical Movements from All Four Approaches

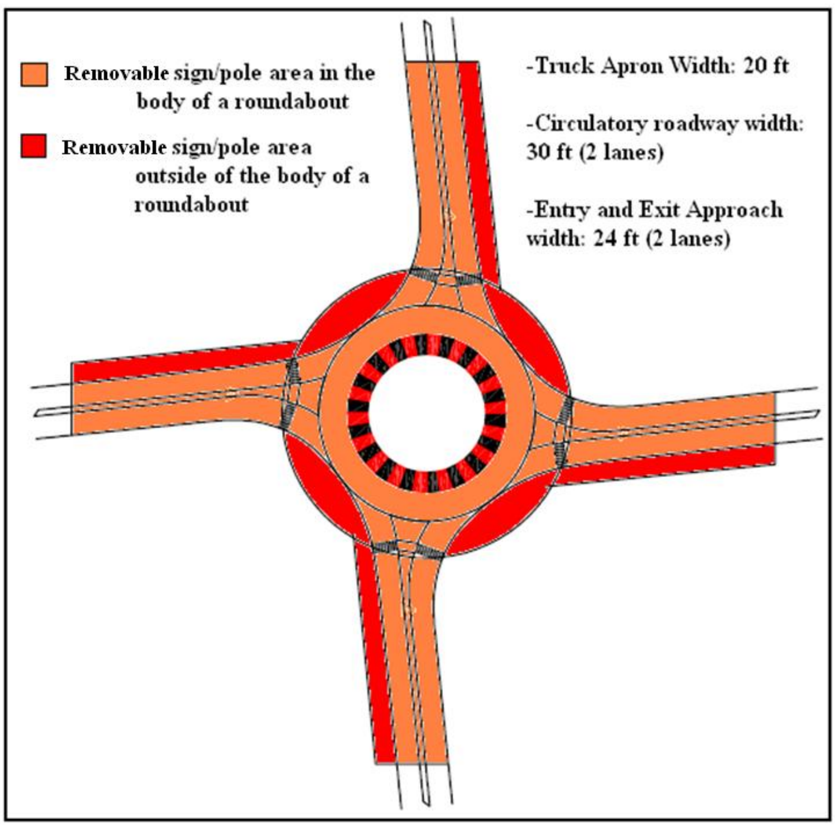


FIGURE 6.16
A Final Template Illustrating the Removable Sign Area, and the Areas Where No Permanent Obstructions, Inside and Outside the Body of the Roundabout

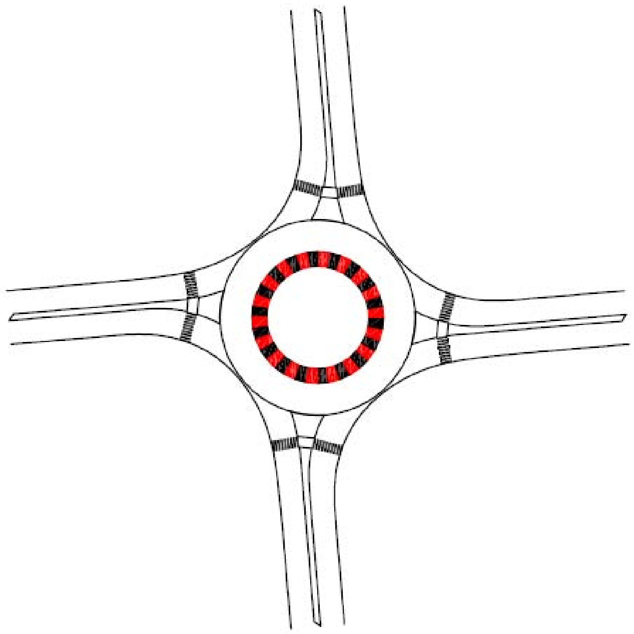


FIGURE 6.17
Final Roundabout Design with 220 Foot Inscribed Circle Diameter, 20 Foot Truck Apron, and 40 Foot Left Offset for Each Approach

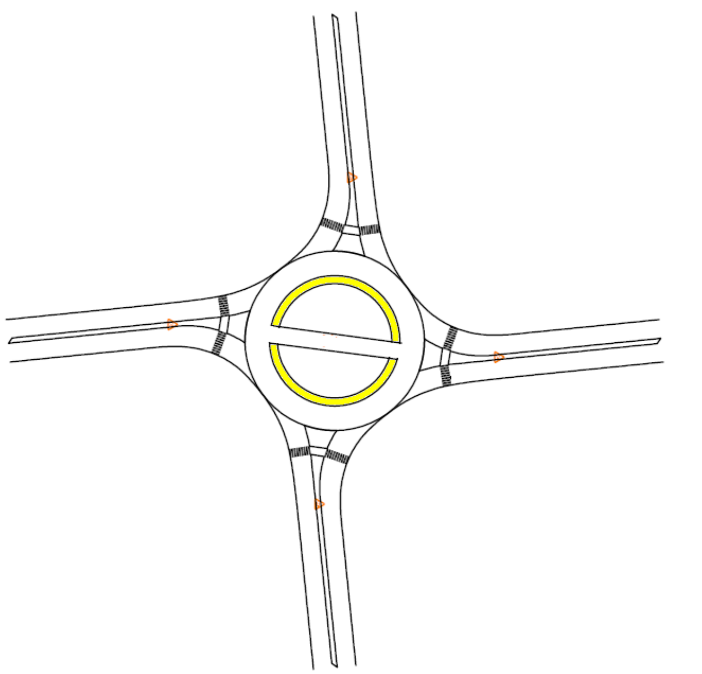


FIGURE 6.18
Redesigned Roundabout with Straight Passage through the Center Island (Assuming Vehicles Are Able to Go over the Splitter Island)

6.4 Testing of Check Vehicles on Kansas Roundabout Drawings

A few drawings of Kansas roundabouts were checked for space requirements for the seven OSOW check vehicles using AutoTURN software.

6.4.1 Wellington Roundabout

The Wellington roundabout was constructed at the intersection of US-81 and US-160 in the city of Wellington, Kansas and will be used initially as an illustration to check the accommodation of the seven OSOW check vehicles and find the space requirements of these check vehicles. An alternative way will also be suggested for this roundabout to better accommodate these seven check vehicles, which minimizes the need for building an extra truck apron that might be necessary.

The Wellington roundabout was used as an example of what needs to be done at a complex intersection to accommodate OSOW. The authors are not in any way suggesting this is what should have been done in the real situation. However, it is assumed local truck and OSOW needs were balanced against the desirability of having a roundabout or other alternatives, and considering right-of-way needs.

The Wellington roundabout has four approaches US-160/16th Street, US-81/North A Street, 16th Street, and US-81/15th Street. These approaches were called approach 1, approach 2, approach 3 and approach 4 simultaneously in the drawings and this report for easy reference. Figure 6.19 shows the Wellington roundabout with names of the 4 approaches labeled.

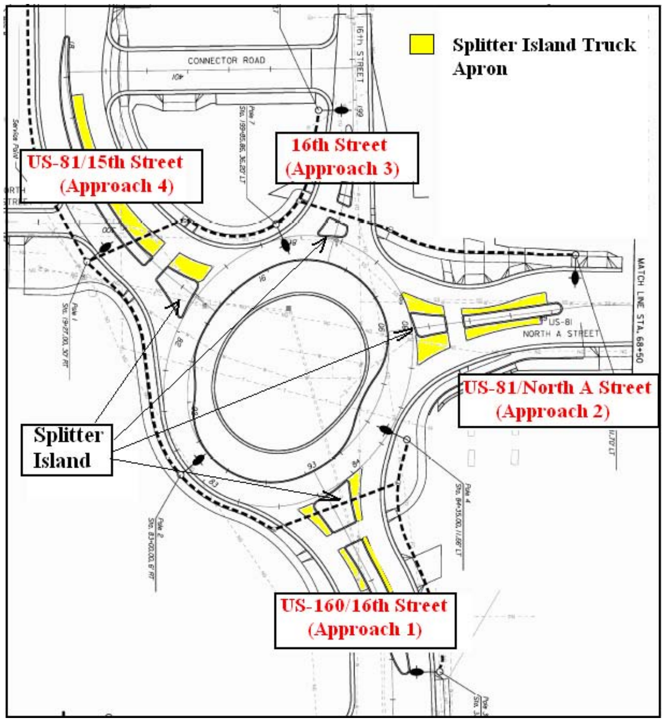


FIGURE 6.19
The Wellington Roundabout with Four Approaches

For each approach, right-turn movements, through movements, and left-turn movements were considered for each of seven check vehicles by using AutoTURN. The simulations were made in such a way that the front tires of the vehicle do not ride on the splitter island or roundabout outer curb. However, the rear tires sometimes do because of space constraints of having to ride up onto the outer curbs or splitter islands of the roundabout to maneuver a particular movement. All vehicles enter through their entering lane, and no movement was made in the opposite direction of travel to prevent the vehicle from riding over the curb, splitter island, or center island.

The plan of the Wellington roundabout was received from KDOT personnel as a PDF-formatted, AutoCAD drawing. This PDF drawing of the Wellington roundabout was set up as an image on the AutoCAD screen according to scale and vehicle simulations were run on top of the drawing. It can be observed from the Figure 6.19 that approach 1, approach 2, and approach 4 has a splitter island truck apron installed, which gives the sense they were initially designed to accommodate truck movements. Also, as these three approaches are U.S. highways, these roads might have a lot of truck activity. (The authors were told that OSOW were routed around this roundabout location.) However, approach 3 has no truck aprons installed, presumably because the designers had information there are no large trucks entering or exiting approach 3. Therefore approaches 1, 2, and 4 will be considered for all seven OSOW check vehicles entering (right-turn, through movement, and left turn movement) and exiting. Approach 3 will be only considered for checking the entering and exiting movement of WB-67, which is basically a design vehicle for most state highways in the U.S.

Figure U.1 to Figure U.39 in Appendix U shows all possible movements of the seven OSOW check vehicles for approaches 1, 2, and 4 and WB-67 for all possible movements for approach 3 which needs more space. In the above mentioned figures, two red lines represent the front-tire tracks of a vehicle and the center red line indicates the path of the vehicle traversed by the front portion of the vehicle. The green lines represent the rear-tire tracks of the vehicle. The blue lines represent the vehicle body clearance, sometimes referred as a "swept path." It can be concluded there is not enough space for seven OSOW check vehicles to maneuver through the roundabout paved area and truck apron. Though in the checked paths it was assumed the front tires were not to mount curbs, splitter islands, and the center island, it was found that the maneuver was impossible without the rear tires riding over the curbs, splitter island, and center island. It was also found that the WB-67 design vehicle was not accommodated in the roundabout within its apparent designed, traversable area. It was also determined that the left-turn movement of the 165-ft. beam check vehicle from approaches 1, 2, and 3 was not feasible in a normal way with the available roundabout space. Also, it was observed that among the seven OSOW check vehicles, the 55-meter wind blade, the 165-ft. beam, and the wind tower upper midsection are critical vehicles which need extra paved area and more vehicle clearance to maneuver through different movements.

Figure 6.20 is an integrated picture showing all possible vehicle simulations with the seven OSOW check vehicles for all approaches. This figure can be used to calculate the extra truck apron that might be required to accommodate truck movements that require more space and also the removable sign area. Based on the front-tire impressions and rear-tire impressions from Figure 6.20, the extra paved area required to be constructed at this roundabout to accommodate these movements can be calculated and is shown in Figure 6.21. Based on the vehicle body clearance from Figure 6.20, the removable sign can be calculated and is shown in Figure 6.22.

It can be concluded from Figures 6.20, 6.21, and 6.22 there is a need of a fully traversable central island, and an external truck apron of variable widths at different locations if it were necessary to maneuver various movements of seven OSOW check vehicles through the roundabout as designed. Therefore, a fully traversable central island truck apron would be necessary. (Note: *The authors believe this is an example location where, should OSOW need to be accommodated, a fully traversable central island should be considered. These are discussed with examples in other parts of this report.*) An alternative was tested where these seven OSOW check vehicles were allowed to ride over curbs and splitter islands and made to go in the opposite direction of traffic so that they don't use any extra space other than splitter islands and a fully traversable center island. Figure U1.1 to Figure U1.18 in Appendix U1 shows all critical movements of the seven OSOW check vehicles for all approaches. Figure 6.23 is an integrated picture showing all possible critical vehicle simulations with the seven OSOW check vehicles for all approaches. (Again, critical vehicle simulations are selected vehicle simulations among all possible simulations requiring comparatively more swept path space) This figure can be used to calculate any extra truck apron that might be required to accommodate truck movements that requires more space and also the removable sign area. It has been found there is no need of any external truck apron for this alternative as this case has fully traversable center island and splitter islands, and the seven OSOW check vehicles are allowed to go in the opposite direction of traffic if required to stay in the paved area of the roundabout. Figure 6.24 shows the removable sign area at the roundabout, which is most of the area in the roundabout, hashed in the figure, which is the removable sign area within and beyond the roundabout.

