State-of-the-Art in U.S. Roundabout Practice

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ABSTRACT

Roundabout practice in the United States has evolved considerably over the past fifteen years since the first modern roundabout was built in the United States in 1990. Professionals guiding the early years leaned heavily on experience gained in other countries, principally Australia and the United Kingdom. In the late 1990s, FHWA guided the development of its document, *Roundabouts: An Informational Guide*. This document was more than merely a synthesis of existing international documents; it introduced new concepts and began to define an American roundabout practice. Since its publication, a wide variety of activities have influenced roundabout design in the United States, including the construction and evaluation of many roundabouts across the United States, the active development of supplemental guidance materials by several States, increased awareness and research on the accessibility of roundabouts to pedestrians with vision disabilities, and so on. This paper presents the author's view on the current state of practice in the United States, including a vision of where things may be heading in the coming years.

1. BACKGROUND

Circular intersections have been used in the United States for at least a century. Columbus Circle in New York City, built in 1905, is often acknowledged to be the first circular intersection in the United States, although there are reports of an unpaved circular intersection in New England dating back to the early 1800s. Rotary intersections were built through the 1950s; these commonly had large diameters, higher speeds (particularly as vehicles became more powerful), and either free-merge entries or entries where the entering traffic had priority over circulating traffic. These types of intersections were included in U.S. design documents as recently as 1965 (American Association of State Highway Officials, 1965). Further documentation of the early practice in the US can be found in Jacquemart (1998).

The first modern roundabout in the United States was built in 1990 in a suburb of Las Vegas, Nevada, and over the past fifteen years several hundred roundabouts have been built throughout the United States. The early years of roundabout design can be attributed to a number of trailblazing American and international professionals who either directly or indirectly influenced early development and implementation in the United States, including Ken Courage, R. Barry Crown, Peter Doctors, Georges Jacquemart, Edward Myers, Michael Niederhauser, Leif Ourston, and Michael Wallwork.

In 1997, FHWA initiated an effort to develop what became known as *Roundabouts: An Informational Guide* (Robinson, et al., 2000), hereafter referred to as the "FHWA Roundabout Guide." The intent of this document was to bring into one document the state-of-the-art in roundabout practice from around the world, adapting to U.S. practice. However, during its development it became clear that international practice varied considerably, with professionals having considerably different opinions on the “best” way to plan, analyze, and design a roundabout (the conflict continues to this day). Therefore, the authors forged what was intended to be a US practice, similar in many ways to international practices but anchored wherever possible to fundamental principles already well established in US practice, such as the speed-radius relationships in the AASHTO Green Book (AASHTO, 2005). In addition, the authors worked closely with professionals throughout the US and internationally to include elements that had never been previously discussed in similar international documents. These included a discussion of multilane vehicle path overlap, bicycle treatments, accommodations for pedestrians of all abilities, and recognition of the various system interactions between roundabouts and other nearby traffic control devices or facilities. The FHWA Roundabout Guide was published in 2000 and has been distributed widely around the United States and internationally.

Since the publication of the FHWA Roundabout Guide, several States have initiated efforts to develop State-level design guidance, typically in the form of a supplement to the FHWA Guide. These include the following States:

- Arizona (Lee Engineering and Kittelson & Associates, Inc., 2003)
- California (California Department of Transportation, 2003)
- Kansas (Kittelson & Associates, Inc. and TranSystems Corporation, 2003)
- New York (New York State Department of Transportation, 2000)
- Pennsylvania (Michael Baker Jr., Inc., 2001)
- Washington (Washington State Department of Transportation, 2004), and
- Wisconsin (Wisconsin Department of Transportation, 2004).

In the author’s opinion, these State guides have served several purposes (Rodegerdts, et al., 2005):

1. The State guides provide more detail in areas that were covered lightly or not at all in the FHWA Roundabout Guide. For example, the Kansas DOT guide provides information not found in the FHWA Roundabout Guide on topics such as conversions from one to two lanes, multilane circulatory striping, and concrete joint patterns.

