

# Turbo Roundabout Design Guidelines Translated to the USA

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## ABSTRACT

Turbo roundabouts are multi-lane roundabouts with spiral road markings and with entry and circulating lanes separated by raised lane-dividers. The Turbo Roundabout was introduced in the Netherlands to solve capacity and safety issues that often occur in standard multi-lane roundabouts. The safety and capacity success of the Turbo Roundabout prompted the author to visit with Dutch engineers in March 2017 to help transfer this innovative intersection design to the USA. In this paper the geometric design of turbo roundabouts is compared to design vehicles and current practice in the USA. A comparison between design guidelines in the Netherlands and the USA may be helpful in promoting this new intersection design.

## 1. Turbo Roundabouts in the Netherlands

The turbo roundabout is an innovative arrangement of a two-lane roundabout that has revolutionized roundabout design in the Netherlands since 1998. Entering and exiting a typical two-lane roundabout can be complicated for some drivers, which may lead to crashes due to lane changing inside the roundabout. The turbo roundabout eliminates some of the most severe conflict points on a roundabout and reduces the need to change lanes (1). There are currently 435 turbo roundabouts with 324 located in the Netherlands and 111 located in other countries, mainly in Europe (2).

## Essential Features

The most important feature of the turbo roundabout is the spiral lane marking to eliminate the necessity of weaving or changing lanes. This results in both an increase in safety as well as an increase in the capacity of the roundabout. The turbo roundabout does not have two lanes throughout the whole roundabout, but only over the sections where two lanes are required. At least one of the exits should have two lanes, and some exits may have only one lane (3). Figure 1 shows a typical turbo roundabout in the Netherlands at the intersection of a major street with a minor street.

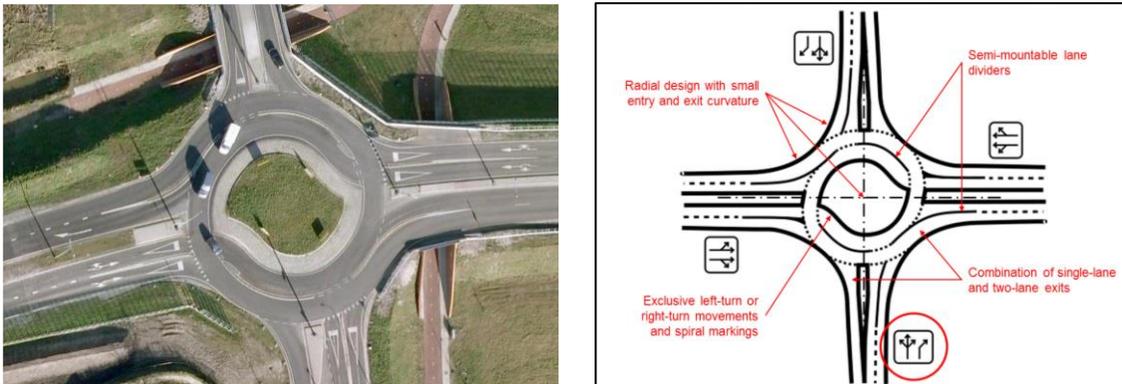


Figure 1. Typical Turbo Roundabout in the Netherlands (Weber)

When compared to a typical two-lane roundabout a turbo roundabout reduces the number of potential conflict points from 16 to 10. This is mainly the result of the elimination of the weaving conflicts (a reduction of 4 conflicts) in the roundabout. A further benefit is that traffic in the main direction, only must consider crossing one lane before entering the roundabout (a reduction of 2 conflicts) (4). Since weaving in the roundabout is no longer necessary, the lane divider can be slightly elevated (Figures 2 and 3). The mountable lane divider induces traffic to keep to its own lane, and this helps to prevent sideswipe collisions that can occur not only upon entering the roundabout, but also when exiting. Heavy and oversized vehicles can traverse the lane dividers if necessary, as shown in Figure 3.

