Reducing Older Driver Injuries at Intersections Using More Accommodating Roundabout Design Practices

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ABSTRACT

This research investigates a strategy to ameliorate the largest source of unintentional injuries in the United States, motor vehicle crashes, by improving the ability of our most vulnerable drivers, the elderly, to safely negotiate the most dangerous and demanding of all traffic situations—intersections. Studies have shown that 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 but increasing frailty, represent the fastest growing segment of the driving public. Coupled with an overwhelming reliance by seniors on private vehicle travel to meet their personal mobility needs, these trends make it imperative to somehow enhance the proficiency of older drivers at intersections.

The present research suggests a way to meet this goal through improvements in highway design and operations, specifically the use of the modern roundabout. 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. If all drivers, and especially older drivers, would increase their use of these highway facilities, and use them properly, a system-wide savings in traffic injuries and fatalities is a very high probability. Accordingly, this research sought to a) identify elements of roundabout design and operations that were problematic for older drivers, and b) develop recommendations and guidelines for countermeasures with the potential to improve the comfort, confidence, and safety of seniors in using roundabouts.

To accomplish the objectives of this study, a series of focus groups (Phase I), in which drivers above the age of 65 provided feedback, were held to determine potential design elements at roundabouts, such as highway geometrics, traffic signs, and pavement markings that may be problematic to older drivers. Following the identification of these elements, structured interviews (Phase II), using participants in the same age group, were conducted to evaluate potential countermeasures that could be implemented for

improving the comfort, confidence, and safety of older drivers who use these facilities. The results of this study 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 treatment are presented.

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CHAPTER 1
INTRODUCTION

This chapter describes the problem statement, the study objectives, and the structure of the research.

1.1 PROBLEM STATEMENT

Intersections are entities on highway networks where conflicts between vehicles are the most prevalent. According to the National Highway Traffic Safety Administration (NHTSA) (2000), it is estimated that 43 percent of all crashes occur at or near an intersection. Furthermore, injury and fatal crashes account for about 43 percent and 22 percent at these locations, respectively. Crashes occurring at intersections can be very severe, particularly for the ones classified as right-angle and left-turn collisions. As reported by Viano et al. (1990), occupants of vehicles involved in this type of crash are often subjected to serious injuries. Fildes et al. (1998a, 1998b) even reported that about 25 percent of all injury crashes and 40 percent of all fatal and serious injury crashes are the result of a side-impact collision.

Since crashes have important negative societal impacts, the American Association of State Highway and Transportation Officials (AASHTO) (2002) developed a *Strategic Highway Safety Plan* in collaboration with a group of public and private safety organizations to significantly reduce deaths caused by crashes on U.S. highways. The plan identifies, among others, two key areas for reducing traffic-related deaths:

- improving the design and operation of highway intersections and
- sustaining proficiency in older drivers.

The plan proposed by AASHTO presents similar objectives as the agenda prepared by the U.S. Department of Health and Human Services (2000) in the document titled *Healthy*

People 2010. The product of this research meets the objectives proposed by these agencies.

There is a significant opportunity to ameliorate the greatest source of unintentional injuries in the United States, motor vehicle crashes, through improved highway design practices. 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 (note: for the sake of simplicity, the subsequent use of the term "roundabout" in the text refers to "modern roundabout"). Further evidence of the recognition of the relevance of implementing modern roundabouts is the commissioning of a new project under the National Cooperative Highway Research Program: NCHRP Project 3-65: *Applying Roundabouts in the United States*. However, given the fact that negotiating a roundabout can be highly complex, it is important that the design guidelines for roundabouts consider the needs and limitations of older drivers.

Modern roundabouts are circular intersections that are characterized with a yield control for all entering traffic. Figure 1.1 illustrates the major characteristics of a roundabout. The approaches of the roundabout are normally channelized and are designed to allow a maximum speed of 50 mph. Additional information about the various design elements of roundabouts are described in Chapter 2.

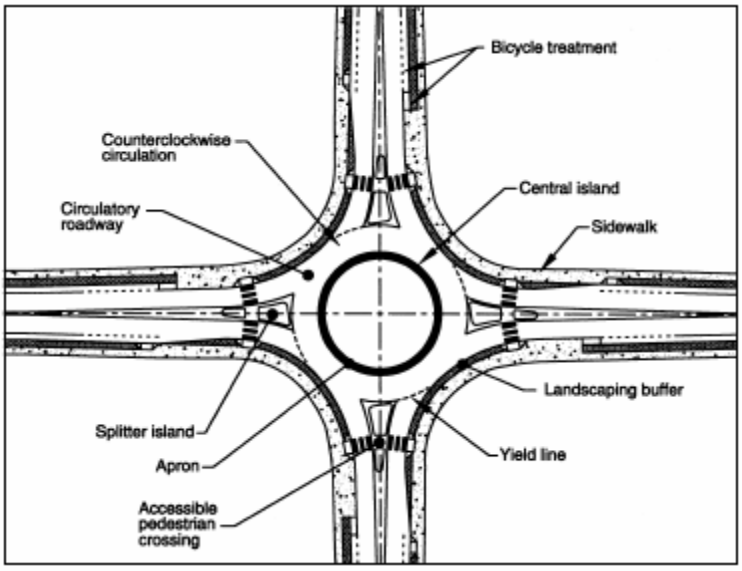


Figure 1.1 Characteristics of a Roundabout (Robinson et al. 2000)

Many studies have shown that regular intersections converted to roundabouts offer a substantial reduction in the number of crashes. Elvik (2003) reported that such conversions reduced the total number of injury crashes by the order of 30 to 50 percent. He also indicated that roundabouts reduced fatal crashes by 50 to 70 percent. Similar values were found by Persaud et al. (2001), who used the empirical Bayes (EB) method for estimating the safety effects of converting regular intersections to roundabouts in the United States. Persaud et al. indicated that the total number of crashes can be reduced by 39 percent when the regression-to-the-mean is accounted for in the analysis. They also reported a reduction of 90 percent for fatal and incapacitating injury crashes.

The safety benefits presented above are attributed to three basic mechanisms (Robinson et al. 2000). First, roundabouts eliminate the right-angle and left-turn collisions typically occurring at unsignalized or stop-controlled and signalized intersections. The most prevalent accident types found at roundabouts are rear-end and sideswipe accidents, both associated with less severe outcomes. Second, the speed differentials between the vehicles traveling through a roundabout are significantly reduced, thereby reducing conflict potentials between vehicles traveling at different speeds. The main purposes of roundabout design are to slow down the operating speed of vehicles negotiating the roundabout and make the vehicle speeds more uniform, thus decreasing the probability of

a collision. Third, accident severity is also significantly reduced because of the slower operating speeds at the facility type. Simple physics dictate that lower speeds are associated with lower probability of injury.

Older drivers are significantly over-represented in intersection-related collisions. Staplin et al. (2001) reported that, given the characteristics of the driving population, between 48 and 55 percent of all fatal crashes involving a driver 80 years old or older occur at intersections. This is more than twice that for drivers age 50 or less (23 percent). Older drivers are frequently involved in left-turn crashes, which as explained above have severe consequences (Brainin 1980, Garber and Srinivasan 1991, Staplin and Lyles 1991, Lord et al. 1998). Viano et al. (1990) specifically examined multi-vehicle side-impact collisions where older people were occupants of the vehicle being broadsided. The physical tolerance to impact forces caused by a collision is significantly reduced from the age of 40 and above. The authors also indicated that occupants with poor health are less likely to recover fully after being involved in right-angle collisions.

The U.S. Census Bureau has estimated that the population of people over age 65 will increase from about 12.4 percent in 2000 to 20 percent by 2030. The Administration on Aging (AOA) (1998) estimates that the total annual mileage driven by older drivers will increase by more than 400 percent between 1990 and 2020. Similarly, 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). The numbers reported by the AOA and Staplin et al. suggest that the proportion of crashes involving older drivers is bound to increase. The AOA even expects that elderly traffic fatalities could triple by 2030. Since health and quality of life for this group depend so strongly upon their independent mobility, and mobility needs are met so often through the use of private automobiles, it becomes essential to focus on efforts that will maximize their safety on the roadways, particularly at intersections.

1.2 STUDY OBJECTIVES AND SCOPE OF WORK

The objectives of this research study are:

- to determine potential design elements, such as roadway geometry, infrastructure, traffic signs, and pavement markings at roundabouts that may be problematic to older drivers, and
- given the outcome of the previous point, to develop recommendations and guidelines for countermeasures with the potential to improve the comfort, confidence, and safety of seniors in using roundabouts.

This work will focus on design guidelines that are especially sensitive to the driving task of elderly drivers. The goal is to increase the confidence of older drivers to use roundabouts, while at the same time improving their understanding of the operational (vehicle control) requirements for safely negotiating these facilities.

Specific consideration of the older driver as a user of the roundabout when designing these facilities is appropriate because of the expected surge in their numbers in the years ahead, their frailty and resulting vulnerability to injury when involved in a crash, and the particular problems with certain types of collisions at intersections evidenced by this group. Given the reasonable expectation that seniors will continue to rely overwhelmingly on the private automobile to meet their transportation needs, any changes to the highway system that significantly improve safety at intersections will be of particular benefit to this group—assuming, of course, that they do not hesitate (and preferably will seek out the opportunity) to use the safest intersection designs, i.e., roundabouts. Hence, the preparation of new roundabout design guidelines for engineers and planners will facilitate a change in current designs and therefore future installations—resulting not only in injury and fatality reductions for older drivers but also for all other road users utilizing roundabouts.

Each subsequent section of the report presents the outcome of the study objectives:

- Chapter 2 reviews the literature on crash statistics involving older drivers, the design of modern roundabouts, and human factors issues for older drivers negotiating a roundabout,
- Chapter 3 summarizes the results of the exploratory analysis conducted on the crash data obtained in this study,
- Chapter 4 presents the results of the Phase I focus group study,
- Chapter 5 describes the characteristics of the Phase II structured interviews conducted in this study,
- Chapter 6 summarizes the results and analyses conducted for the Phase II study, and
- the final chapter synthesizes the methods and results of this study and discusses potential improvements for the design of modern roundabouts in order to foster the use of these facilities by the group most at risk of injury due to intersection crashes.

CHAPTER 2
LITERATURE REVIEW

This chapter summarizes the literature on older driver safety and modern roundabouts. The review covers four areas:

- a general overview of statistics describing how the driving population is aging and the significance of these changes for highway safety,
- intersection crash characteristics,
- a summary of modern roundabout design elements and safety features, and
- human factors issues bearing on the use of modern roundabouts by older drivers and how they governed the work accomplished in this project.

2.1 OVERVIEW

As explained in the previous chapter, it is expected that the proportion of people above the age of 65 will increase significantly in the United States over the next 20 years (AOA 1998). Consequently, it is expected that about one-fifth of the driving population in the United States will be above the age of 65 (Staplin et al. 2001).

Older drivers are at a greater risk to be involved in a collision. When annual mileage is taken into account, the crash rate for drivers age 65+ is about 1.5 times that for drivers in the age group of 35 to 64 (Cerelli 1992). The crash rate for drivers above the age of 85 is almost three times the crash rate of average drivers. Younger drivers are involved in more collisions, but, given the fact they drive more often, their crash rate is lower than that for drivers above the age of 85. Cerelli also found that older drivers are significantly over-involved in left-turn crashes at intersections. As detailed above, this type of crash is associated with the most severe injury outcome.

The frailty of older persons is another important factor. Older drivers are at much greater risk to be severely, if not fatally, injured when involved in a crash. For instance, Cerelli (1992) reported that the likelihood of a driver above the age of 85 to be fatally injured is

10 times that of the drivers in the age group 30 to 60. For the same crash type, Evans (2001) noted that at age 70, a driver is three times more likely to be killed than a 20-year-old driver. Other research also corroborates the greater risk of severe injuries of older drivers when they are involved in a collision (Griffin 2004, Barancik et al. 1986, Zhang et al. 2000, Evans 1988, Li et al. 2003).

The statistics presented above raise two important concerns. First, the number and proportion of older drivers is expected to increase significantly over the next 20 years and subsequently their exposure to motor vehicle crashes. Based on current trends, this increased exposure will result in an increase in crashes among older drivers, with a corresponding increase in severe injuries and fatalities for this group. To address this public health concern, highway design practices, particularly the ones applied to intersections, must become more sensitive to the needs and limitations of older drivers (Staplin et al. 2001).

2.2 INTERSECTION CRASH CHARACTERISTICS

Older drivers have been found to be significantly over-represented in intersection-related collisions. According to Staplin et al. (2001), given the characteristics of the driving population, between 48 and 55 percent of all fatal crashes involving a driver above 80 years old happen at intersections. This percentage is more than twice the percentage found (23 percent) for drivers less than 50 years old. Garber and Srinivasan (1991) concluded that elderly drivers have significantly higher involvement ratios when compared to other age groups. This involvement ratio was higher at rural intersections than at urban intersections.

Crash involvement rates for older drivers at signalized intersections are higher than at unsignalized intersections. Stamatiadis et al. (1991) hypothesized that the problems older drivers experience at signalized intersections relate to the higher traffic volume associated with this type of intersection. Similarly, Staplin (1999) noted that higher traffic volumes increase the demand on older drivers compared to the lower volumes normally associated with unsignalized intersections.

Garber and Srinivasan (1991) have reported that as driver age increases, drivers are more prone to be involved in a left-turn collision. This characteristic is typical for both signalized and unsignalized intersections. The age group 80+ is almost twice as likely to get involve in this type of crash as the 15 to 19 age group. They estimated that 35 percent of the drivers above 80 years old were involved in a left-turn collision. Knoblauch et al. (1995) found that the age group 65+ had significantly higher involvement rates in left-turn collisions at unsignalized intersections (two-stop controlled) than drivers age 50 to 64.

Griffin (2004) reported similar results using Texas crash data, noting that drivers in the age groups 65+, 75+, and 85+ were 1.22, 1.34, and 1.42 times more likely, respectively, to be turning left when involved in a collision than a comparison group aged 55+. In the 55+ age group, the driver was turning left in 61 percent of the cases. The corresponding proportions of left-turning crashes were 78.4 percent, 85.5 percent, and 89.7 percent for the groups 65+, 75+, and 85+, respectively. This trend, illustrated in Figure 2.1, shows that the proportion of crashes where a driver turns left during a crash increases as the age of the driver increases. Drivers age 64+ are also more likely to be involved in multi-vehicle crashes, which often involve left-turn movements (Cook et al. 2000, Hakamies-Blomqvist 1993, Strano 1994, Cooper 1990a).

The type of signal phasing at intersections also influences the risk of collisions involving older drivers. At signalized intersections with no exclusive left-turning phase (green arrow), the crash involvement ratio is even higher for older drivers than at intersections with an exclusive left-turn phase (Stamatiadis et al. 1991). This outcome highlights the difficulty that older drivers may experience making judgments regarding acceptable gaps and maneuvering through traffic streams when no protective phase is provided. This difficulty has also been self-acknowledged by older drivers who were surveyed in a British Columbia study (Cooper 1990b).

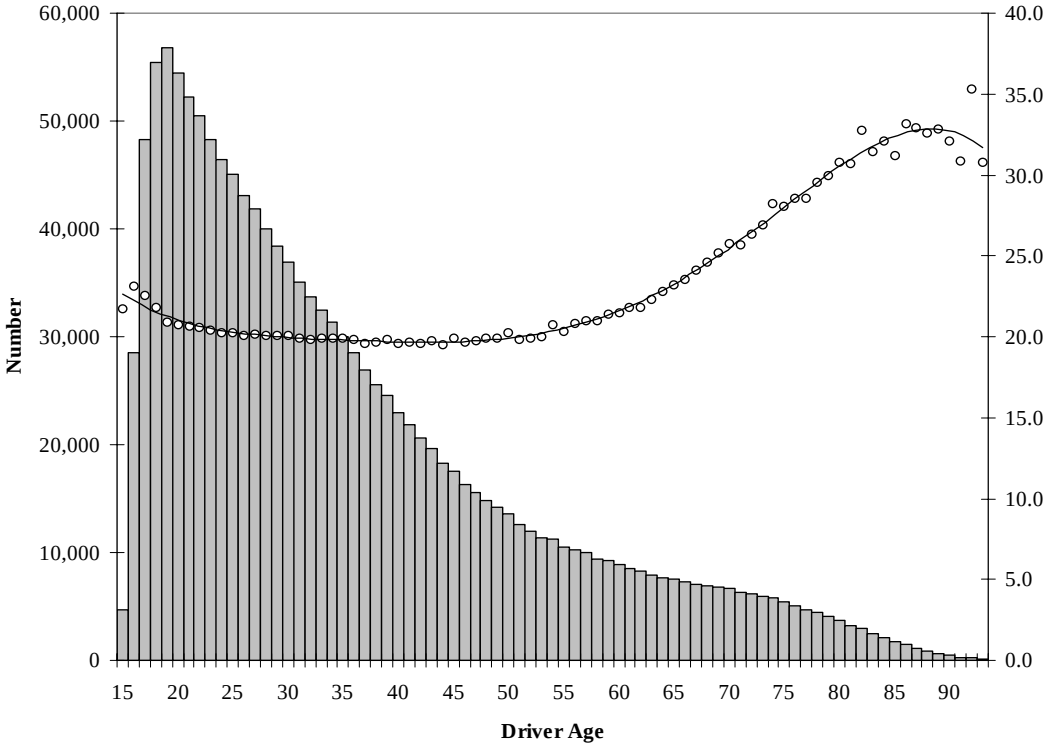


Figure 2.1 Number and Percent of Drivers in Injury Crashes Who Were Involved in Left-Turn Crashes by Age (Griffin 2004)

The likelihood of a driver above the age of 85 to be fatally injured in a crash is 10 times higher than for drivers in the age group 30 to 60 (Cerrelli 1992). As discussed earlier, older drivers are disproportionately involved in crashes involving turning movements when compared with younger drivers. These incidents are characterized as "angle" crashes, which typically include a side impact that can result in fatal chest and abdominal injury due to contact of the driver or passengers with the vehicle interior (Viano et al. 1990). It is estimated that about 25 percent of all older driver injury crashes and 40 percent of all fatal and serious injury crashes are the result of a side-impact collision (Fildes et al. 1998a, Fildes et al. 1998b).

In summary, there is compelling evidence that older drivers have difficulty negotiating regular intersections, with a corresponding increase in their likelihood of being involved in a collision. Most often, these collisions involve turning movements, especially left turns, resulting in a type of crash described by side impacts that are associated with an elevated risk of serious injuries and fatalities. It may therefore be argued that intersection

design enhancements that reduce the possibility of such crashes and their consequences (injuries) hold significant benefit for all drivers, but in particular for the older driver group. Identifying such enhancements, and finding ways of facilitating the use of new and safer intersection designs by older drivers, is at the heart of the present research.

2.3 MODERN ROUNDABOUTS

This section is divided into two parts. The first part describes the key design elements of modern roundabouts. The second part summarizes the safety characteristics of this type of facility.

2.3.1 CHARACTERISTICS OF MODERN ROUNDABOUTS

Modern roundabouts differ from other types of circular intersections, similar to the ones commonly built in the 1960s in the United States, in terms of several important design elements. As described by Robinson et al. (2000), modern roundabouts:

- must have yield control used on all entry points,
- the circulating vehicles must have right of way,
- pedestrian access is only provided at the legs of the roundabout,
- no parking is allowed within the circulatory roadway or the entries, and
- all vehicles are required to circulate counter-clockwise inside the circulatory roadway.

