Accommodating Oversize/Overweight Vehicles at Roundabouts: Survey Results and Preliminary Designs

Ranjit Godavarthy
Department of Civil Engineering
Kansas State University
Phone: (785) 317 6069
e-mail: ranjitg@ksu.edu

Eugene R. Russell, PhD., P.E.
Professor Emeritus
Department of Civil Engineering
Kansas State University
Phone: (785) 539 9422
e-mail: geno@ksu.edu

Dean Landman
Adjunct Professor
Department of Civil Engineering
Kansas State University
Phone: (785) 220 1588
e-mail: dlandman@ksu.edu

Abstract:

There is considerable evidence that roundabouts are the safest most efficient form of traffic control for most intersections. The potential use of roundabouts with all their inherent benefits may be greatly diminished because they may not be able to accommodate oversize/overweight (OSOW) vehicles sometimes called "Superloads". To use these OSOW vehicles as a design vehicle for roundabouts would be very costly and inefficient, and more importantly, negate the benefits of roundabouts which rely on being designed to operate at slower speeds from adequate deflection. Large roundabouts with little deflection and wide lanes would encourage higher speeds which would likely reduce the safety benefits. The problem, therefore, is how to accommodate OSOW vehicles without sacrificing the integrity, safety and other benefits of roundabouts.

The objective of the study was to survey and compile current practice to fill in gaps in knowledge on the effects that OSOW vehicles have on roundabout location, design, and accommodation. The secondary objective of this study includes using design software such as TORUS and Autoturn to show the effects of OSOW on a prototype single lane roundabout and a prototype double lane roundabout to illustrate things that need to be considered for the types of

design modifications that may be necessary to accommodate OSOW vehicles at roundabouts.

A Total of 4 surveys have been conducted (2 successfully completed, 1 with very limited success and 1 in progress which is expected to be very informative) with U.S State DOTs and OSOW Haulers, and personal interviews with Roundabout Design Consultants to compile various issues like bottle necks on the highway system, problems of OSOW vehicles on state's highways and specifically at roundabouts, possible design issues and mitigation strategies. This writing is primarily from the results from the first 2 surveys conducted with the 50 U.S States and preliminary designs to mitigate OSOW problems at roundabouts.

INTRODUCTION ABOUT PROBLEM OF OSOW AT ROUNDABOUTS

The safety and traffic operational benefits of roundabouts for the typical vehicle fleet (automobiles. and small trucks) have been well documented (*a, b*). 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 at an ever increasing rate. 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 the growing potential use of roundabouts with all their benefits may be greatly diminished because they may not accommodate oversize/overweight vehicles. For example, the state of Oregon currently has a moratorium on roundabout construction because of complaints from the trucking industry (Source: Private e-mail from Rich Crossler-Laird, Oregon DOT). The design vehicle for a roundabout, as in any design, should be the largest vehicle that can reasonably be anticipated for normal use. However, OSOWs are vehicles that use the roadway by special permit and travel on a random basis. Their physical characteristics may exceed the dimensions given for standard, recommended design vehicles recommended in "A Policy on Geometric Design of Highways and Streets" the book of standards followed by all states (AASHTO, 2004) (*c*). There is also a question of policy regarding which roundabouts in a state need to accommodate OSOW, which is beyond the scope of this study.

Most USA roundabouts are intentionally designed to operate at slower speeds, by using narrow curb to curb widths and relatively tight turning radii. However, if the design geometrics are too restrictive, roundabout use by the OSOW vehicles may be difficult or even impossible. Therefore, the central issue is how to accommodate OSOW vehicles where appropriate without sacrificing the integrity, i.e. safety and operational efficiency of the roundabout. Typical OSOW vehicles 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 could become more difficult and could potentially lead to reduced or prohibited roundabout use if OSOW cannot be accommodated.

STUDY OBJECTIVE

The main objective of this research is to 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. This will be achieved by conducting different surveys with all 50 U.S States and the trucking industry. . However, only 2 surveys have been successfully conducted and documented, one produced inadequate results and the remaining one is in progress. This paper primarily discusses the results for the first 2 surveys conducted with all 50 U.S States.

The objective of the first survey, which sought general information about states' permitting policies, was to find information about the permits that are required for different states to transport OSOW loads and to determine the type and extent of all bottlenecks for OSOW on their roads. The second survey was specifically aimed at more information on the impact of roundabouts and sought detailed information regarding their roundabout and their issues with OSOW loads.

The secondary objective of this study included a literature review and personal contact of experienced designers to determine existing design strategies to mitigation OSOW problems with roundabouts. Also, as part of this phase the authors used existing design software such as TORUS and Autoturn to show the effects of OWOW on a prototype single lane roundabout and a prototype double lane roundabout to illustrate things that need to be considered for the types of design modifications that may be necessary to accommodate OSOW vehicles at roundabouts.

LITERATURE REVIEW

Accommodating larger vehicles at roundabouts in not a new practical challenge. There are many practical measures that have been developed to accommodate larger trucks at roundabouts such as fully traversable center islands (similar to mini-roundabouts), widened entry and exit lanes, right turn bypass lanes, partially traversable central island truck aprons, gated pass-through lanes, lane striping, and others. Each of these methods carry design trade-offs in terms of the safety and speed control of passenger cars and small trucks, so each should be considered for site specific conditions (*d*). An optimal roundabout design is a design which safely and efficiently accommodates most road users. Therefore frequencies of use by various users are considered for an optimal roundabout (*d*).

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 1 shows pictures of a few of the treatments to accommodate truck right turns (*d*).