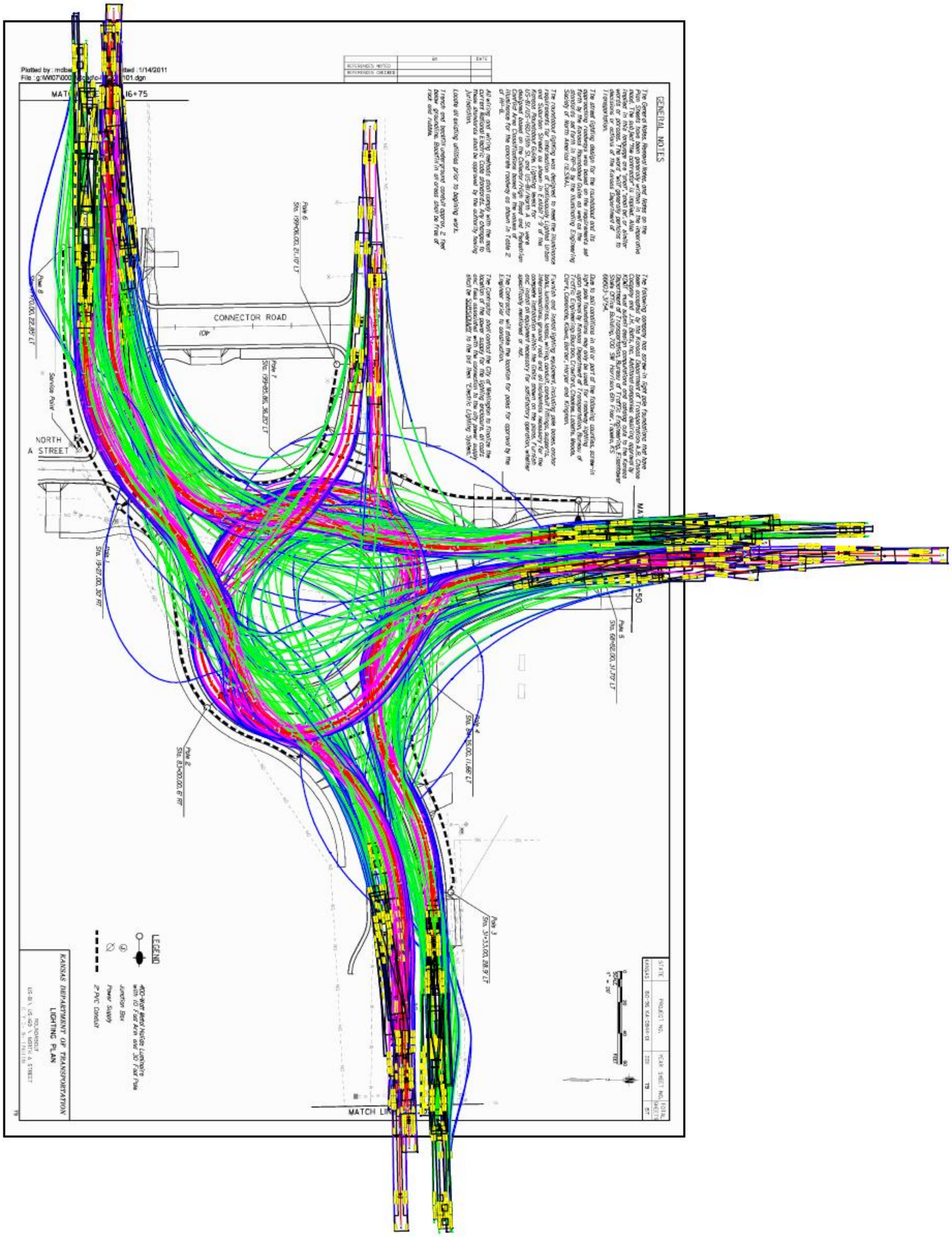


FIGURE 6.20
Wellington Roundabout Showing All Possible Vehicle Simulations for All Approaches with the Seven Check Vehicles

(Note: For each approach, right-turn movements, through movements, and left-turn movements were considered for each of seven check vehicles by using AutoTURN as explained in detail in section 6.4.1.)

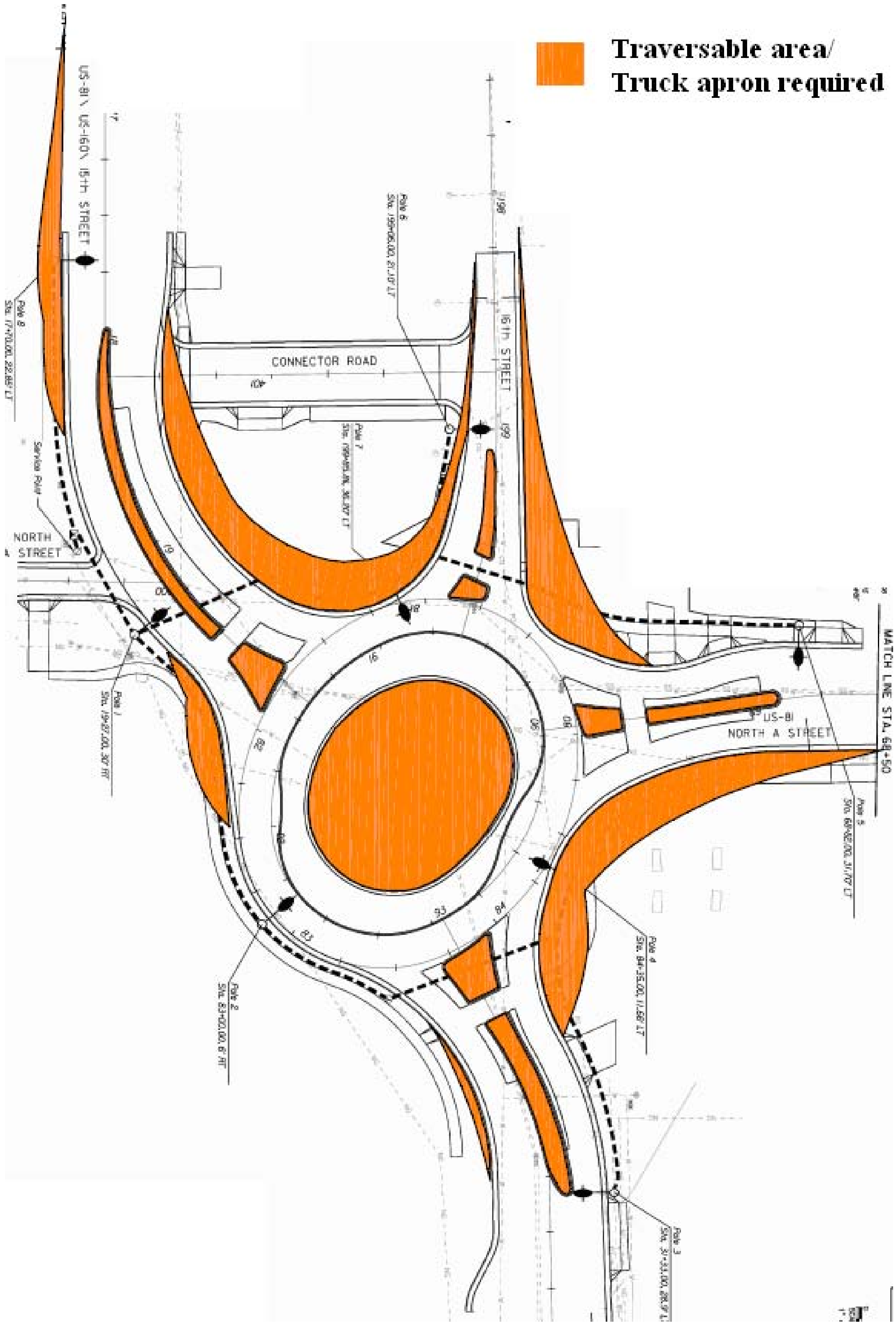


FIGURE 6.21
Extra Traversable Area/Truck Apron Required for Wellington Roundabout Based on Vehicle Simulations Shown in Figure 6.20

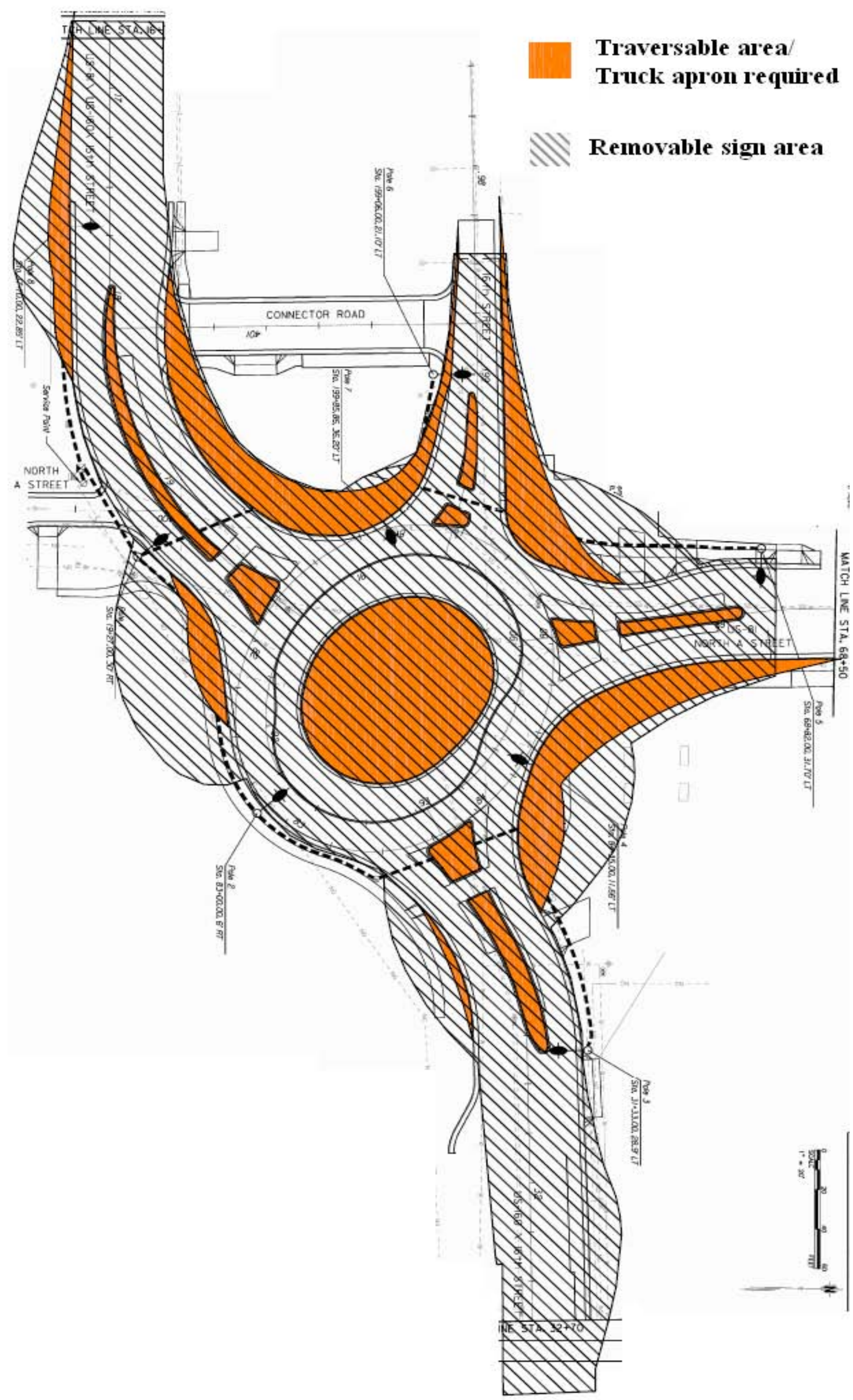


FIGURE 6.22
Extra Traversable Area Required and Removable Sign Area for Wellington Roundabout Based on Vehicle Simulations Shown in Figure 6.20

