A Strategy to Reduce Older Driver Injuries at Intersections Using More Accommodating Roundabout Design Practices

by

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Abstract

This paper reports on a laboratory study investigating strategies designed to improve the ability of our most vulnerable drivers, the elderly, to safely negotiate the most dangerous and demanding of all traffic situations—intersections—through increased use of modern roundabouts. Compared to conventional intersections, roundabouts have the demonstrated potential to significantly reduce the most injurious (angle) type of crashes and slow the operating speed of all vehicles, while maintaining a high capacity for moving traffic through an intersection. This research sought to identify elements of roundabout design and operations that were problematic for older drivers, and develop recommendations and guidelines for countermeasures with the potential to improve the comfort, confidence, and safety of seniors in using roundabouts. The results show that design elements improving the path guidance of older drivers are critical for designing roundabouts. Recommendations about potential countermeasures related to advance warning signs, guide signs, yield treatment, directional signs, and exit treatments are presented.

Keywords: Older driver, intersection, roundabout, safety, engineering countermeasure.
Introduction

More crashes occur at intersections, resulting in more injuries and fatalities, than in any other driving situation; and this risk is exacerbated for older persons who, with their declining functional abilities and increasing frailty, represent the fastest growing segment of the driving public. It is anticipated that the population of older drivers will increase from 33.5 million in 1995 to more than 50 million in 2020, which will account for about one-fifth of the driving population in the United States (Staplin et al., 2001). Coupled with an overwhelming reliance by seniors on private vehicle travel to meet their personal mobility needs, these trends make it imperative to somehow lessen the risk of older drivers at intersections.

Over recent years, there has been an extensive effort to improve the designs of signalized and unsignalized intersections. An innovative design element that has shown to significantly improve intersection safety is the use of modern roundabouts (Elvik, 2003; Persaud et al., 2001; Flannery et al., 1998). In many countries, a substantial number of conventional intersections have been replaced with roundabouts in order to provide a safer environment for drivers. In the United States, modern roundabouts are still rarely used but have been implemented steadily over the last few years and are expected to become increasingly popular alternatives for context-sensitive design and/or traffic calming applications within the next few decades.

Older drivers are significantly over-represented in intersection-related collisions. Staplin et al. (2001) reported that between 48 and 55 percent of all fatal crashes involving a driver 80 years old or older occur at intersections, more than twice the rate for drivers age 50 or less (23 percent). Frailty is also an important contributing factor; an individual’s physical tolerance to the impact forces caused by a collision is significantly reduced from age 40 on (Viano et al., 1990). Because the number of conflict points within an intersection is greatly reduced, and because all traffic moves in the same direction, it is an underlying premise of this research that, by encouraging older drivers to use roundabouts in preference to conventional intersections, both the frequency and severity of crash involvement by this group can be reduced.

Figure 1 illustrates the main characteristics of a modern roundabout.
The objectives of this research study were two-fold. The first objective was to determine potential design elements, such as roadway geometry, traffic signs, and pavement markings at roundabouts that may be problematic to older drivers. Focus groups with drivers age 65 and older were undertaken for this purpose. Based on the outcomes of this problem identification phase (Phase I), a second objective was to develop recommendations and guidelines for countermeasures with the potential to improve the comfort, confidence, and safety of seniors in using roundabouts (Phase II). This was done using structured interviews, together with a simulated approach to and negotiation of a roundabout in which selected characteristics were enhanced as per the focus group results.

Method: Phase I

For Phase I, a total of four focus group meetings were held in College Station and Marble Falls, Texas. A total of 41 subjects above the age of 65 participated in the focus groups, divided into groups of 10 or 11 subjects each. Each session lasted for two hours, with a break in the middle, and was moderated by one of the team members. Recruitment of group participants was performed through telephone solicitations and printed material posted in venues such as retirement communities, senior and community centers, Veterans of Foreign Wars (VFW) lodges, and churches.

At the beginning of the meeting, the moderator briefly explained the topic of the focus group and the objective of the Phase I study. After introductions, the moderator began the session by explaining the characteristics of roundabouts using a drawing placed on an easel at the front of the room, and by showing an instructional video illustrating the rules of a modern roundabout and how to safely negotiate a roundabout.