All the elements listed above must be present for an intersection to be classified as a modern roundabout. In addition, roundabouts usually include design features aimed at improving the safety or the capacity of the facility, as described below. Figure 2.2 shows an example of the comparison between a roundabout and a traffic circle as a function of the traffic control criterion for the entrance of the facility.

A) Modern Roundabout B) Traffic Circle

Figure 2.2 Comparison of Roundabouts with Traffic Circles: Traffic Control (Robinson et al. 2000)

Roundabouts can be further classified under six basic categories according to their size, environment, and number of lanes:

- *Mini-Roundabout*: maximum entry design speed of 15 mph, circle diameter of 45 to 80 ft, only one entering lane per approach, and typical daily service volumes of 10,000 vehicles per day.

- *Urban Compact*: maximum entry design speed of 15 mph, circle diameter of 80 to 100 ft, only one entering lane per approach, and typical daily service volumes of 15,000 vehicles per day.

- *Urban Single Lane*: maximum entry design speed of 20 mph, circle diameter of 100 to 130 ft, only one entering lane per approach, and typical daily service volumes of 20,000 vehicles per day.

- *Urban Double Lane*: maximum entry design speed of 25 mph and circle diameter of 150 to 180 ft.

- *Rural Single Lane*: maximum entry design speed of 25 mph, circle diameter of 115 to 130 ft, and typical daily service volumes of 20,000 vehicles per day.

- *Rural Double Lane*: maximum entry design speed of 30 mph and circle diameter of 180 to 200 ft.

This study focuses only on urban single- and double-lane roundabouts since they are the most commonly built facilities in the United States. Although single- and double-lane roundabouts were used in the Phase I focus groups study, a multilane roundabout was utilized in the individual interviews conducted in the Phase II structured interviews study. Double-lane (referred to as "multilane" hereafter) facilities were found to be more complex for older drivers. In addition, there exist more safety and design issues for this type of facility than at single-lane roundabouts, as described below.

During the design process, the design and traffic engineer is required to consider many features that may be influenced by the anticipated use of a highway facility. These include site-specific requirements and the need to accommodate all road users, including pedestrians and cyclists. In addition, the engineer should perform various performance studies, such as capacity and safety analyses.

The basic geometric elements of a roundabout are illustrated in Figure 2.3. Some of the most important design elements include the following (Robinson et al. 2000):

- The *central island* is the area in the center of the roundabout around which traffic circulates. As described above, the size of the radius is determined by the location and the number of lanes inside the circulatory roadway. The size of the island plays a key role in determining the amount of deflection imposed on the through vehicle as well as the speed at which it can travel within the roundabout. Smaller central islands are associated with higher vehicle speed.

- The *splitter island,* which is used to separate entering from exiting traffic, deflects and slows down entering vehicles and acts as a safety area for pedestrians. The size of the island will be governed by the number of lanes inside the circulatory roadway. Splitter islands are usually raised and should be at least 50 ft in length.

- The *approach* includes the widths of entering and exiting lanes, and the vertical grade. To ensure safety, stopping sight distance should be provided on the approach

of each leg connecting the roundabout. The grade for vertical profile should not be greater than 2 percent on either side of the roundabout.

- The *landscaping buffer* is used to separate pedestrian and vehicular traffic as well as to improve the aesthetic of the roundabout. Landscaping should be used to enhance the visibility of the central island in order to clearly indicate to the driver the presence of the island in the middle of the roundabout. However, the stopping sight distance inside the circulatory roadway should still be maintained. In other words, the shrubs or other types of vegetations should not be high enough to prevent drivers from seeing vehicles approaching or already inside the roundabout.

- The *pedestrian crossing* is a passageway located prior to reaching the yield line. The design of pedestrian crossings is often dependent on specific laws of the governing state. In general, pedestrian crossings need to be designed to accommodate pedestrians with visual and physical mobility impediment.

- The *truck apron*, which is part of the central island, accommodates the path of the rear left wheels of larger vehicles. The width of the apron can vary from 3 to 13 ft and should be designed to discourage their use by passenger vehicles. Aprons are usually raised by one or two inches above the circulatory roadway.

Other geometric design elements include the cross slope of the circulatory roadway, the grade at the approaches, sight distance requirements, and entry angle. The reader is referred to Jacquemart (1998) and Robinson et al. (2000) for additional information about the features of modern roundabouts.

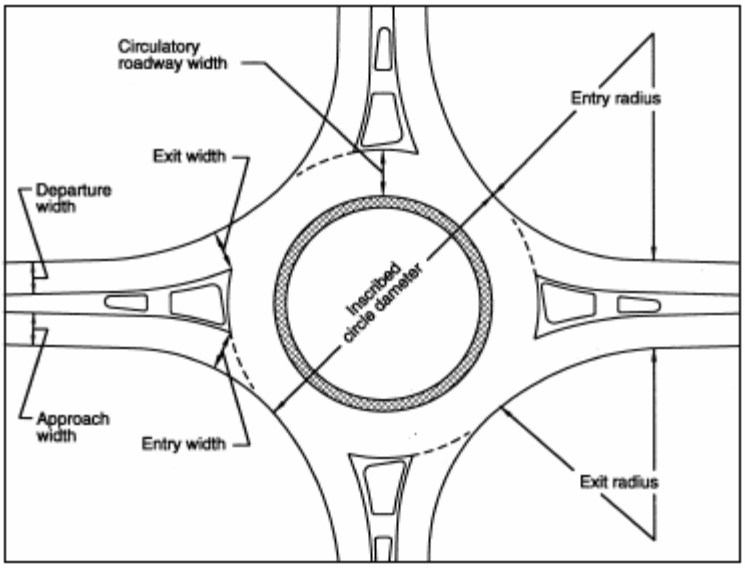


Figure 2.3 Basic Geometric Design Elements of a Roundabout (Robinson et al. 2000)

The concept of roundabout signing is very similar to signing used for regular intersections. Proper advance warning, directional guidance, and regulatory control are critical elements for minimizing the risk of driver expectancy problems. The *Manual on Uniform Traffic Control Devices for Streets and Highways* (*MUTCD*) (FHWA 2003) provides some guidelines for installing traffic signs and pavement markings at roundabouts.

The *MUTCD* (FHWA 2003) requires the use of advance warning signs for all types of intersections. The manual suggests the template W2-6 for providing advance warning for roundabouts. It allows, although does not require, a plaque with the words "Traffic Circle" to be placed under the warning sign. This plaque should follow the W16-12 template. The advance warning sign and the plaque are placed 450 ft on each leg upstream of the roundabout. This distance is needed for a speed limit of 30 mph (see Table 2C-4 in the *MUTCD* for additional information on other distance requirements for different speed limits). The advance warning sign is illustrated in Figure 2.4.

Figure 2.4 Advance Warning Sign (FHWA 2003)

The *MUTCD* (FHWA 2003) does not provide any specific guidelines for the installation of guide and lane control signs on the approaches of multilane roundabouts. If guide signs are used, they are required to be placed about 200 ft from the roundabout.

Regulatory control at the entrance of roundabouts is a critical design element, for both the safe and efficient operation of the roundabout. There are two types of regulatory control, namely regulatory signs and pavement markings. The *MUTCD* (FHWA 2003) requires two yield signs located on each side of the entrance area on each approach, one on the splitter island and one on the right-hand side. Although not mandatory, the *MUTCD* suggests the use of isosceles triangles pointing toward the approaching vehicles for pavement marking. This design is a substitute to the yield bar commonly used for yield-controlled approaches.

It is important to note that the current edition of the *MUTCD* (FHWA 2003) does not provide any guidance on the use of directional and guide signs located either on the approach or inside the roundabout. However, Robinson et al. (2000) recommends the use of chevrons and arrow signs located on the central island in order to provide guidance to motorists who are about to enter the roundabout. They also recommend the use of exit guide signs to designate the destination of each exit from the roundabout. They recommend the signs be placed on the splitter island facing the turning traffic.

2.3.2 ROUNDABOUTS AND SAFETY

This section briefly discusses the safety characteristics of roundabouts and specific design considerations aimed at improving the safety at roundabouts. Due to the limited nature of this study, issues related to pedestrians, bicyclists, and individuals with disabilities are not covered in this section.

As described in Chapter 1, many studies have shown that regular intersections converted to roundabouts offer a substantial reduction in the number of crashes (Elvik 2003, Persaud et al. 2001). The safety benefits are attributed to types of collisions eliminated, the reduction in speed differential between vehicles, and the lower speed at which vehicles collide when a crash occurs (Robinson et al. 2000).

A conflict point is defined as a location where vehicle paths can potentially cross and result in a crash. Conventional wisdom indicates that a reduction in the number of conflict points leads to an improvement in the safety of the intersection. Figure 2.5 illustrates that roundabouts have fewer conflict points than conventional four-legged intersections. This reduction in conflict points partially explains why roundabouts experience lower crash rates than regular intersections.

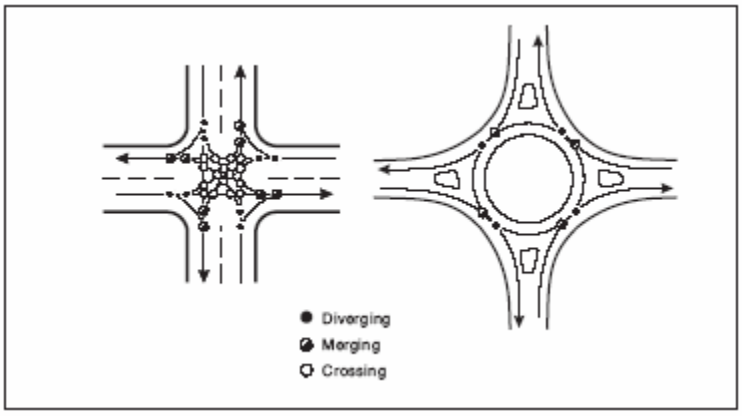


Figure 2.5 Number of Conflict Points for Single-Lane Roundabouts and Four-Way Stop Control Intersections (Robinson et al. 2000)

The number of lanes in a roundabout can also affect its safety. According to Robinson et al. (2000), single-lane roundabouts provide greater safety benefits than multilane roundabouts. They explained that single-lane roundabouts have less conflict points. Similar findings were also noted by Persaud et al. (2001), who reported more safety gains for single-lane than multilane facilities when regular intersections were converted to roundabouts. Single-lane roundabouts also have greater safety benefits for pedestrians because of shorter crossing distances that reduce the exposure time to be involved in a collision.

Multilane roundabouts, on the other hand, generally experience more crashes than single-lane roundabouts. The addition of a second lane in the roundabout increases the likelihood of a sideswipe crash (i.e., increase in the number of conflict points). Furthermore, having two lanes at exit and entrance also increases the chances of a collision between vehicles exiting or entering the roundabout. Robinson et al. (2000) reported that these kinds of conflicts at multilane roundabouts "can be prevalent with drivers who are unfamiliar with roundabout operation" and recommend driver education as a remedial measure. It is important to note, however, that the additional conflict points generally result in low-speed sideswipe crashes, which are still less severe than right-angle or left-turn collisions occurring at regular intersections. Although the multilane roundabout offers less safety benefits than single-lane roundabouts, multilane roundabouts still experience significantly less crashes, both in numbers and severity, than regular signalized and unsignalized intersections (Persaud et al. 2001).

It can therefore be concluded that it would be beneficial for engineers, planners, and designers to pay close attention to the following features when designing roundabouts in order to improve operational efficiency of roundabouts:

- reduce the number of conflict points where appropriate because this may result in a reduction in the likelihood of multiple-vehicle crashes and the associated injury severity;

- reduce the speed of vehicles traveling through the roundabout in order to reduce the severity of crashes; and
- reduce the speed variations when a vehicle negotiates the circulatory traveled way, with the goal of reducing the severity and rate of single-vehicle crashes.

Persaud et al. (2001) reported that intersections that did not exhibit an improvement in safety when converted to a roundabout exhibited some deficiencies in terms of one or more of these features.

2.4 AGING, HUMAN FACTORS, AND ROUNDABOUT DESIGN

Human factors researchers have identified a broad range of driver performance capabilities and limitations that change with normal aging and with the diseases that are commonly experienced in old age (see Staplin et al. 2001, Holland 2001, Caird et al. 2002). The present discussion focuses on the most important human-related factors associated with the use of roundabouts by older drivers.

Age-related changes in functional abilities with the greatest potential impact on the safe and effective use of roundabouts by older drivers include (Dewar 1995, Tarawneh et al. 1993, Staplin et al. 1999):

- narrowing of the visual field,
- poorer contrast sensitivity,
- reduced arm and leg strength,
- limited head/neck flexibility,
- slower decision making or “complex” reaction time,
- problems with selective attention,
- divided attention and attention switching, and
- slower visual information processing speed.

Visual attention processes and related cognitive functions have been shown to be particularly good predictors of intersection crash experience among older drivers (Ball

and Owsley 1991, Owsley et al. 1991). A reduced "useful field of view" and a pre-attentional stage of information processing reduces the ability of the individual to divide attention between central and peripheral tasks, resulting in a failure to detect emerging threats and conflicts with other traffic and pedestrians. This is further aggravated if the central task is complex, as is the case during the approach to and negotiation of a busy (conventional) intersection.

Data describing the impact of age-related functional changes on roundabout use in the United States are scarce due to the recent introduction of these features in significant numbers. It is reasonable to assume that consequences of age-related performance limitations will exist, however, based on the array of difficulties and challenges experienced by seniors when negotiating conventional intersections. According to Staplin et al. (1999), older drivers have reported having difficulty in:

- reading street signs (27 percent),
- driving across an intersection (21 percent),
- finding the beginning of a left-turn lane at an intersection (20 percent),
- making a left turn at an intersection (19 percent),
- following pavement markings (17 percent), and
- responding to traffic signals (12 percent).

A survey of older drivers by Cooper (1990b) confirmed these characteristics. About 24 percent of the respondents in his study also recognized that left-turning maneuvers gave them difficulties.

More recently, Griffin (2004) found an association between driver age and fragility, illness, "perceptual lapses," and left-turn crashes, based on analyses of 25 years of police-reported crash data from the state of Texas (see Table 2.1).

Table 2.1 Relative Likelihoods of Death, Illness, and Perceptual Lapses as a Function of Driver Age, Controlling for Other Crash Factors (Griffin 2004*)*

	Older Driver Age Category		
	65 +	*75+*	*85+*
Death	*1.78*	*2.59*	*3.72*
Illness	*1.83*	*2.38*	*3.06*
Perceptual lapse	*1.56*	*1.89*	*2.17*

Inferences about problems that older drivers will be more likely to experience at roundabouts also can be drawn from focus group data obtained by Staplin et al. (1997) and Benekohal et al. (1992). It is understood that the same age-related performance limitations that underlie these problems could lead to similar difficulties when using roundabouts. Specific problems identified by older drivers in the two studies included:

- performing smooth turning movements around tight radii,
- turning their heads to observe possible conflicting vehicles at an intersection,
- seeing raised curbing and medians at night and during rainy conditions (they report that they often hit these raised roadway features),
- dealing with turning lanes where the driver is caught in a turn only lane—this is particularly at locations where there is poor visibility of pavement markings or road signs,
- seeing potential conflicts with other road users in a timely manner when making a right turn,
- keeping in a lane and avoiding potential sideswipes with vehicles when using a dual left-turn lane, and
- merging with the adjacent traffic stream when a traffic lane is dropped.

There are many driving situations in which an older person with functional decline can adjust his or her behavior and thus limit or control exposure to risk. For an individual with visual field loss and/or an attentional deficit manifested as a reduction in the "useful field of view," more active scanning of the environment may help compensate. However,

if head/neck flexibility is also limited, this would not be possible. Drivers with a loss in peripheral field also may attempt to compensate by increasing their lateral eye movements. Unfortunately, the effectiveness of this strategy reduces with age as the older driver has a reduced capability to maintain such eye movements (Szlyk et al. 1991). In the case of left-turn situations, a strategy reported by focus group participants is to find and use intersections with a "protected" left-turn signal (exclusive turn on green arrow) as much as possible and, in other circumstances, to look for ways to substitute three right turns (with traffic) instead of a left turn (across traffic) (Staplin et al. 1997).

The strategies used by drivers with (age-related) performance limitations illustrates both a self-awareness of increased risk that is tied to specific road and traffic conditions, and a willingness to modify their driving habits to reduce risk. In the specific case of intersections, where the self-perceptions of increased crash risk on the part of older drivers mirrors the data reported in many studies on this subject, the task facing highway designers and engineers is to present this group with an alternative that they will not only be *able* to use but will *want* to use because it is perceived to be safer and easier. The modern roundabout, with its requirements for lower operating speeds for all entering vehicles and the dramatic reduction of conflict points within the intersection, could potentially present such an option.

It is important to note that there may be older drivers that do not realize age-related declines in their abilities and how it can affect their driving. Gaining a better understanding of which design practices can foster acceptance and even generate a preference among older drivers for the use of roundabouts is central to this research. The human factors evidence cited above and found in the literature reviewed for this study suggests that priorities in this regard need to include (although not be limited to) the following:

- providing advance warning to allow for adequate distance and time to anticipate potential conflicts and to provide for the increased decision and response time of older drivers;

- clearly marking exit points and their associated destinations to accommodate (older) drivers who otherwise might slow or stop in traffic due to navigational confusion or disorientation;
- designing the roundabouts so that the design and operation of the roundabout would not require multiple responses in rapid succession, which disproportionately penalizes (older) individuals due to slower complex reaction time and slower processing speed;
- limiting tasks requiring an older driver to divide attention during entry and negotiation of a roundabout;
- providing advance guidance, specifically with reference to lane configuration and lane assignment as this could reduce uncertainty in selecting the appropriate approach lane;
- providing information before and at the entry to the roundabout to minimize confusion about right-of-way rules and operating procedures;
- providing cues to assist drivers with gap selection, before they begin an entry maneuver, because of the diminished ability of older drivers to rotate the head and neck from side to side; and
- providing good visibility of road markings, signing, and any physical features such as medians, islands, and raised channelization to accommodate age-related diminished visual capabilities.

More generally, it can be emphasized that the traffic control devices and physical layout and appearance of roundabouts need to be *uniform* from one installation to another. In addition, education and outreach would be very beneficial when a new roundabout is introduced in a community, helping older and other driver age groups realize the safety benefits of these features.

2.5 SUMMARY

This chapter summarized the literature on older driver safety and modern roundabouts. The first topic of the review presented a general overview of statistics describing how the driving population is aging and the significance of these changes for highway safety. The

statistics presented under this topic raised two important concerns. First, the number and proportion of older drivers is expected to increase significantly over the next 20 years and, with it, their exposure to motor vehicle crashes. Second, this increased exposure will result in an increase in crashes among older drivers, with a corresponding increase in severe injuries and fatalities for this group.

The second topic covered intersection crash characteristics. The literature has shown that older drivers have difficulty negotiating regular intersections, with a corresponding increase in their likelihood of being involved in a collision. Most often, these collisions involve turning movements, especially left turns, resulting in a type of crash described by side impacts that are associated with an elevated risk of serious injuries and fatalities.

The third topic focused on modern roundabout design elements and safety features. The basic functions of several geometric design elements of modern roundabouts as well as the use of proper traffic control devices were described. Research results indicate that regular intersections converted to roundabouts offer a substantial reduction in the number and severity of crashes. In addition, single-lane roundabouts offer greater benefits to safety than multilane facilities. Despite the safety benefits of roundabouts, designers and engineers need to consider various aspects related to the use of roundabouts and the needs created by age-related declines in drivers.