2. The State guides present studies more current than the FHWA Roundabout Guide, whose content was completed back in 1999, such as the 2000 study sponsored by IIHS on updated US safety findings (e.g., Kansas DOT guide; also published under Persaud, et al., 2001).

3. The State guides allow a state to set their own policies, such as using a specific software package for analysis (e.g., New York State DOT and Wisconsin DOT guides).

4. The State guides modify some of the recommendations in the FHWA Roundabout Guide to reflect the current thinking of our profession, such as the gap

recommendations for intersection sight distance. These changes do not necessarily reflect the incorporation of specific research; rather, they reflect expert opinions regarding reasonable ranges of values for specific parameters based on practical experience. Examples of these types of parameters include the recommendations on maximum desired entry speed and ranges of typical inscribed circle diameter (Kansas DOT guide).

The number of roundabouts in the United States is difficult to assess, but there is general agreement that the number presently ranges in the hundreds but will soon reach over 1000. A recently survey published in 2003 (Eisenman, et al., 2003) determined that there were at least 300 roundabouts in operation in the US as of 2002, with Colorado, Maryland, and Washington having the largest numbers. The vast majority of these have been in urban or suburban settings, with fewer than twenty sites in rural locations (the majority of these have been primarily in Maryland). The author estimates that there are upwards of 500 roundabouts now in the US, with at least 50 additional roundabouts being constructed each year in recent years. The trend has been exponential, as a greater number of States and local agencies are implementing roundabouts each year, building on the success of previous installations.

2. SAFETY ANALYSIS

The safety performance at US roundabouts has been remarkably strong and compelling. Research to date suggests that the safety performance of roundabouts in the US is comparable to that of other countries around the world. Recent studies of the safety performance relative to the form of intersection and control that they replaced have shown consistently strong improvements in crashes, with an overall reduction of property damage only crashes of 41 percent and an overall reduction in injury crashes of 72 percent (Eisenman, et al., 2003). These statistics are being further updated with a larger database of sites as part of NCHRP 3-65.

3. OPERATIONAL ANALYSIS

Current operational analysis methods in the United States rely heavily on methods developed internationally. The FHWA Roundabout Guide presented a series of operational models for various categories of roundabouts that are based either directly on international models for similar roundabout types (the model for urban compact roundabouts is based on a German empirical capacity model) or by adapting international models using assumed parameters (the models for single-lane and double-lane models are based on the British empirical capacity equations with assumed values for the six geometric parameters). The Highway Capacity Manual (HCM) 2000 includes a single-lane capacity model based on an analytical formulation with values for critical headway (critical gap) and follow-up time based on early US data.

Perhaps more so in the US than in other countries, there are widely divergent and strongly held opinions about the “best” analysis method to use in designing roundabouts. Proponents of the UK empirical regression technique argue against the validity of the gap acceptance approach favored by the Australians; proponents of the Australian methods argue against the insensitivity of lane use by the UK method. As a result, there is no universally established analysis method in the US at this time.

Research is underway (NCHRP 3-65) that is intended to examine US operational performance and recommend operational models for incorporation into the next update of the HCM. While the hope is that the presence of a model calibrated to US conditions will bring closure to this debate, the strongly held opinions by various proponents will almost certainly ensure that the debate is likely to continue for the foreseeable future.

4. GEOMETRIC DESIGN

The geometric design of roundabouts has a significant effect on the operational performance and safety of the intersection. While there is no consensus within the US or internationally about the specific effect that individual geometric parameters on operational or safety performance, there is general agreement about the need for certain basic principles to be accommodated within a roundabout design. These are articulated in the FHWA Roundabout Guide and several of the individual State guides.

4.1 Design speeds and design vehicle

Design speeds and design vehicle are fundamental to the design of every roundabout. There is generally universal agreement that design speed plays a major role in the design of a roundabout. Vehicle speeds should generally be kept low and consistent through a roundabout. This benefits all modes: slow speeds reduce the likelihood and severity of vehicle-vehicle collisions, and bicycles and pedestrians are much safer in an environment with slower speeds.

