ROUNDABOUTS

Improving Road Safety and Increasing Capacity

JOE BARED

Approximately one-half of the accidents on the U.S. highway system occur at intersections, where drivers are confronted with through, right-turn, and left-turn maneuvers and capacity is restricted. Attempts to improve the safety of motorists at these points began in the 1930s and 1940s with the construction of traffic circles in several states. As a result of design and alignment of right-of-way defects and nonuniform signing, however, the circles did little to promote safety. Moreover, they tended to constrict traffic flow.

The roundabout, a variation of the traffic circle, may provide a solution to these problems in some instances. In Western Europe, where this type of intersection is commonly found, changes in roundabout design, along with changes in traffic regulations, have noticeably increased road safety and capacity. Now many highway engineers in the United States have become advocates for roundabouts as a means to reduce accidents and improve traffic flow.

Roundabout Characteristics

Roundabouts are distinguished from traffic circles by their operational and design characteristics. The key operational feature is that traffic must yield at entry to traffic already within the circle. Deflection of a vehicle's path at entry and exit is an important design feature. Other salient design characteristics are entry angles of between 20 and 60 degrees; crosswalks upstream of the yield line; the absence of parking in the roundabout; and splitter islands, which reduce speed, deter left turns, and provide refuge to pedestrians, at all approaches (Figure 1). To qualify as roundabouts, circular intersections must also meet certain lighting, signing, and sight distance requirements.

Where Do Roundabouts Make Sense?

Roundabouts can be beneficial in certain conditions and locations. They may provide a greater measure of safety at sites with high rates of right-angle, head-on, left/through, and U-turn accidents. In addition, they may be considered for sites with visibility problems because they have tight entry radii, which are conducive to speed reduction.

In general, these structures may be desirable at locations where all-way stop control currently exists; at signalized locations with low or medium traffic volumes; and at entries into urban and suburban areas, where they can create a gateway effect through traffic calming. Roundabouts may also be desirable in rural and suburban areas where they do not affect the progression of network-controlled signalization or signalization at adjacent intersections and at unsignalized and signalized diamond interchanges. The structures may not be effective when the flow of heavy vehicles is great or long delays on one approach exist.

Safety Versus Road Capacity

As noted above, roundabouts can improve road safety and increase capacity, but one benefit can

Joe Bared is research highway engineer, Safety Design Division, Turner-Fairbank Highway Research Center, Federal Highway Administration.

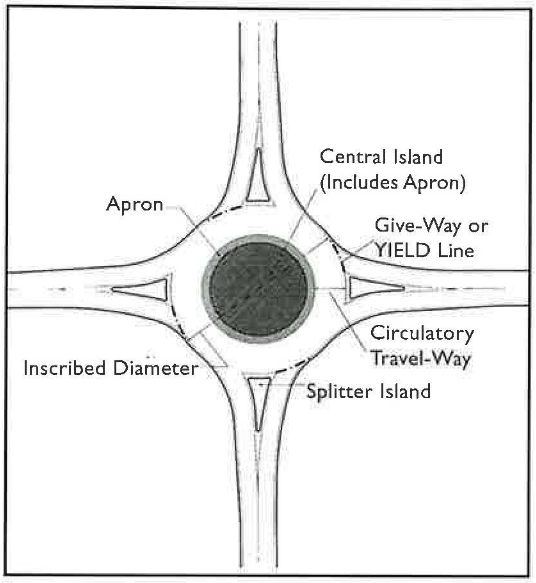


FIGURE 1 Typical design of single-lane roundabout.

come at the expense of the other. Increasing the inscribed diameter of roundabouts, which can range from 15 meters (49 feet) to more than 100 meters (328 feet), will not substantially increase road capacity. That benefit can be realized by adding entry lanes or increasing the width of such lanes. However, both actions increase the potential for traffic conflicts. Widening entry lanes is particularly detrimental to the safety of cyclists.

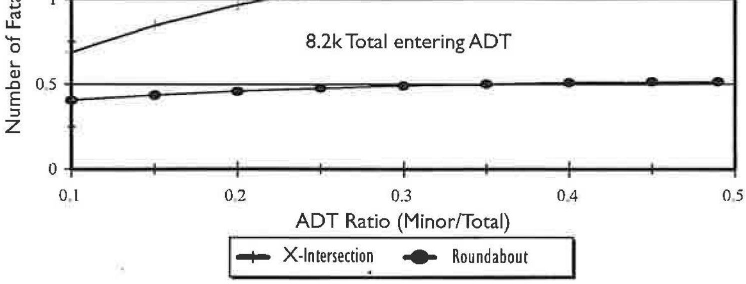


FIGURE 2 Estimated number of accidents at X-intersections and roundabouts for specific average daily traffic.

NOTE: It is assumed that 90 percent of the average daily traffic entering the structures is through traffic, 5 percent is left-turn traffic, and 5 percent is right-turn traffic.