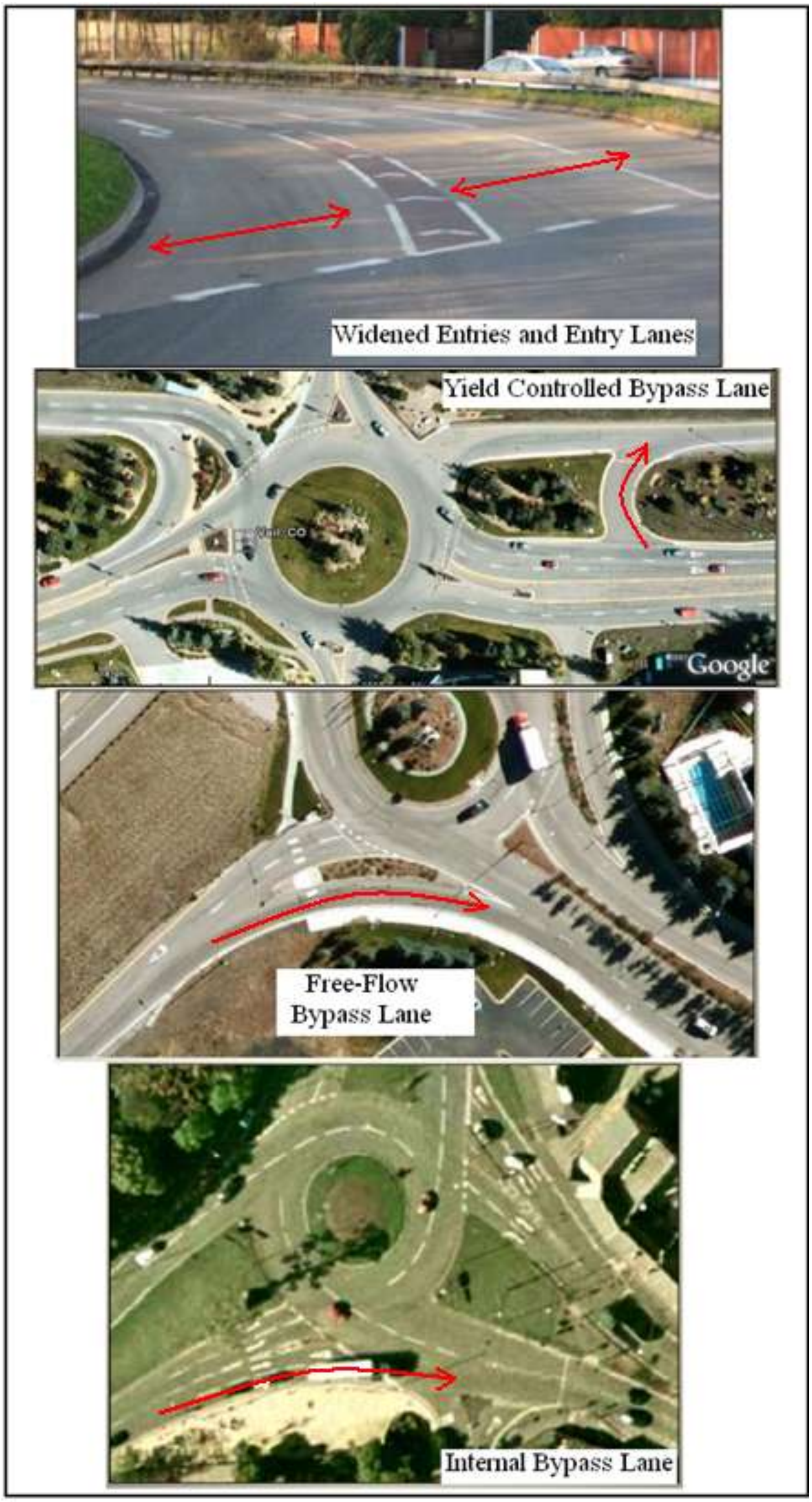

Figure 1: Treatments for accommodating truck right turns (*d*)

Truck aprons are designed to provide maneuvering space for large vehicles in a roundabout while still providing deflection for smaller vehicles, i.e. large vehicles are expected to use the truck apron (available for their wheels to mount the apron) when necessary. They should be capable of being mounted by semi-trailers and OSOW but unattractive to smaller vehicles. A truck apron allows the designer to design a smaller, safer roundabout for small vehicles while not seriously restricting large trucks. An apron may not be necessary if speed control and truck maneuvering space can be provided without an apron which usually requires wider lanes; however, this usually results in a higher speed roundabout. A fully raised island provides an effective lateral deflection without truck aprons. The truck apron has to be well designed because, the height and slope of the apron can create clearance and stability problems for trucks (*d*).

A truck apron field study (not OSOW) was conducted at I-17/Happy Valley Road, Phoenix in July 2007. Peak hour apron use by semi-trailer trucks (semis) and large single-unit trucks was observed. Data showed that out of 624 trucks observed 77% of them did not use the apron. Among the trucks that did use the apron, most (67%), of them 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 (*e*).

Design engineers should inquire whether the route may potentially carry oversized vehicles and then incorporate the needs of those vehicles in the design. Roundabouts should generally not be designed to provide normal circulation using an oversized truck as the design vehicle since this could result in excessive dimensions and higher speeds for the majority of users. Where oversized vehicles can be reasonably anticipated, the truck apron and central island design may need to be modified to accommodate the larger vehicles (*e*).

SURVEY-1 RESULTS

The first OSOW survey was conducted through American Association of State Highway and Transportation Officials (AASHTO) member contacts from 50 U.S States. The objective of the first survey is to get information regarding the permits that are required for different states to transport OSOW loads and to determine the bottlenecks which may exist for OSOW on their roads. A Zoomerang (existing automated electronic response tool) survey was used to electronically distribute the survey to the AASHTO officials who could answer it (looked comically?) and return it by hitting a “done” button. A total of 40 U.S States responded to the survey (Figure 2). Of those who responded, 36 States (Alaska, Arkansas, California, Connecticut, Delaware, Florida, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Oregon, Pennsylvania, South Dakota, Texas, Utah, Virginia, Washington, West Virginia, and Wisconsin) responded to the complete survey as prepared and 4 states (Alabama, Georgia, Ohio, and Tennessee) responded to a follow-up survey sent to get their contact information for survey two, planned for a later stage.

Some of the key responses are as follows:

Five responding states Alaska, Arkansas, California, Maine, and South Dakota do not have a category for different types of OSOW loads and the remaining thirty two states do have a category.

North Dakota and North Carolina requires a permit for the transporters by both State Statute and DOT Policy to use the states highway system for loads that exceed state statutes. 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. The remaining 32 States require a permit by State Statute.

Twenty eight (28) of the responding states don't have a typical design vehicle to aid in determining needed roadway geometry for OSOW vehicles. Eight (8) States (Alaska, California, Connecticut, Maine, Missouri, New York, and Wisconsin) have a typical design vehicle to aid in determining needed roadway geometry for OSOW vehicles.