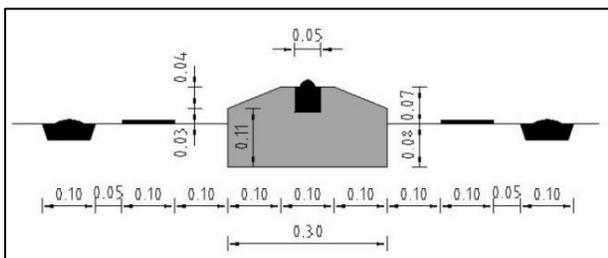


Figure 2. Turbo Roundabout Raised Lane Divider Detail (Fortuijn)



Figure 3. Turbo Roundabout Raised Lane Divider (Fortuijn)

Because of the lane dividers, drivers need to choose the correct lane before they enter the roundabout. Drivers should be assisted by clear signposting and lane marking. In the Netherlands, all turbo roundabouts have entries that are perpendicular to the circulatory roadway which is commonly called “radial design” in the USA (Figure 4). Also noteworthy, on my tour of over 50 turbo roundabouts in the Netherlands, the author was impressed by the large twin overhead lane assignment signs and at least 4 sets of large lane assignment symbols on the approaches to each of the turbo roundabouts. The capacity of a turbo roundabout is about 25% to 35% higher than the capacity of a conventional two-lane roundabout, depending on the balance of the traffic volumes on the approaches. The main reason for the higher capacity of the turbo roundabout is the reduction of conflict points for traffic entering and exiting the roundabout (3).



Figure 4. Advance Lane Assignment Signs and Legends (Fortuijn, DeBaan)

On a typical turbo roundabout there are 10 conflict points for vehicles, while on a two-lane roundabout there are 16. This represents 60% more conflict points, including four weaving conflicts and two exiting conflicts, which amount to a higher accident risk for a two-lane roundabout (Figure 5). A turbo roundabout is therefore a significantly safer option. A quantitative safety data comparison of the conversions of several 2-lane roundabouts to turbo roundabouts in the Netherlands was completed in 2015 using 3 years “before” to 3 years “after” data. The conversion from 2-lane roundabouts to turbo roundabouts resulted in a 53% reduction of injury accidents (2).

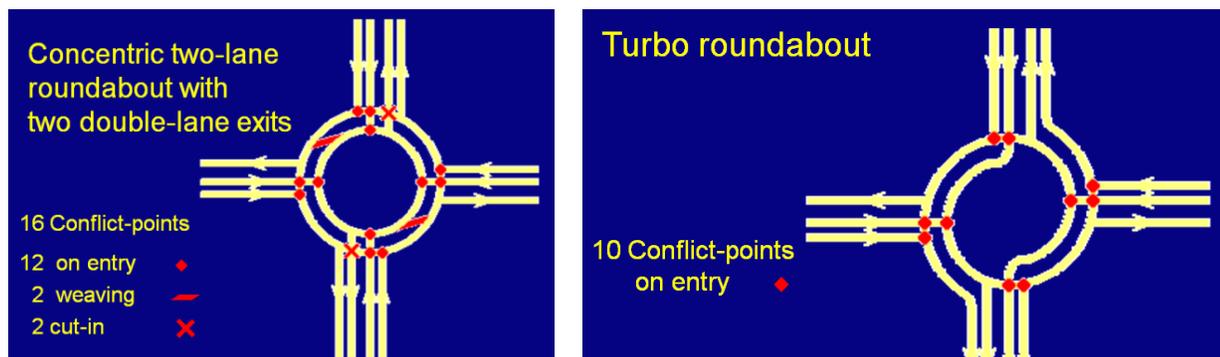


Figure 5. Conflict Points Comparison: Two-lane Roundabout vs. Turbo Roundabout (Fortuijn)

Research from the Netherlands makes a comparison between turbo roundabouts and traffic signal and yield controlled intersections. It shows that a 70% reduction of accidents resulting in serious injuries can be expected when introducing a

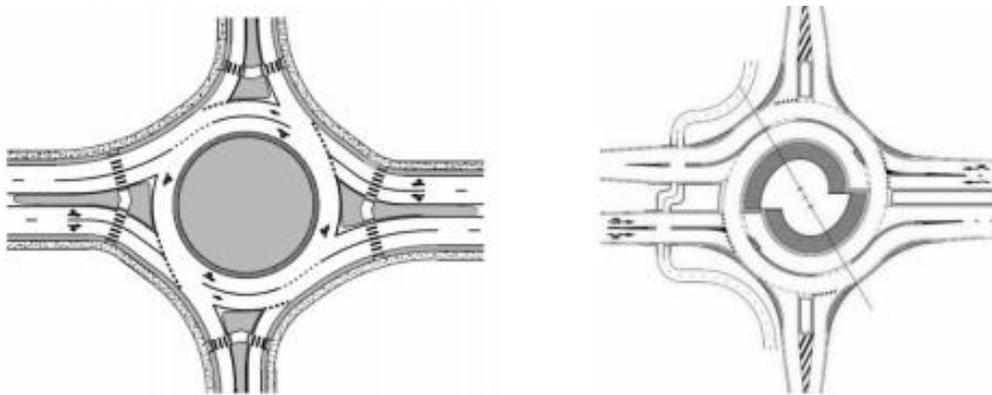
turbo roundabout at such an intersection. The same applies to the introduction of a one-lane roundabout, however this would result in a lower intersection capacity (5).