Safety Analysis

Research in Europe during the past 5 years has shown that accident rates can be decreased by replacing conventional intersections with roundabouts. The Netherlands achieved a 95 percent reduction in injuries to vehicle occupants at locations where roundabouts were installed (*1*). On inter-urban highways in France, the average number of accidents resulting in injuries was 4 per 100 million vehicles entering roundabouts, compared with 12 per 100 million vehicles entering intersections with stop or yield signs. The safety of roundabouts, installed mostly in France's urban and suburban areas, including residential areas, was generally superior to that of signalized intersections (*2*). (Researchers noted that large roundabouts with wide entries and heavy bicycle traffic appeared to be less safe than other roundabouts.) In Germany the number of accidents was 1.24 per 1 million vehicles entering small roundabouts, compared with 3.35 for signalized intersections, and 6.58 for old traffic circles (*3*). In Norway an extensive accident analysis also revealed that roundabouts are safer than signalized intersections. The number of accidents resulting in injuries was 3 per 100 million vehicles entering three-arm roundabouts and 5 per 100 million vehicles entering three-arm ("T") signalized intersections; it was 5 for four-arm roundabouts and 10 for four-arm ("X" or "cross") signalized intersections (*4*).

In the United States, a recent study confirms the safety benefits of roundabouts. An investigation of six sites in Florida, Maryland, and Nevada revealed that the conversion of T and X intersections (stop controlled and signalized) to roundabouts decreased accident frequency (*5*). According to the study, which was sponsored by the Federal Highway Administration, the reduction was statistically significant.

Given that roundabouts have only recently begun to appear in the United States, highway agencies have had little opportunity to gather empirical data on the safety benefits of the structures. Fortunately, similarities between accident-prediction models developed in the United Kingdom for roundabouts and those developed in the United States for cross intersections allow agencies to compare in theory the safety of both types of intersections. Both the U.K. and the U.S. models yield estimates of accidents resulting in nonproperty damage (*6, 7*). In addition, both models use state-of-the-art regression analysis (Poisson and negative binomial) and samples of sufficiently large size to relate accidents to particular highway characteristics. On the basis of these similarities, one could draw the conclusion that roundabouts in the United States have the potential to increase safety when compared with convential intersections, just as they are projected to do in the United Kingdom.

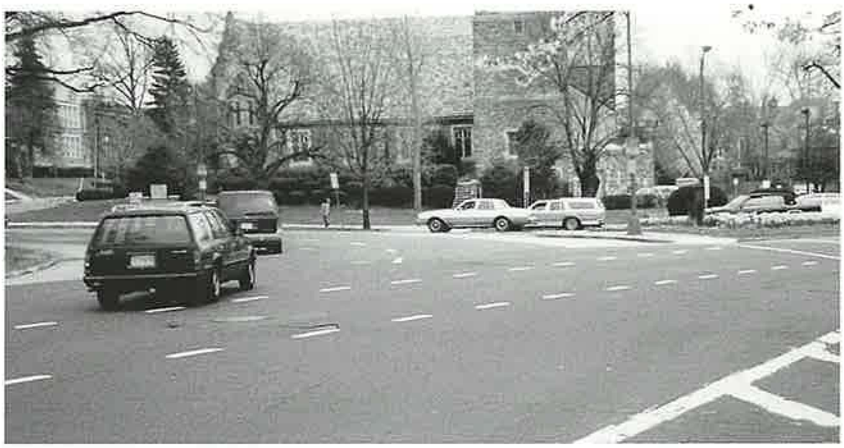
One note of caution should be sounded: the safety record of roundabouts for one group of road users is mixed. Pedestrians using roundabouts have long been considered at least as safe as those using conventional intersections because the prevailing speed on these structures is slower, and splitter islands provide refuge from automobile traffic. However, many countries have documented increases in accidents involving bicyclists after roundabouts were installed. On the other hand, the Netherlands reported a decrease of 1.3 to 0.37 injuries per year to bicyclists at 181 conventional intersections converted to mini-roundabouts (*8*).

Traffic-Delay Analysis

In the United States, roundabouts are expected to improve traffic flow. According to the *Florida Roundabout Guide,* traffic delay on single-lane roundabouts with four approaches is lower than that on any other type of intersection as long as the number of entering vehicles does not exceed approximately 2,100 per hour. The reduction in delay ranges from 0 to 10 seconds per vehicle, depending on the volume of traffic entering the roundabout and the type of intersection traffic control. Approximately 4,000 vehicles per hour can enter two-lane roundabouts with four approaches. Traffic delay on these structures is noticeably lower (10 to 13 seconds per vehicle) than that on conventional intersections with signalization (*9*).