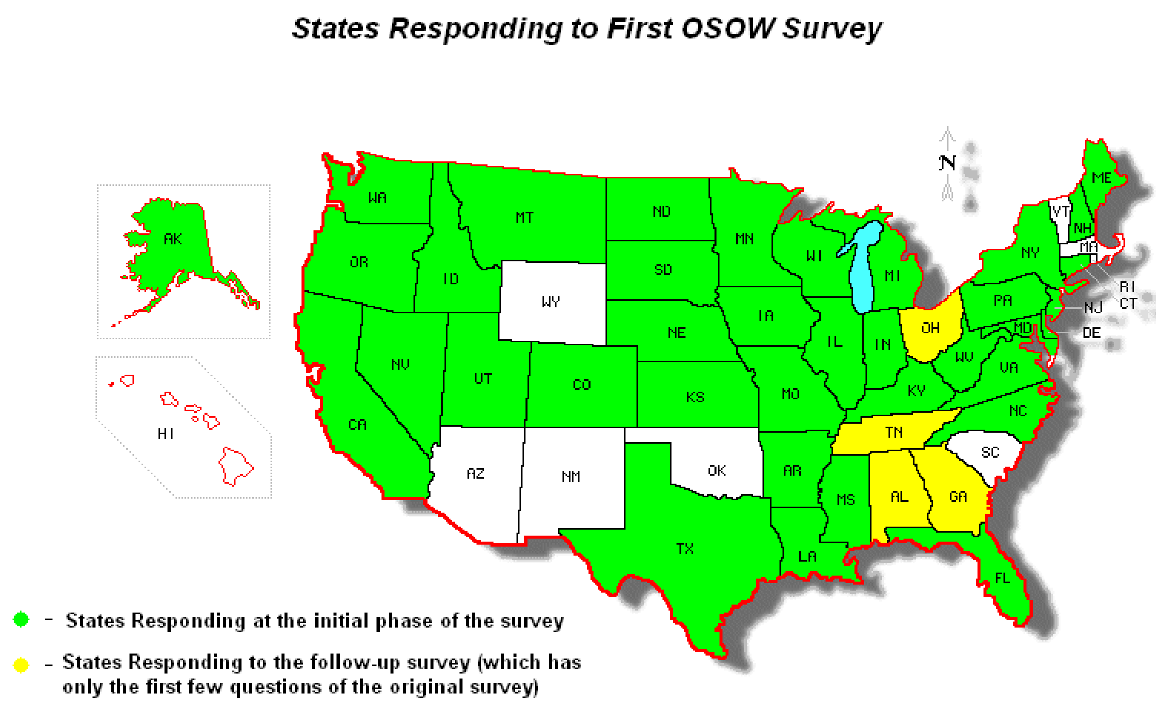

Figure 2: States that responded to the first survey

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

In regard to the question," Are any of these, restrictions a problem for your OSOW loads?" The reported restrictions, with the percentage of respondents reporting that the restriction is a known problem to OSOW, are shown below. Table 1 gives the restrictions by states.

- Bridges 100%
- Curbs 18.9%
- Interchanges 56.8%
- Intersections 64.86%.
- Overhead structures 89.2%
- Overhead wires 40.5%
- Rail- highway grade crossings, 48.6%
- Raised channelization 18.9%
- Roundabouts 35.1% s
- Signs and signals 70.3%
- Utilities 48.6%

(Note that roundabouts are not the only obstructions to OSOW; in fact, they are not the major obstruction)

Table 1: Number of states having various restrictions as a problem for their OSOW loads

Restriction	**Number of States responding that the restriction is 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 solutions to the restrictions provided by the respondents are:

- Utilize automated routing and analysis system to ensure none of the items listed above in table 1 are involved in a specific route of an oversize vehicle.
- Reroute the vehicle/load to a highway that will accommodate the load.
- Raising overhead wires on rare occasions "jumper" bridges.
- Stop use of fixed cross arms for signal lights or have them able to swing out for high loads.
- Requires 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 are Connecticut, Idaho, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, New York, Nevada, Ohio, Virginia, and Wisconsin.

SURVEY-2 RESULTS

A second survey was conducted with all 50 U.S States to obtain further detailed information specifically regarding their roundabouts and roundabout issues with OSOW loads. Kansas State University's AXIO online electronic survey was used to distribute the prepared survey through American Association of State Highway and Transportation (AASHTO) committee members in in all 50 States. By repeated reminders and follow-up calls, 100% survey response rate was obtained in this second survey. The results from the second survey are summarized below.

Alabama, Hawaii, Idaho, North Dakota, Oklahoma, Texas, Utah, and West Virginia reported that they do not have modern roundabouts (built after 1990) on state highways. The remaining states have modern roundabouts on state highways. Among all the states that have modern roundabouts, Delaware, Nebraska, and Rhode Island reported that they do not have modern roundabouts on non-state roadways. Figure 3 shows the approximate number of modern roundabouts provided by the respondents. The authors stress these numbers are approximations by whoever answered the survey and may not be accurate, and if no response was made to the question the state is not included in the list.

