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

by

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Abstract

This paper briefly summarizes 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 demonstrated the 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 develop and evaluate countermeasures with the potential to improve the perceived comfort, confidence, and/or safety of seniors in using roundabouts. Research methods included focus groups and structured interviews utilizing photographs which had been edited to include novel traffic control devices. The results suggest that design elements that improve the path guidance for older drivers is necessary to encourage roundabout use by this group. Recommendations for improved practice related to advance warning signs, guide signs, yield treatments, 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 most other driving situations; and this risk is exacerbated for older persons who, with their declining functional abilities but 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 (Flannery et al., 1998; Persaud et al., 2001; Elvik, 2003). 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 crashes. 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 crash is significantly reduced from age 40 on (Viano et al., 1990). Because the number of conflict points within a modern roundabout 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.

(Insert Figure 1 here)

This research study was conducted to develop and evaluate countermeasures with the potential to improve the perceived comfort, confidence, and/or safety of seniors in using roundabouts. This was accomplished using structured interviews, together with a simulated approach to and negotiation of a roundabout in which selected characteristics were enhanced, based on input from earlier focus groups. Four groups including a total of 41 drivers age 65 and older viewed videos (from a driver’s perspective) and still photos of roundabouts, then discussed particular elements of these facilities with which they had issues or concerns that could affect their willingness to use the roundabout, or their feelings of comfort or safety. Five specific types of signs and related traffic control elements on single lane roundabouts emerged from the focus groups as targets for countermeasure development and evaluation, as described in this report.

Method

A series of structured interviews were conducted in College Station, TX, and Tucson, AZ, to evaluate countermeasure alternatives developed by the research team to address issues and concerns raised in older driver focus groups. A total of 31 interviews were held, one at a time, with drivers age 65 and older who did not participate in any other phase of this research. All participants were required to hold a valid driver license and drive at least once a week. The participants, 14 Men and 17 Women, were recruited from the community through word of mouth and solicitation flyers provided to senior centers. Each person received $40 for participating in the 2-hour session. All participants provided informed consent as approved by the Texas A&M University Institutional Review Board.

The countermeasures evaluated in this research focused on five specific roundabout design elements: advance warning signs, lane control signs, directional signs, yield treatments, and exit sign treatments. 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 visualization of the different alternatives. A brief description of each alternative is presented in Table 1.

[Insert Table 1 here]

The countermeasure 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 countermeasures were selected with the aim of improving the path guidance of older drivers negotiating a 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 evaluation process 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. A Latin-square design was used to control for possible effects of presentation order.

Each subject viewed the simulated video presentations for each alternative. Then, the subjects were asked to rate the perceived change in terms of safety, comfort, and confidence between Countermeasure #1 and Base Condition, and between Countermeasure #2 and the Base Condition, respectively. A separate rating was provided for each of the three attributes evaluated. 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.’ Supplemental interviews elicited additional comments about subjects’ likes and dislikes relating to each countermeasure tested.

**Results**

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 perceived comfort, confidence, and/or safety of older drivers in using modern roundabouts, as reported below.

**Advance warning sign.** Analyzes 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 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 review of subjects’ comments suggests that use of the redundant plaque bearing the legend “ROUNDABOUT” will best meet the needs of older drivers—at least during the initial period 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.

**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.
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 (\( F = 7.47; \text{df} = 1, 30 \)); \( p < 0.03 \) for confidence (\( F = 5.16; \text{df} = 1, 30 \)); and \( p < 0.02 \) for safety (\( F = 5.88; \text{df} = 1, 30 \)). 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 \( p < 0.03 \) (\( F = 5.09; \text{df} = 1, 30 \)), 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 (\( F = 20.62; \text{df} = 1, 30 \)), confidence (\( F = 18.18; \text{df} = 1, 30 \)), and safety (\( F = 11.54; \text{df} = 1, 30 \)). 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 countermeasures developed and evaluated in this research are all, to a large extent, focused upon the need to enhance seniors’ expectancy about the operational requirements at a roundabout—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 study 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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**References**


### 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>
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<tbody>
<tr>
<td><strong>A. Advance Warning Signs</strong></td>
<td>The advance warning sign template [W2-6] was used according to the guidelines</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>
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<td>proposed in the MUTCD (FHWA 2003).</td>
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<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>
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<tr>
<td><strong>C. Directional Signs</strong></td>
<td>The Base Condition shows a central island without any guide signs or special</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>
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<td>(one-way sign)</td>
<td>pavement marking guiding the traffic circulating inside the roundabout, as per</td>
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<td>the guidelines proposed by the MUTCD (FHWA, 2003).</td>
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<td><strong>D. Yield Treatment</strong></td>
<td>The standard R1-2 yield sign was provided on both sides of the road at the</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>
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<td>entrance of the roundabout. This condition represents the standard set by</td>
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<td>Section 2B.10 of the MUTCD (FHWA, 2003).</td>
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<td><strong>E. Exit Treatment</strong></td>
<td>The Base Condition consisted of placing a street exit sign (based on the D1</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>
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<td>series) prior to reaching the exit; the sign was placed between two intersecting</td>
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<td>streets facing inward toward the traffic in the circle.</td>
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Figures

Figure 1. Basic roundabout geometric design elements. (Robinson et al. 2000)
Figure 2. Design Element A: Recommended roundabout advance warning sign (shown without optional speed advisory panel).
Figure 3. Design Element B: Recommended roundabout lane control sign.
Figure 4. Design Element C: Recommended directional sign placement on the center island.
Figure 5. Design Element D: Recommended yield treatment (used on both sides of the road at the entrance to a roundabout).
Figure 6. Design Element E: Recommended exit sign treatment (may be supplemented by a redundant upstream sign on the roadside).