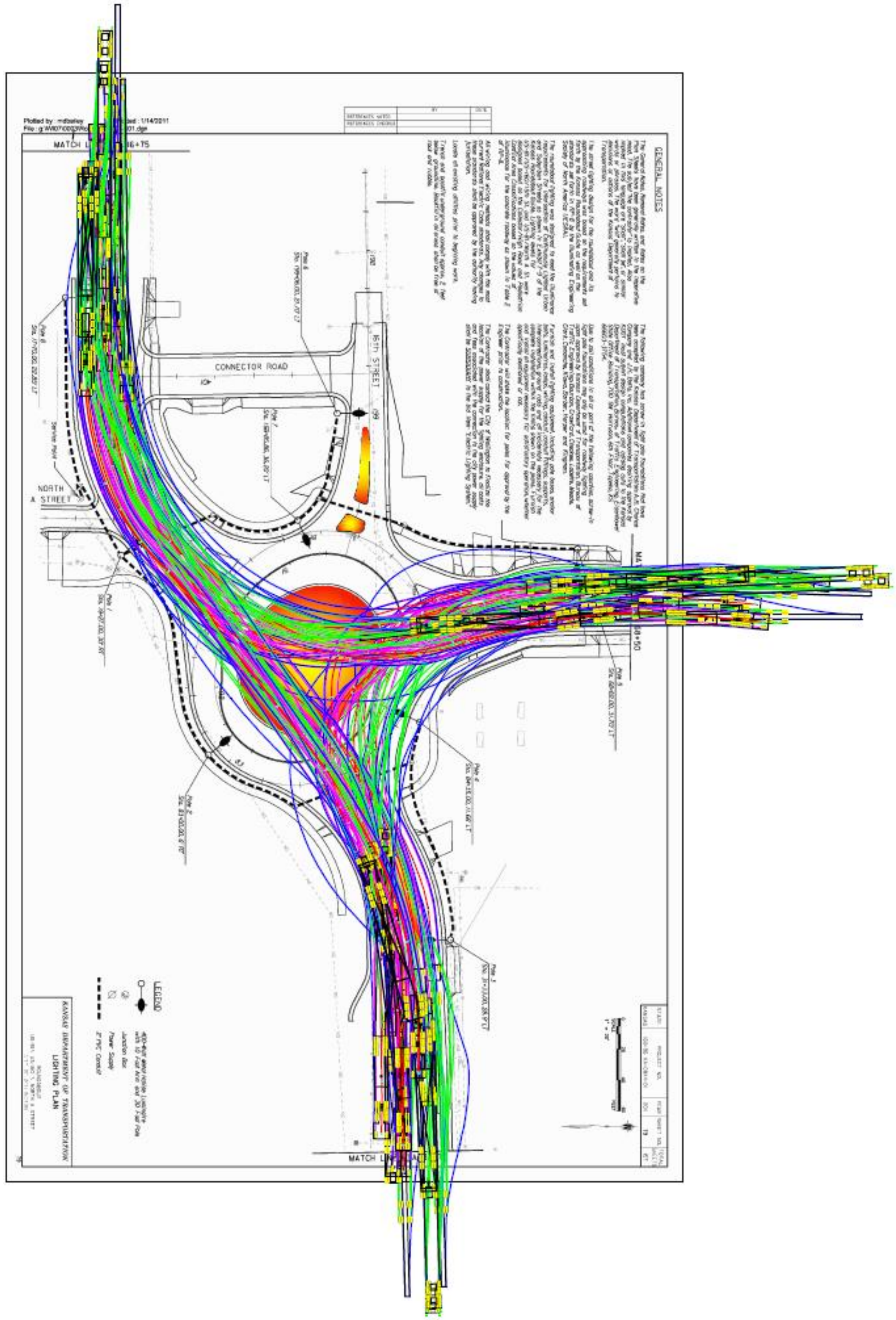


FIGURE 6.23
All Possible Vehicle Simulations for All the Approaches for Wellington Roundabout When the Central Island Is Made Fully Traversable

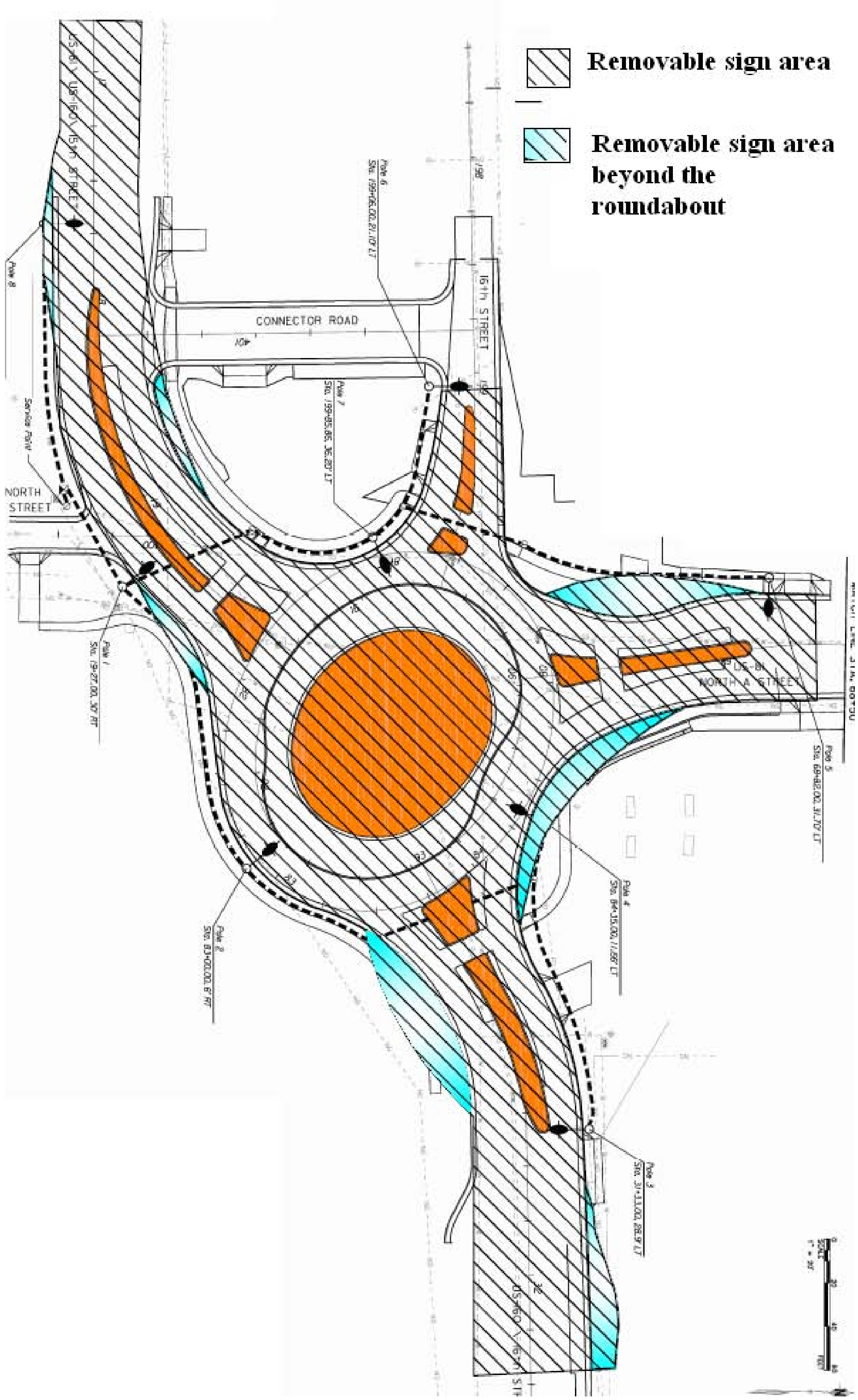


FIGURE 6.24
Extra Traversable Area and Removable Sign Area Required for Wellington Roundabout Based on Vehicle Simulations from Figure 6.23

6.4.2 Garnett Roundabout

The Garnett roundabout, constructed at the intersection of US-59 and US-169, is used here to check for the accommodation of the seven OSOW check vehicles and find the space requirements of these check vehicles. The plan of the Garnett roundabout was received from KDOT personnel as a PDF format AutoCAD drawing. This PDF drawing of the Garnett roundabout was set up as an image on the AutoCAD screen according to the scale, and the vehicle simulations were run on top of the drawing using AutoTURN software.

Figure 6.25 shows the Garnett roundabout with three approaches. Based on the geometry of the roundabout, possible movements of the seven check vehicles were assumed as approach 1 to approach 3, approach 2 to approach 3, and approach 3 to approaches 1 and 2. Three different alternatives that could have been used for this roundabout to better accommodate these seven check vehicles will be illustrated. They are to be named as Case 1, Case 2, and Case 3 and are illustrated in this report.

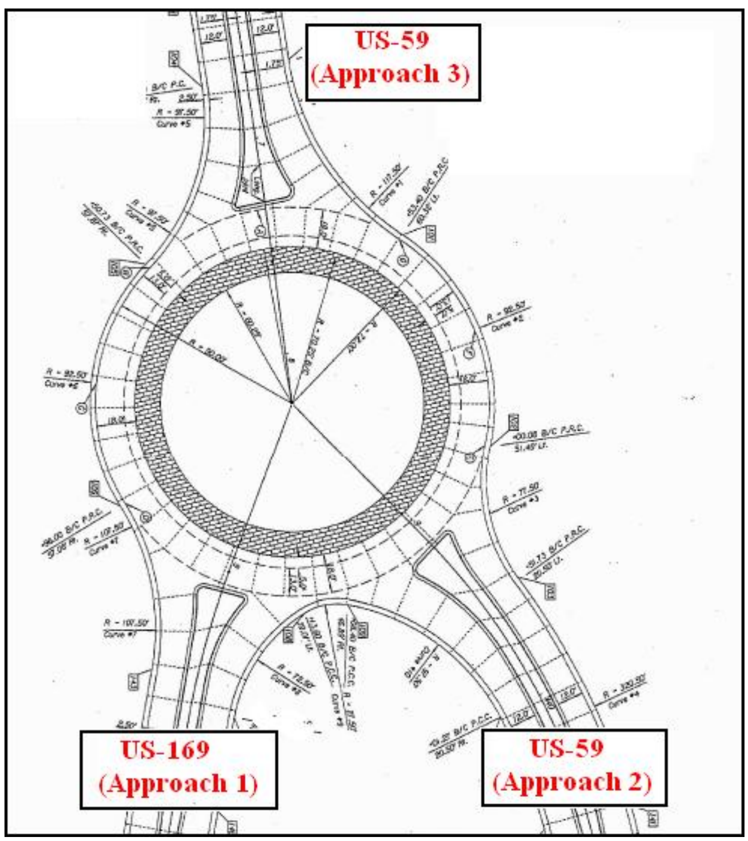


FIGURE 6.25
Garnett Roundabout with Three Approaches

6.4.2.1 Garnett Case 1

The initial condition considered is for the seven check vehicles to traverse the roundabout in the normal way they are supposed to travel, i.e. they are not allowed to enter or maneuver in the opposite direction of normal traffic. The front tires of the truck are assumed to not ride up on splitter islands, curbs, and center islands and use only the space dedicated for trucks to use. However, the path of the rear tires may ride over the curbs, splitter islands, or center islands when there is not enough space. Vehicle simulations were conducted for all possible movement of the seven check vehicles using AutoTURN. Critical vehicle simulations for this case were presented from Figures V.1 to V.12 in Appendix V. Figure 6.26 is an integrated picture showing all critical vehicle simulations for all approaches. This figure can be used to calculate the extra truck apron that might be required to accommodate truck movements that require more space and also the necessary, removable sign area. Based on the front-tire and rear-tire paths from Figure 6.26, the extra paved area that is required to be constructed at this roundabout to accommodate these movements can be seen and is shown in Figure 6.27. Based on the vehicle body clearance from Figure 6.26, the removable sign area can be determined and is shown in Figure 6.28. This figure also shows an area where standard signage (or any permanent fixture) can be installed in the body of the roundabout, which is hashed in a light yellow color. Figure 6.29 is a combination of Figures 6.27 and 6.28 (showing extra paved area required and removable sign area).

FIGURE 6.26
Garnett Roundabout Showing All Critical Vehicle Simulations for All Approaches

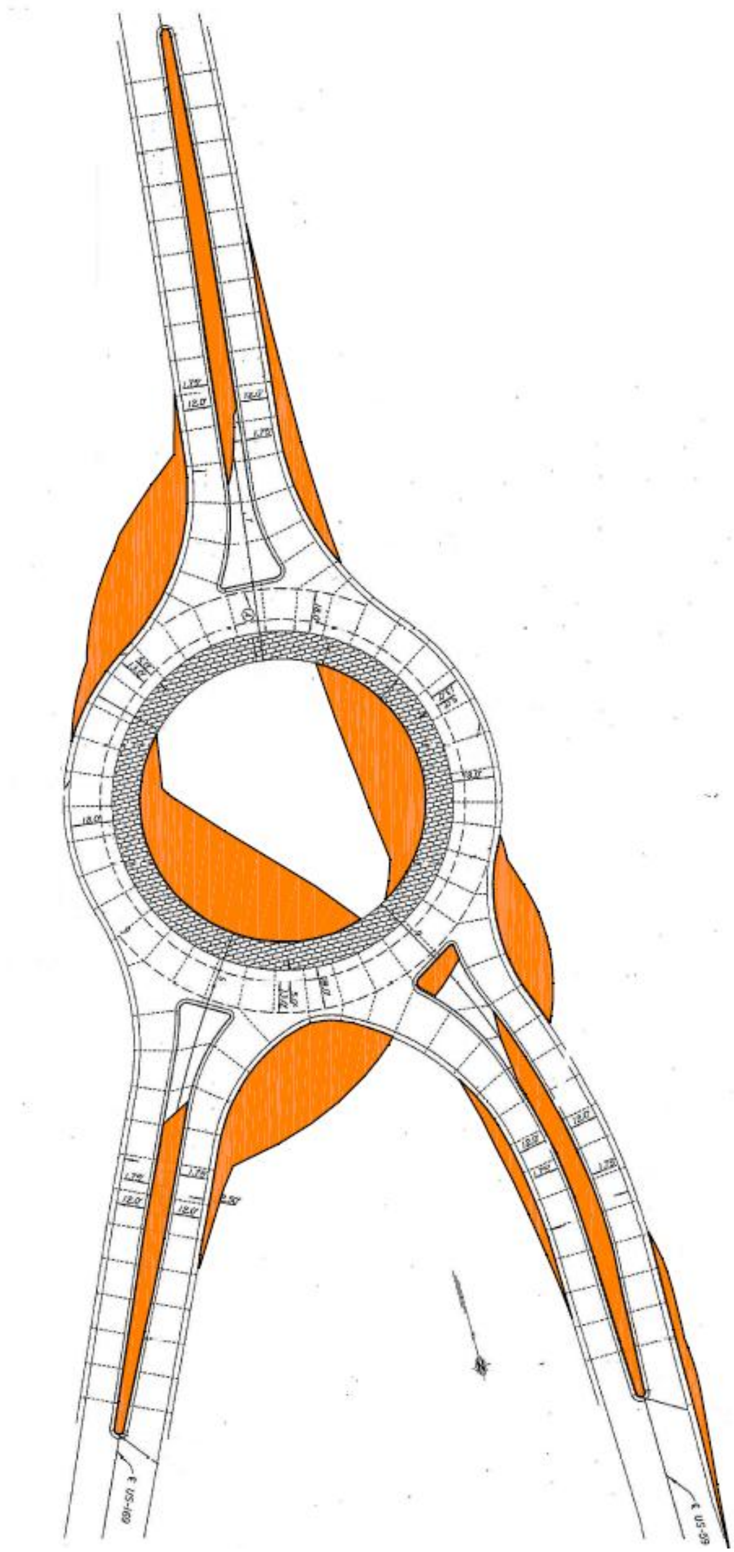


FIGURE 6.27
Extra Traversable Area/Truck Apron Required for Garnett Roundabout Based on Vehicle Simulations in Figure 6.26