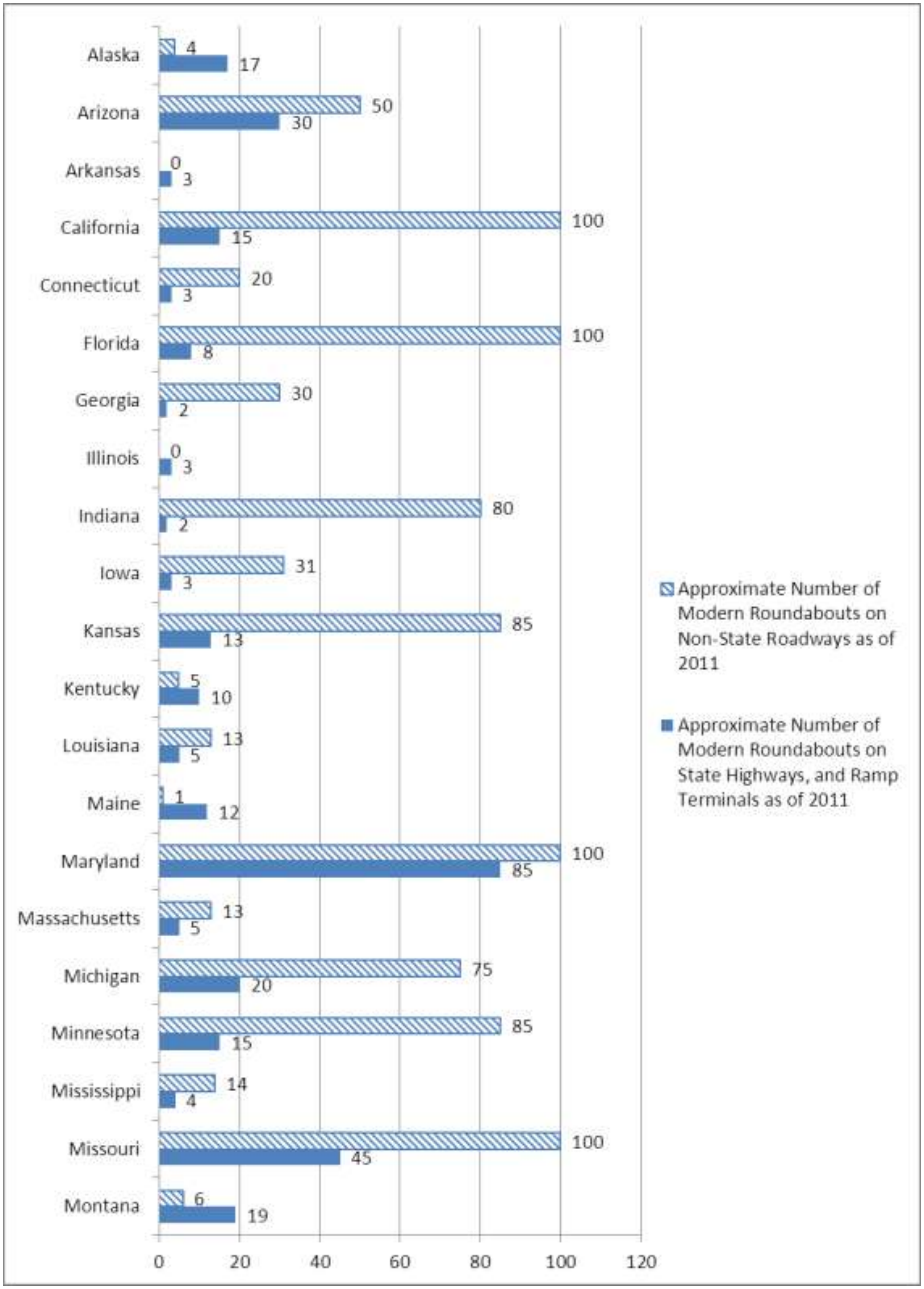

Figure 3: Approximate number of roundabouts

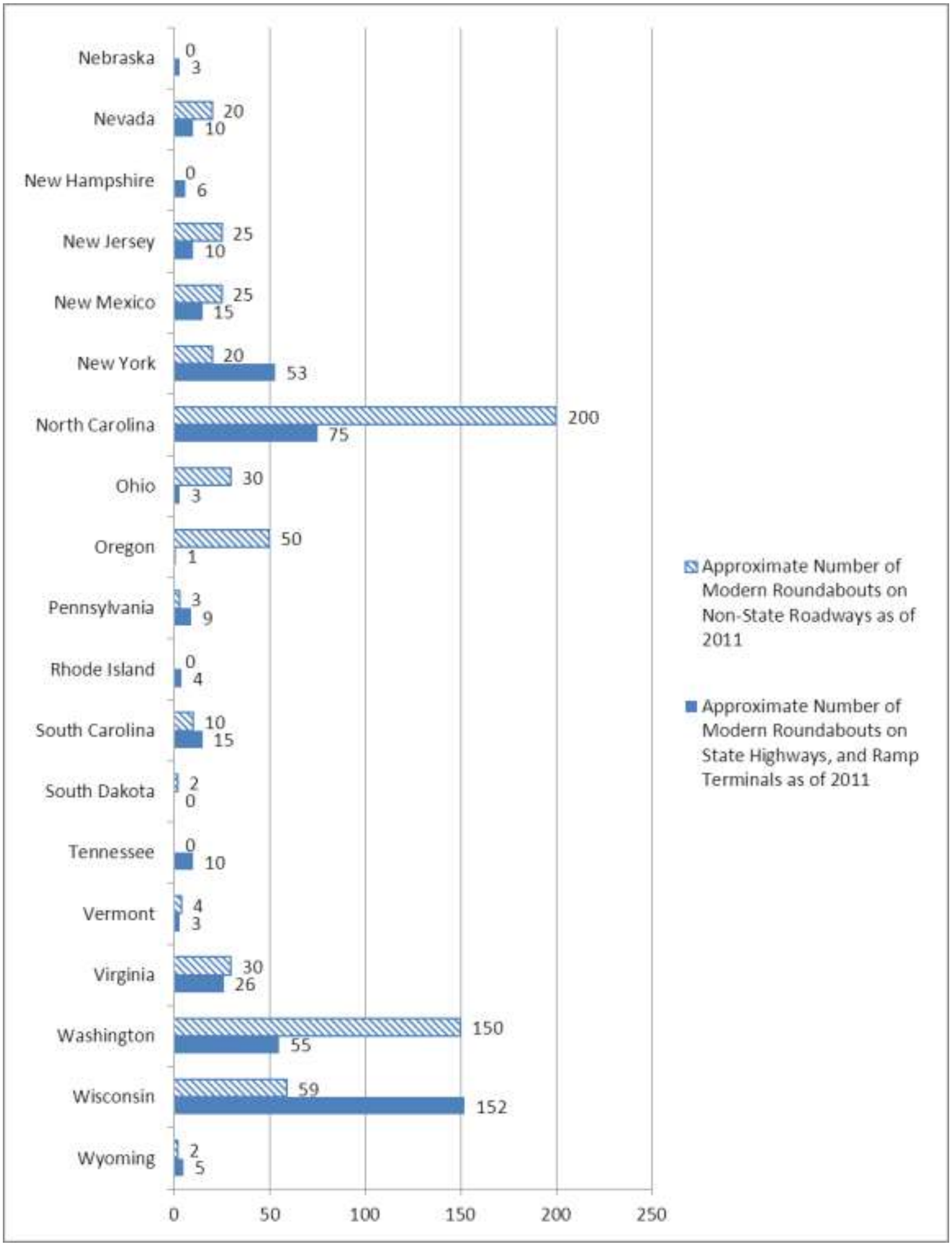

Figure 3: Approximate number of roundabouts

One of the most informative questions on Survey 2 was the question in which they 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 the study are paraphrase below.

