Can Modern Roundabouts Safely Accommodate All Users?

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Abstract

The authors have studied the safety, operational and environmental benefits of roundabouts for motorists for several years. There has been considerable research in recent years that has documented significant safety benefits, particularly in decreased injury crashes and fatalities, when modern roundabouts have replaced stop sign and traffic signal control. One reliable U.S. study concluded that where roundabouts replace stop signs and traffic signals, overall crashes are reduced 39%, injury crashes are reduced 76% and fatal crashes are predicted to decrease 90%. They have the potential to save thousands of motorists' lives. Research results also have concluded that roundabouts significantly reduce delay, stopping and queuing; and along with these reductions, motor vehicle emissions are also reduced. The effects on pedestrians and bicycles have not been studied much in the United States; however, international studies indicate that roundabouts are safer for pedestrians than intersections with conventional traffic control and no more dangerous for bicyclists. There is concern that roundabouts are not accessible to blind and low-vision pedestrians and the access-board has put language in draft guidelines that would require pedestrian signals at all roundabouts. The challenge is to find a solution(s) to make roundabouts accessible without slowing or stopping their growth, which could negate roundabouts' life saving benefits to motorists. This paper presents the issues involved in finding a balance that will accommodate and benefit all roundabout users.

INTRODUCTION

In regard to motor vehicles. The safety, operational, environmental and economic benefits of the modern roundabout are beginning to be well documented in the United States (US). The increased safety of pedestrians has been documented internationally albeit US experience and studies have been limited. The safety of bicyclists traveling through roundabouts has been acceptable in foreign countries but needs additional study in the US. The safety and mobility of blind and low vision pedestrians has been questioned by the US Access Board (ACB) and several advocates for blind and low-vision pedestrians.

Roundabout advocates in the traffic engineering community have been "challenged" to find ways to design roundabouts so they do not impede the mobility or increase the risk to blind and low vision pedestrians. The alternative or default for not doing so can be found in the draft guidelines for public rights-of-way:

> "To provide safer crossings at roundabouts, the draft guidelines would require pedestrian activated crossing signals at each roundabout crosswalk, including those at splitter islands." (Access Board, June 2002)

This paper will look at the benefits, disbenefits, and needs of all roundabout users and the issues related to roundabout growth in the US. Trains and trams also may use a roundabout, and this is common in some foreign countries, but will not be covered in this paper.

MOTOR VEHICLES

Safety. In the authors' opinion, the greatest benefit to promoting the growth of the modern roundabout is motor vehicle safety. Studies are available that document their great potential for decreasing intersection crashes, injuries and fatalities. Although too easily accepted and "shrugged off" the numbers of persons killed and injured on US highways is a national tragedy. Earliest estimates for 2003 report 43,220 persons killed and 2,819,000 injured (NHTSA, 2003). A large component of this carnage is the numbers killed, injured in intersection crashes – 9,410, intersection related deaths in 2003 (NHTSA, 2002). From red light running alone 800 to 1,000 persons are killed annually. In 2002, 207,000 intersection crashes, 178,000 injuries and about 920 deaths were attributed to red light running (FHWA, Safety-Stop Red Light Running Facts, http://safety,fhwa,dot.gov/fourthlevel/pro_res_srlr_facts.htm). Each year stop sign violations are associated with about 200 fatal crashes and 17,000 injury crashes. A study of stop sign violations examined the frequency of driver compliance with stop signs at unsignalized marked and unmarked pedestrian crosswalks near schools. Thirty-seven percent rolled through the crosswalk. Seven percent did not even slow down (National Safe Kids Campaign). There is a relatively simple traffic control "device" or system to dramatically reduce crashes, injury and death US intersections – the modern roundabout.

Numerous studies from the United Kingdom, Europe, Australia, New Zealand and other countries with thousands of modern roundabouts report significant decreases in crashes, injuries and deaths at roundabouts compared to traditional forms of intersection traffic control. In the US roundabouts are relatively new and before and after crash data is limited. One study funded by the Insurance Institute for Highway Safety (IIHS) studied crashes before and after roundabouts had replaced signals at 24 intersections in the US. The study used state-of-the-art statistics and data from seven states and found a 39 percent decrease in all crashes, a 76 percent decrease in injury crashes and predicted a 90 percent decrease in fatal crashes (Persaud, Retting and Garder, 2001).