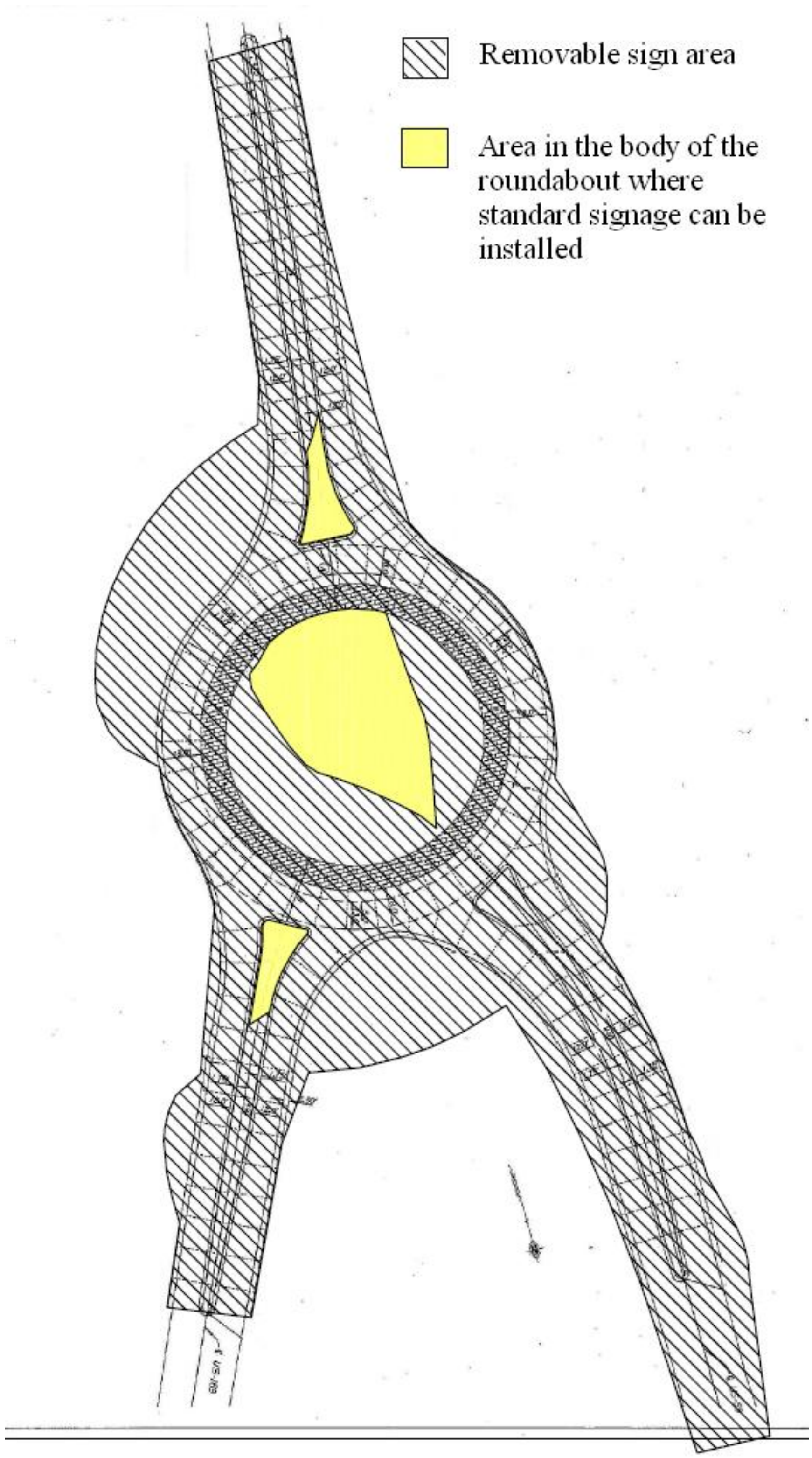


FIGURE 6.28
Removable Sign Area Required for Garnett Roundabout Based on Vehicle Simulations in Figure 6.26

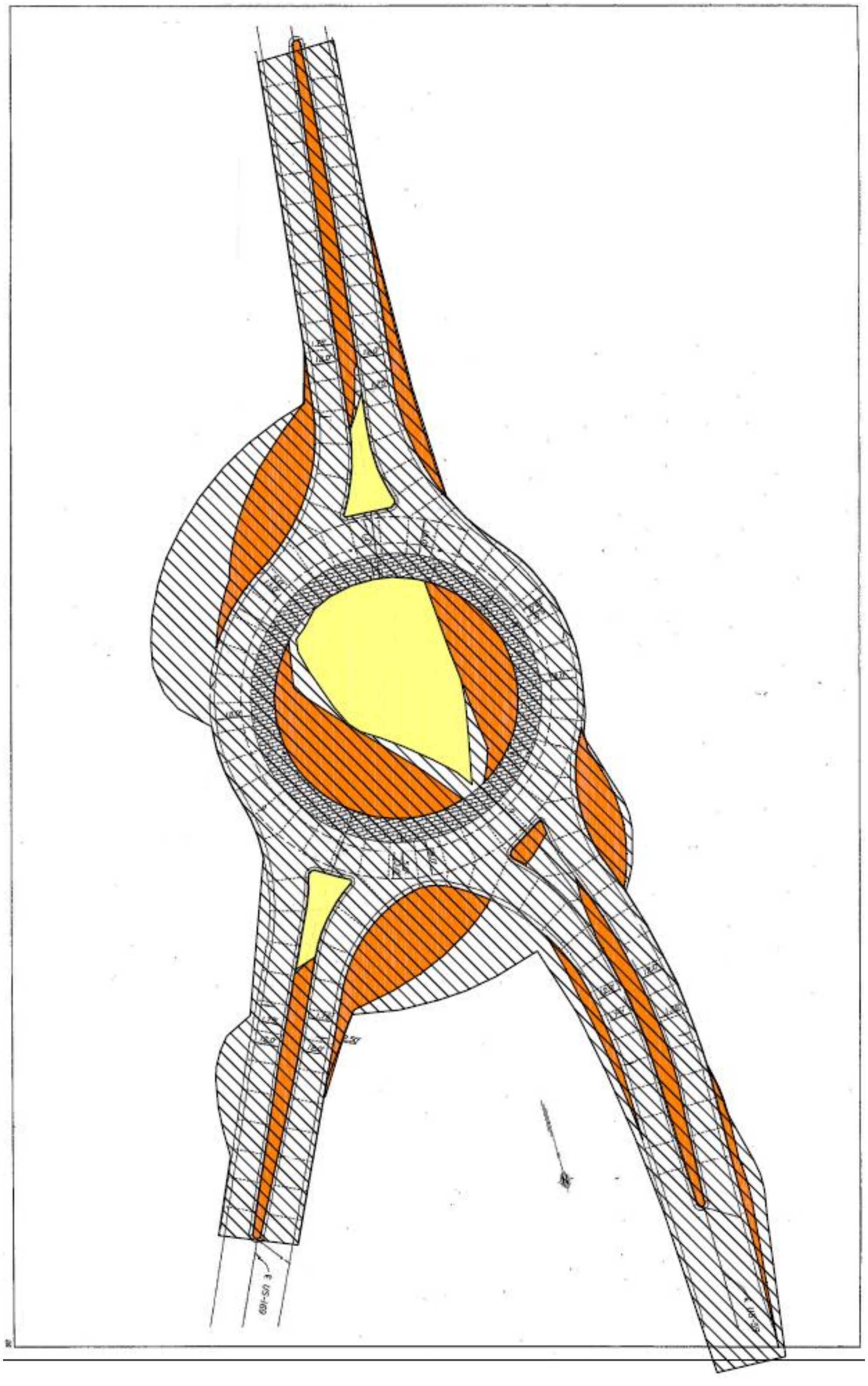


FIGURE 6.29
Extra Traversable Area and Removable Sign Area Required for Garnett Roundabout Based on Simulations in Figure 6.26

6.4.2.2 Garnett Case 2

The second alternative is considered where the trucks travel in opposite direction of traffic while entering, exiting, and maneuvering through the roundabout (assumed to have necessary and legal traffic control), and they are allowed to ride over the splitter islands while entering and exiting. However, the front tires of the truck are simulated in such a way that the swept path of a vehicle uses minimal center island space. Vehicle simulations were conducted for all possible movements of the seven check vehicles using AutoTURN. Critical vehicle simulations for this case were presented from Figures V1.1 to V1.11 in Appendix V1. Figure 6.30 is an integrated picture showing all critical vehicle simulations for all approaches. This figure can be used to determine the extra truck apron required to accommodate the truck movements which requires more space and also the removable sign area. Based on the front-tire and rear-tire tracks from Figure 6.30, the extra paved area required to be constructed at this roundabout to accommodate these movements can be seen in Figure 6.31. It can be observed that all approaches should be fully traversable and therefore, if there is any signage warranted on the approaches, they must be removable signs. Based on the vehicle body clearance from Figure 6.30, the removable sign is shown in Figure 6.32. This figure also shows an area where standard signage can be installed in the body of the roundabout, which is hashed in a light yellow color. It can be observed that Case 2 needs less “extra paved area” and “removable sign area” when compared to Case 1. Figure 6.33 is a combination of Figures 6.31 and 6.32, i.e. extra paved area required and removable sign area.

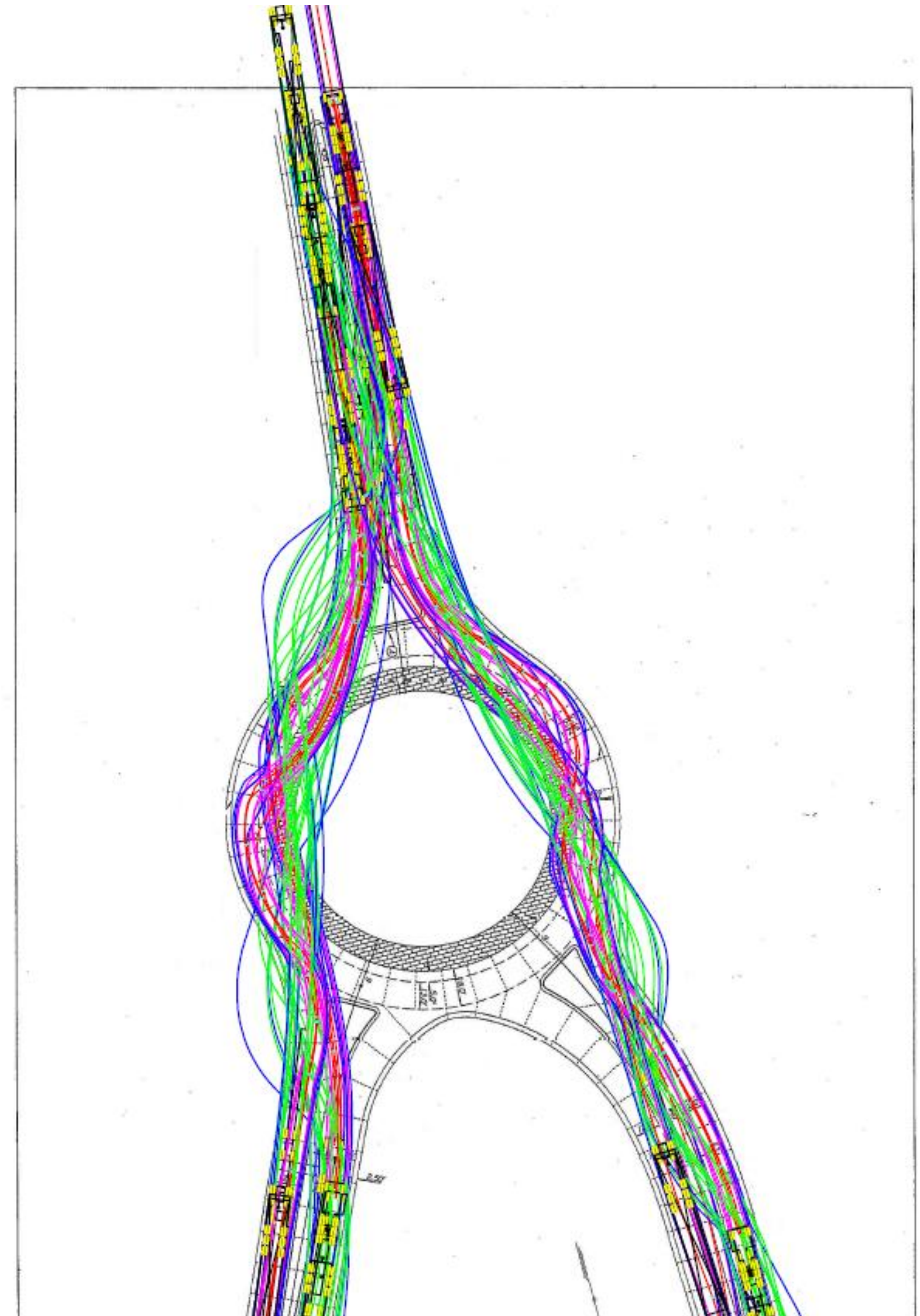


FIGURE 6.30
Garnett Roundabout Showing All Critical Vehicle Simulations for All the Approaches When Trucks Were Allowed to Travel in Opposite Direction of Traffic While Entering, Exiting, and Maneuvering through the Roundabout