The effect of design vehicle is more obvious than design speed. Most roundabouts on or adjacent to State highway facilities are designed for trucks that can travel on the Interstate Highway System. These typically require inscribed circle diameters of at least 130 ft (40 m). However, some roundabouts built to date in the US have been built in lower volume areas where the need to accommodate such large design vehicles is less. As a result, many residential roundabouts, for example, are much smaller, having inscribed circle diameters in the 80 to 100 ft (25 to 30 m) range.

4.2 Pedestrians

Pedestrian treatments continue to be an area of experimentation and improvement in the US. Much of the current debate regarding pedestrian accessibility centers on the challenges faced by pedestrians who are blind or visually impaired.

In the US, the Americans with Disabilities Act (ADA) of 1990 has significantly influenced the debate of how to accommodate pedestrians at roundabouts. In June 2002, the US Access Board (the agency within the US Department of Justice that administers ADA) published draft guidelines for public rights-of-way that, among other things, would require some form of “signalization” at all roundabout crosswalks (US Access Board, 2002). This drew considerable national attention, and ITE and FHWA hosted a roundabout accessibility summit in October 2002 to discuss the issue and assist the Access Board in revising its recommendations (ITE, 2002). Ongoing research has suggested strong indications of a difference in accessibility to pedestrians depending on visual ability, with difficulty increasing with increased traffic and number of lanes. The problem is not unique to roundabouts, as pedestrians with visual impairments have difficulty at many uncontrolled locations and at channelized right turn lanes at signalized intersections. However, there is increased recognition within the transportation profession of the need to find a solution. To address this, AASHTO, FHWA, and the Access

Board are funding a national research project (NCHRP 3-78) that is intended to recommend solutions to address the usability of roundabouts and channelized right turns by pedestrians with visual disabilities.

At present there are no universally acceptable solutions to this problem. While signalization of some sort is perceived within some circles to be the only workable solution, others perceive signalization as being so economically unworkable in some cases as to eliminate the roundabout as a possible treatment. Others have been examining the possibility of less expensive treatments that may yield acceptable results, but the extent to which these treatments successfully address the problem is still being determined. The author believes that this issue has already become one of the most dominant and polarizing issues regarding roundabouts in the US and will continue to be for the next few years.

4.3 Bicycles

Bicycle treatments are less well defined and studied in the US, in large part to a lower density of cycling in the US than in, for example, European countries. The general practice is to recognize that cyclists have a wide range of abilities, ranging from those who ride their bicycles regularly for utility purposes (e.g., commuting, shopping) to those who ride occasionally for recreation purposes. Cyclists also span a wide range of age groups with varying levels of ability, with young children having underdeveloped skills in terms of properly judging hazards in traffic.

As a result, roundabout design in the US generally accommodates cyclists in two ways. First, the roundabout is designed to allow cyclists to merge with the vehicular traffic stream in advance of the roundabout. Bike lanes are not provided at the entry to the roundabout nor within the roundabout. In addition, a ramp is commonly provided to allow cyclists uncomfortable sharing the lane with motor vehicles to join a sidewalk or multi-use path that runs around the perimeter of the roundabout; examples of these ramps are shown in Figure 1. Depending on State laws, the cyclist may be required to dismount to use the sidewalk, although the author has rarely observed cyclists doing this in practice. No universally accepted standards have been established in the US for accommodating cyclists, so this is an area that is likely to continue to evolve in coming years.

(a) Example of bike exit ramp
Cape Coral, FL, USA
Photo: Lee Rodegerdts

(b) Example of bike entrance ramp
Lake Oswego, OR, USA
Photo: Lee Rodegerdts

Fig. 1 - Examples of bike ramp treatments.

5. MULTILANE ROUNDABOUT ISSUES

Multilane roundabout design is an area of great interest in the US, particularly among State Departments of Transportation. Approximately one third of the roundabouts in the US are multilane roundabouts. Many candidate intersections on State highway facilities in urban areas either have the need for multilane entries under existing conditions or are projected to need multilane entries by the design year (typically 20 years beyond the opening date of the roundabout).