The last topic described human factors issues related to the safe negotiation of modern roundabouts by older drivers. Some important age-related changes in functional abilities with the greatest potential impact on the safe and effective use of roundabouts by older drivers include narrowing of the visual field; poorer contrast sensitivity; reduced arm and leg strength; limited head/neck flexibility; slower decision making or “complex” reaction time, problems with selective attention, divided attention, and attention switching; and slower visual information processing speed. The evidence of age-related changes suggests that the priorities of this research should focus on the advance warning mechanisms and providing appropriate information at entry and exit points for the safe and efficient use of roundabouts by older drivers.

The next chapter summarizes the results of the exploratory analysis conducted on the crash data obtained in this study.

CHAPTER 3
CRASH DATA ANALYSIS

This chapter summarizes the results of the exploratory analysis conducted on the crash data obtained in this study. The primary objective of this analysis was to evaluate the characteristics of crashes involving older drivers at roundabouts and identify any potential safety issues for older drivers using this type of facility.

This chapter is divided into four sections. The first section briefly describes the two datasets collected for this analysis. The second section summarizes the exploratory analysis performed on both datasets. The third section presents a discussion on the outcome of the crash data analysis, and the last section provides a chapter summary.

3.1 CRASH DATA

This section describes the crash data collected in this study. The crash data included drivers above the age of 60 who were involved in a collision at the entrance to or inside a roundabout. Although Phases I and II of this study focused on the age group 65+, the research team included crashes involving the age group 60 to 64 to increase the sample size for the exploratory analysis. The first dataset contains crash data obtained from the Insurance Institute for Highway Safety (IIHS) study on the safety effects of converting regular intersections to roundabouts (Persaud et al. 1999). The second dataset contains crash data obtained from National Cooperative Highway Research Program (NCHRP) 3-65. This project seeks to develop methods for predicting the safety and operational impacts of roundabouts in the United States. Information on exposure (or entering flows) could not be obtained for this study. Consequently, the actual risk of collision for the age group above 60 could not be estimated.

3.1.1 IIHS DATASET

The first dataset contains crash data from six states: California, Colorado, Florida, Maine, Maryland, and Vermont. This dataset was used for the study performed by Persaud et al.

(1999 & 2001) on behalf of IIHS on the safety evaluation of converting regular intersections to roundabouts. Crash data were collected at 18 roundabouts that were converted during the period 1992 to 1997 inside the six states listed above. Persaud et al. only included roundabouts that were designed using appropriate design standards (see Robinson et al. 2000). Table 3.1 summarizes the characteristics of the data collected in their study. The data includes information on the year of installation, crash counts for the before and after periods, and the number of months for both periods.

Table 3.1 Characteristics of Crash Data of Roundabout Conversions (Persaud et al. 1999)

State	Jurisdiction	Year Opened	Control Type Before‡	Months Before/ After		Crash Count Before			Crash Count After		
						All	Injury		All	Injury	
							A†	B†		A†	B†
California	Santa Barbara	1992	3	55	79	11	3	0	17	6	2
Colorado	Avon	1997	2	22	19	12	0	0	3	0	0
Colorado	Avon	1997	2	22	19	11	0	0	17	1	1
Colorado	Avon	1997	6	22	19	44	7	4	44	1	1
Colorado	Avon	1997	1	22	19	25	4	2	13	0	0
Colorado	Avon	1997	6	22	19	48	10	4	18	0	0
Florida	West Boca Raton	1994	1	31	49	4	1	1	7	0	0
Florida	Ft. Walton Beach	1994	2	21	24	14	4	2	4	0	0
Florida	Bradenton	1994	1	36	63	5	2	0	1	0	0
Florida	Gainesville	1992	6	48	60	4	1	1	11	3	3
Maryland	Lisbon	1993	1	56	68	40	15	10	14	3	1
Maryland	Lothian	1995	1	56	38	34	24	9	14	3	2
Maryland	Cearfoss	1996	1	56	35	18	9	6	2	1	0
Maryland	Leeds	1995	1	56	40	20	15	12	10	1	1
Maryland	Taneytown	1996	1	56	28	30	15	8	4	1	1
Maine	Gorham	1997	1	40	15	20	6	2	4	0	0
Vermont	Manchester	1997	1	66	31	2	2	0	1	1	1
Vermont	Montpelier	1995	2	29	40	3	3	1	1	1	1
Total						345	121	62	185	22	14

† Category A includes possible injury; Category B excludes possible injury
‡ 1 = four-legged one street stopped; 2 = three-legged one street stopped; 3 = four-legged all-way stop; 6 = signal

In this dataset, crashes occurring in the after period were used for the analysis. The dataset included information about the crash type, crash severity, number of vehicles, and the age of each driver involved in the collision. Unfortunately, the research team was unable to obtain a hard copy of the original crash report. Thus, the team was unable to manually verify the fields shown in the electronic database.

Table 3.2 summarizes the number of crashes involving drivers above the age of 60 by state. Of the 185 crashes that occurred at a roundabout, only 21 involved a driver above the age of 60.

Table 3.2 Number of Crashes Involving a Driver above 60 Years Old

State	Number of Crashes
Colorado	8
Florida	7
Maine	1
Maryland	5
Total	21

3.1.2 NCHRP 3-65 DATASET

The second dataset contains crash data obtained from five states: Colorado, Kansas, Michigan, Vermont, and Washington. The data were collected for the years 1996 to 2003 inclusively. The original crash reports were provided by the research agency leading this study. Only the first page of the reports was provided. Consequently, information on the gender and severity of the crash was not always available. The data were coded electronically using the same fields as the ones used for the IIHS study in order to simplify the merging process of both datasets.

Table 3.3 summarizes the number of crashes by state for drivers above 60 years of age. The data analyzed included 52 crashes.

Table 3.3 Number of Crashes Involving a Driver above 60 Years Old

State	Number of Crashes
Colorado	23
Kansas	4
Michigan	4
Vermont	1
Washington	20
Total	52

3.2 EXPLORATORY ANALYSIS OF CRASH DATA

This section summarizes the exploratory analysis conducted on the crash data. The results of this analysis are presented separately for each dataset. Given the small sample size, it is important to point out that the results may not be statistically significant. In addition, the results cannot be generalized to other roundabouts found in the United States. Nonetheless, the outcome of this analysis provides interesting results that may be useful for future research studies that will hopefully include higher sample sizes.

Table 3.4 shows the number of crashes by age group. This table illustrates that about 70 percent of drivers involved in a collision were below 70 years of age. Despite this high percentage, this outcome does not necessarily imply that this category of drivers is at higher risk because exposure is not included in Table 3.4. In other words, the age distribution of drivers who use these facilities is not known.

Table 3.4 Number of Crashes by Age Group

Age Group	IIHS	NCHRP 3-65	Total
60-64	10	17	27
65-69	4	19	23
70-74	3	9	12
75-79	4	5	9
>=80	0	2	2
Total	21	52	73

Table 3.5 summarizes the number of crashes by type. This table shows that 36 percent and 29 percent of older drivers were involved in rear-end and angle collisions at these 18 roundabouts, respectively. Angle collisions involve a driver who failed to yield at the entrance of the roundabout or the gore area. Sideswipe collisions involve vehicles already traveling inside the roundabout. This type of collision occurs when a vehicle changes lanes inside the roundabout.

Table 3.5 Number of Crashes by Type

Crash Type	IIHS	NCHRP 3-65	Total
Angle	8	11	19
Rear-End	6	18	24
Sideswipe	0	16	16
Other	7	7	14
Total	21	52	73

Table 3.6 summarizes the number of vehicles involved per crash at the 18 roundabouts identified in this research. This table shows that most collisions involve two vehicles. In fact, less than 10 percent involve a single-vehicle collision.

Table 3.6 Number of Vehicles in the Crash

Crash Type	IIHS	NCHRP 3-65	Total
1 Vehicle	3	5	8
2 Vehicles	18	45	63
3 Vehicles	0	2	2
Total	21	52	73

Figure 3.1 shows the number of crashes by time of day. About 60 percent of the crashes occurred in the afternoon.

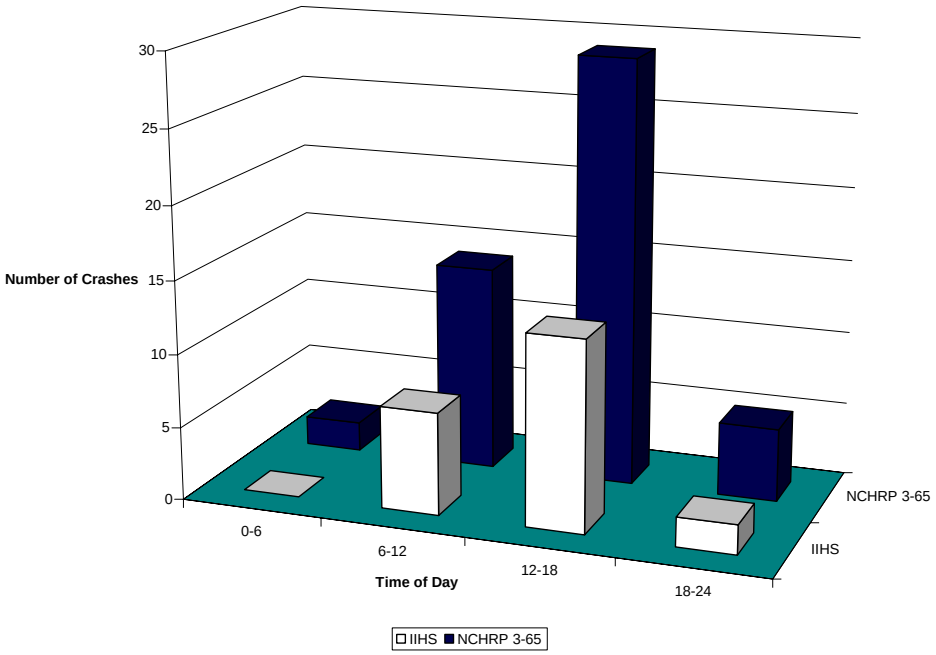


Figure 3.1 Number of Crashes by Time of Day

3.3 DISCUSSION

The analysis of the crash data carried out in this study indicates that older drivers are frequently involved in rear-end and angle collisions. They are proportionally more

involved in these two types of crashes than the average driver is involved in roundabout-related crashes.

Flannery and Elefteriadou (1999) and Flannery (2001) determined that angle and rear-end collisions accounted for about 27 percent and 24 percent, respectively, of all crashes (all age groups included) occurring inside a roundabout (see Table 3.7). In their study, the remainder of the crashes involved a driver who lost control of the vehicle. In about 60 percent of these crashes, it was determined that the driver entered the roundabout at excessive speeds. It is important to note that the sample size used in Flannery and Elefteriadou's study is relatively low. Thus, the comparison between their dataset and the ones used herein may not be conclusive.

Table 3.7 Number of Crashes by Type (All Age Groups) (Flannery and Elefteriadou 1999)

Crash Type	Number of crashes (%)
Angle	9 (27.3)
Rear End	8 (24.2)
Loss of Control	15 (45.5)
Other	1 (1.0)
Total	33 (100.0)

Despite the limitations noted above, it appears that older driver drivers are over-represented in rear-end and angle collisions. This may indicate that some older drivers are confused about the principles of safe negotiation of a roundabout. It may also be possible, based on the known age-related declines, that a number of older drivers have difficulty judging gaps for vehicles already inside the roundabout.

The NCHRP 3-65 dataset seems to suggest that older drivers were frequently involved in sideswipe collisions. This type of collision may be indicative of the difficulty older drivers have when exiting the roundabout or with changing lanes inside the roundabout. In fact, this type of collision is not uncommon for older drivers (Staplin et al. 1997,

Benekohal et al. 1992). Finally, the involvement of older drivers in multiple-vehicle collisions may be a result of potential safety issues related to the decision-making and path guidance processes at roundabouts for this category of drivers.

3.4 SUMMARY

This chapter described the characteristics of roundabout-related crashes involving drivers above the age of 60. Two datasets containing 73 crashes in total were obtained for this analysis. The results of the exploratory analysis seem to suggest that:

- older drivers are frequently involved in multiple-vehicle collisions (90 percent) and
- they are over-represented in rear-end and angle collisions compared to younger drivers.

These characteristics may be a result of difficulties that older drivers experience with the decision-making and path guidance processes when negotiating a roundabout. These difficulties are particularly important when they enter a roundabout, as detailed in the exploratory analysis. In an attempt to determine whether or not older drivers have difficulty with the processes described above, a focus group study was conducted using a sample of 41 older drivers. The results of the Phase I focus groups study are presented in Chapter 4.

CHAPTER 4
PHASE I FOCUS GROUPS

This chapter summarizes the results for the first series of focus groups performed in this study. The primary objective of the Phase I study was to determine potential design elements, such as roadway geometry, infrastructure, traffic signs, and pavement markings at roundabouts that may be problematic to older drivers. These focus groups allowed for a detailed discussion for several design elements of modern roundabouts.

This chapter is divided into five sections. The first section briefly describes the important basic principles for conducting focus groups. The second section explains the objective of the Phase I study. The third section explains how the focus groups were conducted. The fourth section describes the demographic information of the participants. The last section summarizes the results of the discussions reported by the participants.

4.1 METHODOLOGY

A focus group (formally known as *group depth interview*) is an interactive discussion between a relatively small number of participants that allows for the development of qualitative data. It provides a rich body of data expressed in the participants' own words and context, as opposed to regular interview techniques (Stewart and Shamdasani 1990). The contemporary focus groups usually involve somewhere between 8 to 12 individuals who discuss a particular topic under the guidance of a moderator. This moderator is in fact the key to assuring that the group discussion runs effortlessly. He or she may be more or less directive with respect to the discussion, given the information sought from the participants and the objective of the study.

Focus groups have been used frequently in social sciences (Morgan 1988, Stewart and Shamdasani 1990, Templeton 1994). They are very useful during the beginning stages of a research project and are often followed by other types of studies, such as surveys, that provide more quantifying data with a larger part of the population. They are particularly

useful when very little is known about the phenomenon of interest. Some common uses of focus groups include:

- obtaining background information on a topic of interest,
- generating hypotheses to generate further research,
- stimulating new ideas,
- learning how respondents talk about the phenomenon of interest, and
- interpreting previously obtained quantitative results.

The concepts and principles originally developed for studies in social sciences are now being used in other fields, such as in traffic engineering (Picha et al. 1995, Henk and Khun 2000, Redmon 2003).

The key to using focus groups successfully is to assure that their use is consistent with the objectives and purpose of the study. It is therefore important to understand the strengths and limitations for using focus groups. Table 4.1 summarizes some key advantages and disadvantages about conducting focus group studies.

Considering the strengths and limitations of focus groups as discussed above and summarized in Table 4.1, the research team believes this methodology was appropriate to meet the objectives of Phase I. The focus group provided a positive and supportive environment for obtaining important feedback on design elements that were problematic for older drivers. The discussions allowed the participants to generate interesting new ideas and comments that may not have been possible if the participants were interviewed separately.

Table 4.1 Advantages and Disadvantages of Focus Groups (Morgan 1988, Stewart and Shamdasani 1990)

Strengths
• Focus groups provide data from a group of people quickly and at less cost than interviewing every subject individually. • Focus groups allow the researcher to interact directly with the participants. • The open response format provides an opportunity to obtain large and rich amounts of data in the respondents' own words. • Focus groups allow respondents to react and build from the responses of other group members. • The results of focus groups are easy to understand.
Limitations
• The small number of respondents that participate and the nature of the recruiting practices may limit generalization to a larger population. • The responses from the subjects are not independent from each other. • Some participants may be more dominant than other participants. • The open-ended nature of the responses often makes the summarization and interpretation of results difficult. • The moderator may be biased and knowingly or unknowingly provide cues for specific desirable answers.

4.2 PHASE I STUDY OBJECTIVE

The objective of the Phase I focus groups study was to discuss design elements of roundabouts that could be problematic to older drivers. It is a known fact that drivers in this age group have different needs than younger drivers (Staplin et al. 2001, Holland 2001). Thus, the research team was interested in knowing which elements may be problematic to older drivers in order to prepare the evaluation of countermeasures in Phase II of the study.

4.3 FOCUS GROUP ADMINISTRATION

A total of four focus group meetings were held in College Station and Marble Falls, Texas, in January and February 2004. The meetings were divided into groups of 10 or 11 subjects each. A total of 41 subjects above the age of 65 participated in the focus groups; one more person than initially planned joined the last group. Each session lasted for two hours, with a break in the middle, and was moderated by Dr. Susan Chrysler, who is a member of the research team. For each meeting, another team member helped coordinate the presentation of the audio-visual material that consisted of video clip segments and pictures of different design elements of roundabouts. Each subject received $40 at the end of the meeting for participation in the study. The next three sections summarize the approach used for conducting the focus groups.

4.3.1 RECRUITMENT

The recruitment of the subjects was performed through various means, including phone calls and printed material posted in venues such as retirement communities, senior and community centers, Veterans of Foreign Wars (VFW) lodges, and churches. To be included in the study, the participants needed to be above 65 years of age and drive at least three times a week. No prior knowledge of roundabouts was required to participate in the study.

The research team initially contacted potential candidates who had agreed to participate in focus groups held by the Texas Transportation Institute (TTI) in College Station and Houston, Texas. The team was successful in recruiting 10 participants for the meeting in College Station. Unfortunately, the team was not as successful in recruiting enough subjects in Houston. After a three-week attempt, it was decided to refocus the recruitment effort to Marble Falls, Texas. This city has many retirement communities and provided a broad group of participants living in different parts of the United States. Three focus groups were held in Marble Falls. Although a special effort was made to recruit minority participants, no minority subjects agreed to participate in Phase I of the study.

Unfortunately, some minority participants contacted the research team after the Phase I recruitment process was completed.

4.3.2 THE FOCUS GROUP INTERVIEW PROCESS

The focus group meetings were held in a small room suitable for the size of the focus group. When the participants entered the room, each person was given a packet of material that would be necessary for participation in the focus group study. The packet included a brief overview of the project and its objective, a consent form, a sample sheet with an illustration of a roundabout, scratch papers, and a name card; the survey instrument used in Phase I can be seen in Appendix A. At the beginning of the meeting, the moderator briefly explained the topic of the focus group and the objective of the Phase I study. The expectations of the participants during the focus group and the compensatory agreement were also discussed at this time. The moderator made clear to the group that everyone must participate and provided general guidelines to encourage participation. The participants were notified that the session would be audio recorded for a better analysis of the data. The moderator identified the CDC as the funding agency.

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 rudimentary rules to navigate through roundabouts. This video was produced by the Washington Department of Transportation (WSDOT) and graciously provided for use in this study. This video explains the rules of a modern roundabout and shows important concepts about how to safely negotiate a roundabout. The participants were asked to put any comments or questions on paper for discussion at the end of the video. At the end of the segment, the moderator asked the participants to provide their initial thoughts on roundabouts, their usefulness, and any concerns the participants might have toward these facilities. The moderator also asked for an assessment of how well a job the instructional video did in providing adequate information to describe how to navigate inside these facilities.

The rest of the meeting focused on different design elements of roundabouts. The following design elements were selected for the Phase I study:

- single-lane roundabouts,
- multilane roundabouts,
- central islands,
- splitter islands/approach gore,
- warning and approach guide signs,
- entrance area signs and pavement markings, and
- street name signs at exit.

A series of video clips taken from the driver's perspective were shown for each design element (see Appendix A for excerpts). These video clips were provided by WSDOT and were recorded by a specially equipped van. In some instances, the video clips were supplemented by a series of pictures and photographs that provided clearer images of the design elements. After each segment, the group was asked to comment on any issues or concerns one may have toward the selected design element. The moderator tried to minimize her involvement in guiding the responses of participants. Only when the participants did not provide any feedback did she ask specific questions about the selected design element.