- Concerns about long trailers 53 feet plus and long doubles >hundred and 120 feet,
- Trucks are required to stay in lane in the approaches,
- Lowboy vehicles (those with only a few inches of vertical under clearance) were a major consideration and one roundabout that had been built to limit vertical roundabout clearance to approximately 3 inches,
- Concerns about not identifying a roadway network based on geometric design limitations,
- Concerns about roundabouts with tight radii; also clearance issues,
- Concerns about long loads,
- Issues with oversize loads writing up on the exterior curb; also clearance issues,
- Issue with high-profile curbs on truck apron,
- Concerned with too narrow lanes,
- Concerned that drivers do not understand that truck aprons are designed to be mounted by tractor trailer combination vehicles,
- Concerns over placement of signs and landscaping,
- Concerns over misinformation used by lobbyists to reduce or eliminate roundabouts on state highways,
- Concerns about objects in the center island,
- Concerns about two or more roundabouts built too close together – 300 feet minimum suggested,
- Concerns about self propelled farming equipment or machinery and emergency response vehicles,

It is interesting to note that the most mentioned concern was vertical clearance, i.e not enough clearance under low truck trailers to not scrape or “hang up” on curbs and truck aprons which many OSOW loads need to go over, , which was mentioned six times – seven if the concern over the roundabout’s outside curb height was mentioned. Long loads were mentioned three times. The state of Washington indicated that they have all sorts of problems with standard intersections but have not had any issues with roundabouts. This is similar to our list of general problems with OSOW that ranked roundabouts 9th out of 11 “bottlenecks” or problem locations for roundabouts.

However, Washington responded with the suggestions that mountable Curbing, removable signage, addressing stationary landscape features, and larger radius design to accommodate longer vehicles.

A related question was question 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 department of transportation (DOT) concerns. However, some insight comes from respondents answers to this question as paraphrased below:

- Alaska responded that meetings with the trucking company involved led to better design templates and larger diameter roundabouts overall. Also, in heavy trucking areas, roundabouts were designed for full use of individual lanes and truck aprons; however, they reported that OSOW will have to straddle multilane approaches and multi-lanes in the roundabout in some restricted areas.
- One state reported that the permits department gave a permit which allowed an OSOW load 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 that they did coordinate with the OSOW permit section to determine vehicle sizes and geometric requirements on permitted routes. The authors believe that this should be a universal practice.
- Getting long loads through roundabouts many times requires removal of permanent signing, special law enforcement action and/or rerouting of some OSOW loads.
- Oregon reported some specific problems which are worth quoting; however, they will be quoted in the paragraph below along with some other material received from Oregon. The state of Oregon has some issues which could possibly affect the growth of roundabouts not only in Oregon but elsewhere, should trucking associations oppose 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. As a result the Oregon DOT suspended the design and construction of roundabouts in the state. It was reported on the survey that the Oregon officials are currently meeting with the OTA (Oregon trucking Association) representatives and so far have had a positive response to working out issues and concerns of the trucking industry.
- Washington reported a unique problem with a roundabout in a local agency which the local agencies did not want: i.e. they did not want the OSOW load 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.

The above views from different states lead to an understanding that, communication is very important. That 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 for access to some OSOW permitted state routes.

Another question with potential 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?". A Wisconsin/Minnesota study which we are closely monitoring appeared to be the most relevant. Although directed toward ordinary non permitted trucks (commonly referred to as “18 – Wheelers”) as well as OSOW loads it is notable also that they have developed a statewide freight network, where on some of it, any roundabouts have to be checked for seven OSOW check vehicle configurations (Peter Lynch, personal communication). The authors of this paper believe that all states could benefit from a freight network in general and a study of developing OSOW routes, then be sure that roundabouts on these routes are designed and built to accommodate all trucks that must be accommodated.

Washington reported that one roundabout project in particular had 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 and traversable. Again, as indicated above in other survey question responses and comments, vertical clearances and mountable curbs appear to be one of the most, if not the most, reported concerns in OSOW transport through roundabouts.

The Wisconsin respondent answered that mega high (16'+) and wide (16'+) and long (225'+) and/or heavy (350K+) OSOW loads, on occasion needed to be rerouted. However, they state that most of the OSOW fleet can get through roundabouts either in the normal direction of traffic (counterclockwise) or counter flow (clockwise with necessary police traffic control) depending on roundabout design and year built. They do suggest that removable signs, wide truck aprons and tapered or custom center islands are modifications that can make roundabouts more friendly 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, obstructions in the center island and placement and provision removal of signs are important potential countermeasures)

Maine mitigated similar problems as the one mentioned in the paragraph above (vertical and horizontal clearance) at a roundabout by providing a roadway overlay 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 and got stuck. Again, the authors believe states should have clear policies within the laws of the state for designated OSOW routing.

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. (Note: truck aprons are designed for roundabouts to allow truck wheels to mount them providing more space equivalent to a wider lane, while having a 3" or more curb to discourage small vehicles from going over them) They have heard that the drivers are afraid of the load 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 caused issues with trucks not using the apron and damaging the outside curbs, etc. This situation and North Carolina goes along with the fact that the need for education was mentioned more than once and the survey responses.

It can be summarized that clearance issues are one of the most observed concerns that the responding states hear from the companies that deal with vehicles requiring a permit. Additional concerns that were mentioned are roundabouts with tight radii, oversize loads riding up on the exterior curb, narrow lanes, lack of understanding of the drivers that truck aprons are designed to be mounted by large trucks as necessary, objects in the center island, trucks required to stay in lane in approaches, and concerns from farming and emergency response vehicles. Some of the suggested mitigation strategies are mountable curbing, removable signage, addressing stationary landscape features, and larger diameter roundabouts to accommodate longer vehicles while not increasing speeds that will result in reducing safety benefits for all vehicles.

AUTOTURN SIMULATIONS ON TORUS GENERATED ROUNDABOUTS

As a next step in this study, Autoturn and Torus software was used to generate roundabouts and run OSOW vehicle simulations on the torus generated roundabouts to observe the space requirements of these huge vehicles. Autoturn and Torus were used for their ease in developing the prototypes shown for illustrative purposes and not as an endorsement by the authors that all designers should use only these tools, i.e that is a designer's choice.

