Key Findings and Conclusions from the Study: Accommodating Oversize/Overweight Vehicles at Roundabouts

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ABSTRACT

Safety and traffic operational benefits of roundabouts for the typical vehicle fleet of automobiles and small trucks have been well documented. Roundabouts can offer several advantages over signalized and stop-controlled intersections. However, the potential growth of roundabouts with all their benefits may be greatly diminished if they cannot accommodate oversize/overweight vehicles (OSOW). OSOWs are a reality for industry and critical for certain industries and states' economies. Industry must rely on state highways to move OSOW loads. The main objective of this paper are to point out key aspects of current practice and research by various states and countries related to the effect that accommodating OSOW have on roundabout location, design. A literature review uncovered no published reports on OSOW accommodation per se; however, information on the advantages of having designated truck and OSOW networks is discussed. The authors make an argument that states should conduct a study to develop a freight network, including OSOW segments which need to be accommodated in accordance with state and federal commerce laws and policies and the state's economy. The authors relied primarily on surveys, personal contacts, unpublished material and case studies. Survey results are summarized. Examples of accommodating OSOW in general, and various turning movements, found in the literature and personal contacts are provided as examples of ideas and concepts that could be considered, and possibly adapted to the needs of a specific site. The paper will present a summary of the key aspects of the study and present findings and conclusions.

Key Findings and Conclusions from the Study: Accommodating Oversize/Overweight Vehicles at Roundabouts

1.0.INTRODUCTION

Safety and traffic operational benefits of roundabouts for the typical vehicle fleet (automobiles. and small trucks) have been well documented.(NCHRP 572, NCHRP 672). 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. The year 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. The design vehicle for a roundabout, as in any design, should be the largest vehicle reasonably anticipated for normal use. However, Oversize/Overweight vehicles (OSOW) use the roadway by special permit and travel infrequently . Further, their physical characteristics may greatly exceed the dimensions given for standard design vehicles as described in "A Policy on Geometric Design of Highways and Streets" (AASHTO, 2011).

This research project was 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 filled in many 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 manuals.

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, 12'9" wide and almost 15 foot high, and with an average weight of 218,000 pounds (Jim Brewer, Personal communication). 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. A better understanding and sharing of current practices is essential for states that permit such movement, and for the industries 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. The authors believe, and it has been accomplished by some experienced designers, that OSOW needs can be accommodated at roundabouts on routes with roundabouts as long as the physical and operating characteristics of the OSOW using the route are known. In all cases where the authors contacted a survey respondent who indicated that OSOW were no problem, they indicated it was because they knew

the physical and operating characteristics of OSOW that would be using the route and designed accordingly.

Although truck and OSOW routing are beyond the scope of the project, it became apparent to the authors during the study that this is an important issue. 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.

Based on material gathered for this study, surveys and interviews, it may be possible to accommodate OSOW at roundabouts with designs that consider the following: 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, easily mountable curbs 3 inches or less, and with signs, light poles etc. outside of the turning paths and/or designed to be easily removed (Russell, Landman and Godavarthy, 2012).

2.0 LITERATURE REVIEW

The authors believe consideration should be given by all states to develop freight routes and include OSOW segments of these routes. Thus, literature related to planning and developing freight and OSOW routes was reviewed. .FHWA has published a manual, "Statewide Freight Plan Template lists several reasons why statewide freight planning is important (Keenan and Quinn., June 2011):

. 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-through, 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. These methods will be reviewed in more detail below in this report.

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 laneMaterial from the roundabout guide, second edition, which the authors consider directly relevant to this study follow (NCHRP 672, 2011). The guide points out larger roundabouts *sometimes* [emphasis added] need to be designed for larger trucks (WB-67) or to accommodate OSOW while attempting to maintain deflection for smaller vehicles. (The authors believe that the language in the guide should be stronger and state that deflection *must* be achieved.) The guide states that space requirements may make it impossible and require OSOW to be rerouted and the guide points out that the truck apron should be designed such that the truck aprons are traversable to trucks but discourage passenger vehicles from using them. The guide further states truck aprons should generally be 3 to 15 foot wide and have a cross slope of 1% to 2% away from the center island. Although not specifically stated in the guide, the authors believe it is meant for roundabouts that need to accommodate OSOW. 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 they traveled way. The guide does suggest 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".