At the end of the session, the participants were given a demographic information sheet. At that point, they were asked if their views had changed about the usefulness of roundabouts or if they had any other thoughts about this type of facility. Before leaving the premises, the participants were asked to sign a form to acknowledge the receipt of their compensation for their participation.

4.3.3 CHARACTERISTICS OF PARTICIPANTS

A total of 41 volunteer drivers participated in the four focus group studies. The participants represented diverse backgrounds in terms of education level, driving experience, and areas of residence. This is summarized in Tables 4.2 to 4.5. Almost all

the subjects owned a vehicle, and all participants had more than more 25 years of driving experience.

Table 4.2 Distribution of Age Group by Gender

Age Group	Male	Female	Total
65–69 Years Old	5	6	11
70–74 Years Old	7	7	14
75–80 Years Old	8	4	12
>= 80 Years Old	2	2	4
Total	22	19	41

Table 4.3 Level of Education by Gender

Level of Education	Male	Female	Total
Some High School	1	0	1
High School Graduate	5	9	14
Some College	6	6	12
College Graduate	6	2	8
Some Graduate School	2	1	3
Graduate Degree	2	1	3
Total	22	19	41

Table 4.4 Type of Area of Residence by Gender

Area of Residence	Male	Female	Total
Rural	6	8	12
Small City	15	9	24
Suburbs	1	2	3
Total	22	19	41

Table 4.5 Frequency of Driving by Gender

Frequency of Driving	Male	Female	Total
Few Times a Week	2	8	10
Once a Day	4	4	8
Several Times a Day	16	7	23
Total	22	19	41

Table 4.6 summarizes the subject's prior knowledge about roundabouts. As shown in this table, most subjects have negotiated a roundabout before. However, many indicated that the facilities they used were not considered modern roundabouts but rather other forms of traffic circles (as discussed in Chapter II, modern roundabouts are designed differently than traditional roundabouts).

Table 4.6 Knowledge of Roundabouts by Study Participants

Used a Roundabout Before	Male	Female	Total
Yes	18	13	31
No	4	6	10
Total	22	19	41

4.4 SUMMARY OF FOCUS GROUP RESULTS

A qualitative assessment of the data from the four focus groups was conducted to identify specific design elements of roundabouts that may be problematic to older drivers. An important factor in assessing the focus group data is the "subjective" nature of the responses. As stated above, the comments reported by the participants may be difficult to summarize. Thus, two steps were taken to ensure that the data collected from the focus groups were used to their maximum efficiency:

1. A transcript of the audio recordings was prepared using the tape recordings from the sessions. A different summary was prepared for each meeting. Notes taken by the team members present at the meetings were reconciled with the comments recorded on the tape if the voices were inaudible on the tape.

2. Separate summaries were prepared for each group and for each design element. The results were then condensed by design element.

The next few sections present the results for the focus group meetings by design element. The results also include a description of the material presented to the participants.

4.4.1 SINGLE-LANE ROUNDABOUTS

For single-lane roundabouts, four series of video clips were shown to the participants. Two roundabouts were presented, and for each one, the first run depicted a through movement while the second run showed a left-turning movement, as shown in Figures 4.1 and 4.2, respectively.

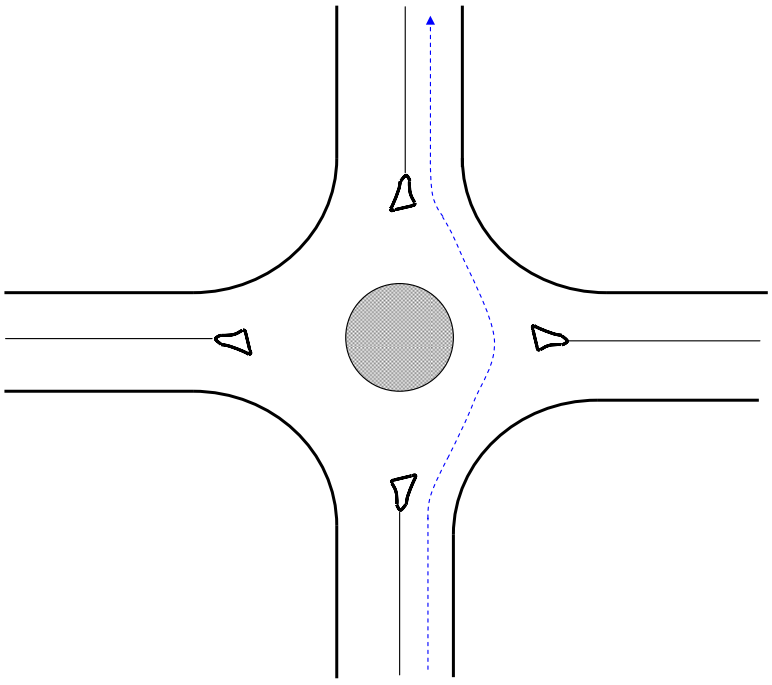


Figure 4.1 Vehicle Maneuver Depicting a Through Movement

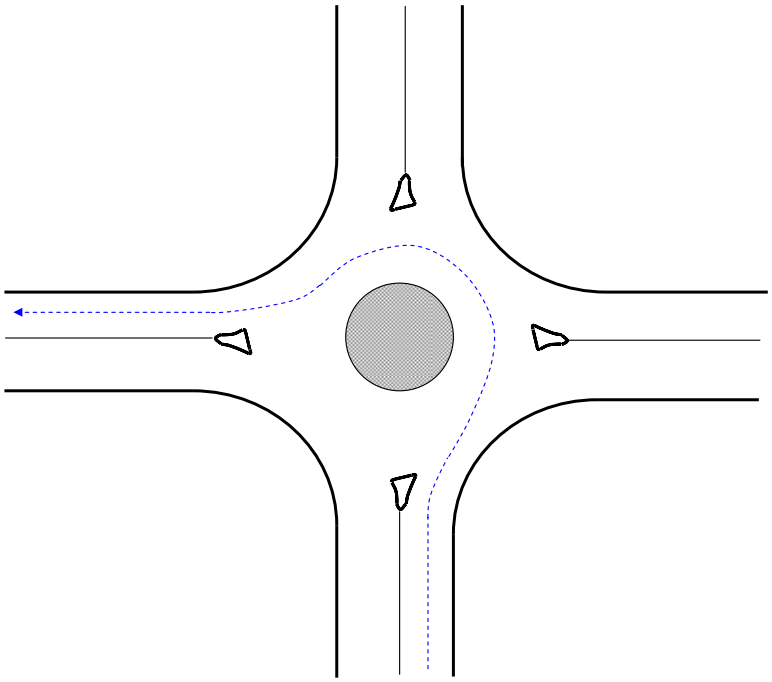


Figure 4.2 Vehicle Maneuver Depicting a Left-Turning Movement

The participants reported interesting comments about single-lane roundabouts. For instance, the most frequent comment was related to the width of the traveled way inside the roundabout. Many participants were concerned about the lack of room to maneuver inside the roundabout in the event of a driver error. As reported by one participant: "single-lane roundabouts do not provide room for an emergency maneuver." The next comment dealt with the safety impacts of missing an exit. In this case, the participants were concerned about the perceived increase in crash risk for someone who navigates inside the roundabout a second time in order to leave at the initial intended exit.

The last important comment was related to the yield signs placed at the gore area. Some participants reported having difficulty understanding the rules governing yield signs. They were confused about whether they were required to stop when entering the roundabout when no vehicle was present inside the roundabout. Finally, a few participants indicated that they favored single-lane roundabouts over regular three- or four-legged intersections, as long as they were provided with enough information to maneuver safely inside the roundabout.

4.4.2 MULTILANE ROUNDABOUTS

Similar to single-lane roundabouts, four series of video clips were presented to the subjects. The clips depicted the same runs as the previous ones described above.

Some participants preferred multilane roundabouts to single-lane roundabouts. They reported that a wider traveled way provided additional space needed for emergency maneuvers. However, this view was not shared by all the participants. Other participants drew attention to the complexity of multilane facilities. They noted that multilane roundabouts were quite complex, especially when the facilities were subjected to high traffic activity. They perceived multilane facilities as having a higher crash risk than single-lane facilities. In addition, they were concerned about the consequences of making an error since the likelihood of hitting another vehicle was higher (i.e., hitting another vehicle could result in a greater risk of injury).

Another comment reported by the groups was related to the type of information provided by traffic signs. Some participants noted the importance of placing guide signs on the approach prior to reaching the roundabout. In order to prevent risky lane changes once inside the roundabout, the participants noted the importance of being given adequate information to select the appropriate lane when entering a multilane roundabout.

4.4.3 CENTRAL ISLANDS

For this design element, two video clips were shown to the participants. The first video clip showed a central island built out of concrete (i.e., a 6-in. raised curb), while the second video clip showed an island with tall shrubs in the middle. Following the presentation of the video clips, the participants were shown six pictures depicting various types of landscaping (see Appendix A).

The most frequent comment was related to the type of landscaping used within the central island. The majority of participants agreed that central islands should contain, as a minimum, some type of landscaping, but a few preferred a bare-boned central island. Where their opinions diverged was about the height of the shrubs within the central

island. About half the people preferred tall over shorter shrubs. People who preferred tall shrubs commented that it shielded other vehicles, thus allowing them to be less distracted by the movement of other vehicles near or within the roundabout. On the other hand, the participants who preferred lower shrubs stated that properly seeing other vehicles was very important to minimize collision risk.

The next comments dealt with nighttime driving conditions. All participants agreed on the following two observations. First, shielding the headlights of opposing vehicles with the landscaping inside the central island was crucial if they were to travel through a roundabout at night. This observation is not surprising given the fact that many older drivers have problems with high intensity glares at night (Holland 2001). Second, many participants drew attention to the use of street lighting at roundabouts. Again, all agreed street lighting is needed to allow for proper visibility of the physical characteristics, traffic signs, and pavement markings at and on the approaches to the roundabout.

4.4.4 SPLITTER ISLANDS AND GORE AREA

Three video clips were presented for this design element. The video clips showed a small-, average-, and large-sized raised splitter island. Eight pictures were also presented to the groups. The pictures showed a wide variety of splitter island designs, such as widths, lengths, types of landscaping, and pavement markings.

The most recurrent comment provided by the participants concerned the physical characteristic of the splitter island. Many participants preferred raised splitter islands rather than islands created with pavement markings. They believed that raised islands would prevent drivers from performing a U-turn prior to reaching the roundabout. There was no particular preference between long versus short raised splitter islands.

Next, participants noted their dislike of splitter islands with tall shrubs. In this case, they were concerned about not properly seeing pedestrians already engaged in the crosswalk. A few participants favored the use of yellow pavement markings on the curb because it would apparently assist with nighttime driving.

4.4.5 WARNING AND APPROACH GUIDE SIGNS

Two video clips depicting the road environment prior to reaching the roundabout were presented to the participants. Following the presentation of the video clips, 16 pictures were shown to the four focus groups. The pictures were grouped under two categories: 1) warning signs and 2) approach guide signs (see Appendix A). The warning signs are used to warn drivers about an upcoming roundabout. The approach guide signs are used to provide information on the characteristics of the roundabout, such as the name of the intersecting streets, lane assignment, and exit information.

The most frequent comment was related to the use of advance warning signs at roundabouts. In fact, the participants were all in unison about being properly warned of an upcoming roundabout. For this category of signs, most preferred a warning sign with a pictogram depicting a roundabout rather than a warning sign with the words “roundabout ahead.” It should be pointed out that some participants were more familiar with the term “rotary” than with the word “roundabout.” Another frequent comment reported by the groups dealt with speed limits. A large number of participants indicated that advance warning signs should provide the speed limit for vehicles approaching the roundabout. Providing this information would be useful, not for themselves, but for other drivers. As discussed below, older drivers are very concerned about the behavior of other drivers, particularly when speeding is involved.

The third most common comment was related to the lack of advance warning signs that show the number of lanes inside the roundabout. Most participants agreed with this observation. They noted that providing the number of lanes would help them choosing the appropriate lane prior to reaching the roundabout.

Next, the participants raised important issues about guide signs currently used at roundabouts. For instance, many commented about the amount of information provided on a single sign. In other instances, it was the number of signs used simultaneously that was problematic. In both cases, too much information was provided to the road users. The participants also had difficulty understanding the information provided by some of

the guide signs presented in the focus group (see Figures 4.3 and 4.4). Overall, traffic signs providing information about lane selection (for multilane roundabouts) were favored over traffic signs showing street names at the roundabout. Some participants indicated that street names should be shown on traffic signs used for the lane assignment. Participants identified choosing the proper lane prior to reaching the roundabout as an important element in the driving task.

Figure 4.3 Guide Sign with Lane Assignment

Figure 4.4 Guide Sign with Street Names

4.4.6 ENTRANCE AREA SIGNS AND PAVEMENT MARKINGS

For this part of the presentation, two series of pictures were shown to the participants (see Appendix A). The first series presented pictures illustrating various characteristics of entrance area signs and pavement markings located in the gore area. The second series focused on the same design elements, but for those located on the central island. In both cases, traffic signs and pavement marking were used to provide path guidance to drivers about to enter the roundabout.

For the first series of pictures, the most frequent comment was related to yield signs. Almost all participants agreed that a yield sign should be placed on either side of the entrance. This observation was more critical for multilane facilities. Some people thought the sign “YIELD TO TRAFFIC IN CIRCLE” should be placed under the yield sign. Interestingly enough, many participants were confused by the sign “CIRCLE HAS RIGHT OF WAY.” They thought the choice of words was poor for that particular sign.

Some participants reported, as discussed previously, that they experienced problems understanding the rules governing yield signs.

The second most frequent comment was associated with pavement markings. It seems that many participants were confused by the small triangles depicting yield signs on the pavement. They did not understand their meaning. After the moderator described the actual purpose of the marking, the participants indicated that they still preferred a solid straight line going across the traveled way given the fact they are commonly used on intersection approaches that are yield controlled.

The most common comment made by the participants for the second series of pictures was related to directional signs. The participants preferred chevrons or one-way signs used separately rather than when they are used together. Many participants were perplexed when both signs were used simultaneously. They reported that these signs are usually employed in a different context: one-way signs are used to designate one-way streets, while chevrons are used to designate horizontal curves on highways.

The second most frequent comment was associated with the location of the signs within the central island. About half the participants preferred seeing the directional sign when they approach the roundabout (i.e., facing the approach at 90^{o}) rather than when they enter the gore area (with an angle). Figures 4.5 and 4.6 show the position of the signs when they are seen from the approach and the gore area, respectively.

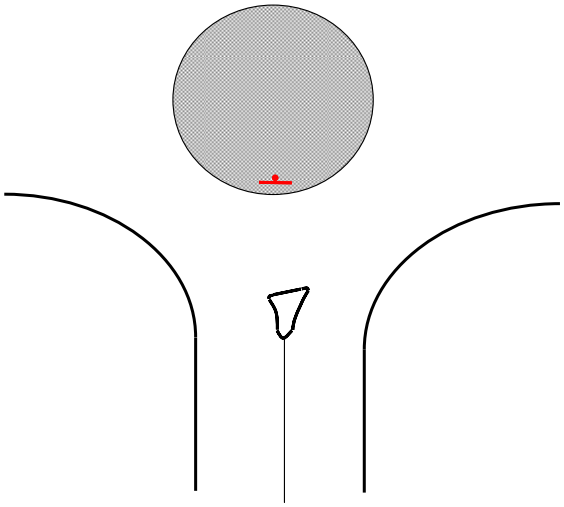


Figure 4.5 Placement of One-Way or Chevron Signs: Facing the Approach

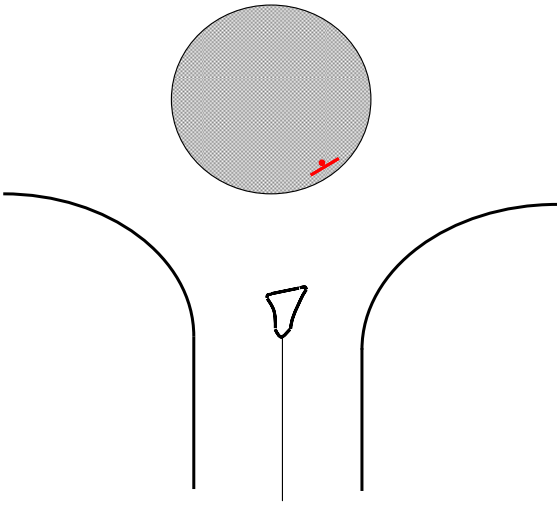


Figure 4.6 Placement of One-Way or Chevron Signs: Facing the Gore Area

4.4.7 STREET NAME SIGNS AT EXIT

Three video clips were shown to the participants. The video clips showed a wide variety of street name signs, including different shapes, sizes, and locations within the roundabout. The video clips were complemented with a series of 10 pictures.

The most frequent comment was related to the position of the street name signs inside the roundabout. The participants indicated that street name signs should be located on the splitter island rather than on the traveled way prior to reaching the exit, as shown in Figures 4.7 and 4.8, respectively. The participants also indicated that street name signs with an arrow pointing toward the exit provided better information than street name signs commonly used for regular intersections.

The second most frequent comment was associated with the use of guide signs combination with street name signs at the approach to the roundabout. The participants commented that guide signs should be used in conjunction with street name signs. They would apparently significantly help with the lane assignment and navigating inside the roundabout. The last point raised by the participants was related to design consistency. Some people indicated that consistency in the design of signs is the most critical factor in better understanding the basic principles for negotiating a roundabout. Accordingly, traffic signs used at roundabouts need to be consistent with other signs used in other parts of the highway network.

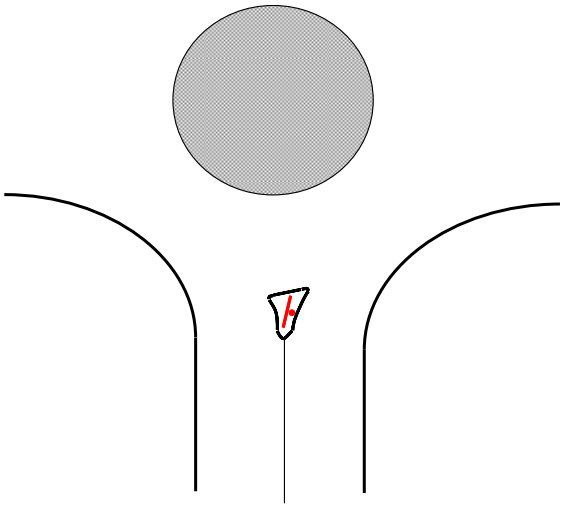


Figure 4.7 Street Name Sign Located on the Splitter Island

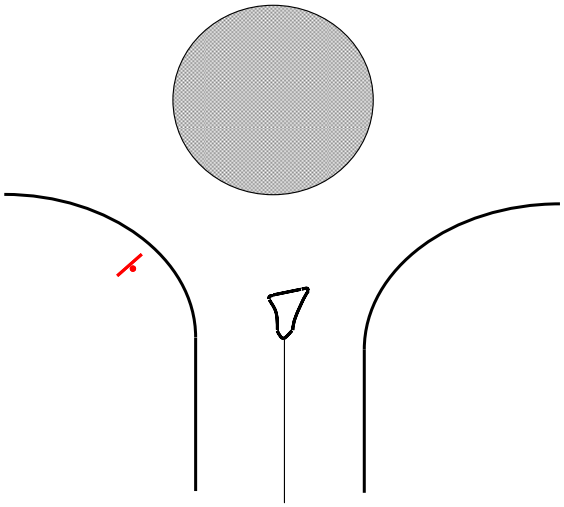


Figure 4.8 Street Name Sign Located Adjacent to the Traveled Way

4.4.8 FINAL INTERVIEW COMMENTS

At the end of each focus group, the moderator allowed the participants to provide any additional information not covered in the session. At this point, the moderator also asked whether their views had changed about the usefulness of roundabouts.