5.1 Vehicle path overlap

One of the major developments in the geometric design of multilane roundabouts in the US has been the recognition of a concept known as "path overlap." Multilane entries and exits should be designed to accommodate side-by-side movement of vehicles without abrupt changes in the trajectories of those vehicles. Abrupt changes in vehicle trajectories, particularly when unguided by curbing, often result in path overlap. The consequence of path overlap in the US has been found to be substantial, with significant detriments to safety and capacity. Path overlap was first discussed in the FHWA Roundabout Guide and has since been expanded upon in several State guides.

5.2 Signing and pavement markings

A second major evolving practice in the US at multilane roundabouts is the use of signing and pavement marking, particularly as it relates to lane use on the approach to the roundabout and within the circulatory roadway. As with other elements of design, early US practice has relied on the experience of other countries. As a result, the early multilane roundabouts in the US have seen a wide range of treatments, ranging from no striping at all within the circulatory roadway per typical British practice, to exit striping per typical Australian practice, to concentric striping common in northern Europe. These variations in striping can have significant operational and safety consequences.

The design of traffic control devices and illumination at roundabouts is evolving in the United States. The National Committee on Uniform Traffic Control Devices (NCUTCD), the volunteer group that assists FHWA in managing the technical content of the Manual on Uniform Traffic Control Devices, has a number of technical committees that are reviewing and updating the current limited guidance on roundabouts. At the time of this writing, a draft chapter on pavement markings for roundabouts has been prepared by a roundabout task force and reviewed by the various sponsor organizations of the NCUTCD. The major contribution of this new work is an extensive treatment of pavement markings at multilane roundabouts.

The task force's initial work was guided in part by a set of presentations made by R. Barry Crown, issues raised by representatives from the New York State DOT, and the author's work on the FHWA Roundabout Guide and other documents. In particular, Crown presented a set of principles (Crown 2003) that the author believes serves well as an overall framework for developing positive guidance within multilane roundabouts. Some of these key principles are as follows, as adapted by the author:

- The design of the striping, arrows and lane use control is an integral part of the geometric design of a roundabout. Each driver executing a major turning movement must be able to enter and exit without changing lanes within the roundabout. Drivers must be given plenty of time to select the correct approach lane for their desired exit.

- The design of the geometry and striping should attempt to balance distribution of traffic across the approach lanes and to establish proper lane use as far in advance of the roundabout as possible. Unbalanced lane use can create very large queues and delays unless the average volume-to-capacity ratio on an approach is moderate. This can create increased potential for crashes due to the consequent incorrect lane use to bypass queues.

- It is not always possible to achieve a circulatory striping design that works for all anticipated conditions. Sometimes the striping needed from one entry clash with that needed for another entry during the same peak period (what Crown refers to as an "internal spiral conflict"). In other cases, different volumes and turning distributions throughout the day may require very different striping layouts (what Crown refers to as an "external striping conflict"). In either of these cases, it may be better to use no striping or partial striping that accommodates only the major traffic streams. The minor streams then "fit in" around the main flows. Partial spirals are very difficult to get right and give all drivers a clear unambiguous message. Crown cautions that wrong spirals can be worse than no spirals.

- Closely spaced roundabouts are designed as one system. The mutual interaction between signing, striping and geometry is more critical and complex than at a single roundabout. Drivers should be directed into the correct approach lane into the system that leads to their desired exit from the system without changing lanes. This may require additional lanes for striping consistency rather than capacity.

Although the overall safety performance record for US roundabouts has been quite good, a few multilane roundabouts have experienced poor safety performance upon opening and received follow-on treatment to correct the apparent safety deficiencies. Perhaps the most notable is the Gateway roundabout in Clearwater Beach, Florida, shown in Figure 2 in its original and current configurations. The roundabout's early record of frequent fender-bender crashes made national news as a cover story in *The Wall Street Journal* (2002). It has since received a variety of adjustments that have been instructive in the design of multilane roundabouts. In particular, the circulatory roadway striping was modified to guide exiting vehicles, and the entries and exits were widened and realigned to minimize vehicle path overlap. The modifications have resulted in reportedly dramatic reductions in collisions (Stidger, 2004).