Following the presentation of the video, the moderator focused discussion among the participants on each of the following topics: *single-lane roundabouts; multilane roundabouts;*
To facilitate discussion of each topic, participants watched video clips of an approach to and travel through a modern roundabout. The videos were recorded from the driver’s perspective using a van especially equipped for this purpose. In some instances, the video clips were supplemented by still photos that provided clearer images of the design element or feature of interest. For each topic, the group was asked to talk about any issues or concerns that could affect their willingness to use the roundabout, and their feelings of comfort or safety.

Results: Phase I

Overall, the focus group participants most frequently raised concerns about three aspects of using roundabouts. The first concern was related to familiarity with this roadway feature; approximately 75 percent agreed that they would not have any problem using a roundabout if it were located in an area or neighborhood where they drive frequently. This outcome is entirely consistent with the overarching emphasis on driver expectancy in the FHWA Highway Design Handbook for Older Drivers and Pedestrians. Next—and not unrelated to the prior concern—the older discussants voiced a need for advance information about lane selection and exit location to reach a desired destination via a roundabout. Third, a large majority of participants raised concerns about the behavior of other drivers, particularly citing a need for speed control. They noted that, because drivers do not need to stop at a roundabout it is perceived that it increases the risk of a collision if a driver does not yield to other vehicles. The speed of vehicles approaching the roundabout was also an issue; if (other) motorists are driving too fast as they approach a roundabout, the likelihood of rear-end collisions will increase.

More specifically, discussants’ comments identified preferences with regard to a number of roundabout design elements and operational characteristics. In regard to the splitter island and gore area, many participants preferred raised splitter islands rather than islands created with pavement markings because they believed raised islands would prevent drivers from performing a U-turn prior to reaching the roundabout. Warning and approach signs received considerable attention, with most discussants preferring a warning sign with a pictogram rather than a sign with the words “roundabout ahead.” In addition, a large majority of participants indicated that advance warning signs should provide the speed limit for vehicles approaching the roundabout.

For entrance area signs and pavement markings the most frequent comments were related to yield signs. Almost all discussants agreed that a yield sign should be placed on both sides of the entrance; some thought a panel bearing the legend “YIELD TO TRAFFIC IN CIRCLE” should be placed under the yield sign, because of their confusion about the rules governing traffic movements at the entrances to roundabouts. The second most frequent comment specified the need for signs within the central island that convey the direction of traffic movement within the roundabout.

Finally, discussants identified the need for improvements to street name exit signs. Their first concern was that street name signs should be located on the splitter island at a given exit rather than on the roadside of the traveled way prior to reaching the exit. Augmenting street name signs with an arrow pointing toward the exit was also suggested. These comments were stimulated by the perceived safety impacts of missing an exit, as discussants cited a perceived
increase in crash risk for someone who must navigate the roundabout a second time in order to leave at the desired exit.

**Method: Phase II**

For Phase II, a series of structured interviews were conducted in College Station, TX, and Tucson, AZ. A total of 31 interviews were held, one at a time, with older drivers who did not participate in Phase 1. During each interview, subjects evaluated countermeasure alternatives developed by the research team to address issues and concerns raised in Phase I. These evaluations were performed in response to animated video presentations simulating an approach to and traversal of a roundabout. The animations were constructed by editing (via Photoshop™) static images of enhanced features (countermeasure alternatives) into the driver’s view of an existing roundabout. The roundabout used as the context for evaluating the countermeasure alternatives was unfamiliar to all subjects participating in this phase of the research.

The countermeasures evaluated in Phase II focused on five specific roundabout design elements highlighted in the focus group discussions. For each design element, three alternatives were evaluated—a Base Condition, Countermeasure #1, and Countermeasure #2. The base conditions generally represented existing standards of engineering design and practice. The reader is referred to Lord et al. (2005) for a detailed description and a illustration of the different alternatives. A brief description of each alternative is presented in Table 1.
Table 1. Description of countermeasure alternatives for selected roundabout design elements.