Given the input presented by all participants, about 75 percent of the subjects provided a relatively positive feedback about the use of roundabouts at intersections. A few

participants acknowledged that their views had changed since the start of the session. On the other hand, about one-quarter of the participants found roundabouts confusing and preferred regular intersections to roundabouts. Some were reluctant to experience changes and learn new rules. Many participants, from both spectrums, still preferred to execute a left turn at a signalized intersection with a full-protected left-turning phase than making a left-turn movement using a roundabout. Despite the advantages described in the instructional video, some participants still believed that roundabouts are more dangerous than regular intersections.

The opinion of participants who provided positive feedback regarding modern roundabouts was usually conditional on the following three observations. First, they reported that they needed to be familiar with their driving environment. Indeed, they would not have any problem using a roundabout if it were located in an area or neighborhood where they drive frequently. In addition, they indicated that knowing the intended destination before they executed their trip would help negotiate these facilities. Second, many participants pointed out that they needed to be properly informed prior to reaching the roundabout, especially if they drove in an unfamiliar environment. The lane selection and intended exit was the key factor for this observation. Third, a large majority of participants raised important concerns about the behavior of other drivers. Although this statement is true for every type of driving environment, the participants were particularly concerned about the fact that drivers do not need to stop at a roundabout, thus increasing the perceived risk to be involved in a collision if a driver does not yield to other vehicles. The speed of vehicles approaching the roundabout was also a concern to a few participants. They noted that drivers may be driving too fast as they are approaching a roundabout, thus increasing the likelihood of rear-end collisions.

4.5 SUMMARY

This chapter summarized the results for the first series of focus groups. It briefly described the theory and principles related to focus groups, including their strengths and limitations, and provided a detailed discussion of how the focus groups were conducted in this study. The results of the study indicate that older drivers are somewhat positive

about the use of roundabouts at intersections, as long as they are familiar with the environment where roundabouts are located and as long as certain criteria are met in terms of information provided to the driver. The most important issues raised in the discussions are related to the level of information provided prior to reaching the roundabout and once the driver enters the roundabout. As such, older drivers need to be properly warned of an upcoming roundabout to allow for proper lane selection prior to the approach and given detailed information about where they need to exit. The behavior of other drivers was also a concern to many study participants.

These findings suggest that there are particular countermeasures most deserving of evaluation in the next phase of the research. These measures particularly provide aid in terms of the decision-making process and path guidance during the negotiation of roundabouts. It also indicates that there is a need to determine their effects on the perceived safety and comfort of using roundabouts by older drivers. The hypothesis is that an improvement in the decision-making and path guidance tasks would reduce the likelihood of older drivers perpetrating errors that may lead to a crash. In addition, they would help reduce the perceived complexity of these facilities by older drivers.

The next chapter summarizes the results of Phase II, a study of proposed countermeasures aimed at improving the safety of older drivers at roundabouts.

CHAPTER 5
PHASE II STRUCTURED INTERVIEWS

This chapter describes the characteristics of Phase II, the structured interviews study. The primary objective of Phase II was to evaluate a series of countermeasures aimed at improving the perceived comfort, confidence, and safety of older drivers when they are using roundabouts. Ten countermeasures were evaluated in Phase II. The assessment of perceived comfort, confidence, and safety levels was performed using Likert rating scales.

This chapter is divided into eight sections. The first section describes the methodology utilized for conducting structured interviews. The second section describes the objective of the Phase II study. The third section summarizes how the structured interviews were administered. The fourth section describes the recruitment process. The fifth section describes the structured interview process. The sixth section explains the characteristics of the selected design elements and countermeasures. The seventh section describes the demographic information of the participants who were interviewed. The last section provides a summary.

5.1 METHODOLOGY

A structured interview is an interactive discussion between an interviewee and an interviewer, in which each subject is asked a fixed set of questions. In many instances, the questions are asked in a predetermined order. In addition, it is not uncommon to find respondents who are asked to choose from a preset series of potential answers (e.g., Likert scale).

The goal of a structured interview is to ensure consistency among the subjects' responses. As reported by Breakwell (1995), "a structured interview yields information, which is easily quantified, and the data are usually framed for analysis." The structured interview allows the interviewer to recognize when a respondent has difficulty understanding or interpreting a question and employ proper techniques to assist the interviewee without

jeopardizing the integrity of the interview (GAO 1991). In addition, structured interviews provide an opportunity for the interviewer to observe the behavior of the interviewee when the person answers the questions. It should be noted that structured interviews are used frequently in social sciences and human resources.

Some of the limitations of structured interviews include little room for unanticipated discoveries. This is particularly accurate when the respondents can only select their response based on a fixed series of answers. Findings suggest that people may feel constrained since they are not free to give information (Breakwell 1995). Although the structured interviews in this study were very stringent, the participants were allowed to freely provide additional information that could be useful for the research team at the end of the interview. Comments reported by the participants were noted during the interview.

5.2 PHASE II STUDY OBJECTIVE

The objective of Phase II, the structured interviews study, was to evaluate a total of 10 countermeasures for five different design elements. The countermeasures were evaluated using the change in perceived comfort, confidence, and safety between the countermeasures and the nominal or base conditions.

5.3 STRUCTURED INTERVIEW ADMINISTRATION

A total number of 31 interviews were held in College Station, Texas, and Tucson, Arizona, during June 2004. Again, one more participant than originally planned was interviewed. Each subject was interviewed individually between one and one-and-a half hours. All subjects were interviewed by the co-principal investigator, Ms. Ida van Schalkwyk (henceforth designated as the interviewer), to ensure consistency for the data collected among the participants. All the material was presented using static images and animated video presentations showing the approach to and traversal of the roundabouts. It is important to note that the interviews were conducted from the perspective that the subject would be unfamiliar with the environment where the roundabout was located. In addition, the animated presentations were used to put the selected design elements in their

context and were not utilized to improve conspicuity or to evaluate the information process of the participants. Each participant received $40 at the end of the interview for participation in the study. The next three sections summarize the approach used for conducting the interviews.

5.4 RECRUITMENT

The recruitment of the participants was performed through various means, including phone calls and printed material posted in venues such as retirement communities, senior and community centers, VFW lodges, and churches. To be included in the study, the participants needed to be age 65 years or above and drive at least three times a week. No prior knowledge of roundabouts was required to participate in the study.

The research team initially contacted potential candidates who had agreed to participate in focus groups held by TTI in College Station. The team was successful in recruiting 29 participants for the series of interviews in College Station. Another effort to recruit participants was performed in Tucson, Arizona, and two additional participants were selected. A special effort was made to recruit minority participants, which resulted in the inclusion of two Hispanic participants.

5.5 THE STRUCTURED INTERVIEW PROCESS

The structured interview meetings were held in a conference room at TTI in College Station, Texas, and at an off-campus building in Tucson, Arizona. When the participant entered the room, he or she was given a brief overview of the project without providing any information that might create biases on the part of the participant. At this time, the participant also received a consent form. Adequate time was provided for the participant to carefully read through the form before signing. The interviewer answered any questions related to the consent form. The interviewer identified the CDC as the funding agency and also briefly discussed the role of the CDC in injury prevention.

The participant was then given instructions regarding the use of a roundabout and typical features characteristic of a roundabout. The interviewer then presented an overview of the three different stages of the interview: a pair-by-pair comparison of alternatives for each design element, a direct comparison of the three alternatives per design element, and questions about the use of roundabouts. During each session, the interviewer observed the behavior of the participants during the evaluation of the countermeasures and noted instances where particular problems were raised by the participants about the information provided by the base condition or the countermeasures.

At the end of the session, each participant completed a demographic information sheet. Also included in the questionnaire were questions that tested whether their views had changed about the usefulness of roundabouts or if they had any other thoughts about this type of facility. Before leaving the premises, the participants were asked to sign a form to acknowledge the receipt of their compensation for their participation.

5.6 CHARACTERISTICS OF SELECTED DESIGN ELEMENTS

A multilane roundabout located in the state of Washington was selected as the study site. This site provided various features relevant to this part of the study. In addition, the images recorded at that site were deemed superior to the ones taken at the other sites. The images were provided by WDOT. WDOT personnel captured still images using a specially equipped van that replicates the view from a driver's perspective. A different image was taken every 10 ft. The run showed in a driver's perspective a vehicle approaching, entering, and going around a roundabout. In all, 64 images were recorded at the selected site.

After the site was selected, all the images used in this part of the work were digitally manipulated to reflect either one of the three alternatives: Base Condition, Countermeasure #1, and Countermeasure #2. To eliminate selection biases during the interview process, the research team designated the Base Condition as the first drive, Countermeasure #1 as the second drive, and Countermeasure #2 as the third drive in the survey instrument.

The digital manipulation was performed by the Environmental Management group at TTI using Photoshop imaging software. This group specializes in landscape architecture and urban planning research. The base condition was created to reflect the nominal design standards for roundabouts, as proposed by the *MUTCD* (FHWA 2003) (see Figure 5.1). The countermeasures were selected based on the outcome of the Phase I focus groups study and in the literature (e.g., Kinzel 2003). The process for the selection of the countermeasures for each design element is discussed below.

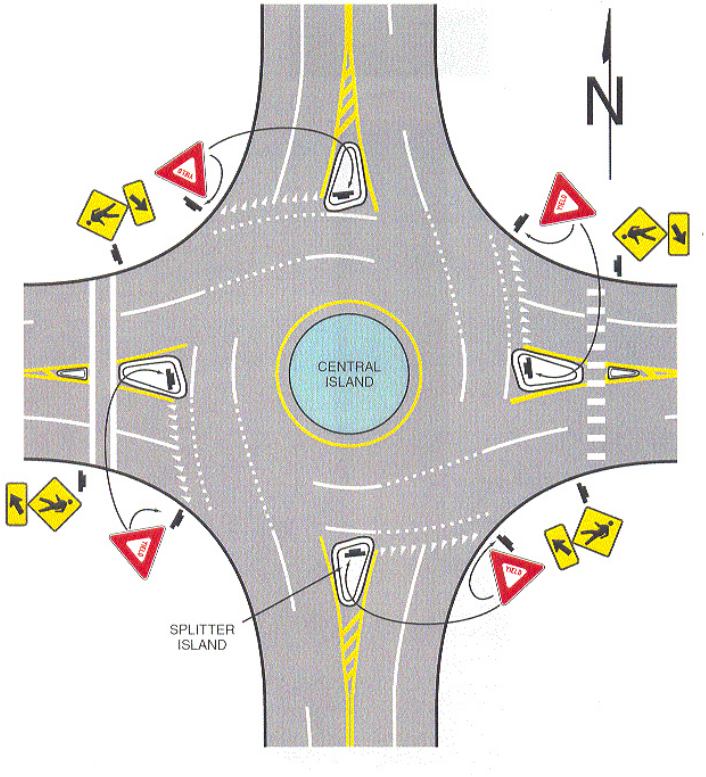


Figure 5.1 Current Design Standards for Roundabout Intersections (FHWA 2003)

The research team collaborated very closely with the graphic artist to ensure that the manipulated elements closely resembled the ones installed or used on actual roads. For instance, the size, color contrast, readability, and conspicuity were verified to guarantee that all digital enhancements were as close as possible to the real design elements used on the highway system. All the static images and animated presentations used in the

interview are available in CD-ROM format. The reader can contact the authors of this report for obtaining the material. The files are formatted in Adobe Acrobat PDF format.

The five design elements selected in Phase II were determined given the outcome of the Phase I focus groups study and specifically identified the needs of the older driver at roundabouts. The design elements evaluated included the following:

A. advance warning signs,
B. roundabout lane control signs,
C. directional signs (one-way indication),
D. yield treatment, and
E. exit treatment.

The descriptions of the Base Condition, Countermeasures #1, and Countermeasure #2 for each design element are presented in the next five sub-sections. In the text below, the first alternative designates the Base Condition, the second alternative signifies Countermeasure #1, and the third alternative designates Countermeasure #2.

5.6.1 DESIGN ELEMENT A—ADVANCE WARNING SIGNS

Design Element A is related to warning drivers about an upcoming roundabout. The purpose for evaluating different alternatives is to determine the most effective method to provide advance warning to older drivers.

Figure 5.2 shows the three alternatives tested for Design Element A. The figure provides the context in which the signs are used. All subsequent figures are shown in the same manner.

Base Condition: For the Base Condition, the advance warning sign template W2-6 for roundabouts was used according to the guidelines proposed by the *MUTCD* (FHWA 2003). The *MUTCD* requires the placement of an advance warning sign on each leg leading to a roundabout.

Countermeasure #1: Countermeasure #1 was aimed at re-emphasizing the message provided to motorists about the upcoming presence of a roundabout. Two changes were made: 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. The solid circle was added based on the results of a study by Kinzel (2003). Kinzel reported that the placement of a solid black circle on the warning sign could reinforce the presence of an obstruction inside the roundabout (in this case the central island). The plaque was added because the *MUTCD* recommends the use of the template W16-12 at the approach of a roundabout. The *MUTCD* proposes a plaque with the words "TRAFFIC CIRCLE." However, the transportation community is now shifting toward the term "ROUNDABOUT," and the research team decided on this term. In addition, results from Phase I have shown that the participants were more familiar with the term "ROUNDABOUT."

Countermeasure #2: For Countermeasure #2, 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). The plaque followed the specifications template W13-1 of the *MUTCD*. Providing an advisory speed on the approach was raised as a potential countermeasure in Phase I.

a) Base Condition

b) Countermeasure #1

c) Countermeasure #2

Figure 5.2 Design Element A—Advance Warning Signs

5.6.2 DESIGN ELEMENT B—ROUNDABOUT LANE CONTROL SIGNS

Design Element B is associated with the type of control needed to guide traffic entering the roundabout. The purpose of the roundabout lane control sign is to provide sufficient information to allow drivers to make appropriate lane selection prior to entering the roundabout.

The three treatment alternatives tested for Design Element B are shown in Figure 5.3. Participants in Phase I reported that choosing the proper lane before arriving at the roundabout was an important factor for safely negotiating the roundabout. It should be pointed out that some of these alternatives are currently used by local and state transportation agencies.

Base Condition: The Base Condition for Design Element B was modeled after the R3-8 series of advance intersection lane control signs. Based on the guidelines of the *MUTCD* (FHWA 2003) and other exiting signs used by transportation agencies, the Base Condition consists of using a simple lane control sign with solid lines displaying the two possible routes for traveling through a roundabout (one for each entering lane).

Countermeasure #1: For Countermeasure #1, a solid black circle representing the central island was added to the left lane's route, but not for the right lane's route. The black circle was not included for the right lane's route because Kinzel (2003) hypothesized that the addition of the circle would make the sign harder to read from a relatively long distance.

Countermeasure #2: Countermeasure #2 consisted of adding the text "LEFT LANE" and "RIGHT LANE" under the corresponding routes. Pictures of existing signs used in the state of Washington were shown during the Phase I focus groups study and were met with much approval by the focus groups (see Appendix A).

a) Base Condition

b) Countermeasure #1

c) Countermeasure #2

Figure 5.3 Design Element B—Roundabout Lane Control Signs

5.6.3 DESIGN ELEMENT C—DIRECTIONAL SIGNS

Design Element C is related to the use of directional signing inside the roundabout. The purpose of directional signing is to help drivers understand the direction of the traffic flow inside the roundabout. In other words, this design element is aimed at enhancing the path guidance of drivers and, therefore, preventing drivers from turning left when they enter the roundabout (wrong direction).

Figure 5.4 shows the three alternatives evaluated for this part of the study. At this point, directional signing for roundabouts is not required by the *MUTCD* (FHWA 2003). Consequently, many transportation agencies have developed their own guidelines, which means that a wide variety of guidelines exist across the United States.

Base Condition: The Base Condition for Design Element C 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*.

Countermeasure #1: For Countermeasure #1, a one-way sign (template R6-1) was placed on the central island. The sign was positioned facing the centerline of the approaching roadway. At this location, drivers will see the sign as they approach the roundabout (for more details, see Figure 4.5).

Countermeasure #2: For Countermeasure #2, the same one-way sign was placed on the central island directly in front of the driver's entry point at the gore area rather than facing the centerline of the approaching roadway (see Figure 4.6). The offset placement for Countermeasure #2 puts the sign more directly in the driver's line of sight from the yield line.

a) Base Condition

b) Countermeasure #1

c) Countermeasure #2

Figure 5.4 Design Element C—Directional Signs

5.6.4 DESIGN ELEMENT D—YIELD TREATMENT

Design Element D is related to the yield treatment at the entrance of a roundabout. As described in Chapter 2, an important characteristic of roundabouts was the yield treatment. The problem about older drivers experiencing difficulties with the yielding maneuver was illustrated in Chapter 3 and was also noted by the participants of the Phase I focus groups study. The purpose of evaluating different alternatives was to determine which alternative minimizes the difficulty older drivers may experience at the entrance area of a roundabout.

Figure 5.5 illustrates the three alternative designs for Design Element D. It should be pointed out that only one yield sign is visible in these figures. The two yield signs can be seen from further way (see Appendix B).

Base Condition: For the Base Condition, 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).

Countermeasure #1: For Countermeasure #1, a yield line consisting of solid white isosceles triangles was added to the Base Condition. Section 3B of the *MUTCD* recommends using a yield line to indicate the point behind which vehicles are required to yield at the entrance of a roundabout or intersection. This particular yield line design was introduced by the *MUTCD* very recently.

Countermeasure #2: Countermeasure #2 included all the components used for Countermeasure #1, but added a plaque with the notation “TO TRAFFIC IN CIRCLE” below the yield signs. The plaque was modeled after the *MUTCD* specification R1-2a. The *MUTCD* recommends the term “TO ONCOMING TRAFFIC,” but given the input obtained in the Phase I study, the research team decided to use the substitute term describe above.

a) Base Condition

b) Countermeasure #1

c) Countermeasure #2

Figure 5.5 Design Element D—Yield Treatment

5.6.5 DESIGN ELEMENT E—EXIT TREATMENT

Design Element E is used to provide information about the exit treatment. Exit treatments refer to signing and/or markings that are supposed to help guide drivers toward the right exit when they are already traveling inside the roundabout. Exit treatments were included in this study because participants of the Phase I focus groups study identified that the provision of adequate information at the exit point was a critical element for negotiating a roundabout.

Figure 5.6 shows the three alternatives for Design Element E. Since the right-hand side of the original images could not be seen between the entrance point and the first exit, the street exit sign for the Base Condition had to be relocated (i.e., in the images). Thus, the street exit sign for the Base Condition was placed prior to reaching the second exit. During the interview process, the participants were warned about the change in location.

Base Condition: The exit treatment used for the Base Condition consists of placing a street exit sign prior to reaching the intended exit. The sign was placed between two intersecting streets facing inward toward the traffic in the circle. The sign specifications matched the guidelines proposed by the *MUTCD* (FHWA 2003) for the D1 series.

Countermeasure #1: For Countermeasure #1, 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.

Countermeasure #2: The second countermeasure added an arrow on the street exit sign used for Countermeasure #1. Template D-D1 of the *MUTCD* was used to this effect. This configuration can already be seen at many roundabouts in the United States.

a) Base Condition

b) Countermeasure #1

c) Countermeasure #2

Figure 5.6. Design Element E—Exit Treatment

5.6.6 DESCRIPTION OF THE EXPERIMENTAL PROCEDURE

This section summarizes the experimental procedure for the Phase II study. The experiment was conducted in three parts. In Part A, the participants were asked to perform a pair-by-pair comparison of treatment alternatives. In Part B, the participants had to compare all three alternatives simultaneously for each design element and answer a series of questions about their preference on the proposed alternatives. In Part C, participants were asked to answer general questions about the use of roundabouts. The survey instruments for this experiment are provided in Appendix B.