One of the best lists of OSOW mitigation examples uncovered in the literature was a list provided by the Wisconsin DOT (WisDOT). Some mitigation examples deployed by WisDOT to date include:

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. *Allow trucks to cross over median (stamped, depressed, or corrugated) in counter flow direction before 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)(Private e-mail. Peter Lynch, 2011)*

3.0 METHODOLOGY AND DATA

In addition to the literature search discussed above, to obtain additional information and data needed to complete the study, the following were performed:

- surveys of all the states and a sample of the trucking industry,
- personal contact with designers and researchers and examples provided, and
- simulations of OSOW operations at roundabouts.

3.1 Surveys

To compile current practice and research by various states, two surveys were conducted and sent to the 50 states. The first survey sought general information on permitted vehicles and problems they encounter with some questions regarding roundabouts near the end. A second survey was keyed specifically to concerns states had with accommodating OSOW at their roundabouts.

These two surveys were followed by two surveys to the OSOW/trucking industry to get information on their views and input on roundabout issues and solutions to accommodation.

3.1.1 Discussion of Survey Results

Results of the State Surveys. Details of the responses are contained in the project final report and appendices. Presented here is a sampling of key facts from both surveys that the authors of this report believe are key to understanding issues related to concerns and problems of accommodating OSOW at roundabouts.

The first key point the authors would like to point out is that roundabouts are not the only obstruction to OSOW on States' highways. This is clearly pointed out by respondents' answers in survey number one to the question of known restrictions to OSOW on their state's highways.

The answers are ranked and summarized below:

- 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%

Note that of the 11 know obstructions to OSOW reported by respondents, roundabouts were ranked number 9, lower than overhead wires, utilities, rail – highway grade crossings, interchanges, intersections, signs and signals, overhead structures and bridges. Only bridges were reported as obstructions by 100% of the responding states. The main point is that all but roundabouts have existed for many years and accommodation strategies have been worked out for them, and no one suggests they cannot coexist with roundabouts on our highways. Roundabouts are no different.

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

Survey two was intended to obtain further, detailed information regarding roundabouts and the issues with OSOW loads at roundabouts. One of the key questions was where 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 most pertinent to this study are paraphrased below:

- concerns about trailers, longer than 53 feet and long doubles, longer than 120 feet,
- we now require trucks to stay in lane in the approaches,
- lowboy vehicles were a major consideration at one that has now been built to limit vertical roundabout clearance to approximately 3 inches,
- our concern is that we do not identify 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 when 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,
- 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,
- concerns about farming and emergency response vehicles.

Considering all answers by respondents, the most mentioned concern was vertical ground clearance, which was mentioned six times – seven if the concern over the outside curb was mentioned. Long loads were mentioned three times. This was later found, in surveys to industry to also be a major concern of truck drivers and/or the trucking industry.

Fifteen (15) States responded that they interact with OSOW vehicle or trucking associations on designs such as roundabouts. In general, it is clear that they followed procedures to determine what OSOW would use the routes and the physical and operational characteristics and designed accordingly.

The above sample answers, lead the authors to a clear understanding and conclusion that communication is very important. Important communication 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.

Results of Industry Surveys.

The two surveys, referred to here as surveys 3 and 4, developed and sent to truckers and/or trucking associations were quite different in their approach, and had some different questions. Survey 3. Note that in the pooled fund report that is the basis for this paper, there is not room for table sand charts but numerous tables and charts and comment can be found in the full report (Russell, Landman and Godavarthy, 2012)

Survey 3 was sent by the researchers to a sample of trucking firms advertised on various web sites as trucking companies that hauled or provided escort services to OSOW loads. Not a single one of the firms responded to the survey after it was sent, even after some follow up calls were made. There was; however, one good source of information obtained to the questions of survey three. An officer with the Specialized Carriers and Rigging Association (SC&RA) was very cooperative. He informed the researchers that he had a national meeting with 13 of his regional managers coming up and he would discuss the survey with them. The survey answers sent were a composite of answers by him and the 13 regional managers of SC&RA. (Ball, private communication, 2011)

Again, the issue of clearance was brought up a number of times. This also included horizontal clearance. For example, it was pointed out that flowers, ornaments, statues, etc. can add to the beauty of roundabouts but are in many cases obstructions to OSOW horizontal clearance. The authors conclude that this is a consideration and should be eliminated or to a minimum where OSOW are expected.

The response to the question about how roundabouts could be designed to accommodate OSOW without greatly increasing the size and cost included this statement: *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."