Maryland is a leading state in constructing modern roundabouts on state highways. They have eight that have been in use long enough to report reliable before and after crash statistics. Crashes per year dropped from 4.98 to 1.8, a 64% reduction. Injury crashes per year dropped fro. 3.0 to 0.5, an 83% reductrion. Crash rates dropped from 1.53 per MEV to 0.97 per MEV. Injury crash rates dropped from 0.48 per MEV to 0.11 per MEV (Maryand, SHA, 2001).

Using the IIHS study results and NHTSA 2002 statistics, if there had been modern roundabouts at all US intersections in 2002, there would have been a potential for up to 8,469 less deaths and tens of thousands fewer injury crashes. Roundabouts at all intersections is unrealistic, however, the authors believe converting just 50 percent of the intersections with crash histories would result in an annual decrease of several thousand motor vehicle, intersection crashes.

At a well designed modern roundabout, speeds are low, generally less than 25 mph, and deflection and entering angles are such that most crashes that do occur are same-direction sideswipe. The deadly, right angle crashes that occur at intersections with traditional traffic control, many at high speed, are essentially eliminated.

Operations. Kansas State University (KSU) has been studying the operational effects of 11 roundabouts in Kansas since 1996. These studies have been reasonably consistent in showing decreases in vehicle delay, stopping, queuing, and degree of saturation at all roundabouts studied when compared to stop signs or signals. A summary of the average results from 11 Kansas roundabouts show the following reductions: Average Intersection Delay reduced 65%, Maximum Approach Delay reduced 71%, 95% Queue length reduced 44%, Proportion of Vehicles Stopped reduced 52% and Degree of Saturation reduced 53%. All reductions were statistically significant (Russell and Mandavilli).

Environmental Effects. Using data available from the Kansas Roundabout Operational studies, the computer program aa SIDRA was used to theoretically estimate vehicular emissions. In all cases, emissions were significantly reduced. This reduction was not unexpected as vehicular emissions are related to delay (excess idling) and stopping. Results from the KSU emissions studies show the following average results: Hydrocarbons reduced 65%, Carbon Monoxide reduced 42%, Oxides of Nitrogen reduced 47%, Carbon Dioxide reduced 58% (Vedula).

PEDESTRIANS

Safety. In 2003, 4,672 pedestrians were killed in motor vehicle crashes which represents 10.6 percent of all deaths from motor vehicle crashes in 2003 – another “too-high” statistic. About 23% are intersection related (NHTSA, 2003)

There is insufficient US data to make reliable conclusions regarding the safety of the average pedestrian when crossing at a roundabout. (Mobility challenged pedestrians will be covered in another section below.) The low vehicular speed of a well designed roundabout, 15 to 25 mph, by itself create a safer condition.

A literature review study of the relationship between vehicle speeds and pedestrian fatalities and injuries found that higher vehicular speeds are strongly associated with both a greater likelihood of pedestrian crash occurrence and more serious injuries. The study authors estimated that 5% of pedestrians would die where struck by a vehicle traveling 20 mph, compared with fatality rates of 40, 80 and nearly 100 at speeds of 30, 40 and 50 mph or more, respectively (Preusser and Leaf, 1999).

Another study claims that the probability of a pedestrian being killed when hit by a vehicle is 3.5% when the vehicle is traveling at 15 mph but increases more than ten times to 37% at 31 mph and 83% at 44 mph (Limpert, 1994).

Studies have shown that a driver’s field of vision or peripheral vision angle which spans 150° at 30 mph, decreases two thirds to 50° at 60 mph (Limpert, 1994). What this means is that motorists driving at 25 mph or faster have difficulty perceiving that a pedestrian is waiting to cross a roadway, slowing down and stopping--and the typical river usually speeds up assuming another car will stop (Burrington, et al, 2000).

Also, International experience indicates that modern roundabouts increase pedestrian safety. A German before and after study of 25 intersections that were converted from stop signs or traffic signals to modern roundabouts showed a 75% decrease in average vehicle pedestrian crashes (Brilon, et al, 1993). In the Netherlands a before and after study of 181 intersections converted from stop signs or signals to modern roundabouts showed a 73% decrease in average vehicle – pedestrian crashes. (Schoon and Van Minnen, 1994). In Sweden, researchers compared empirical vehicle-pedestrian crash data from 72 roundabouts with expected values from comparable signalized intersections and concluded that for single lane roundabouts vehicle-pedestrian crashes at the roundabouts were 3 to 4 times lower then predicted crashes at comparable signalized intersections; and for two-lane roundabouts, crash risk was similar to comparable intersections (Brude and Larson, 2000). Researchers in the Netherlands examined the safety changes when 181 intersections with ADTs from 4000 to 18000 were converted to roundabouts. All pedestrian injury crashes decreased 73% and fatalities decreased 89% (Schoon and van Minnen, 1993).