5.6.6.1 Part A: Pair-by-Pair Comparisons of Alternatives

In Part A, the interviewer presented animated video presentations of the Base Condition and Countermeasure #1 for each design element. After each run, the participant was asked to rate his or her perceived change in terms of safety, comfort, and confidence. The process was then repeated between the Base Condition and Countermeasure #2. After each run, the participant had the opportunity to view still photographs taken from the video clips to assist them during the rating process.

In order to remove first-order effects, the order of the presentation of the five different design elements was calculated using a Latin square design. The design was estimated using the methodological approach proposed by Kirk (1982). Table 5.1 shows the order of the presentation for each participant.

Table 5.1 Presentation Order of Design Elements

Subject #	First	Second	Third	Fourth	Fifth
1 to 6 + 31	A	D	E	B	C
7 to 12	D	B	C	E	A
13 to 18	E	C	D	A	B
19 to 24	B	E	A	C	D
25 to 30	C	A	B	D	E

For each pair-by-pair comparison, a seven-level Likert rating scale was used to measure the perceived change in comfort, confidence, and safety. The moderator read the two series of questions to the participants (see Appendix B).

The first series included the following questions:

1. Compared to the first drive, how would your level of **comfort** change, if at all, based on the new feature included in the second (or third) drive?

2. Compared to the first drive, how would your level of **confidence** for using the roundabout correctly change, if at all, based on the new feature included in the second (or third) drive?

3. Compared to the first drive, how would your **feeling of safety** change, if at all, based on the new feature included in the second (or third) drive?

The second series of questions included (rated on a 10-point scale):

> Thinking about 10 average drivers your age, how many do you think will feel comfortable when they see the sign or marking that is shown:
>
> 1. in the first drive _____out of 10 drivers will feel comfortable.
>
> 2. in the second (or third) drive _____ out of 10 drivers will feel comfortable.

5.6.6.2 Part B: Direct Comparison of All Three Alternatives

In Part B, the participants had to evaluate all three alternatives for each selected design element and choose one or more alternatives, given a series of questions. The goal was to determine if the countermeasures truly enhanced the decision-making and path guidance processes of older drivers. More specifically, the research team wanted to evaluate whether older drivers were less likely to make driver errors with the proposed countermeasures.

The elements covered in Part B included the following:

- assess which scenario they preferred most,
- identify scenario(s) that were the easiest to understand,
- identify scenario(s) that were particularly difficult to understand,
- assess the scenario that best provided the necessary information to allow for a safe negotiation of the roundabout (questions were developed for each feature to test this element—refer to Appendix B), and
- assess the alternative that would be best at acquiring the desired actions by drivers to allow for a safe negotiation of the roundabout (questions were developed for each feature to test this element—refer to Appendix B).

5.6.6.3 Part C: General Questions about Roundabouts

Part C tested the perception of older drivers about the general use of roundabouts. The goal was to determine potentially risky behavior of older drivers at roundabouts. Using a seven-scale Likert scale, the behavioral characteristics evaluated in this part included the following:

- the likelihood an older driver would avoid using a roundabout;
- the likelihood an older driver would make a full stop at the entrance of a roundabout (e.g., yield), whether or not there is traffic in the circle; and
- the likelihood an older driver would remain in the outside lane of the roundabout at all times when negotiating a roundabout, regardless of the destination, i.e., whether there's any indication that older drivers are uncomfortable with using the inside lane of the roundabout and the associated lane changes.

Similarly, the research team tested the differences in perceived safety when a participant had the choice between the following traffic control devices:

- a left turn at a roundabout,
- a left turn at an intersection with "4-WAY STOP" control,

- a left turn at a signalized intersection but without a protected left-turn phase, and
- a left turn at a signalized intersection with a protected left-turn phase.

In this case, the objective consisted of determining whether or not roundabouts increased the perceived safety compared to other traffic control measures at intersections. A six-level Likert rating scale was used to measure the perceived change in safety.

5.7 CHARACTERISTICS OF PARTICIPANTS

A total of 31 participants took part in the structured interviews. The participants represented diverse backgrounds in education level, driving experience, and geographical areas, as seen in Tables 5.2 to 5.6. Almost all participants owned a vehicle and had more than 25 years of driving experience. It should be pointed out that some participants did not answer all questions.

Table 5.2 Distribution of Age Group by Gender

Age Group	Male	Female	Total
65–69 Years Old	1	6	7
70–74 Years Old	7	6	13
75–80 Years Old	4	2	6
>= 80 Years Old	2	3	3
Total	14	17	31

Table 5.3 Level of Education by Gender

Level of Education	Male	Female	Total
Some High School	0	1	1
High School Graduate	1	5	6
Some College	4	7	11
College Graduate	3	1	4
Some Graduate School	0	1	1
Graduate Degree	6	2	8
Total	14	17	31

Table 5.4 Type of Area the Subjects Live by Gender

Type of Area	Male	Female	Total
Rural	3	4	7
Small City	9	11	20
Suburbs	1	0	1
Large City	1	2	3
Total	14	17	31

Table 5.5 Frequency of Driving by Gender

Frequency of Driving	Male	Female	Total
Few Times a Week	0	6	6
Once a Day	2	2	4
Several Times a Day	9	8	17
Unknown	3	1	4
Total	14	17	31

Table 5.6 Knowledge of Roundabouts by the Study Participants

Used a Roundabout Before	Male	Female	Total
Yes	10	13	23
No	1	2	3
Unknown	3	2	5
Total	14	17	31

5.8 SUMMARY

This chapter described the characteristics of the Phase II structured interviews study. The primary objective of Phase II was to evaluate a series of countermeasures aimed at improving the perceived comfort, confidence, and safety of older drivers when they are using roundabouts. The chapter briefly described the principles for conducting structured interviews, their strengths and limitations, and the content of and manner in which the interviews were conducted. The experiment used animated video presentations and still pictures. Five design elements were evaluated:

A. advance warning signs,
B. roundabout lane control signs,
C. directional signs (one-way indication),
D. yield treatment, and
E. exit treatment.

For each design element, three different alternatives were evaluated: the Base Condition, Countermeasure #1, and Countermeasure #2.

To accomplish the objective of the Phase II study, participants were interviewed one at the time to solicit their opinion about their perceived comfort, confidence, and safety for the different proposed alternatives. A total of 31 participants were interviewed in Phase II.

The interview process was separated into three parts. In Part A, the participants were asked to perform a pair-by-pair comparison between the base condition and each countermeasure. In Part B, the participants had to compare all three alternatives simultaneously for each design element and answer a series of questions about their preference on the proposed alternatives. In Part C, participants were asked to answer general questions about the use of roundabouts and other types of traffic control at intersections. The next chapter summarizes the results of the Phase II study.

CHAPTER 6
PHASE II STUDY RESULTS

This chapter summarizes the results and analyses conducted for Phase II, the structured interviews study. The summary follows the original three-part survey structure performed in the Phase II study. Consequently, this chapter is divided into three sections that focus, respectively, on a pair-by-pair comparison between each countermeasure and the base condition (Part A), a direct comparison of alternatives for each design element (Part B), and a summary of the perceptions and general views held by study participants regarding the general use of roundabouts (Part C).

6.1 PART A—SUMMARY RESULTS OF PAIR-BY-PAIR COMPARISONS OF TREATMENT ALTERNATIVES

In Part A, the participants viewed animated video presentations of the base condition and the two proposed countermeasures, and performed separate comparisons between the base condition and each of the two countermeasures. The experimental design was described in Chapter 5. As described in the previous chapter, the first alternative designates the Base Condition, the second alternative designates Countermeasure #1, and the third alternative designates Countermeasure #3.

Bipolar rating scales were used for these comparisons, and participants were asked to rate their perceived change (if any) in confidence, comfort, and safety for each pair of test stimuli they viewed. The rating scales used a Likert-type scale anchored by the most negative response (value = 1) and the most positive response (value = 7) to each question comparing one of the countermeasures to the base condition. After completing the responses, the participants provided, using a 10-point rating scale, their opinion on the comfortable level older drivers from the general population would experience for each alternative. These ratings therefore only pertained to the absolute level of comfort associated with each alternative and do not quantify the change in perceived comfort between alternatives.

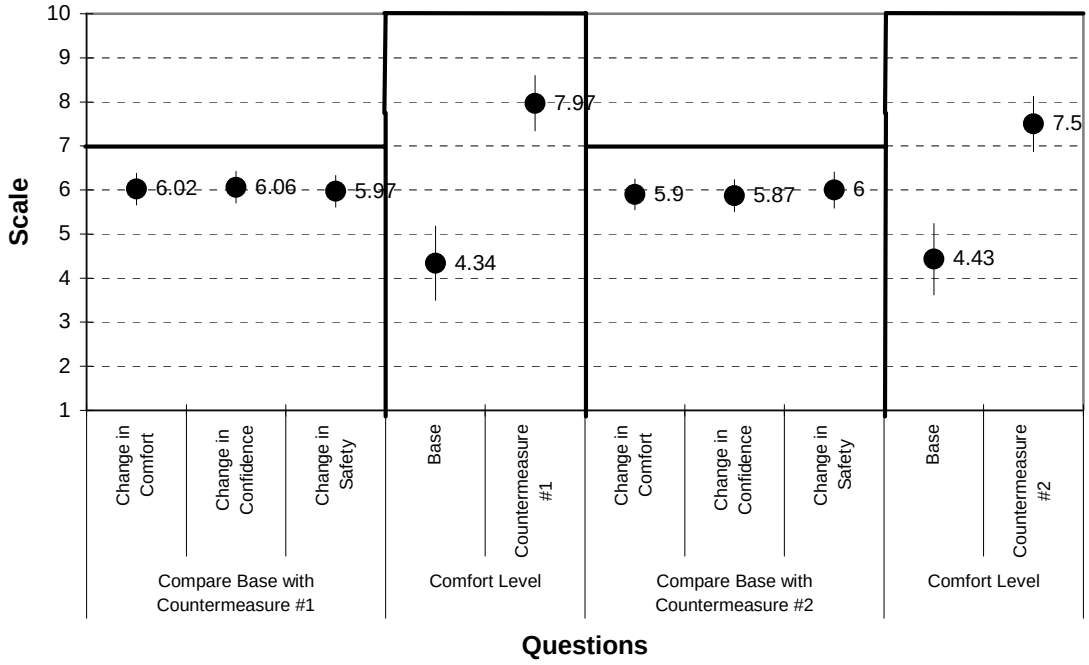
The order of the presentation of the five different design elements was calculated using a Latin square design (see Table 5.1). For each pair-by-pair comparison, the participant also had the opportunity to view still photographs of the roadway environment that were extracted from the animated video presentations.

The results of the pair-by-pair comparisons for each design element are presented in this section. The actual rating scores for each countermeasure are summarized first, grouped by design element. An analysis of variance (ANOVA) was applied to the change scores, and to the absolute ratings of the change in perception, to determine whether there were significant differences between the countermeasures and the base condition.

6.1.1 DESIGN ELEMENT A—ADVANCE WARNING SIGNS

Design Element A, which consisted of the installation of an advance warning sign on the approaching leg, is used to warn a driver of an upcoming roundabout. The Base Condition reflected the current design standards for warning drivers of an upcoming roundabout. For Countermeasure #1, a plaque with the text "ROUNDABOUT" was added to the advance warning sign shown in the Base Condition. Countermeasure #2 consisted of adding a plaque with an advisory speed of 30 mph under the advance warning sign. During the Phase I focus groups study, participants stressed the importance of providing adequate information about an upcoming roundabout and the safe speed to negotiate the roundabout.

The average response rates for Design Element A are provided in Figure 6.1. The vertical bars represent the 95th percentile confidence interval on the estimated mean. The first five observations show the average response rate between the Base Condition and Countermeasure #1. The last five observations show the average responses between the Base Condition and Countermeasure #2. It should be pointed out that the comparisons in columns 1, 2, 3, 6, 7, and 8 utilized a 7-point rating scale. On the other hand, the comparisons in columns 4, 5, 9, and 10 employed a 10-point scale.



Note: Comparisons 1, 2, 3, 6, 7, 8: 7-point scale; Comparisons 4, 5, 9, 10: 10-point scale

Figure 6.1 Rating Scores for Advance Warning Signs

Figure 6.1 illustrates that the perceived change in comfort, confidence, and safety relative to the base condition was similar for both Countermeasures #1 and #2. In both cases, the participants felt more comfortable, confident, and safer with the countermeasures in place than with the base condition. Second, the confidence intervals are relatively small; most participants assigned ratings close to 6 (out of 7). Third, most participants believed that older drivers in the general population would be more comfortable using the roundabout with either Countermeasures #1 or #2 implemented versus the Base Condition. However, there was greater variability in these responses, as can be seen from the wider confidence intervals for observations located in columns 4, 5, 9, and 10.

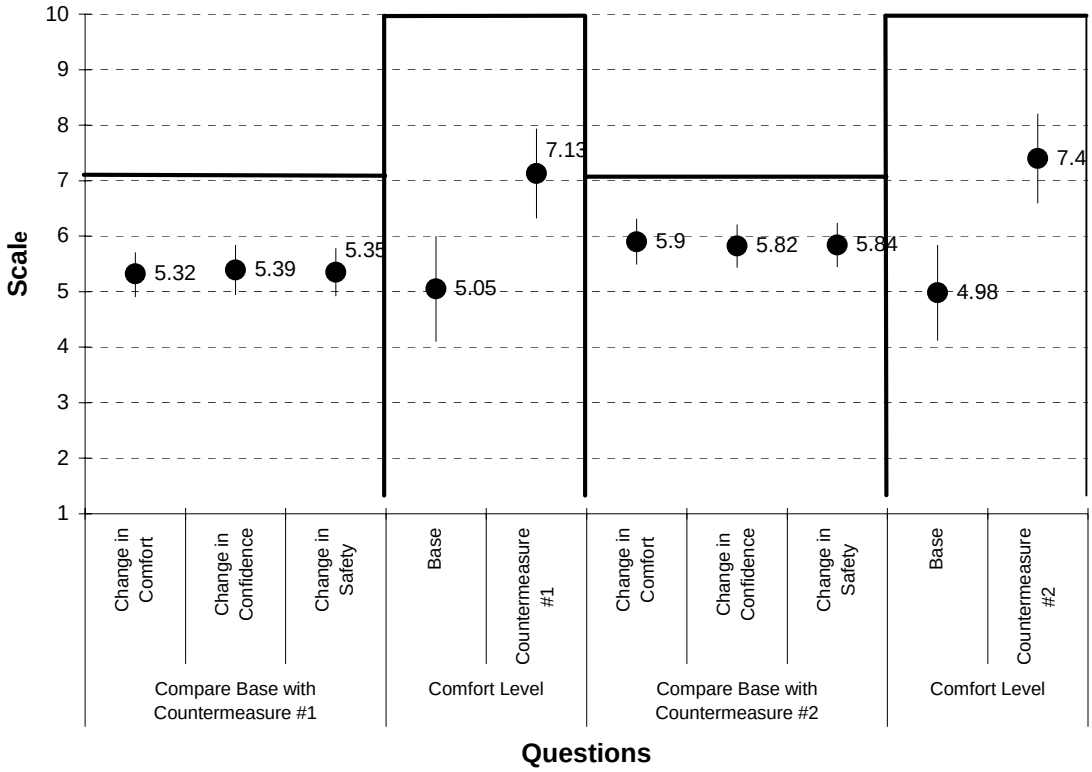
The differences in the ratings of subjects were tested for statistical significance using an ANOVA (*F*-test) for planned comparisons. The comparison between Countermeasures #1 and #2 was not statistically significant for any pair of scores (the minimum *p*-value is 0.30). In other words, the participants did not exhibit a statistically significant preference

for either Countermeasure #1 or Countermeasure #2 in terms of comfort, confidence, or safety.

6.1.2 DESIGN ELEMENT B—ROUNDABOUT LANE CONTROL SIGNS

Design Element B is used to provide information to enable the driver to select the correct lane when approaching the roundabout, given the intended destination of the driver (i.e., turning left or right or traveling through the roundabout). The Base Condition represents the nominal condition as proposed by the *MUTCD* (FHWA 2003). Countermeasure #1 modified the base condition by including a solid black circle representing the central island inside the left lane's route. Countermeasure #2 added the text "LEFT LANE" and "RIGHT LANE" below the corresponding routes (i.e., the arrows on the sign).

Figure 6.2 shows the mean ratings and 95 percent confidence intervals for comparisons involving roundabout lane control signs.



Note: Comparisons 1, 2, 3, 6, 7, 8: 7-point scale; Comparisons 4, 5, 9, 10: 10-point scale

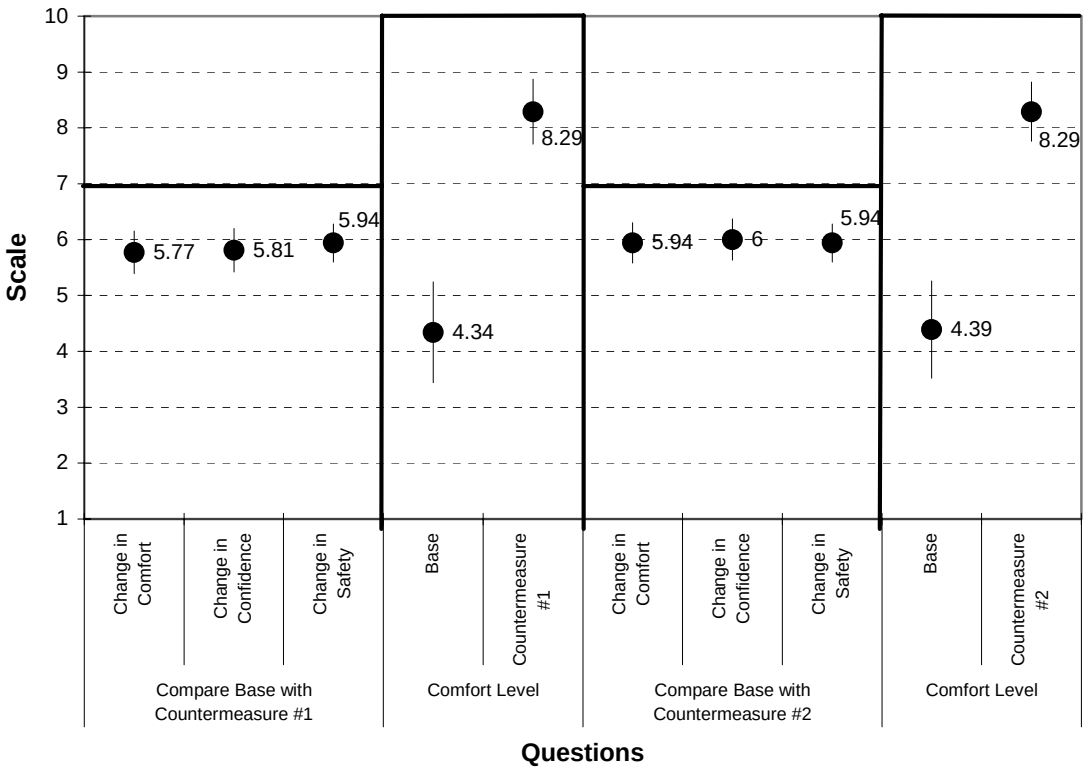
Figure 6.2 Rating Scores for Roundabout Lane Control Signs

Figure 6.2 shows results similar to those shown in Figure 6.1, with somewhat lower scores for Countermeasure #1. The perceived change in comfort, confidence, and safety for Countermeasure #1 was on average a little higher compared to the base condition. This was also reflected in participants' ratings of the comfort level of older drivers using the roundabout with the base and the countermeasures in place, rated on the 10-point scale.