This task was carried out by considering a prototype single lane roundabout and a prototype double lane roundabout. Wisconsin Department of Transportation (WisDOT) Freight Operations Section has developed inventory of 7 OSOW check vehicles for designing the roundabouts for OSOW vehicles. The 7 check vehicles (shown in Figure 4) that are considered from the WisDOT vehicle library are 55 meter wind blade NL (Vehicle Length (L)=209ft), 80' mobile home (L=112.5ft), 165' beam L (L=201.10ft), Combine (28.80ft), Wind tower section 78L (L=112.50ft), Wind tower upper mid-section (L=148.80ft), and WB-67(L=103ft). These 7 OSOW check vehicles from WisDOT vehicle library were considered to perform the vehicle path simulations on the Torus generated roundabouts and see if these vehicles can be accommodated or need any modifications.

Design Vehicle

Roundabouts are internationally designed to slow traffic, narrow curb-to-curb widths and provide tight turning radii. However, the roundabout should be designed in such a way that it can accommodate the largest vehicle that is likely to use the intersection (*f*). This vehicle is called as a design vehicle and it dictates many of the roundabouts dimensions, particularly for single lane roundabouts. WB-50 vehicles are commonly the largest vehicles along urban collectors and arterials and large trucks such as WB-67 may need to be considered at intersections on interstate freeway or state highway systems (*f*).

Single lane roundabout

To draw roundabouts using Torus software, initially an inscribed circle diameter needs to be determined for a particular location. According to NCHRP 672 (*f*), the inscribed circle diameter for a single lane roundabout is in the range 130 to 180 ft. when the design vehicle is WB 67. As the present roundabout is designed for vehicles that are larger than the WB 67 vehicle, the upper limit of the inscribed circle diameter range (180 ft.) is selected.

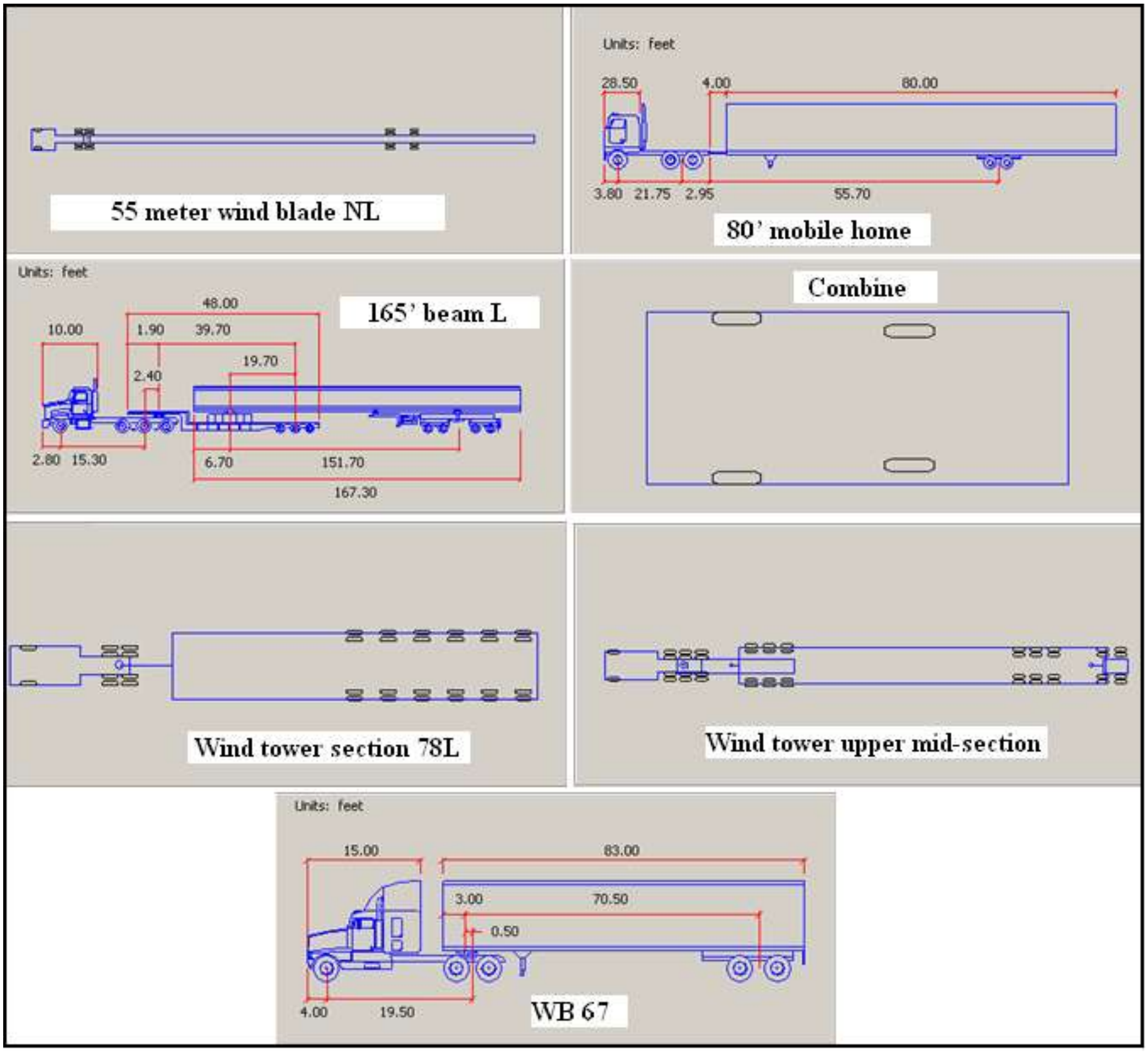

Figure 4: 7 OSOW check vehicles from the Wisconsin DOT vehicle library (Source: E-mail from Patrick Fleming, Wisconsin DOT)

The Torus generated single lane roundabout has a default designed center island truck apron width of 10 ft. This truck apron width is 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. is initially assumed which accommodates the left turn movement of a WB 67. Each approach was designed in such a way that the approach has a 15 ft. (randomly selected) left offset to the center of the roundabout. Figure 5 shows the roundabout designed with Torus software with the specifications mentioned above. Torus uses the guidelines from "Roundabouts: An Informational Guide (FHWA-RD-00-067) (*g*)" for designing its roundabouts. However, this study designs the roundabouts based on the guidelines provided from the latest roundabout guide (*f*). As the design specifications from the latest roundabout guide are different from the initial version, the Torus software detects some errors while generating the roundabouts which can be ignored. It was assumed that OSOW trucks are considered to be able to go over the splitter island at the approach and exit to safely traverse a roundabout. It was also assumed that the drivers can enter from any lane and change into any lane at any point for the purpose of maneuvering through the roundabout. Right turn maneuvers, through maneuvers, and left turn maneuvers of the 7 check vehicles will be considered for checking and redesigning the geometry of the roundabout as necessary. Figure 6 shows an example right-turn simulation of a 'Wind tower section 78L' traversing a right turn (enters from approach 3 and exit into approach 4). From Figure 6, the three parallel red lines in the path of the vehicle are the front tire tracks and the blue lines are the rear tire tracks as the vehicle traverses a right turn. The yellow hashed area represents the swept area of the load.