BICYCLES

Considering the low volume of bicycle traffic in the U.S., plus the fact that roundabouts are relatively new, there is no reliable U.S. data on the effect of roundabouts and bicycle travel. In countries such as Sweden and the Netherlands where bicycle travel is extensive, special provisions for bicycles are common. In the Netherlands, School and Minnen studied bicycle safety and concluded the safest approach was to conduct separate bike paths so that the bicycles crossed the path of vehicles outside of the roundabouts--usually yielding to motor vehicles (Schoon and Minnen, 1994).

In the U.S., the primary recommendation is to not have bicycle lanes run through a roundabout, but to terminate them some distance prior to the roundabout. At the termination, a bicycle ramp to an adjacent sidewalk is usually provided. Thus, a bicyclist has the option of riding through the roundabout or diverting to the sidewalk via the ramp and riding or walking his/her bicycle through the roundabout on the sidewalk shared with pedestrians.

If riding through the roundabout, bicyclists are advised to ride in the center of a lane, particularly in one-lane roundabouts. They should be able to ride at 15 to 20 mph and safely mingle with traffic. The potential danger of riding on the edge of the roundabout circular roadway is that drivers may be tempted to pass them and crowd them off the lane.

There is one issue that has come up on the KSU Roundabout listserve (Roundabouts@ listserv.ksu.edu) and has generated considerable discussion. The bicycle ramp needs to be designed and marked in such a way that blind pedestrians cannot mistake it for an intersection ramp and head out into the roadway traffic lanes.

PEDESTRIANS WITH DISABILITIES

Currently, the issue of "accessibility" may be the "hottest" issue surrounding roundabouts. It is an issue that must be resolved. It needs to be satisfactorily resolved in such a way that a "balanced" solution accommodates all roundabout users and is not detrimental to new roundabout growth. A solution that discourages state and local agencies from constructing roundabouts because of cost or other requirements, is one that could have the effect of discouraging an intersection traffic control with the potential of saving lives, thus costing hundreds of thousands of intersection-related motorists' deaths and injuries over time.

Background. The authors believe that there is a wide range of knowledge and/or understanding of the accessibility issue and some brief background is beneficial. The Americans with Disabilities Act (ADA) was passed and signed into law to protect the **civil rights** of people with disabilities. Title II of the ADA requires that new and altered facilities constructed by, on behalf of or for the use of state and local government entities be designed to be readily accessible to and usable by people with disabilities (28CFR35.151). The Access Board (ACB), an independent Federal Agency, was formed to develop and maintain design guidelines for accessible buildings and facilities, known as the ADA Accessibility Guidelines (ADAAG). The ACB has a similar responsibility in regard to the Architectural Barriers Act (ABA). The ACB's ADA and ABA accessibility guidelines specify *minimum* levels of accessibility in new construction and project alterations and serve as the basis for enforceable *standards* maintained by other agencies, e.g. the US Department of Transportation (DOT) and the US Department of Justice (DOJ). Access for blind pedestrians at street crossings and wheelchair access are typical issues addressed in ADAAG. In the late 1990's the ACB determined there was a need for criteria for public rights-of-way accessibility that are definitive and *enforceable* so that the obligations of state and local agencies are clear when undertaking projects such as constructing or altering streets and sidewalks. As it is their practice, the ACB formed a Public Rights of Way Advisory Committee (PROWAAC) in 1999 that subsequently submitted recommendations to the ACB in 2001. Based on the PROWAAC recommendations, the ACB developed, "Draft Guidelines for Accessible Public Rights-of-Way" (Draft Guidelines). Because the draft guidelines differed from the PROWAAC report in several areas, the ACB made an advance draft of the draft guidelines available for comment by the public. (Available at [http://www.access-board/rowdraft.htm#DRAFT]). Although only 5 paragraphs in the 31-page draft guidelines, the section on roundabout (Roundabouts (1105.6)), and particularly the language that would require pedestrian signals at *all* roundabout crosswalks, created considerable discussion and some controversy. The next step is to consider comments received, revise the guidelines and issuse the revised guidelines in the Federal Register as a Notice of Proposed Rulemaking (NPR), and consider additional comments. After the guidelines are finalized and approved by the ACB, they will be reviewed by the Office of Management and Budget (OMB). Once cleared, by OMB, the final guidelines will be sent to DOT and DOJ who are responsible for enforcement. The final guidelines are not in themselves enforceable or mandatory, however, DOT and DOJ will update their enforceable standards based on the ACB guidelines.