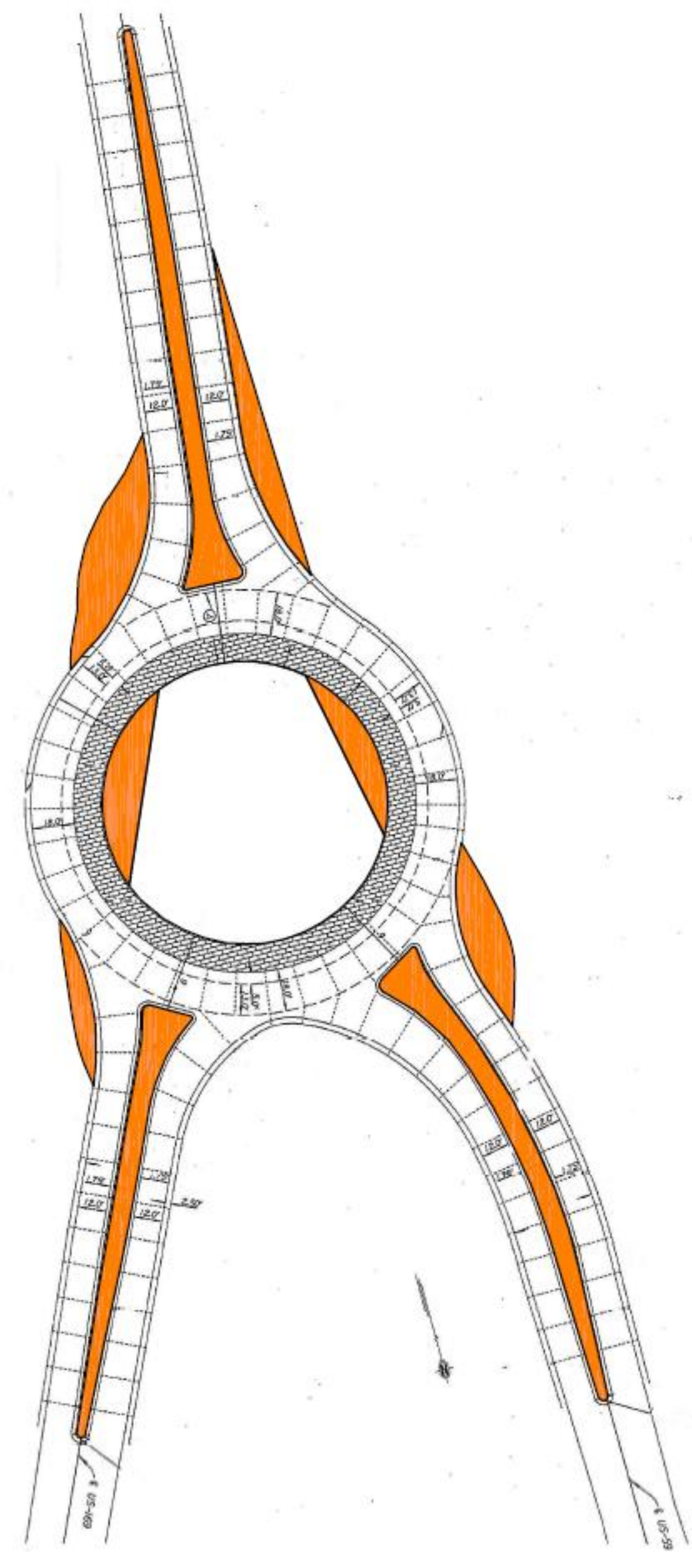


FIGURE 6.31
Extra Traversable Area/Truck Apron Required for Garnett Roundabout Based on Vehicle Simulations in Figure 6.30

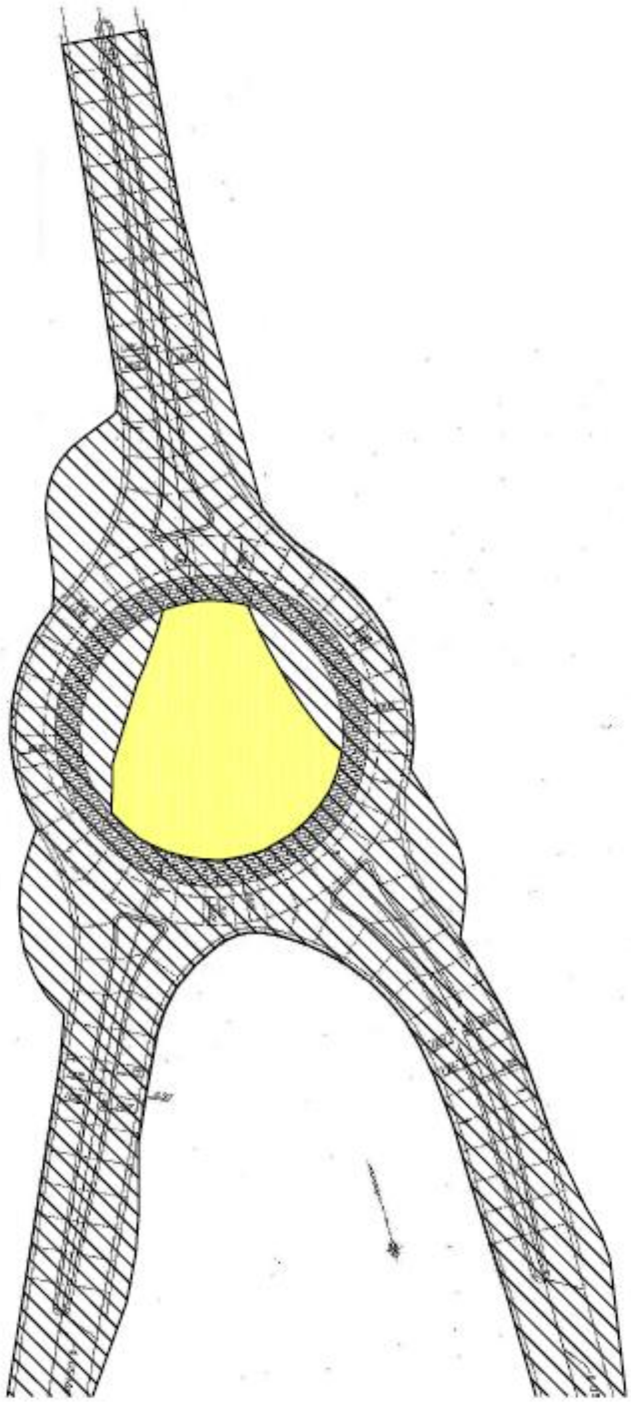


FIGURE 6.32
Removable Sign Area Required for Garnett Roundabout Based on Vehicle Simulations in Figure 6.30

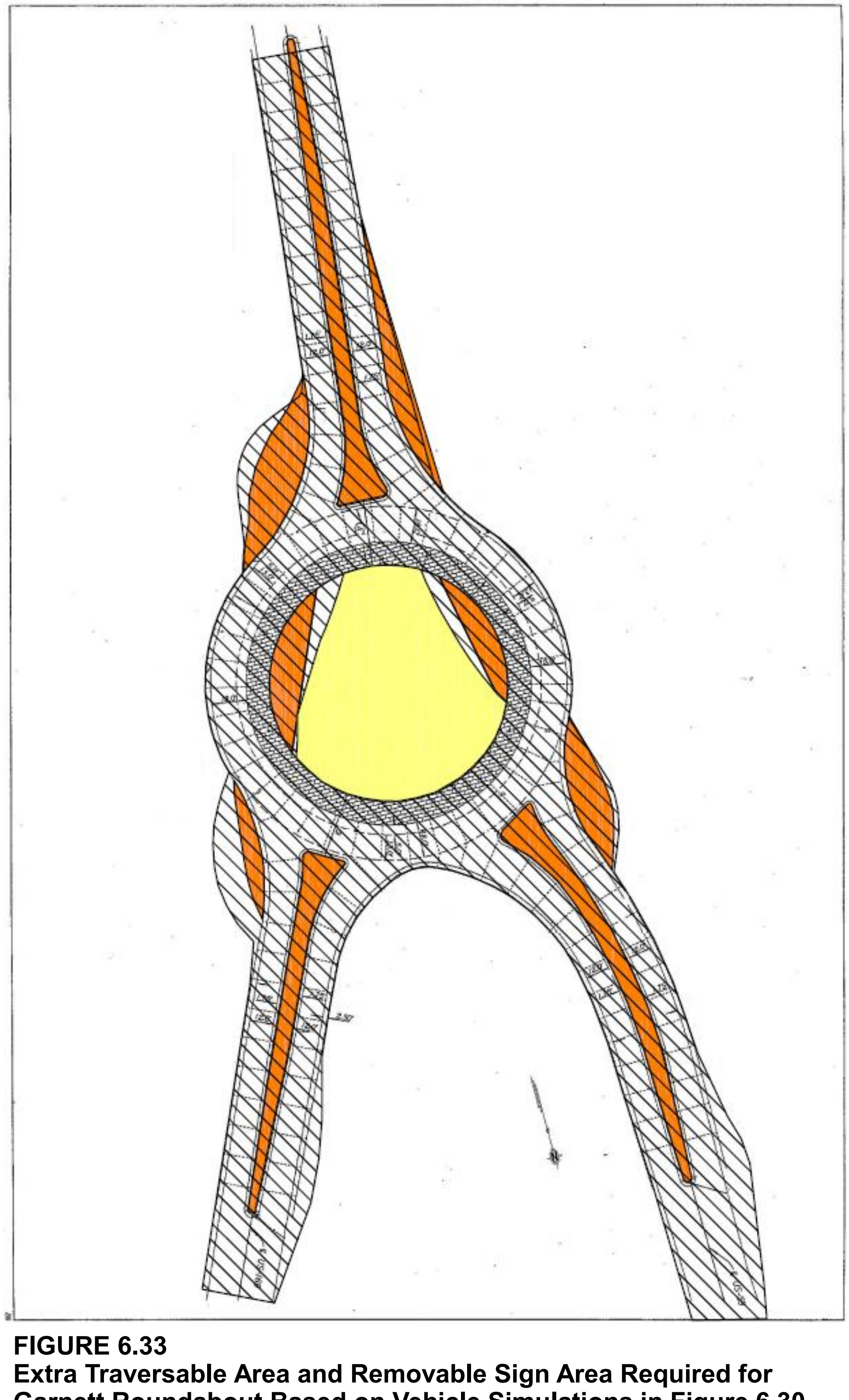


FIGURE 6.33
Extra Traversable Area and Removable Sign Area Required for Garnett Roundabout Based on Vehicle Simulations in Figure 6.30

6.4.2.3 Garnett Case 3

The third alternative is considered where the center island is made fully traversable and the seven check vehicles were allowed to ride over curbs and splitter islands, and allowed to go in the opposite direction of normal traffic so that they don't use any extra space other than splitter islands and a fully traversable center island. Vehicle simulations were conducted for all possible movement of the seven check vehicles using AutoTURN. Figure 6.34 shows the modified design, which has a fully traversable center island and approach, after considering all critical vehicle simulations. Figure 6.35 shows the roundabout with the modified paved area design and removable sign area. It was found that no extra paved area or removable sign area would be required beyond the body of the roundabout.