### **Reduced Right-of-Way and Second Lane Inserted into the Center Island**

Turbo roundabouts require less right-of-way than a standard two-lane roundabout. At least one entry to a turbo roundabout has a second lane inserted on the central island side. Turbo roundabouts normally have radial design where entering traffic flows directly towards the center of the roundabout. These two elements together allow for a reduction in the outside diameter of the intersection.

### **Spiral Roundabouts vs. Turbo Roundabouts**

The majority of multi-lane roundabouts constructed in the USA over the past 20 years follow “spiral striping” as developed in the UK and outlined in the FHWA guide. The current FHWA roundabout guide highlights multi-lane roundabouts with spiral lane markings and spiral transitions. The term “turbo-like roundabout” refers to the various alternative designs or a layout that does not meet all the requirements of a Dutch turbo roundabout. However, a high percentage of the 111 turbo roundabouts constructed outside of the Netherlands have been shown to have regional differences to allow for snowy weather or local preferences but are called turbo roundabouts. Figure 6 shows a common turbo roundabout layout as an alternative to an equivalent spiral roundabout (6).



*Figure 6. Spiral Striping Recommended in NCHRP-672 vs. Equivalent Turbo Striping (Homula)*

### **Turbo Roundabout Checklist**

The following is a summary of design features included in a turbo roundabout:

- ✓ Entries are usually perpendicular to the circulatory roadway (radial design);
- ✓ Mountable raised lane dividers control the traffic path and speed by keeping vehicles in their lane with a smaller roundabout Inscribed Circle Diameter (ICD);
- ✓ At least one entry has a second lane inserted on the central island side;
- ✓ Radial entry lane design;
- ✓ Traffic must choose the appropriate lane for the desired turning movement prior to entering the roundabout;
- and
- ✓ Spiral road markings guide traffic from inside to outside, avoiding weaving and reducing conflicts in the roundabout.

## **2. USA Projects with “Turbo-Like” Roundabout Features Included**

The introduction of the turbo roundabout to design engineers in the USA since 2008 has resulted in the adoption of some of their features in several projects. The following examples are used to illustrate some of the Turbo Roundabout features included in recent USA projects which may be called “turbo-like”.

The original roundabout at the entrance to the Utah Valley University was the first modern roundabout constructed in Utah in 1994. It performed well for 20 years but the school has since grown from 10,000 students in 1994 to over 35,000 students today and most of the students commute to school in single occupant vehicles. The original circle was only 150-ft in diameter and although it was striped for two lanes it has always functioned as a single-lane roundabout.

The reconstructed layout on top of the original layout (shown in Figure 7) includes a turbo-style entry on the northbound entry that allows two lanes at the entry and within parts of the roundabout. The small size of the circle requires the new

lane to be in the inner side of the center island. The entries are all radial design. The diameter is rather small for a two-lane roundabout and may be considered as a “turbo-like roundabout”. If it were to include raised divider islands it could be a “complete turbo roundabout”.



Figure 7. UVU Roundabout First Constructed in 1994, and Re-constructed in 2014, Orem, UT (Horrocks)

This next example on Main Street in Mesa, Arizona constructed in 2018, illustrates how the turbo shape or spiral striping was used to allow exclusive left-turn lanes at the roundabout that includes a light-rail train crossing. Raised lane dividers were evaluated to separate the left-turn lane from the through-lanes during the design but instead, Raised Pavement Markers (RPMs), were utilized (Figure 8). Raised lane dividers would not be impacted by snow plows in the warm Arizona climate but they were not included in the final design.



Figure 8. Main Street/Horne Roundabout, Mesa, AZ (Baranowski, Perrin)

The following example from Salem, Connecticut, is of a roundabout with a raised/stamped brick divider between the two entry lanes. It was constructed in 2012. The lane divider on the entry, consists of a red stamped brick pattern (Figure 9).