In one question of survey three, a list of adjusted mitigation strategies were listed for comment by the responders:

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 all of the above have merit in applicable situations and were encouraged that the response from Survey 3 was in general agreement that they all have "merit". The authors believe that the response below does a good job in summing up the constructive criticism offered in survey three and is repeated as follows:

> *"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."(Survey 3, response to question 10)*

From survey three, responses to the question of lowboy clearance were probably the most informative and/or instructive. 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 a maximum. 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 lane, combined with slope and roadway crown and truck apron all contribute and have to be considered. Drainage inlets could also contribute.

Issues related to ground clearance, such as the type of splitter islands, outside curbs, truck aprons and they're curbs, etc. are definitely problems that need to be studied to a greater extent. The authors conclude that 3 inches should be considered as a maximum height of splitter islands, truck aprons and curbs. Keeping the splitter island height low allows OSOW more flexibility for entering movements of OSOW.

Survey 4

Survey 4 was another attempt to get information directly from the trucking industry. 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. A total of 60 responses were returned and these responses were analyzed. Of the 60 responses, 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 they do not haul OSOW loads *(the basic definition of OSOW is a load requiring a permit, a legal requirement in most states)* and 5 did not answer that question. Thus, several questions which were designed to specifically address OSOW haulers would not apply to them.

It is not clear, and one can only speculate, how representative this particular sample of respondents to survey 4 is of the hundreds or thousands of truck drivers throughout the United States. It could be representative; however, it is a small sample, and possibly 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. There is no way to tell.

The responses to survey 4 were not specifically directed as much as hoped toward specific OSOW restrictions and their solutions, including lacking of constructive criticism or suggestions, due to the limited response of OSOW haulers and drivers. However, 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 through literature review, other surveys and personal contact with designers experienced in accommodating OSOW.

When asked to if they have any specific problems with roundabouts, answers were too general and varied to categorize. Most comments had to do with either ground clearance, tight radii, narrow lanes (or not being able to stay in a lane) and being crowded or cut off by other drivers. Overall, respondents' general comments state or infer that they want bigger roundabouts and wider lanes. The greatest advantage of roundabouts is safety, which requires a relatively small roundabout with sufficient deflection to control speed; however, on routes which must accommodate large trucks and OSOW some trade-offs may need to be made. Legal issues regarding trucks staying in their lanes, and how smaller vehicles drive around or alongside of them is beyond the scope of this study but it has been addressed by a recent study conducted for Wisconsin and Minnesota(Joint Roundabout Truck Study).

The authors agree with a number of sentiments expressed by 17 OSOW respondents' response to the question about what possible solutions do you think might mitigate the roundabout problems that they had expressed in the previous question. Many of the respondents indicated larger roundabouts. The authors believe a WB-67 should be considered as the design vehicle on all state highways and as a "base' design for additional modifications to accommodate

OSOW that need to use roundabouts on key sections. 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 roundabout safety.

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 where there are significant through movements and the authors believe it should be given more consideration in the United States. In response to whether truck drivers understand the purpose of the truck apron or need education, the authors have no hard evidence; however, even the survey, driver respondents disagreed on whether the use of the truck apron is understood are not. As indicated in some answers, and the authors agree, there does appear to be a need for more extensive roundabout education for drivers of all vehicles throughout the United States.

3.1.2 Summary and Conclusions of Industry Survey Results

The overall impression that was evident from an overview of the surveys in their entirety, is that truckers do not like roundabouts. This appears contrary to survey 1, in which 11 obstacles to OSOW were pointed out with a roundabouts being 9 out of 11. Bridges were number one, reported by one hundred percent of the responding states. The authors believe that whereas a roundabout can usually be modified to accommodate OSOW, it is unlikely that a bridge is going to be rebuilt, resulting in detours of hundreds of miles. The authors conclude; therefore, that there is need for better communication between owners, planners and designers of roundabouts and the trucking industry. There is need for education that should go both ways.

3.2 Examples from Personal Contact with Designers and Researchers

The authors received many examples of ideas and concepts from contact with designers and researchers in the US, Europe, and the United Kingdom. Space requirements prohibit including these illustrations in this paper. Only descriptions are presented here; however, the project final report should be examined (Russell, Landman and Godavarthy, 2012). This project final report is referred to below as “the report”.