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 ($p < 0.157$; F = 2.05; df = 1, 30) or in safety ($p < 0.103$; F= 2.74; df = 1, 30). The comfort level improvement with Countermeasure #2 was marginally significant at $p < 0.052$ ($F = 3.91$; df = 1, 30).

6.1.3 DESIGN ELEMENT C—DIRECTIONAL SIGNS

Design Element C is used to show the movement of traffic inside the roundabout. For the Base Condition, no directional signs were used, as per the *MUTCD* guidelines (FHWA 2003). For Countermeasure #1, a one-way sign was installed on the central island, facing perpendicular to the approach connecting the roundabout. At this location, the driver sees the sign as he or she approaches the roundabout. For Countermeasure #2, the one-way sign was also placed on the central island but faced the entrance or the gore area. In this case, the sign is actually seen when the driver enters the roundabout. The ratings for these alternatives are shown in Figure 6.3.



Note: Comparisons 1, 2, 3, 6, 7, 8: 7-point scale; Comparisons 4, 5, 9, 10: 10-point scale

Figure 6.3 Rating Scores for Directional Signs

Figure 6.3 shows almost identical scores for the pair-by-pair comparisons with the Base Condition and Countermeasures #1 and #2, indicating that the location of the one-way

sign on the central island was not important in the eyes of study participants. The statistical test for comfort, $p < 0.52$ ($F = 0.42$; df = 1, 30); confidence, $p < 0.46$ ($F = 0.56$; df = 1, 30); and safety, $p < 1.0$ ($F = 0.0$; df = 1, 30), was not statistically significant. Similarly, the difference in the participants' ratings for comfort was not significant at $p < 1.0$ ($F = 0.0$; df = 1, 29). Nonetheless, the presence of a one-way sign appears to strongly improve participants' ratings of the comfort level experienced by older drivers using the roundabout.

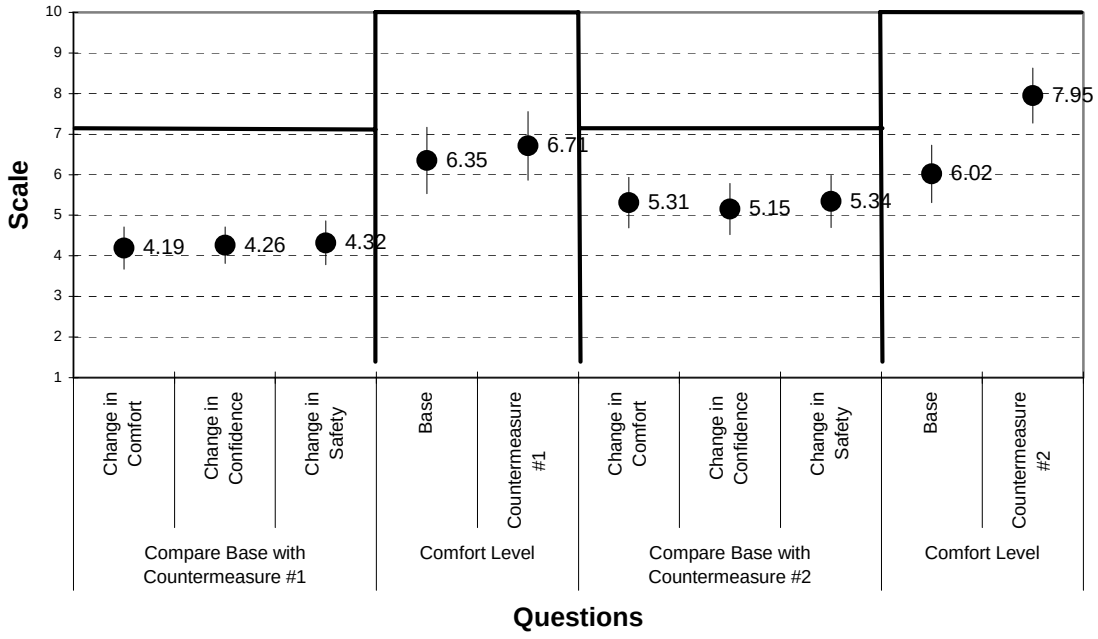
It should be noted that the experimental design, i.e., showing animated video presentations rather than using actual driving conditions, may render the comparison between Countermeasures #1 and #2 for this design element difficult as the difference in the location of the sign was very small. It is possible that the animated video presentations provided inadequate information with regards to the orientation and location of the directional signs.

6.1.4 DESIGN ELEMENT D—YIELD TREATMENT

The yield treatment provides information to drivers who are entering the roundabout about yielding to traffic already traveling inside the roundabout. The Base Condition provided two yield signs located on both sides of the entrance area, without any supplemental pavement markings. For Countermeasure #1, a yield line consisting of isosceles triangles pointing toward the approaching vehicles (as proposed in the *MUTCD*) was added to the base condition. For Countermeasure #2, a plaque with the words "TO TRAFFIC IN CIRCLE" was added below the yield sign to supplement the message conveyed by the "YIELD" signs along with the yield line from Countermeasure #1. Figure 6.4 shows the rating scores for the pair-by-pair comparisons between the base condition and each of the countermeasures.

As can be seen from Figure 6.4, Countermeasure #1 did not improve the participants' understanding of the yield treatment at the entrance of the roundabout. It appeared that many participants either did not understand the meaning of, or were confused by, the pavement markings. This issue was noted by the interviewer. In fact, some participants

thought they were traveling in the wrong direction, given the fact the triangles pointed toward the drivers entering the
roundabout.



Note: Comparisons 1, 2, 3, 6, 7, 8: 7-point scale; Comparisons 4, 5, 9, 10: 10-point scale

Figure 6.4 Rating Scores for Yield Treatment Signs

The results show that the values were clustered around 4, indicating a fairly neutral view of the pavement markings. In other words, they perceived no change in their level of confidence, comfort, or safety in using roundabouts whether this treatment was added to the base condition or not. The same observation can be seen with the participants' comparison of the base condition to this alternative condition vis-à-vis the ratings of older drivers' comfort in using the roundabout. In contrast, Countermeasure #2 elicited a more positive response, which may be attributed to the addition of the supplemental advisory plaque under the yield sign.

The difference between Countermeasures #1 and #2 and the Base Condition was marginally statistically significant for all comparisons with $p < 0.0082$ ($F = 7.47$; df = 1, 30) for comfort, $p < 0.0267$ ($F = 5.16$; df = 1, 30) for confidence, and $p < 0.0183$ ($F =$

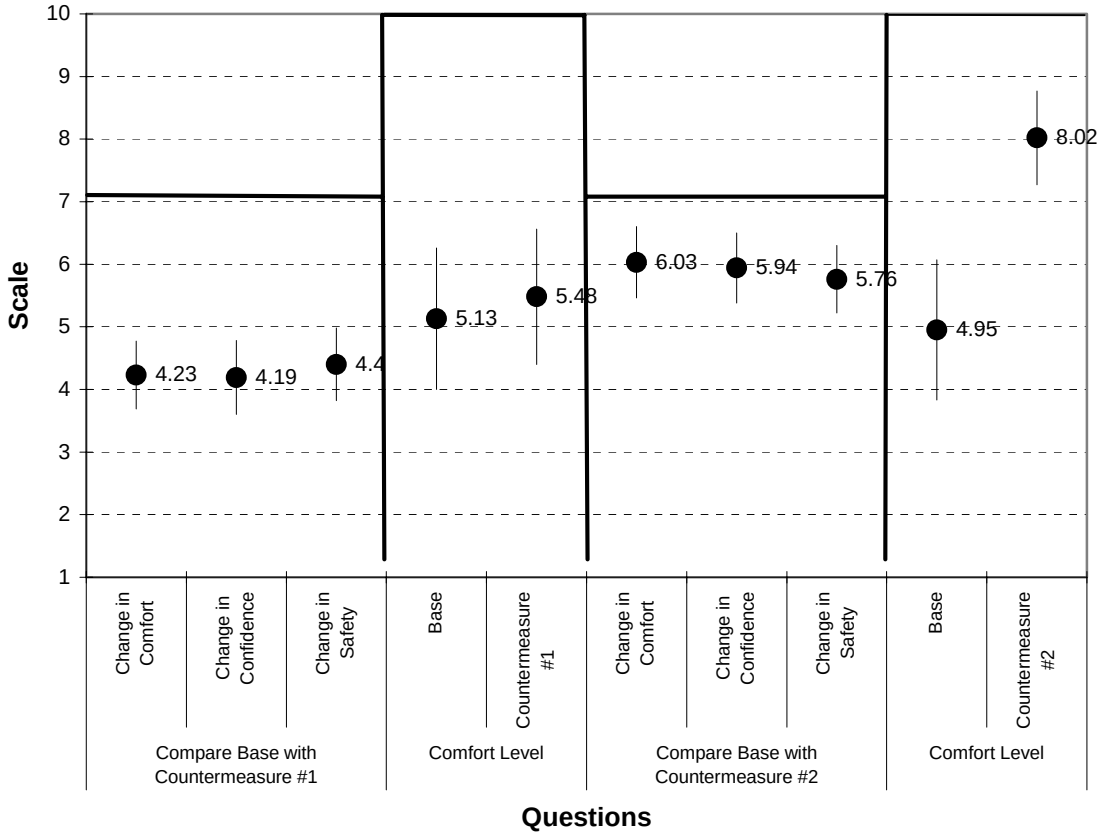
5.88; df = 1, 30) for safety. Figure 6.4 also shows that the increase over the Base Condition in participants' ratings about older drivers' comfort level, on an absolute basis, is greater for Countermeasure #2 than for Countermeasure #1. The improvement in perceived comfort between the Base Condition and Countermeasure #2 was significant at $p < 0.027$ ($F = 5.09$; df = 1, 30).

6.1.5 DESIGN ELEMENT E—EXIT TREATMENT

Exit treatment is used to provide information about the intended exit for drivers passing through the roundabout. In the Base Condition, the street exit sign was placed between two approaches. At this location, the sign provides the street name prior to reaching the intended exit. The same street exit sign was used for Countermeasure #1 but was moved onto the splitter island of the intended exit. The exit sign for Countermeasure #2 was also located on the splitter island, but a horizontal arrow was added to the sign to emphasize the location of the exit. The rating scores for exit signs are shown in Figure 6.5.

Figure 6.5 shows that Countermeasure #1 did not improve the perceived comfort, confidence, or safety of study participants, relative to the Base Condition. The location of the exit sign did not appear to be important to the participants.

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, versus the Base Condition, than with Countermeasure #1 in place. The comparison with Countermeasure #2 was 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).



Note: Comparisons 1, 2, 3, 6, 7, 8: 7-point scale; Comparisons 4, 5, 9, 10: 10-point scale

Figure 6.5 Rating Score for Street Name Signs

6.2 PART B—SUMMARY RESULTS OF DIRECT COMPARISON OF ALTERNATIVES

As described in the previous chapter, a direct comparison of the three alternatives for each design element was performed in Part B of the Phase II study. This approach allowed the participants to compare the three alternatives directly with each other and select one or more scenarios using a series of criteria. The criteria used for ranking the alternatives included the following:

- which scenario was preferred the most,
- which scenario(s) were easiest to understand,

- which scenario(s) were particularly difficult to understand,
- assess the scenario that provides the necessary information to allow for safe negotiation of the roundabout, and
- assess the scenario that would result in the required actions to allow for safe negotiation of the roundabout.

Table 6.1 summarizes the key analyses for the three-alternative comparison. The table shows the most frequent alternatives selected by the participants. It should be pointed out that Table 6.1 includes multiple answers. Consequently, the total number of alternatives selected by the participants may therefore be higher than the total number of subjects.

Table 6.1 Summary of Most Frequently Selected Alternatives

Design Element		Best	Easiest	Difficult	Information	Actions
Advance Warning Signs	Scenario	2	1	B	1	2
	%	58.1%	64.5%	9.7%	77.4%	77.4%
	(C.I.)	(41%–75%)	(48%–81%)	(0%–20%)	(63%–92%)	(63%–92%)
Lane Control Signs	Scenario	2	2	B	2	2
	%	74.2%	71.0%	45.2%	87.1%	83.9%
	(C.I.)	(59%–90%)	(55%–87%)	(28%–63%)	(75%–99%)	(71%–97%)
Directional Signs	Scenario	2	2	B	2	2
	%	83.9%	80.7%	9.7%	93.6%	83.9%
	(C.I.)	(71%–97%)	(67%–95%)	(0%–20%)	(85%–100%)	(71%–97%)
Yield Treatment	Scenario	2	2	1	2	2
	%	61.3%	67.8%	16.1%	80.7%	83.9%
	(C.I.)	(44%–78%)	(51%–84%)	(3%–29%)	(67%–95%)	(71%–97%)
Exit Treatment	Scenario	2	2	B	2	2
	%	87.1%	83.9%	32.3%	90.3%	87.1%
	(C.I.)	(75%–99%)	(71%–97%)	(16%–49%)	(80%–100%)	(75%–99%)

C.I. = 95% Confidence Interval
B = Base Condition
1 = Countermeasure #1
2 = Countermeasure #2

The results of the analysis show that a large portion of the participants found the Base Condition of the lane control signs and exit treatment difficult to understand. On the other hand, Countermeasure #2 was the alternative that was the easiest to understand for four out of the five design elements, the only the exception being the location of the one-way

sign, in which both countermeasures were rated equally. The same outcome can be observed with the information provided by the design element and the required action to allow for a safe negotiation of a roundabout. Finally, participants preferred the plaque with the text “ROUNDABOUT” under the advance warning sign (Countermeasure #1) over an advisory speed (Countermeasure #2) below the warning sign.

The rest of this section focuses on the results obtained for each design element. As described above, these figures include multiple answers. Thus, the percentages may add up to more than 100 percent.

6.2.1 DESIGN ELEMENT A—ADVANCE WARNING SIGNS

Participants selected Countermeasure #2 as the preferred alternative, as seen in Figure 6.6. Countermeasure #1, on the other hand, was the easiest to understand and the one that provided the best information. Interestingly, a small number of participants found the advance warning sign proposed by the *MUTCD* (FHWA 2003) difficult to understand. It is important to point out that *only* descriptive statistics were prepared in this section; inferential statistical tests were not applied in this part of the study because participants were permitted to select one or more groups of alternatives.

6.2.2 DESIGN ELEMENT B—ROUNDABOUT LANE CONTROL SIGNS

Figure 6.7 illustrates that Countermeasure #2 for Design Element B was positively received by a majority of the participants. On the other hand, almost half of the participants found the Base Condition difficult to understand. Countermeasures #1 and #2 were found to be difficult to understand for a few participants. The results seem to suggest that the participants regarded the text “LEFT LANE” and “RIGHT LANE” under the routes as very valuable.

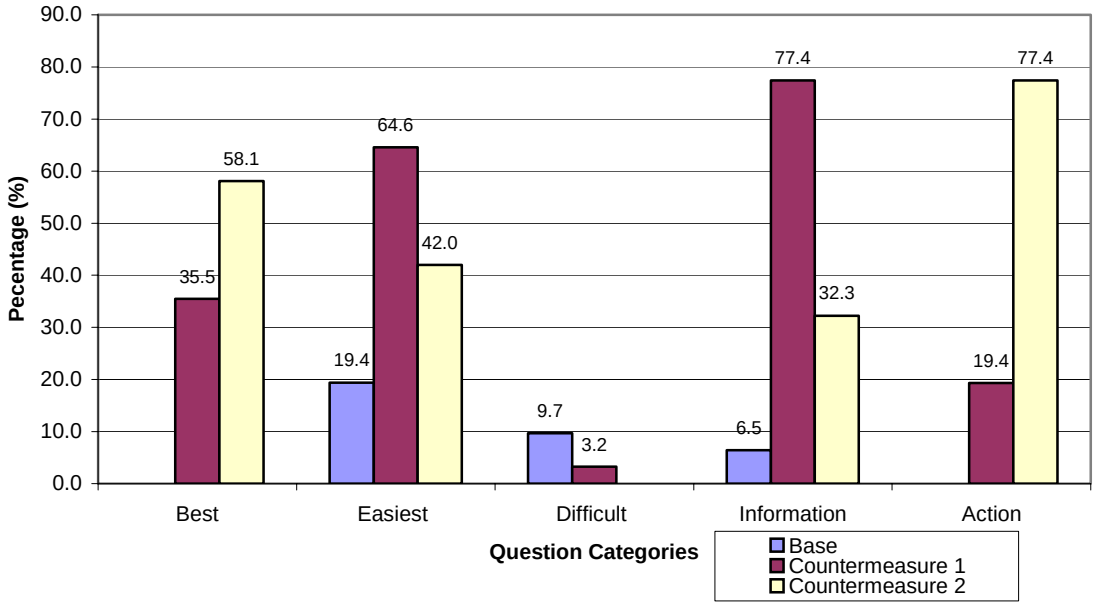


Figure 6.6 Distribution of Responses for Design Element A—Advance Warning Signs

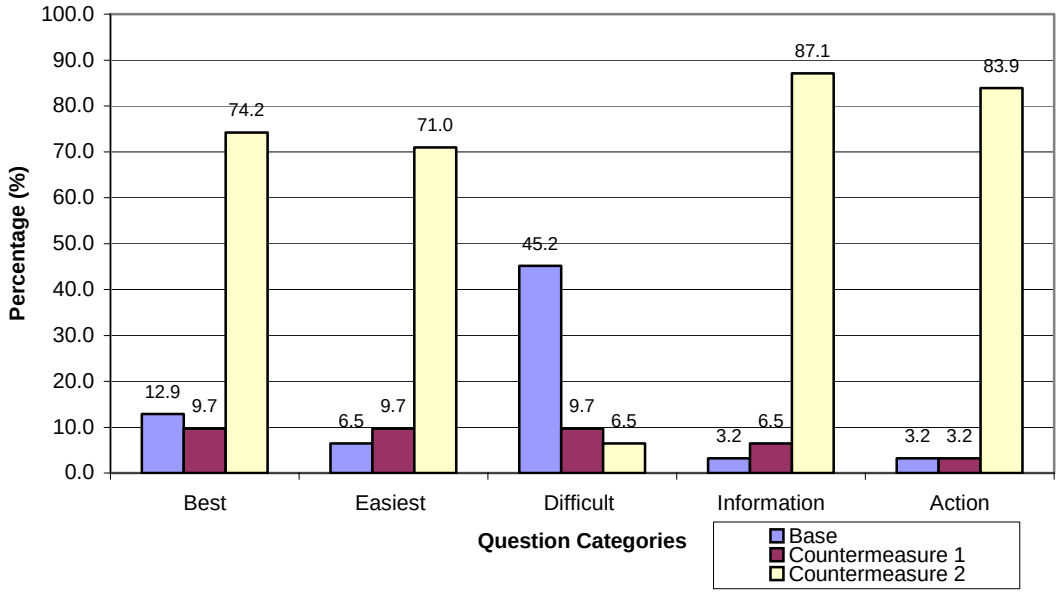


Figure 6.7 Distribution of Responses for Design Element B—Roundabout Lane Control Signs

6.2.3 DESIGN ELEMENT C—DIRECTIONAL SIGNS

The provision of a directional sign was very well received by the participants as shown in Figure 6.8. Although the Base Condition did not create too much difficulty, providing a one-way sign should improve the path guidance process of older drivers. Overall, the sign should preferably be located facing the gore area. This outcome was also reflected in the Phase I study.