Research Efforts

Although further research will be needed to quantify the magnitude of the safety and capacity benefits of roundabouts after more are constructed in the United States, several investigations are currently being conducted. Through an ongoing research agreement with the Federal Highway Administration, Pennsylvania State University will develop traffic capacity and delay models for roundabouts with single-lane approaches. The university will also compare the safety of these structures with that of conventional intersections. In addition, FHWA has initiated research to develop a roundabout microsimulation model to be incorporated into its CORSIM (corridor simulation) software for analyzing traffic flow. The agency is also set to develop a design guide for roundabouts. Finally, the Transportation Research Board's National Cooperative Highway Research Program is documenting the state of the practice with respect to U.S. roundabouts.



TURNER-FAIRBANK HIGHWAY RESEARCH CENTER

Top: Pavement marking of roundabout in Washington, D.C., is not well defined.

Below: Well designed roundabout in France has adequate deflection and well marked central island.

References

1. Shoon, C., and J. Van Minnen. The Safety of Roundabouts in the Netherlands. *Traffic Engineering and Control,* March 1994, pp. 142–48.
2. Brenac, T. Roundabouts in France: Developments, Level of Safety. *Actes du Seminaire Agiratoire 92,* Nantes, France, Oct. 14–16, 1992. Research conducted at the National Institute of Research on Transportation and Safety, Provence, France.
3. Brilon, W., and B. Stuwe. Roundabouts in Germany: Recent Results Regarding Capacity and Safety. *Actes du Seminaire Agiratoire 92,* Nantes, France, Oct. 14–16, 1992.
4. Giaever, T. Application, Design, and Safety of Roundabouts in Norway. *Actes du Seminaire Agiratoire 92,* Nantes, France, Oct. 14–16, 1992. Research conducted by the Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology.

continued on page 27

Joint University Program Wins FAA Award

The Federal Aviation Administration selected the Joint University Program (JUP) for Air Transportation to receive the agency's first Excellence in Aviation award. The new award recognizes the program, operated by a consortium of the Massachusetts Institute of Technology, Ohio University, and Princeton University, for 26 years of important aviation research and development efforts that have helped make the aviation industry more efficient and productive. JUP members receive research grants from funds contributed equally by the Federal Aviation Administration and the National Aeronautics and Space Administration (NASA). Each university's proposals are reviewed by the FAA and NASA. Research results are scrutinized by government and industry researchers in quarterly review conferences.

Through the Excellence in Aviation award, the FAA formally recognizes superior aviation-related research efforts and highlights their benefits. The competitive, nonmonetary award is presented annually to individuals or institutions whose past research benefits the aviation community today.

Roundabouts *continued from page 15*

5. Flannery, A., and T. K. Datta. Modern Roundabouts and Traffic Crash Experience in the United States. Presented at 75th Annual Meeting of the Transportation Research Board, Washington, D.C., 1996.
6. Maycock, G., and R. D. Hall. Accidents at Four-Arm Roundabouts. Transport and Research Road Laboratory, TRRL Report No. 1120, United Kingdom, 1984.
7. Bauer, K. M., and D.W. Harwood. Statistical Models of At-Grade Intersection Accidents. Research Report FHWA-RD-96-125, FHWA, U.S. Department of Transportation, 1996.
8. Shoon, C., and J. Van Minnen. The Safety of Roundabouts in the Netherlands. *Traffic Engineering and Control,* March 1994, pp. 142–48.
9. *Florida Roundabout Guide.* Florida Department of Transportation, 1996.

Public Transportation *continued from page 5*

that are affecting the industry's performance. If the industry is to grow and prosper, greater consideration should be given to common sense business paradigms. Accordingly, the leadership should

- Focus on identifying transit's true market niche, not on persuading the general public to shift to transit because it is less costly or will benefit the environment.
- Concentrate on increasing ridership by building customer loyalty through value-added service improvements.
- Avoid searching for problems that might be addressed by advanced technology; instead identify transit performance problems and investigate the potential of technology for their solution.
- Work with government to remove bureaucratic barriers and simplify the game rules to allow more flexible use of total tax dollars to provide effective service.
- Emphasize those efforts that work and abandon those that do not.
- Lead the culture change of transit organizations by redefining the role of management and focusing on helping employees and customers to participate more fully in improving transit performance.

References

1. COMSIS Corporation. *1990 Nationwide Personal Transportation Survey, Urban Travel Patterns.* Federal Highway Administration, U.S. Department of Transportation, June 1994.
2. Weyrich, Paul M., and William S. Land. *Conservatives and Mass Transit: Is It Time for a New Look?* Free Congress Research and Education Foundation, Washington, D.C., 1996.
3. As a matter of comparison, the average 1994 cost per unlinked passenger trip was $1.91 for fixed route buses, $1.75 for heavy rail, $1.46 for light rail, and $6.57 for commuter rail.
4. Meyer, Henry M. "Mass Transit: Can We Afford It?" *American City and County,* February 1982, pp.37–40.
5. Drucker, Peter F. "Post-Capitalist Society," *HarperBusiness,* New York, p.160.