Initial configuration
Photo: Bruce Robinson (2001)

(b) Current configuration
Photo: Lee Rodegerdts (2005)

Fig. 2 - Gateway Roundabout, Clearwater Beach, Florida.

6. ILLUMINATION

Illumination design guidance in the United States is anchored on the *American National Standard Practice for Roadway Lighting* RP-8-00, prepared by the Illuminating Engineering Society of North America (IESNA, 2000). Its guidance has been adapted for roundabouts in the Kansas Roundabout Guide. A subcommittee within IESNA is preparing a design guide for roundabout lighting at the time of this writing, supported by recent research on US roundabout lighting conducted by Lutkevich and Hasson (2004) and international lighting practices in France, Australia, and New Zealand. Some of their key findings include the following:

- Lighting should be provided at all roundabouts, including those in rural locations.
- Approach lighting is important for providing good visibility throughout the roundabout.
- A minimum level of vertical illuminance at pedestrian crosswalks is recommended.

In general, while some roundabouts in the US have been illuminated using a central set of fixtures, most have been illuminated using a series of fixtures around the perimeter of the roundabout. An example of a roundabout with this type of peripheral illumination is shown in Figure 3.

Photo: Lee Rodegerdts

Fig. 3 - Example of illumination.

7. CONCLUSIONS

Roundabout practice in the US will inevitably continue to evolve over the coming years. The practice has improved considerably with the publication of the FHWA and State roundabout guides and the continued guidance from experts, and the profession as a whole is becoming better versed in the design details that enhance the performance of roundabouts. The technical issue of properly accommodating non-motorized users, particularly pedestrians with visual impairments, is likely to continue to dominate the American debate. It is likely that the findings and recommendations that emerge from this effort will find their ways into other areas of American practice as well as the practices of other countries that are grappling with this problem.

Although NCHRP 3-65 and similar research projects are likely to make major contributions in estimating safety and operational performance at US roundabouts, the author believes that these are merely first steps towards developing fully-realized models for estimating US roundabout performance. Drivers will continue to get comfortable with roundabouts, increasing their efficiency in using roundabouts over time as they have with freeway facilities and signalized intersections. Some of the early roundabouts that were built without the knowledge the profession has today will likely need modifications to realize their full capacity and safety potential, and many roundabouts being built today by newcomers in the roundabout field continue to benefit from expert peer review. Inevitably, as roundabouts become more and more common and more research and experimentation is conducted, the roundabout practice in the US will continue to develop a uniquely American flavor.

In addition to addressing technical details, the author believes that one of the biggest challenges facing roundabout design, and indeed all types of transportation facility design, is one of mindset. Many large organizations rely heavily on standards, codes, and procedures to ensure that they have consistency in design. Many engineers within those organizations are hesitant to seek exceptions to those standards, codes, and procedures, even when a deviation is the best solution for a given problem. The act of proposing and/or accepting a deviation puts the responsibility on the engineer, which exposes the engineer to potential liability to which many engineers have a natural aversion. Many States and other governmental bodies want to establish standards for roundabouts that remove any ambiguity and establish consistency in practice; when combined with many engineers' natural aversion to liability, this can result in an unreasonably rigid application of standards.

The author firmly believes that roundabout design by its nature is anchored more on fundamental principles and a desired outcome than by individually defined components. For example, it is impossible to specify a range of inscribed circle diameters that will work in every situation without creating a range that is so large to be meaningless. While the author respects the opinions of the many professionals who treat the ideal dimensions as inviolate standards, the author respectfully suggests that blind adherence to those standards and other codes without consideration of the unique features of the site under consideration is probably not the best use of our limited resources. For every "standard" one will almost certainly be able to demonstrate a good engineering solution for a given situation that violates that standard. The author believes this is a role and purpose of Professional Engineers and why they, not technicians using codes or standards as a cookbook, make these decisions. The author sees this as a continuing area for education of our profession.

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