The authors emphasize that the ideas and concepts shown and illustrated in the project final report (the report) and described below, are just that, i.e., ideas and concepts. *No attempt was made or was ever intended that the report should be a design guide.* Also, no attempt will be made here to reproduce all examples that were uncovered and included in the project final report; however, a list of examples that the authors consider should be given consideration follow: (Russell, et al, 2012)

1. Kansas state highway roundabouts. These are generally bigger than the typical roundabout but considered appropriate for high-speed state highways with high truck percentages. They accommodate not only WB-67's but also OSOW traveling on Kansas highways.
2. In places where signs need to be removed, it would speed the process to have some system of signs that are easily removed and replaced. Off tracking is a characteristic of large vehicles and most OSOW need extra space outside of the travel lanes. Considerable discussion of this is included in the report.

3. An illustration of a turf stabilization system capable of supporting heavy vehicles is shown and discussed. An example from France shows a photo of a low, level central island which is composed of stabilized turf which allows OSOW to go straight across the central island. Stabilized turf would also have advantages to prevent rutting when wheels go outside of curbs.
4. The authors believe that wide truck aprons, even to the extent that the central island is all or mostly all truck apron (or paved or stabilized soil) have good applicability for accommodating OSOW. Several examples and illustrations are shown in the report
5. In Australia, one of the authors has observed a roundabout with a central island which is essentially a raised level pad of concrete. This would allow OSOW to go straight across.
6. Truck apron details and examples of curb heights are presented and discussed in detail in the report. Several photos of truck apron details are shown. Photos and illustrations from England and the Netherlands make two points, i.e. the elevation is very low and they have a rumble strip providing the incentive for small vehicle drivers from not going up on the truck apron.
7. Another truck apron detail from the Netherlands is to use a rough surface, e.g., cobblestones which would accommodate OSOW but discourage small vehicles because of the roughness. The advantage of this (and the rumble strip idea and number 5 above) would allow having a low elevation for OSOW.
8. Roundabout operational issues are discussed and illustrated. One concept to illustrate is to have a narrow or tapered central island allowing space for extra truck aprons as needed for certain movements. Another concept is to allow counter flow, i.e., traveling clockwise around the roundabout or movement against the normal traffic flow for certain portions of certain movements.
9. An example is presented in the report where a manufacturer needed the ability to transport 165 foot concrete beams with a haul length of 216 feet. The steps listed appear to be typical for this sort of accommodation:
    - Added additional tracking pavement to both the central island and outer curb line locations,
    - Created special truck turning templates in CAD turning software. The manufacture also tested the maneuverability of the design with a scaled model of the beam truck.
    - Located signage and lighting to avoid conflicts. Installed removable sign sleeves in the splitter islands and outside critical curb areas.
    - Installed mountable curbing for additional truck movements, where needed.
    - Paved island areas for truck tracking ability.
    - Set subtle grade changes throughout the roundabout intersections to minimize torque stress on the beams. Designed for steerable rear axles. (Josh Stratka, Strand Associates)
10. Roads through roundabouts to accommodate the through movements are common in Europe. Several examples of these are shown in the final report with photos from the Netherlands and Germany.
11. An example of a temporary, accommodation scenario is discussed and illustrated in the project final report . This is a situation where a 531,000 pound, 210.5 foot long, 19 foot high, abatement tower was accommodated through a roundabout in Kansas by laying down mats to protect pavement and areas where off tracking was necessary.

12. Some design ideas, such as using layouts and parking lots and/or moving scale models over drawings to determine proper turning paths are illustrated in the report.
13. The Wisconsin Department of Transportation (WisDOT) developed a freight network which included an OSOW sub network on which all segments had to accommodate seven check vehicles. The authors believe all states should consider developing their own. However, they were still having "hangups" .
14. WisDOT conducted a study and developed guidelines, which they immediately put into effect (May 3, 2012), to mitigate low vertical clearance problems, i.e., the "hangup" problem, as well as truck apron slope and roadway cross section.

4.0 CONCLUSIONS

4.1 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.

4.2 General, Overall Conclusions

The authors have two general conclusions. The first conclusion, although, arguably, peripheral to the main objective of the study, is that states should conduct 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.

4.3 Conclusions from Surveys

4.3.1 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.
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.
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.

4.3.2 Two Trucking Industry Surveys

4.3.2.1 Specialized Carriers and Rigging Association Response

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.

The authors also 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.

4.3.2.2 Partnered KSU- American Transportation Research Institute (ATRI) Survey

The authors conclude 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.

4.4 Conclusions from Examples of Accommodation

Based on the examples of accommodation uncovered during the study and illustrated and presented in more detail in the report, 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***. This is a critical concept that needs to be emphasized. 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, and detailed in the project final report, clearly illustrates such a procedure.

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Disclaimer

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