Figure 9. Raised Lane Dividers on Entry, Salem, CT (Britnell)

The first recognized and purpose-built turbo roundabout in North America, was constructed in 2010 at the Victoria, BC airport. The lane divider is not raised concrete, but flush-colored pavement (very similar to Salem, CT) to allow for the large airport snow plows to clear the intersection during snow storms (Figure 10).



Figure 10. Victoria Airport Turbo Roundabout, Victoria, BC (Murphy)

Poland currently has about 35 turbo roundabouts. Macioszek compared the two-year crash history of 7 turbo roundabouts in Poland with raised lane dividers to the crash history of 11 turbo roundabouts constructed with only a continuous wide painted line (solid/approx. 10-inch wide white type P-2). The turbo roundabouts with painted lane dividers were found to have a level of safety similar to that found in typical two-lane roundabouts. The number of side-swipe crashes for turbo roundabouts with raised lane dividers was considerably less than that of turbo roundabouts with painted lane dividers (7). Two types of painted lane dividers are shown in Figure 11: one with a large red stripe between two white stripes and one with the single white stripe.



Figure 11. Poznan and Chelm, Poland Turbo Roundabouts with Painted Lane Dividers (Macioszek)

### 3. Issues with Transferring Turbo Roundabouts to the USA

Roundabouts should always be designed for the largest vehicle that can be reasonably anticipated (the design vehicle) (8). In the USA, roundabouts on urban arterials are commonly designed to accommodate a WB-50 (WB15 metric) and sometimes a WB-67 (WB20 metric) design vehicle. Turbo roundabouts have replaced most multi-lane roundabouts in the Netherlands. Turbo roundabouts are able to keep circulating trucks in-lane through the use of wider lanes and outer truck aprons. While on a tour of Rotterdam, the author was quite amazed to see several tractor-trailer trucks commonly enter and go around turbo roundabouts side-by-side with no difficulty.

However, tractor-trailer trucks are longer and wider in the USA with a larger turning radius than those used in Europe (Figure 12). The result is that turbo roundabouts in the USA may have to be larger, with wider circulating lanes, and or they may require larger outer truck aprons. Fortunately, there are software programs that can aid the designer by checking the turning radii of various design vehicles from Buses, tractor-trailers, and oversize vehicles and adjusting for them (9).

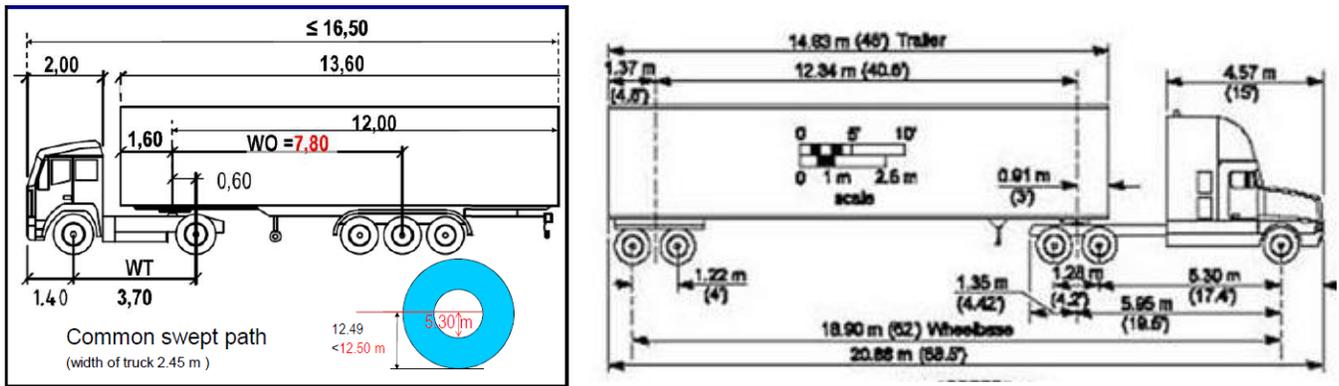


Figure 12. Common Design Vehicle Europe vs. USA (Fortuijn, AASHTO)

To aid in the translation from the Netherlands to the USA, the larger USA design vehicles have been modeled by Transoft Solutions. They followed the Dutch manual which makes the inner lane wider to accommodate the swept path. They compared the circulating lane widths for European design vehicles to USA design vehicles. They discovered a design variable not noted in the Dutch Design Manual called the “opening width”. They found that the swept path influences the circulating lane widths and the opening width. The opening width decreases as the central island radius increases (Figure 13) (10).