Therefore, when OSOW vehicles are expected at the roundabout from two opposite approaches (approach 1 and approach 3), the modified design of the center island is in oval shape as shown in Figure 7. In this oval shaped truck apron and roundabout design, the maximum size of the truck apron width is 30 ft. and the minimum width of the truck apron is 15 ft. However, if we assume that the OSOW loads are entering from all the four directions, then the center island shape will need to be modified again to a circular shape and with a center island truck apron width as 30 ft. as shown in Figure 8. For the above two cases, a 15ft external truck apron should be provided in between two consecutive legs of the roundabout as shown in Figures 7 and 8.

There are some locations where we can expect the OSOW entering the roundabout from two opposite directions and they might use only the through movements. In such cases, providing a special through movement through the center island would make it easier for OSOW vehicles to traverse through the roundabout. Figure 9 shows the design generated in the single lane roundabout when only OSOW through movements are expected from approach 1 and 3. Gates should be provided for the through paths so that only permitted OSOW trucks can legally have access to these paths and avoid regular traffic using them.

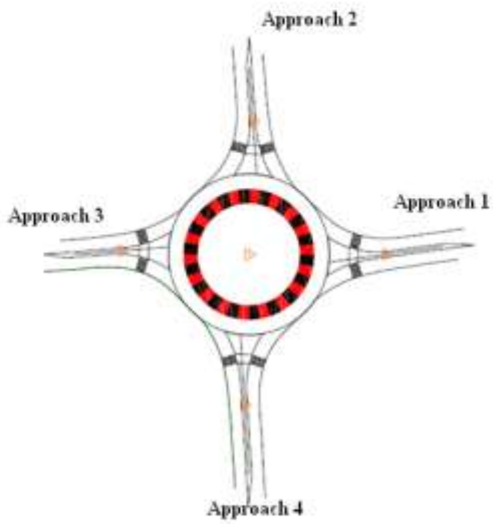

Figure 5: Figure shows a Torus generated single lane roundabout with180ft inscribed circle diameter, 15ft truck apron, and 15ft left offset for each approach.

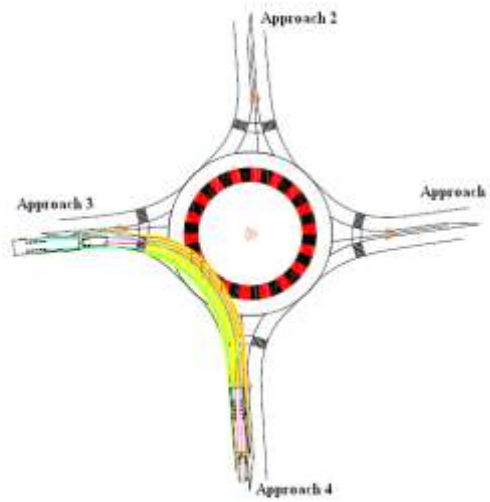

Figure 6: Right turn maneuver of 'Wind tower section 78L'

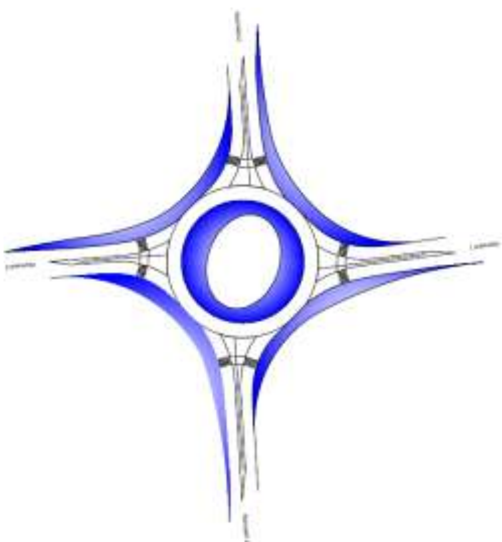

Figure 7: Final design of a roundabout when OSOW vehicles are expected from approach 1 and approach 3.

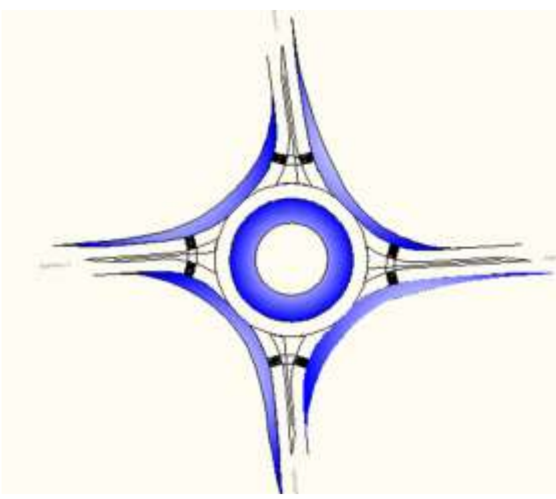

Figure 8: Final design of a roundabout when OSOW vehicles are expected from all approaches.

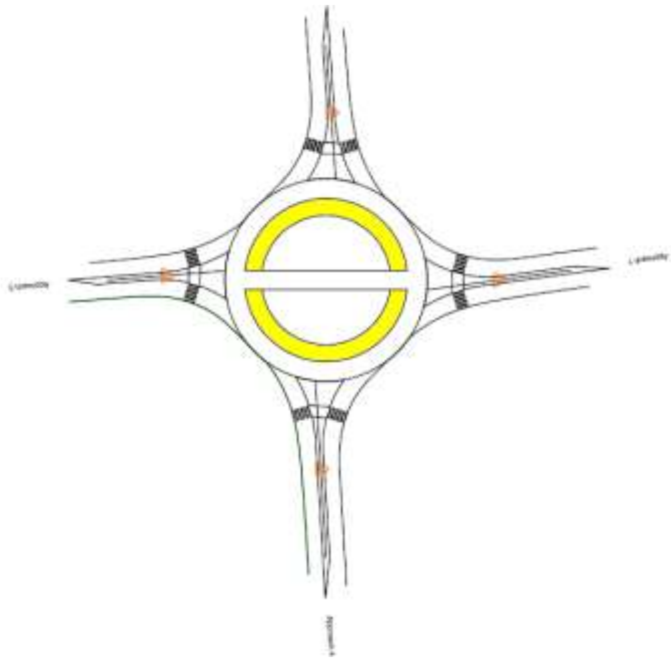

Figure 9: Redesigned roundabout with straight passage through the center island (Assuming trucks are able to go over the splitter island).