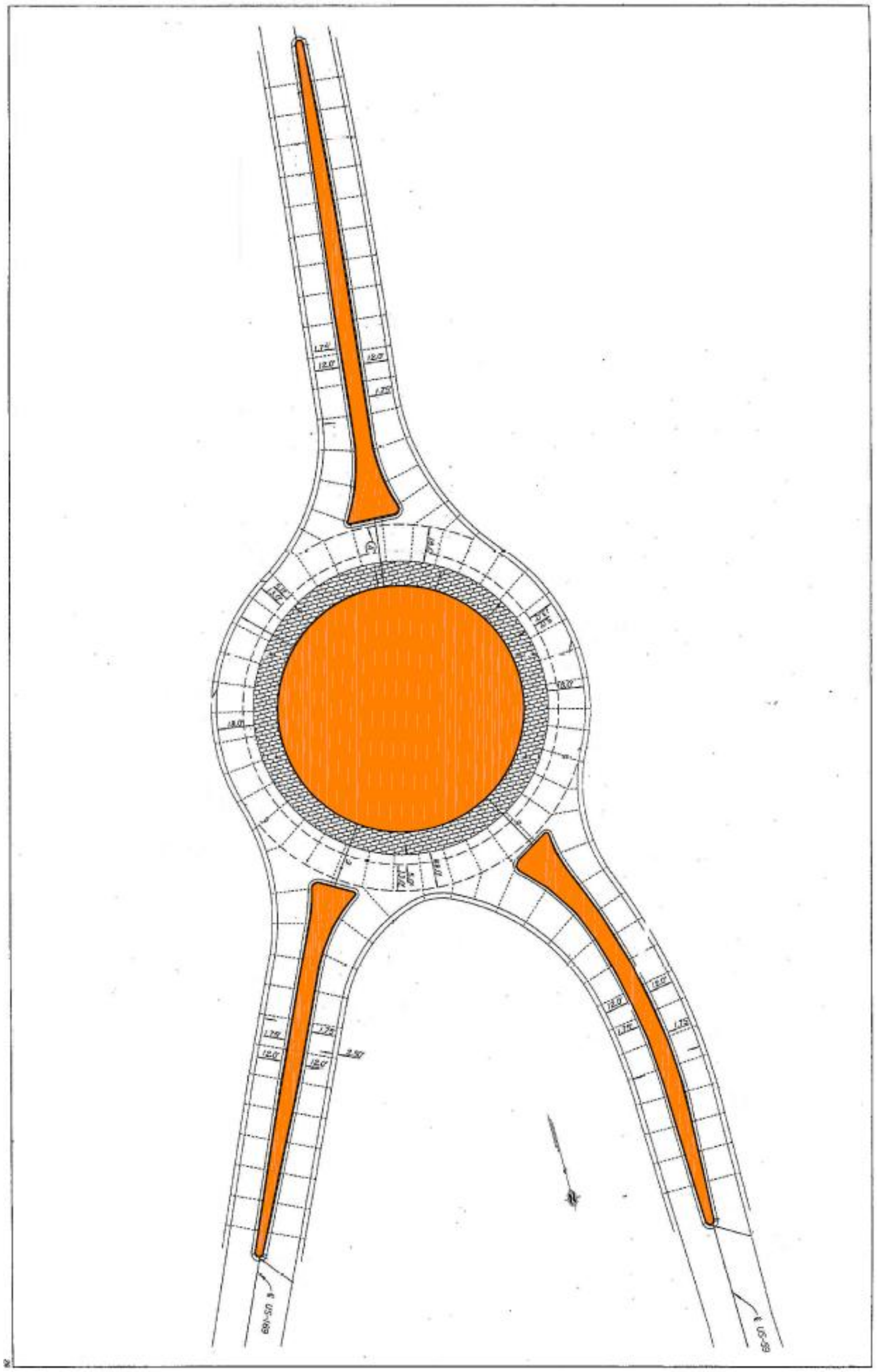


FIGURE 6.34
Extra Traversable Area/Truck Apron Required for Garnett Roundabout When the Center Island Is Made Fully Traversable, and the Seven Check Vehicles Were Allowed to Ride Over Curbs and Splitter Islands, and Allowed To Go in the Opposite Direction of Normal Traffic

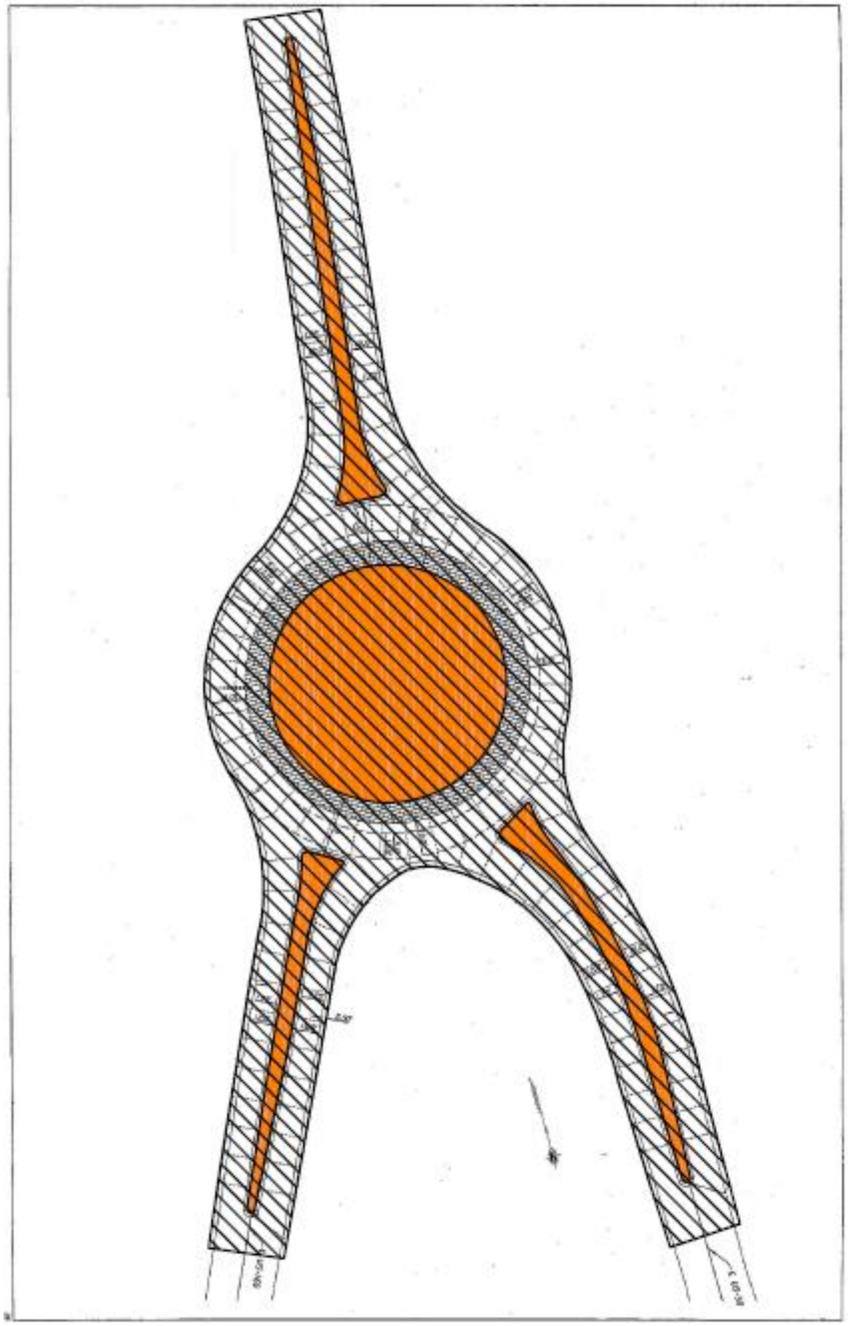


FIGURE 6.35
Extra Traversable Area and Removable Sign Area Required for Garnett Roundabout Based on Vehicle Simulations in Figure 6.34

6.4.3 Arkansas City Roundabout

The Ark City roundabout, constructed at the intersection of US-77 and US-166, is used here to check the accommodation of the seven check vehicles and find the space requirements of these check vehicles. The plan of the Ark City roundabout was received from KDOT personnel as a PDF format AutoCAD drawing. This PDF drawing of the Ark City roundabout was set up as an image on the AutoCAD screen according to scale, and the vehicle simulations were run on the top of the drawing using AutoTURN software. Figure 6.36 shows a sketch of the Ark City roundabout with four approaches.

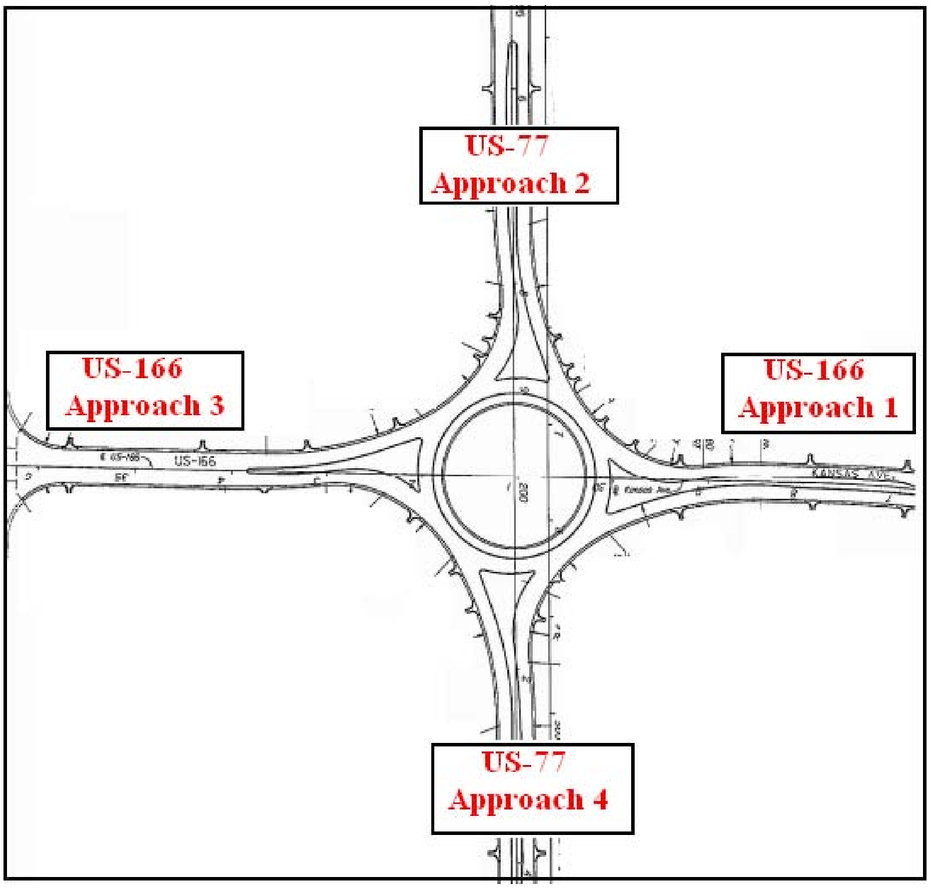


FIGURE 6.36
Arkansas City Roundabout with Four Approaches

As the Arkansas City roundabout is at the intersection of US-77 and US-166, it was assumed OSOW movements only occur through this roundabout on US-77, and they do not turn at this intersection. Therefore, this roundabout was checked for only through movements of the seven check vehicles for Approaches 1 through 4. It was assumed that the seven check vehicles traverse the roundabout in the same direction. The front tires of the truck are simulated to not ride up on splitter islands, curbs, and center islands and use only the space that is dedicated for trucks to use. However, the path of the rear tires may ride over the curbs, splitter islands, or center islands when there is not enough space. Vehicle simulations were conducted for all possible through movements of the seven check vehicles using AutoTURN. Critical vehicle simulations for this case were presented from Figures W.1 to W.12 in Appendix W. Figure 6.37 is an integrated picture showing all critical vehicle simulations for all approaches. This figure can be used to calculate the extra truck apron required to accommodate truck movements that require more space and also the removable sign area. Based on the front-tire and rear-tire paths from Figure 6.37, the extra paved area required to be constructed at this roundabout to accommodate these movements can be determined and is shown in Figure 6.38. Based on the vehicle body clearance from Figure 6.37, the removable sign area can be determined and is shown in Figure 6.39. This figure also shows an area where standard signage, or any permanent fixture, could be installed in the body of the roundabout and is shown hashed in light yellow. Figure 6.40 is a combination of Figures 6.38 and 6.39, showing the extra paved area and removable sign area that would be required.