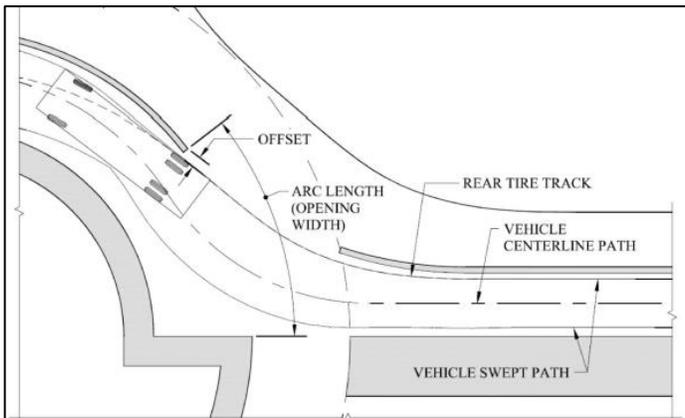


Figure 13. Opening Width of Turbo-Roundabout Spiral Lane and Vehicle Swept Path (Chan)

#### 4. Deer Valley Roundabout – A “Turbo-like Roundabout”

The Deer Valley roundabout is included here to illustrate the successful use of a “raised lane divider” which is a key turbo roundabout design feature. The modifications shown were directly inspired by the turbo roundabouts in the Netherlands. The Deer Valley roundabout was first constructed in 2000 for the 2002 Winter Olympics in Park City, Utah. The roundabout was designed and constructed as a typical two-lane roundabout at a difficult location connecting two ski resorts and a main street shopping area with the Olympic Intermodal transit center. The ski area receives up to 300 inches of snow during the winter and was an ideal location for the Winter Olympics.

The modern roundabout made it possible for buses to directly access the intermodal center using a new improved intersection. Some of the challenges of the project included a skewed intersection, providing a new connection to the Olympic intermodal center, and providing a new section of a bicycle/pedestrian trail that required a roadway underpass (Figure 14). The author participated in the original design of the Park City Intermodal Center including the new roundabout.

The original Deer Valley roundabout performed well during the 2002 Winter Olympics. In the years following the Olympics, the PM peak-hour traffic began to back up to the east into Deer Valley as drivers were hesitant to enter the roundabout when circulating traffic volumes were high. The re-design in 2008 considered several changes to improve traffic flow at the roundabout. The most significant traffic improvement was a mountable raised lane divider installed to separate westbound to northbound right-turn traffic from heavy northbound traffic (Figure 15). The lane divider separates traffic leaving Deer Valley ski resort traffic from the circulating traffic travelling north.

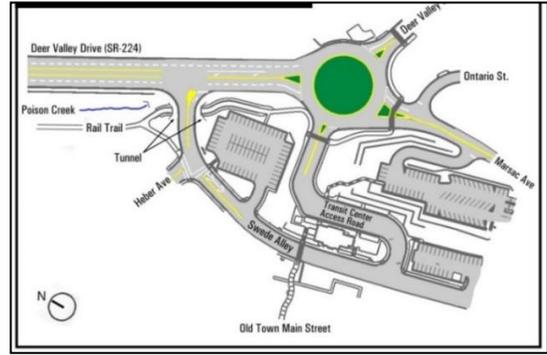


Figure 14. Deer Valley Roundabout Original Design 2000-2008 Looking South (Baranowski)



Figure 15. Deer Valley Rbt. Raised Lane Divider – looking south and north (Baranowski)

The new configuration can service over 1,000 vehicles per hour (vph) at the northbound exit lanes while the overall entering traffic is over 2,000 vph. Side swipe vehicle crashes have been reduced greatly for the years 2008-2018 and traffic capacity has improved by 30%. Peak-hour delays for westbound to northbound traffic have been greatly reduced (by approximately 60%). The mountable raised lane divider is snow-plowable and has helped to reduce the speeds of traffic at the northeast quadrant where it is located. Lane change or weaving type crashes are virtually impossible on the northbound exit of the roundabout. A detailed layout of the changes made to the Deer Valley roundabout is shown below in Figure 16. The Deer Valley roundabout would require more modifications to be considered a “complete turbo roundabout” like the changes shown in Figure 17. These modifications would include reshaping the central island and creating more raised dividers between the circulating and entering lanes.