CONCERNS FOR BLIND AND LOW VISION PEDESTRIANS

The ACB maintains that roundabouts as currently designed do not have the same access to crossing information as sighted pedestrians. They define an accessible roundabout as one that "---will provide non visual information about crosswalk and splitter island location crossing direction and safe crossing opportunities" (Access Board, August 2003).

The most common techniques and cues blind pedestrians use crossing at traditional intersections are based primarily on traffic sounds. Pedestrians who are blind align themselves with the sounds of traffic flow parallel to their path and, at fixed time, signalized intersections, begin to cross when there is a surge of through traffic next to and parallel to them. (Access Board, updated August 2003.) Also, at a traditional intersection the crossing is typically straight ahead, on the same line as the sidewalk.

At roundabouts there are no clear auditory cues that blind pedestrians can align themselves with. The sounds of circulating traffic in the circular roadway in the roundabout mask sounds of vehicles approaching the crosswalk. Also, the crossings are generally not in line with the approach sidewalk but one or two car lengths back from the roundabout entry yield line. The following are key roadway crossing tasks for the blind pedestrians at any intersection (Access Board, August 2003):

- detecting the intersection;
- locating the crosswalk and aligning the body in the direction of the crosswalk;
- analyzing the traffic pattern;
- detecting an appropriate time to initiate the crossing (at signalized intersections, determining the onset of the walk interval);
- remaining in the crosswalk during the crossing;
- monitoring traffic during the crossing; and
- detecting the destination sidewalk or median island.

At a roundabout it may be less clear where and when to cross. The key tasks and traffic characteristics specific to a roundabout are:

- finding the crosswalk;
- having sufficient safe crossing gaps in the traffic stream;
- identifying the gaps and or identifying when cars have stopped for the pedestrian;
- estimating the distances and direction to the splitter island and onto the far curb; and
- staying in the crosswalk.

In a response during the comment period for the draft guidelines, Retting pointed out that although the safety of blind pedestrians at roundabouts has been questioned by advocates of the visually impaired, direct evaluations of crash data are not available (Retting, October 25, 2002). Retting also pointed out that research by Guth, et al (2002) determined that at low-volume, single lane roundabouts, pedestrians observed frequent periods of "all quiet" and suggested that this all quiet may be an effective strategy for identifying acceptable gaps, and that blind pedestrians can cross single-lane roundabouts with relatively little difficulty and risk (Retting, October 25, 2002). Two- and multi-lane roundabouts are definitely more challenging.

Several brainstorming sessions at TRB and conference sessions have suggested a number of possible solutions. It is not the purpose of this paper to discuss these possible solutions, but to emphasis the seriousness of the issue. The best hope for an acceptable, balanced solution that will not impede the great safety benefits of modern roundabouts to motorists is a major NCHRP research project scheduled to start this fall, 2004. The stated objectives of this research project is as follows:

> "---- to recommend a range of geometric designs, traffic control devices, and other treatments that will make pedestrian crossings at roundabouts and channelized turn lanes useable by pedestrians with vision impairment. These recommendations should be suitable for inclusion in transportation-industry practice and policies, including the *AASHTO Policy on Geometric Design of Highways and Streets* and the FHWA *Manual on Uniform Traffic Control Devices*. Exploration of the proper balance among the needs of passenger cars, trucks, pedestrians (including pedestrians with vision impairments), and bicycles is central to achieving the objectives of the research." (NCHRP RFP for Project 3-78 from http://www.trb.org/trb/crp.nsf)

Let's hope the above research finds solutions that find a balance acceptable to all users.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Kansas DOT and the Mack Blackwell Rural Transportation Center for funding several KSU studies of modern roundabouts.

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