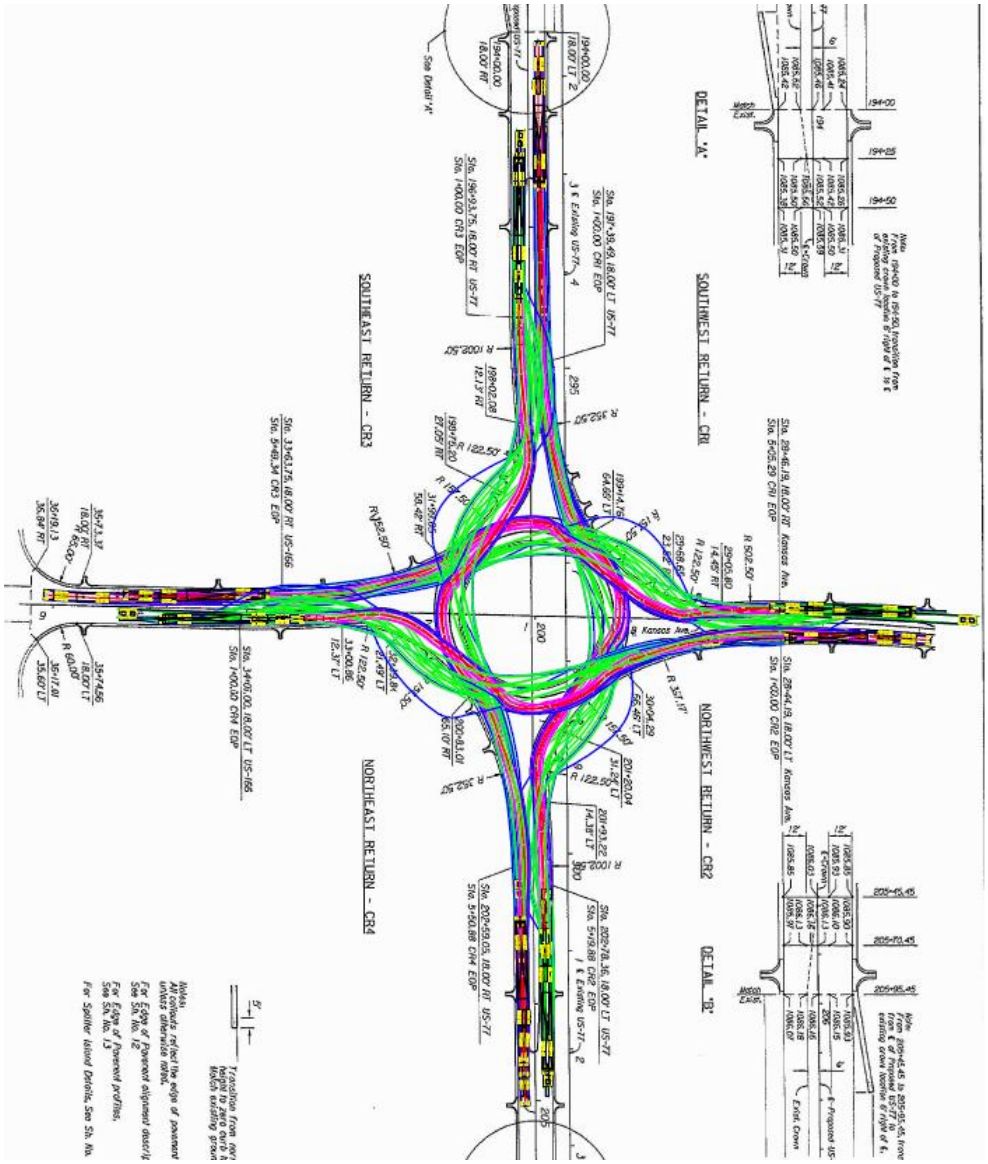


FIGURE 6.37
Arkansas City Roundabout Showing All Critical Vehicle Simulations for All the Approaches

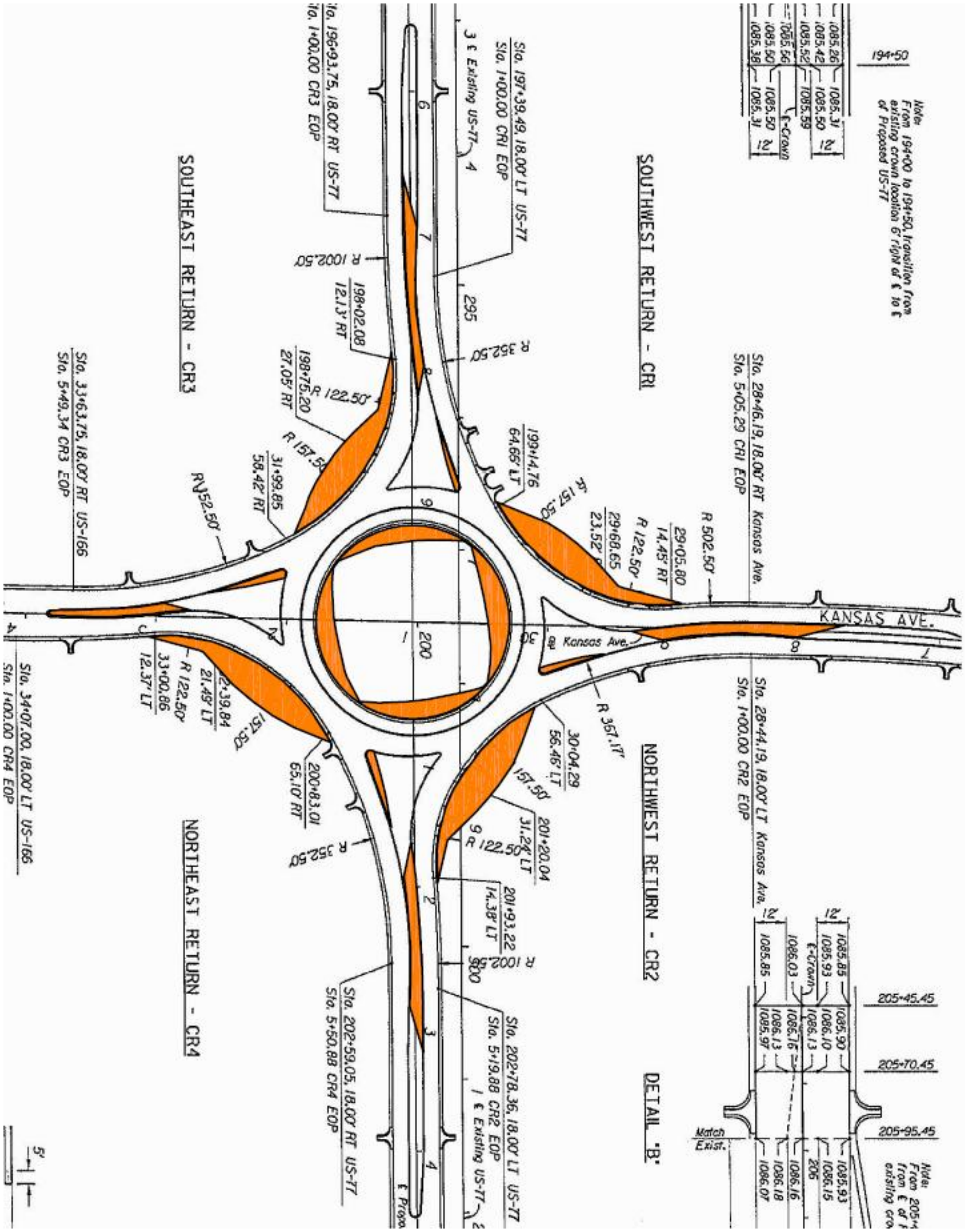


FIGURE 6.38
Extra Traversable Area/Truck Apron Required for Arkansas City Roundabout Based on Vehicle Simulations in Figure 6.37

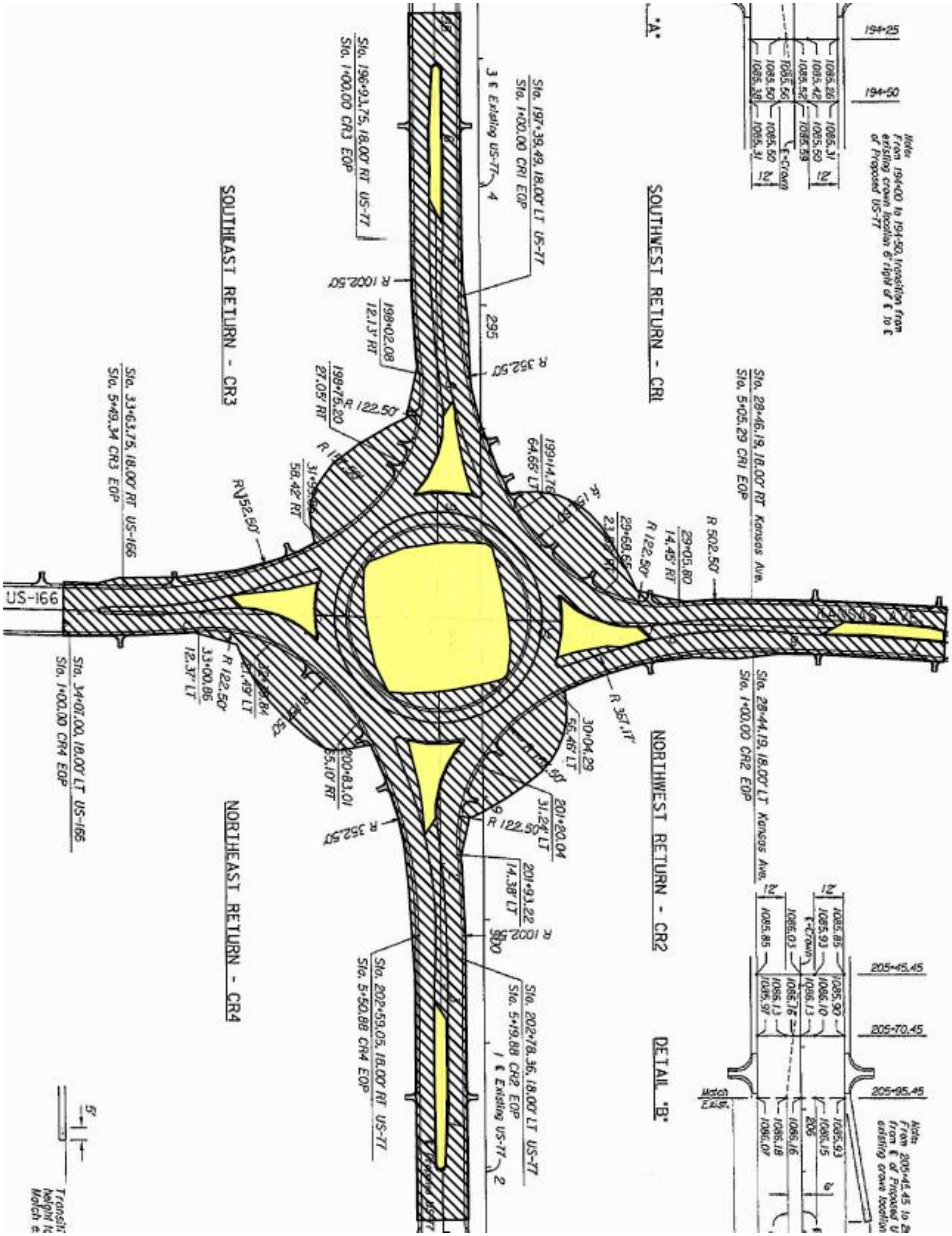


FIGURE 6.39
Removable Sign Area Required for Arkansas City Roundabout Based on Vehicle Simulations in Figure 6.37

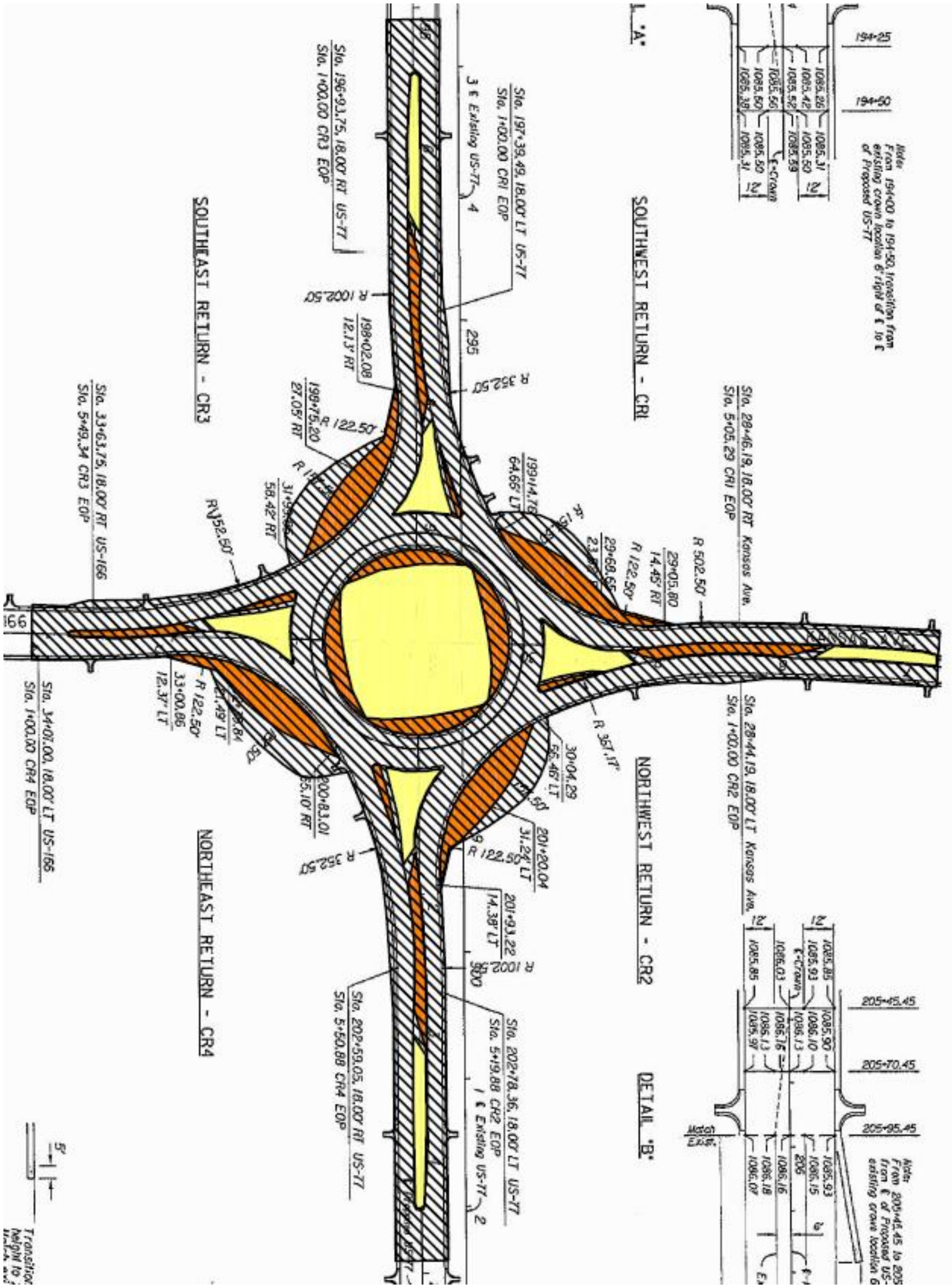


FIGURE 6.40
Extra Traversable Area and Removable Sign Area Required for Arkansas City Roundabout Based on Vehicle Simulations in Figure 6.37

Chapter 7: Conclusions

7.1 General Comments

This research project had two objectives: 1. compile current practice and research by various states and countries related to the effects that Oversize, Overweight vehicles (OSOW) have on roundabout location, design, and accommodation; and, 2. attempt to fill in information gaps with respect to design and operations for this class of vehicle. It should be emphasized here that there was no intent to develop a design manual, and thus, this report should not be considered to be a design manual. States have different needs to accommodate OSOW and roundabouts are generally site specific, and no one solution fits all. Thus, a definite solution for accommodating all OSOW cannot be made. By presenting a compilation of current practice and research, enhancing information on design and operations, and recommending consideration and more study on various concepts and practices, the authors have developed a basic reference for those responsible for, or desiring to, accommodate OSOW at roundabouts in their jurisdiction.