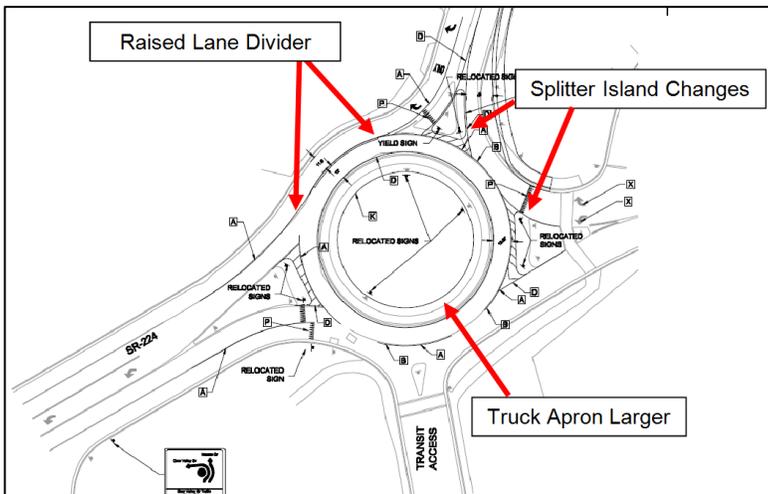


Figure 16. Deer Valley Roundabout Re-design including Raised Lane Divider, in 2008 (Baranowski)

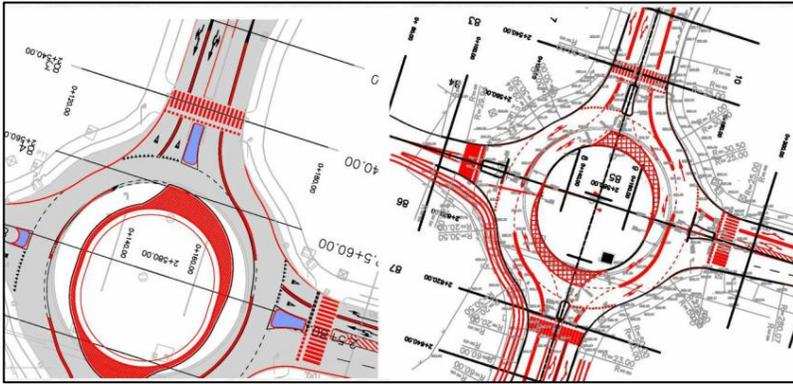


Figure 17. Modifying an Existing 2-Lane Roundabout to be a Turbo Roundabout in Slovenia (Tollazzi)

A modified raised lane divider has been used at 17 turbo-roundabouts in Slovenia which has significant snowfall in Winter. The concrete dividers are flatter than the Dutch design and some include end markers to stand out more in snowy conditions which are common in Slovenia. They also have been found to accommodate motorcycles (Figure 18) (11).



Figure 18. Flatter Raised Lane Divider in Slovenia and End Snow Markers (Tollazzi)

## 5. Summary

The introduction of the turbo roundabout to design engineers in North America has influenced several existing and future roundabout projects. The examples provided, help to illustrate some of the Turbo Roundabout features incorporated in recent projects and may encourage engineers and planners to include variations of Turbo Roundabouts in the future.

The following summarizes the benefits of a Turbo Roundabout and some of the challenges to consider in translating this innovative design to the USA:

- A turbo roundabout eliminates some of the most severe conflict points on a roundabout.
- The most important feature of the turbo roundabout is the spiral lane marking to eliminate the necessity of weaving or changing lanes.
- A mountable lane divider induces traffic to keep its own lane, and this helps to prevent sideswipe collisions that can occur not only upon entering the roundabout, but also when exiting.
- As a result of the lane dividers, drivers need to choose the correct lane before they enter the roundabout.
- Turbo roundabouts require less right-of-way than a standard two-lane roundabout. At least one entry to a turbo roundabout has a second lane inserted on the central island side. Turbo roundabouts normally have radial design where entering traffic flows directly towards the center of the roundabout. These two elements together allow for a reduction in the diameter of the intersection.
- The capacity of a turbo roundabout is about 25% to 35% higher than the capacity of a conventional two-lane roundabout, depending on the balance of the traffic volumes on the approaches.
- The use of turbo roundabouts in the USA will require adjustments to allow for the larger size trucks compared with those in Europe.
- The raised lane dividers are preferable to painted lane dividers but some variation of the raised lane divider may be considered for turbo roundabouts in snowy areas.

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