<table>
<thead>
<tr>
<th>Design Element</th>
<th>Base Condition</th>
<th>Countermeasure #1</th>
<th>Countermeasure #2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Advance Warning Signs</strong></td>
<td>The advance warning sign template [W2-6] was used according to the guidelines proposed in the MUTCD (FHWA 2003).</td>
<td>Two changes were made compared to the Base Condition: 1) a solid black circle was added in the middle of the sign, and 2) a plaque with the text “ROUNDABOUT” was attached below the advance warning sign.</td>
<td>A plaque with an advisory speed of 30 mph was placed below the warning sign used for Countermeasure #1 (i.e., the sign with the solid black circle).</td>
</tr>
<tr>
<td><strong>B. Roundabout Lane Control Signs</strong></td>
<td>The Base Condition was modeled after the R3-8 series of advance intersection lane control signs (FHWA, 2003).</td>
<td>A solid black circle representing the central island was added to the left lane’s route, but not for the right lane’s route</td>
<td>The text “LEFT LANE” and “RIGHT LANE” under the corresponding routes were added to the sign used for the Base Condition.</td>
</tr>
<tr>
<td><strong>C. Directional Signs (one-way sign)</strong></td>
<td>The Base Condition shows a central island without any guide signs or special pavement marking guiding the traffic circulating inside the roundabout, as per the guidelines proposed by the MUTCD (FHWA, 2003).</td>
<td>A one-way sign (template R6-1) was placed on the central island, positioned to face the centerline of the approaching roadway at a 90º angle. In this position, drivers will see the sign as they approach the roundabout.</td>
<td>The same one-way sign was placed on the central island, but directly in front of the driver’s entry point at the gore area rather than facing the centerline of the approaching roadway. This placement puts the sign more directly in the driver’s line of sight from the yield line.</td>
</tr>
<tr>
<td><strong>D. Yield Treatment</strong></td>
<td>The standard R1-2 yield sign was provided on both sides of the road at the entrance of the roundabout. This condition represents the standard set by Section 2B.10 of the MUTCD (FHWA, 2003).</td>
<td>A yield line consisting of solid white isosceles triangles was added to the Base Condition.</td>
<td>This treatment included all of the components noted for Countermeasure #1, but added a plaque reading “TO TRAFFIC IN CIRCLE” below the yield signs.</td>
</tr>
<tr>
<td><strong>E. Exit Treatment</strong></td>
<td>The Base Condition consisted of placing a street exit sign (based on the D1 series) prior to reaching the exit; the sign was placed between two intersecting streets facing inward toward the traffic in the circle.</td>
<td>The same street exit sign from the Base Condition was used but was moved onto the splitter island of the intended street exit; this sign still faced inward toward the traffic in the circle.</td>
<td>An arrow pointing to the exit leg was added on the street name sign used for Countermeasure #1.</td>
</tr>
</tbody>
</table>
The evaluation process for Phase II was carried out using paired comparisons between, first, the Base Condition and Countermeasure #1, then between the Base Condition and Countermeasure #2, for each design element, as viewed by a subject using the animation approach noted above. After each simulated approach to/traversal of the roundabout, a subject was asked to rate his/her perceived change in terms of safety, comfort, and confidence for each countermeasure alternative in relation to the Base Condition. A 7-point, Likert-type scale was used for these ratings, where the endpoints (‘1’ and ‘7’) represented extreme negative and positive perceptions, respectively, and the midpoint (‘4’) represented ‘no change.’

Results: Phase II

An analysis of variance (ANOVA) was applied to the change scores generated by the pairwise comparisons described above to determine whether there were significant differences between the countermeasures and the base condition. ANOVAs were also applied to the absolute ratings to determine if reliable differences existed between participants’ perceptions of Countermeasure #1 and Countermeasure #2. These results support recommendations for the use of specific treatments to improve the comfort, confidence, and/or perceived safety of older drivers in using modern roundabouts, as reported below.

Advance warning sign. Analyses of the participants’ ratings indicated that they felt more comfortable, confident, and safe with both of the countermeasure alternatives than with the Base Condition. Augmenting the advance warning (W2-6) sign with a symbol representing the center island adds context and clarifies the meaning of the circular arrows on the sign. While the comparison between Countermeasures #1 and #2 was not statistically significant, for any of the rating scales, a further consideration of comments offered by discussants in Phase I suggests that use of the redundant plaque beating the legend “ROUNDABOUT” will best meet the needs of older drivers—at least during the initial maintenance cycle following installation of the facility. This recommended treatment is shown in Figure 2. Where warranted by engineering judgment, an advisory speed panel may also be recommended.
**Figure 2. Recommended roundabout advance warning sign**
(shown without optional speed advisory panel).