One caveat should be mentioned. Although the study was specifically about OSOW, it was difficult to clearly separate OSOW from large vehicles in general. Some literature and reviewed studies, and respondent's answers, could be related to either.

7.2 Overview of Approach

7.2.1 Literature Review

To accomplish the above the researchers used the following methodology. First, the usual literature review was conducted in both published literature and unpublished reports. Personal contacts were also made, and some designers provided material.

7.2.2 Surveys

Four surveys were developed, executed and analyzed:

1. a general survey to the 50 states to obtain general information regarding permitted vehicles in general, and the extent of roundabouts in the state,

2. a survey to the 50 states more specifically directed to large vehicle issues, particularly OSOW, and problems with, and solution ideas for, accommodating OSOW at roundabouts,
3. a survey with composite answers by thirteen regional managers of the Specialized Carriers and Rigging Association (SC&RA), and
4. a survey developed and conducted in partnership with the American Transportation Research Institute (ATRI) and sent to their membership.

The first two surveys were intended to get information from states with permitting problems in general and problems with permitted vehicles and roundabouts. The second two were intended to obtain similar information directly from the trucking industry.

7.2.3 Examples of OSOW Accommodation

Examples of accommodating OSOW in general, and various turning movements, found in the literature, surveys, and personal contacts are provided in the report as examples of ideas and concepts that could be considered and possibly adapted to the needs of a specific site. Several examples from England, France, and Germany were also found and are presented. Also, cutting edge research and a state's recent policy on accommodating low ground clearance vehicles that could "hang up" are presented.

7.2.4 Using Check Vehicles for Design

Existing software capable of roundabout design and analysis were studied and that use demonstrated. Vehicle-turn and swept-path analysis software, used to evaluate standard designs or specialized vehicle maneuvers for all types of roadway, highway, and site design projects, were studied and are presented.

7.3 General, Overall Conclusions

From analyzing the review of literature as presented in Chapter 2, the authors have two general conclusions. The first conclusion, although, arguably, peripheral to the main objective of the study , is that states should consider conducting a study to develop a freight network which includes segments where OSOW need to be accommodated, in accordance with state and federal commerce laws and policies and the state's economy. The study should include determining all motor vehicles whose size and turning movements are critical to developing routes on which all segments will accommodate these vehicles, e.g., Wisconsin's seven check vehicles.

The second conclusion is that, as stated in the FHWA roundabout guide, when determining a design vehicle it should involve more than arbitrarily selecting some vehicles such as AASHTO designation WB – 67. All stakeholders should be considered.

7.4 Conclusions from Surveys

7.4.1 Two States' Surveys

1. Ground clearance by "lowboys" is a major problem. This directly relates to just about all vertical elements of a roundabout from the splitter island to outside curbs and truck aprons and associated curbs.
2. Determining what OSOW may use a particular route in which a roundabout is designed, and knowing the dimensions and turning characteristics of the OSOW are essential to accommodate the OSOW in the design. Some states appear to do a good job in this regard. By their silence, i.e., not providing answers to this effect on the surveys, leads the authors to conclude that many states could do a better job in this regard.
3. States should consider developing freight networks in general, and OSOW routes in particular, and develop OSOW check vehicles that represent materials critical to the economy of the state, or area within the state, that need to travel within and throughout the state. Although there may be other good examples, studying the Wisconsin network and considering a similar approach would be a good start.
4. As seen from the respondents answers in the first survey, although roundabouts do have "problems" for OSOW that need accommodation, roundabouts are not the only obstructions to OSOW routing. All

obstructions need to be considered and some routes may not be suitable for OSOW.

7.4.2 Two Trucking Industry Surveys

7.4.2.1 Specialized Carriers and Rigging Association Survey

The response indicated that all the following strategies have merit for accommodating OSOW:

1. Wide truck aprons (12 feet or more) with a minimum slope and mountable curb
2. Custom center islands to address known left turns
3. Tapered center islands to support through movements
4. Paved area behind curb (right side for off tracking)
5. Installing removable signs of setbacks for permanent fixtures (light poles)
6. Allow trucks to cross over the median (stamped, depressed or corrugated) before entering the roundabout, in a counter flow direction, to make a left turn in the opposing lane and then cross back over after the turn.
7. Right turn lanes (sometimes gated).

The authors conclude that these strategies should be considered for accommodating OSOW, as necessary to meet needs.

From this survey, and from all surveys and contacts made during the course of this investigation, the authors conclude that vertical ground clearance in general, and curbs in particular, are a major problem for large trucks and OSOW and definitely need to be mitigated whenever OSOW need to be accommodated.

The authors conclude that ground clearance is an issue that has not been given as much attention as it deserves and must be addressed. The authors further conclude that three inches should be considered as a maximum height of splitter islands, truck aprons and curbs.

7.4.2.2 Partnered KSU- American Transportation Research Institute (ATRI) Survey.

It is clear that the majority of respondents to this survey do not like roundabouts. This appears contrary to survey one in which 11 obstacles to OSOW were pointed out, with a roundabouts being ranked 9 out of 11 identified obstacles. The authors conclude; therefore, that there is need for better communication between owners, planners and designers of roundabouts and the trucking industry. This includes more education on driving roundabouts, particularly in regard to understanding the purpose of the truck apron and proper use of the truck apron. It also includes the need for owners, planners and designers to understand the needs of OSOW.

Although it is not clear how representative this group of respondents is, the authors conclude that several accommodation strategies mentioned merit consideration. Those the authors believe have merit are:

- Laws that make large trucks liable for damages in a crash just for being out of their lane in a roundabout should be reconsidered. (Studies of this issue are underway in Wisconsin and recently the law has been changed in Oregon.)
- To accommodate many OSOW there needs to be sufficient clear areas which in some cases means little or no" hardware" in the central island like flagpoles statues, etc. Also, there is a need in some areas for signs that can be easily removed for the passage of OSOW.
- Roadway and truck apron slope and crown, or sloped circulating lanes, is something that needs more study. There are varying views on these roundabout attributes and not everyone agrees on a best solution.
- Roads through roundabouts, either straight through and gated, or offset with the entrance lining up with the left lane, should be considered.

Finally, based on the overall negative comments in survey 4, the authors conclude that for continued roundabout growth, with its many benefits of safety, the potential to save thousands of lives in reduced intersection crashes, their operational efficiency, their environmental benefits and others, the needs of all users need to be considered.

7.5 Conclusions from Examples of Accommodation

Caveat: The authors emphasize that the ideas and concepts shown and illustrated in chapter 5 are just that, i.e., ideas and concepts. No attempt has been made or was ever intended that this report should be a design guide. Based on the examples uncovered the authors conclude the following:

- wide truck aprons can aid the accommodation of OSOW in many cases. A wide truck apron should be installed if it is needed.
- in some special cases where a need is documented, the central island could be all, or almost all, truck apron, pavement, or stabilized turf.
- the central island may have to be narrowed, tapered or adjusted to some "odd" shape allowing for additional apron, pavement, or stabilized turf to accommodate OSOW off tracking.
- having OSOW travel counter to the normal flow, in many cases can be more cost-effective than other accommodation measures. In some cases this can be done without additional apron. The authors believe that there is no universal policy or laws among all states in regard to the legality of these movements nor does it seem to be clear if non police escorts have authority in all states to direct or control traffic as needed. (A TRB synthesis study has been recommended.)
- not all roundabouts need to accommodate all OSOW movements. For example, in the case of straight through movements roads through the center island should be considered. These can be straight through requiring a gate or offset. For right turn movements, and right turn slip lane should be considered. For left turn movements, counter flow movement appears to be more cost-effective than other solutions; however, a fully transversable central island could also be a solution.
- one of the most pressing problems in regard to accommodation of OSOW is the "hangup" problem. The only reliable study uncovered by the authors has just been conducted in the state of Wisconsin and immediately put into

the Wisconsin DOT's policy and procedures documents, and should be considered by all states.

- The authors further conclude that in regard to the "hangup" problem some examples from England and Europe where rumble strips and or rough surfaces are used to discourage small vehicle drivers from encroaching on internal and external truck aprons (rather than raising the elevation) should be considered.
- The authors conclude that a curb height of three inches should be considered a reasonable maximum. However, research might be needed to confirm that this has no negative effects on safety.
- Where very large loads are infrequent, using temporary methods such as laying mats to protect pavement and off-track areas, should be considered. An example used by the Kansas DOT clearly illustrates such a procedure.

7.6 Conclusions from Vehicle Path Simulations

Caveat: It is emphasized that for the simulations conducted, the seven check vehicles developed by Wisconsin were used. These may not apply to any other state. Also, the specific conclusions in 7.6.2, should be considered in the context of full discussion in Chapter 6 of the report.

7.6.1 Overall Conclusion from Simulations

The authors primary conclusion from conducting great numbers of vehicle path simulation is that given the knowledge of what OSOW need to be accommodated, and their turning characteristics, any knowledgeable designer can do it, provided that right of way is available. It is up to the state to determine the economic benefits or dis-benefits of doing so. This supplements the authors' overall general conclusion (see 7.3) that states should consider conducting a study to develop a freight network which includes segments where OSOW need to be accommodated, in accordance with state and federal commerce laws and policies and the state's economy. The study would include determining all motor vehicles whose size and turning movements are critical and developing routes on which all segments will accommodate these vehicles, e.g., Wisconsin's seven check vehicles. Finally, each states' study would logically include developing a set of check vehicles that is state- or region-specific.

7.6.2 Specific Conclusions from the Check Vehicles Used

Again, considering that the check vehicles used may not apply to all states or sites, the following conclusions based on the set used, could provide insight into some general OSOW needs and accommodation strategies:

- From the simulations of seven check vehicles, checking accommodation at a single lane roundabout, it was found that a single lane roundabout needs more traversable area than a roundabout designed from any AASHTO design vehicle. It generally needs increased width of the center island truck apron and it also needs an external truck apron to accommodate most of the movements effectively.
- The left turn movement of the 55 meter windblade, the 165' beam, and the wind tower, upper midsection, are challenging and might be impossible if the inscribed circular diameter is not large enough to accommodate the turn, as determined by the appropriate turning templates. Sometimes accommodation of the left turns of the 55 meter windblade, the 165' beam, and the wind tower upper midsection from all approaches, leads to a unique shape of the center island which is site specific. However, if these left turns can be accommodated in the opposite direction of travel without traversing the center island, both the traversable area and clearance area of the roundabout can usually be decreased.
- Simulations of the seven check vehicles on the prototype double lane roundabout show that there is no need of an external truck apron, given the set of assumptions used, and assuming right-of-way is available for the size chosen. Also, if the critical left turn movements can be accommodated in the opposite direction of travel, then there is no need of increasing the

width of the center island, truck apron. However, it should be noted that one of the assumptions is that the splitter island should be made fully traversable so that the OSOW vehicles can go over them while maneuvering or travelling in the opposite direction of the traffic. If the height of the splitter island is kept to three inches, this should be possible in most cases. More research should be conducted on the effects of vertical clearance.

- If a roundabout location is needed for only through movements, a straight passage through the center island should be considered if needed. The Wellington Roundabout, the Garnett Roundabout, and the Arkansas City roundabout, used to illustrate OSOW vehicle accommodations, were actually not designed for OSOW vehicles. However, these roundabouts were chosen to illustrate possible *theoretical* redesigning strategies for various cases of OSOW movements. One thing, beyond the scope of this study, that should be considered is the cost/benefit of the modifications.

It is noted that a rear steerable OSOW vehicle can result in better vehicle simulations needing less extra traversable area and clearance requirements when compared to the simulations shown in Chapter 6. However, due to the lack of availability of the rear steerable OSOW vehicle in the AutoTURN file used for this study these simulations were not conducted.

Appendices in a Separate File

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