Double Lane Roundabout

According to NCHRP 672 report (*2*), the inscribed circle diameter for a double lane roundabout is in the range 165 to 220 ft. when the design vehicle is WB 67. As the current roundabout is designed for vehicles that are larger than the WB 67 vehicle, the upper limit of the inscribed circle diameter range 220 ft. is selected for this design.

The Torus generated double lane roundabout has a center island truck apron width of 20 ft. and this width is kept the same for this design of 2 lane roundabout. Each approach is designed in such a way that the approach has a 40 ft. (randomly assumed) left offset to the center of the roundabout. Figure 10 shows the roundabout designed with Torus software with the specifications mentioned above. It was assumed that OSOW trucks are considered to go over the splitter island at the approach and exit to safely traverse a roundabout. It was also assumed that the drivers can enter from any 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 7 check vehicles will be considered for redesigning the geometry of the roundabout.

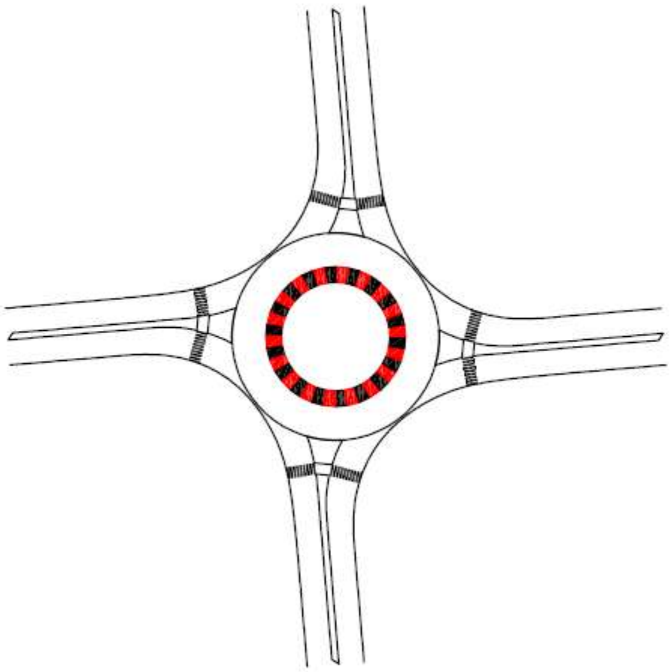

Figure 10: Figure shows a Torus generated double lane roundabout with220ft inscribed circle diameter, 20ft truck apron, and 40ft left offset for each approach.

Some left turn maneuvers of vehicles such as “165 feet beam” and “Wind tower upper mid-section” needs extra space beyond the roundabout paved area to traverse the center island. For such critical moves, the other possible left turn maneuver is by taking the opposite direction without traversing the center island, can be more economical. In such cases, these huge loads are made to traverse left turns in opposite directions for effective utilization of roundabout paved area.

Therefore, based on the vehicle simulations, front and rear tire paths, it was found that there is no need for any additional truck apron for these OSOW vehicles at this two lane roundabout.

SUMMARY AND CONCLUSIONS

Though roundabouts have several safety and operational advantages over signalized and stop controlled intersection alternatives, including, lower delays, shorter queues, better management of speed and opportunities for community enhancement features, the potential use of roundabouts with all their benefits may be greatly diminished on certain routes because they may not accommodate OSOW vehicles. This study has gathered information from 50 U.S. States regarding problems accommodating OSOW vehicles at roundabouts by conducting two surveys. Then with the use of TORUS software, prototype roundabouts and seven typical OSOW loads illustrated the types of design changes that needed to be made in a roundabout to accommodate the OSOW.

The first survey was conducted to find information on permits that are required for different states to transport OSOW vehicles and to determine the bottlenecks for OSOW vehicles. The bottlenecks were: bridges, curbs, interchanges, intersections, overhead structures, overhead wires, rail- highway grade crossings, raised channelization, roundabouts, signs and signals, and utilities.

The second survey was conducted with all 50 U.S States responding to obtain further detailed information specifically regarding their roundabouts and their issues with OSOW loads. Clearance issues, both vertical and horizontal, were among the most observed concerns from the responding states about the roundabout from the companies that deal with vehicles requiring a permit. Additional concerns that were mentioned are roundabouts with tight radii, oversize loads riding up on the exterior curb, narrow lanes, lack of understanding of the drivers that truck aprons are designed to be mounted and driven on by big trucks, objects in the center island hindering horizontal clearance, trucks required to stay in lane on approaches (required by law in some states), and concerns from farming and emergency response vehicles. The mitigation strategies from the study "Accommodating Trucks in Single and Multilane Roundabouts (*d*)" such as fully traversable center islands (similar to mini-roundabouts), widened entry and exit lanes, right turn bypass lanes, partially traversable central island truck aprons, gated pass-through lanes, lane striping, and others can be adopted to overcome these concerns. However, each of these methods carry design trade-offs in terms of speed control of passenger cars and small trucks which affects safety which decreases with increased speed, i.e. large roundabouts with wide lanes and large radii would help OSOW but decrease the safety benefits for all vehicles so each roundabout should be considered for site specific conditions.

The 7 OSOW check vehicles obtained from a Wisconsin DOT study were used to illustrate the necessary types of changes that a designer must make in a prototype single lane roundabout and also a prototype double lane roundabout. It is concluded that an external truck apron and wide central island truck apron should provide clear passage of the seven OSOW check vehicles for the single lane roundabout and an altered central island shape providing an increased central island truck apron should provide clear passage of the seven OSOW check vehicles for the double lane roundabout. These features can be incorporated in such a way as to not increase speed and decrease safety for all vehicles. That is the challenge for designers. However, states should always be in communication with their state trucking needs and should some OSOW vehicles larger than the seven check vehicles need to traverse a route, the dimensions and configuration and turning characteristics of the vehicle need to be determined and with the use of design and checking tools, similar but more extensive design modifications may have to be made.

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