*Roundabout lane control sign.* The perceived changes in comfort, confidence, and safety for Countermeasure #1 were, on average, a little higher in comparison to the Base Condition. Adding text under the route symbol provided higher scores than without the text, but this difference was not statistically-significant for the change in confidence or in safety. However, the comfort level improvement with Countermeasure #2 reached significance at $p < 0.05$ ($F = 3.91; df = 1, 30$), supporting recommendation of this treatment (see Figure 3). It may be noted that the lane control sign is also augmented with the central island symbol, for consistency with the enhanced W2-6 design.
Figure 3. Recommended roundabout lane control sign.

Directional signs. The perceived changes for Countermeasures #1 and #2 were rated higher than the Base Condition, indicating that the use of a directional sign was viewed very positively by the study participants. However, there were no statistically-significant differences between the two countermeasures in terms of subjects’ perceived comfort, confidence, or safety. These results justify the use of a sign to indicate the direction of traffic movement within a roundabout, and suggest that its specific location on the central island may be determined through engineering judgment. Based on comments by study participants, the research team concluded that it is most important to maximize the visibility of the one-way sign to a driver who is just about to enter the roundabout, as per the recommended treatment shown in Figure 4.
Yield treatment. The difference between ratings for Countermeasures #1 and Countermeasure #2 were statistically significant for all comparisons, at p < 0.01 for comfort (F = 7.47; df = 1, 30); p < 0.03 for confidence (F = 5.16; df = 1, 30); and p < 0.02 for safety (F = 5.88; df = 1, 30). At the same time, negative responses for Countermeasure #1 versus the Base Condition suggested that study participants were confused by the inverted triangle pavement markings arrayed across the approach lanes. Given an improvement in perceived comfort for Countermeasure #2 versus the Base Condition, which was significant at p < 0.03 (F = 5.09; df = 1, 30), a recommendation of this alternative follows. This treatment, which includes the addition of a supplemental panel bearing the legend “TO TRAFFIC IN CIRCLE” under YIELD signs at both sides of the entrance to a roundabout, is shown in Figure 5.
Exit sign treatment. Countermeasure #1 did not significantly improve the perceived comfort, confidence, or safety of study participants, relative to the Base Condition. However, the addition of the arrow on the sign (Countermeasure #2) produced more positive responses from participants. They also expressed a strong opinion that older drivers would be more comfortable using the roundabout with Countermeasure #2 in place; the differences in ratings for Countermeasure #2 versus Countermeasure #1 were significant at p < 0.001 for comfort (F = 20.62; df = 1, 30), confidence (F = 18.18; df = 1, 30), and safety (F = 11.54; df = 1, 30). It is important to note that placement of a street name exit sign (with arrow) on the splitter island, as recommended here, does not rule out the redundant placement of an exit sign upstream, on the roadside. Figure 6 presents the recommended exit sign treatment.
General Discussion

The problems with older drivers’ use of roundabouts identified in the Phase I, and subsequently targeted by the countermeasures developed and evaluated in Phase II of this research are all, to a large extent, focused upon the need to enhance seniors’ expectancy about the operational requirements at these facilities—which, for many, have rarely or ever been encountered before. Satisfying this need will hypothetically lead to higher perceived levels of comfort and safety that, in turn, are believed to mediate decisions about route choice. If older drivers can be influenced through design enhancements to choose routes containing roundabouts in preference to conventional intersections, existing safety and operational data suggest that a significant reduction in crashes and injuries for these drivers (and for all drivers) will result.

The specific recommendations emerging from this laboratory research are aimed at improving drivers’ understanding of (a) the fact that a roundabout will be encountered a short distance ahead on the driver’s current path, and (optionally) a safe approach speed to the roundabout; (b) the number of lanes in the roundabout and which lane(s) is(are) to be used to exit the roundabout in a desired direction; (c) the direction of travel of vehicles circulating in the roundabout; (d) the need to yield to vehicles already traveling in the roundabout; (e) the street name or route number of the next exit available in the roundabout; and (f) the location and
specific movement required to exit the roundabout on a given street or route. At the construct level, these recommendations are validated through their consistency with recognized guidelines in this area, in particular the *Highway Design Handbook for Older Drivers and Pedestrians* (Staplin et al., 2001). Additional research that examines seniors’ attitudes and behavior in controlled field studies and, ultimately, confirmation of the present results in naturalistic field observations are necessary before adopting these practices in Federal and State-level design manuals. The commentary of older drivers in this study suggests that information and education about roundabouts delivered at a broader, community level, also will be essential to realize their potential safety benefits, especially where roundabouts have not previously been used.

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