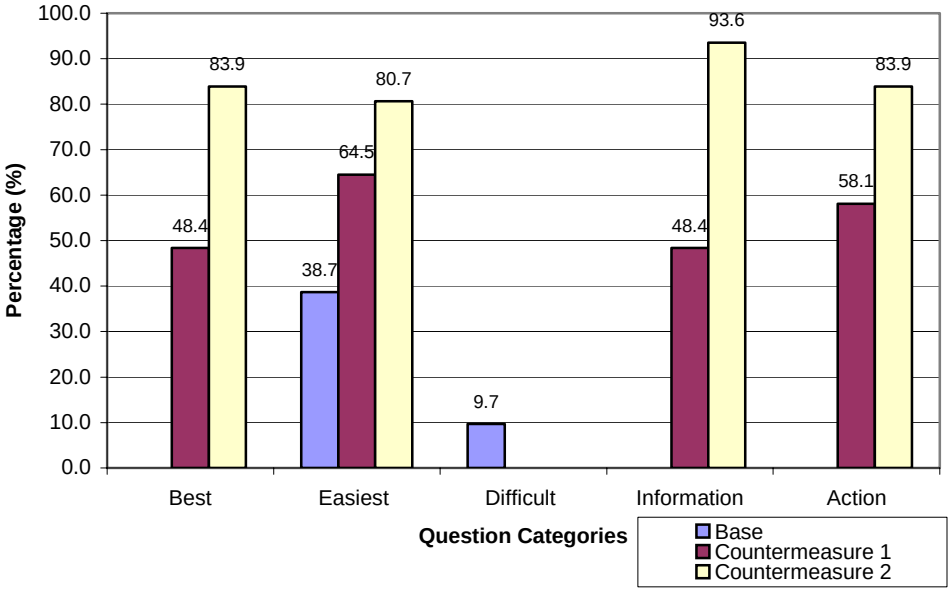


Figure 6.8 Distribution of Responses for Design Element C—Directional Signs

6.2.4 DESIGN ELEMENT D—YIELD TREATMENT

Figure 6.9 illustrates that Countermeasure #2 was selected as the best scenario all around for the yield treatment. Interestingly, despite the issues raised for the base condition in the previous stage of the structured interview, very few participants considered the pavement marking to be problematic during this part of the Phase II study. The difference in response rates can be explained by the fact that the participants now understood the meaning of the isosceles triangles since the interviewer explained the characteristics of the pavement marking at the end of Part A. It is possible that showing the design

elements using static pictures rather than animated video presentations could also better explain this difference.

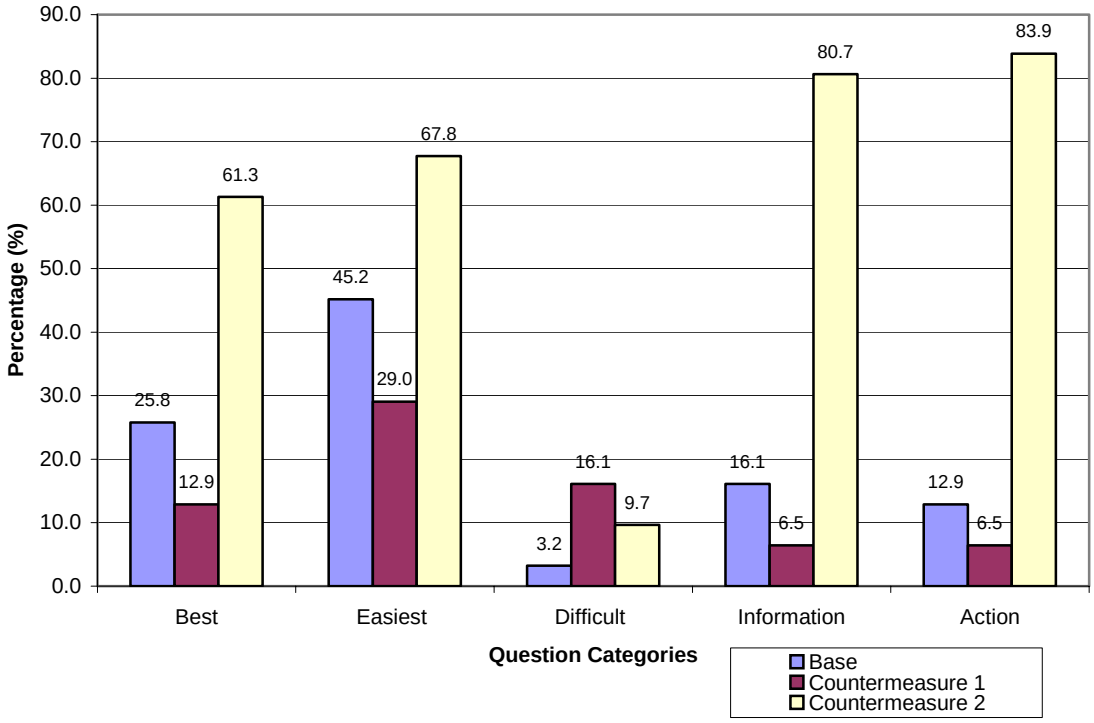


Figure 6.9 Distribution of Responses for Design Element D—Yield Treatment

6.2.5 DESIGN ELEMENT E—EXIT TREATMENT

Figure 6.10 shows that Countermeasure #2 for exit treatment was selected as the preferred alternative for all questions. As was shown in Part A, the participants did not receive the base condition positively. They believed that showing a horizontal arrow on the exit sign was beneficial and reduced uncertainty.

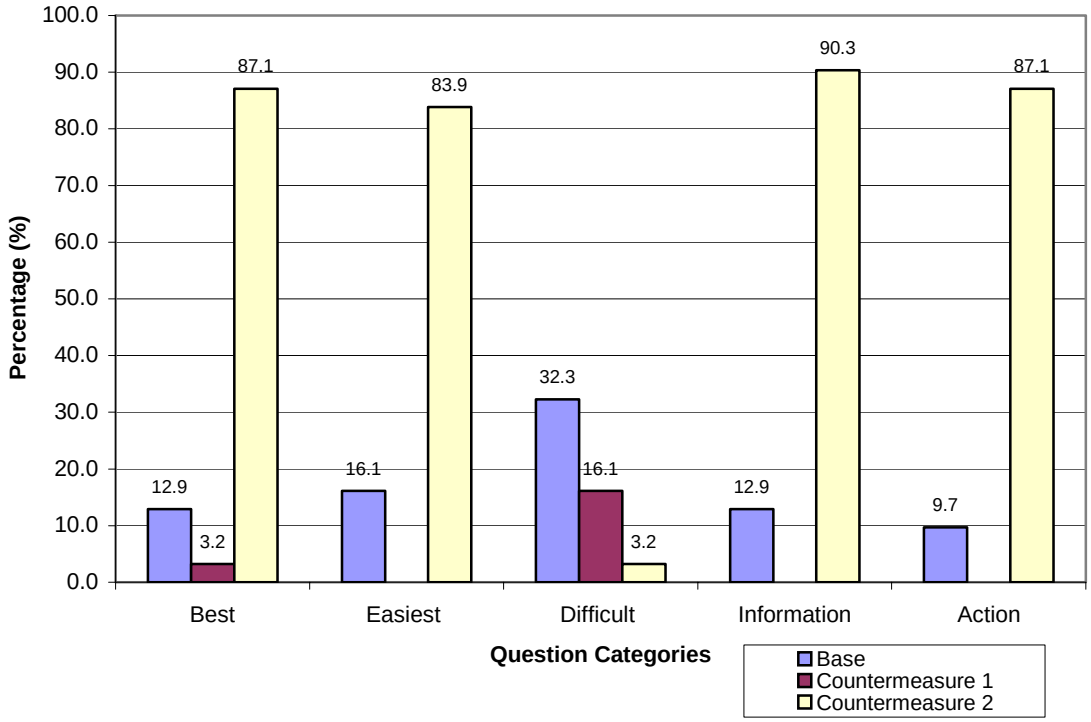


Figure 6.10 Distribution of Responses for Design Element E—Exit Treatment

6.3 PART C—SUMMARY OF PERCEPTIONS AND GENERAL VIEWS

Part C tested the perceptions and general views of the participants regarding the use of roundabouts. The goal was to obtain feedback about:

- the likelihood the participant would avoid using a roundabout;
- the likelihood the participant would come to complete stop at the entrance of a roundabout, whether there are vehicles already engaged in the roundabout or not; and
- the likelihood the participant would remain in the outside lane of the roundabout at all times when using a roundabout, regardless of the destination.

The ratings were evaluated using Likert-type scales, where a participant's response could vary from being in complete disagreement (value = 1) to being in total agreement (value = 6) with the statement presented in each question.

The experiment design also tested the difference in safety when the participant had the choice between making a left turn at an intersection with different traffic control measures:

- at the roundabout,
- at a "4-WAY STOP" controlled intersection,
- at a signalized intersection with a permissive left-turn phase, and
- at a signalized intersection with a protected left-turn phase.

A 7-level rating scale was used to assess the responses, with a value of 1 indicating that the alternative had the lowest level of perceived safety and a value of 7 indicating the highest level of safety.

Figure 6.11 shows the distribution of the responses for the first series of questions. The results show:

- On average, the participants would not avoid a roundabout, since the average score was below 3.

- Many people disagreed with the statement about coming to a complete stop; it would therefore appear that most participants would not stop "unnecessarily" when entering a roundabout (i.e., would not stop unless required by prevailing traffic conditions). This statement contradicts the opinions obtained in the Phase I focus groups study.

- Participants, on average, also indicated that they would not remain in the outside lane of multilane facilities at all times when they negotiated a roundabout. It is important to note that participants may not have completely understood the legality of not remaining on the outside lane when engaged in a roundabout. Thus, this finding may not necessarily be indicative of their actual behavior at roundabouts.

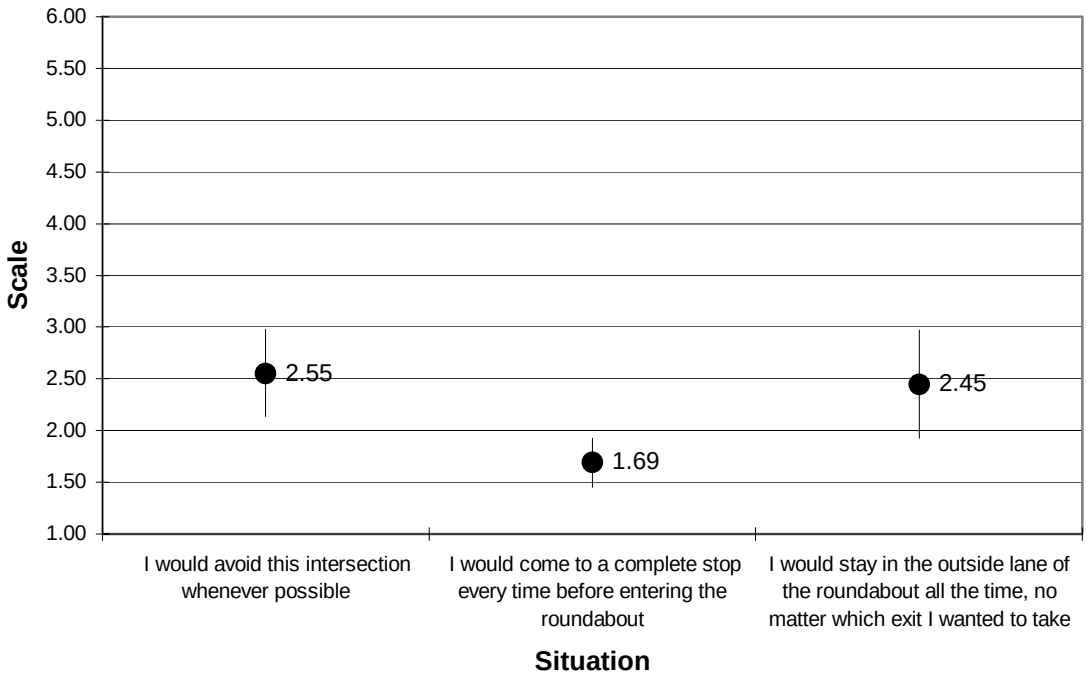


Figure 6.11 Rating Scale for First Series of Questions

Figure 6.12 shows the rating scores for the second series of questions. Participants did not indicate any perceived differences in safety between a roundabout and a four-way stop controlled intersection. Similarly, making a left turn at a signalized intersection with a permissive phase was found to be as safe as making a left turn at a roundabout. Interestingly, most participants felt safer making a left turn at a signalized intersection with a protected left-turn phase than at a roundabout. This outcome is similar to the views expressed by the participants in the Phase I focus groups study. In short, older drivers seem to prefer protected left-turn phasing at signalized intersections over roundabouts.

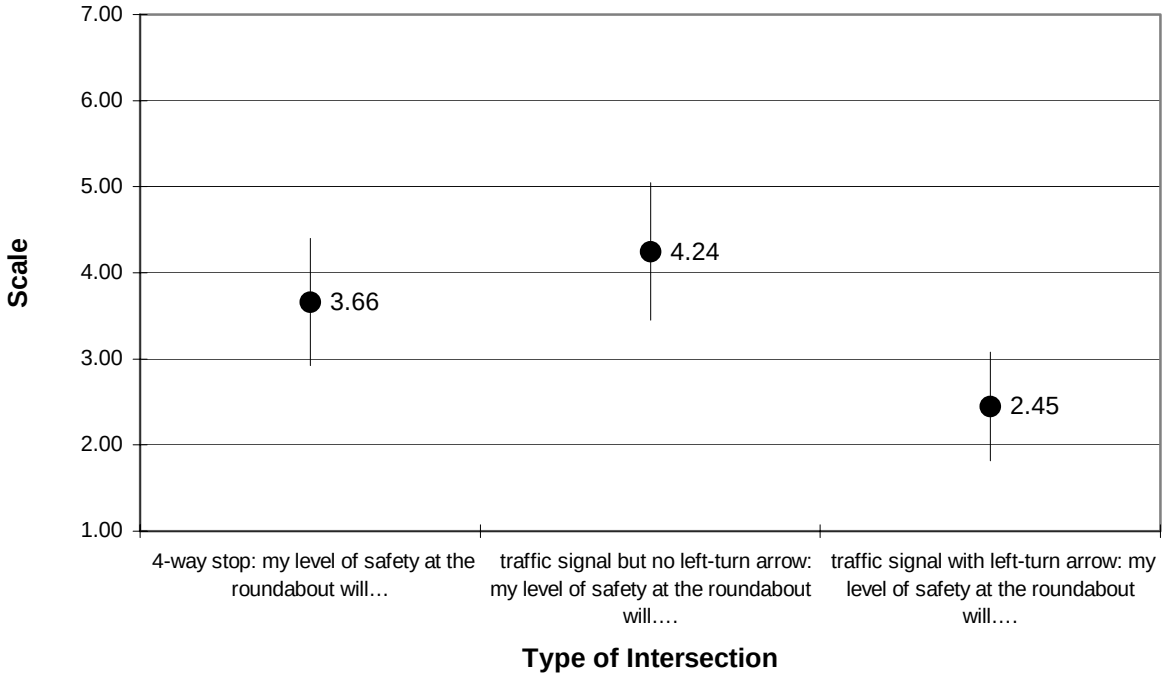


Figure 6.12 Rating Scale for Second Series of Questions

6.4 SUMMARY

This chapter summarized the results and analyses conducted for Phase II, the structured interviews study. The analyses focused on pair-by-pair comparisons between each countermeasure and the base condition, a direct comparison between all three alternatives, and a summary of the perceptions and general views held by study participants regarding the use of roundabouts.

The analyses showed that the participants usually rated the countermeasures positively, with a few exceptions. Providing advance warning signs with the plaque "ROUNDABOUT" and the advisory speed of 30 mph for negotiating a roundabout were both rated positively among participants. Both countermeasures had similar ratings. The participants preferred the use of lane control signs with the text "RIGHT LANE" and "LEFT LANE" over the signs without the text, although the difference was not found to be significant. The installation of one-way signs was found to be positively received by

the participants. Many participants did not understand the yield treatment that made use of isosceles triangles as pavement marking. On the other hand, the plaque “TO TRAFFIC IN CIRCLE” located under the yield sign had a much more positive impact. The location of the exit sign had no effects on the exit treatment. However, the participants were more receptive to signs that showed a horizontal arrow pointing toward the exit.

Overall, results indicate that the participants would not avoid a roundabout if they would have the choice to do so; this outcome is, however, slightly different than the feedback received from the participants of the Phase I focus groups study. Most participants would not stop unnecessarily when entering a roundabout nor would stay in the outside lane of a roundabout.

Despite the fact that roundabouts were generally perceived to be as safe as signalized intersections with a permissive phasing, most participants indicated that they would still prefer making a left turn at a signalized intersection with a protected left-turning phase rather than at a roundabout.

The next chapter summarizes results from the literature review, Phase I, and Phase II of this study and presents opportunities for improving the design of roundabouts to foster their use by older drivers.

CHAPTER 7
SUMMARY AND CONCLUSIONS

This research investigates a strategy to ameliorate the largest source of unintentional injuries in the United States, motor vehicle crashes, by improving the ability of our most vulnerable drivers, the elderly, to safely negotiate the most dangerous and demanding of all traffic situations—intersections. More crashes occur at intersections, resulting in more injuries and fatalities, than in any other driving situation. 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. Coupled with an overwhelming reliance by seniors on private vehicle travel to meet their personal mobility needs—consistently over 90 percent in recent surveys—these trends make it imperative to somehow enhance the proficiency of older drivers at intersections. The present research suggests a way to meet this goal through improvements in highway design and operations, specifically the use of the modern roundabout.

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. If all drivers, and especially older drivers, would increase their use of these highway facilities, and use them properly, a system-wide savings in traffic injuries and fatalities is a very high probability. Accordingly, this research sought to a) identify elements of roundabout design and operations that were problematic for older drivers and b) develop recommendations and guidelines for countermeasures with the potential to improve the comfort, confidence, and safety of seniors in using roundabouts.

A literature review characterized key features of roundabouts, discussed human factors issues in the use of roundabouts, and gave insight into how age-related changes in particular visual, perceptual-cognitive, and physical abilities can translate into highway design parameters. Next, an exploratory crash analysis reinforced the hypothesis that seniors can realize a disproportionate benefit from using roundabouts in preference to

conventional intersections. Focus groups with samples of older drivers further prioritized aspects of roundabout design and operations where the greatest gains in safety and ease of use appear likely. Finally, structured interviews were used in a controlled laboratory simulation (animated video presentation) depicting an approach to and travel through a roundabout, to evaluate countermeasures developed to address these prioritized design and operational elements. Pair-by-pair comparisons between alternative treatments and a base condition, in addition to direct comparisons among countermeasures, provided the substantive empirical data obtained in this research.

The problems with older drivers' use of roundabouts identified in the Phase I study, and subsequently targeted by the countermeasures developed and evaluated in Phase II, 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 presumably lead to higher perceived levels of comfort and safety that, in turn, are believed to mediate decisions about whether to use roundabouts.

The conclusions and recommendations that follow from the study's findings are thus aimed at improving drivers' understanding of:

- the fact that a roundabout will be encountered a short distance ahead on the driver's current path;
- a safe approach speed to the roundabout;
- the number of lanes in the roundabout and which lane(s) is(are) to be used to exit the roundabout in the desired direction;
- the direction of travel of vehicles circulating in the roundabout;
- the need to yield to vehicles already traveling in the roundabout;
- the point during his or her approach to the roundabout that a driver must have decided if it is safe to enter and have slowed or stopped his or her vehicle, if it is not;
- the street name or route number of the next exit available in the roundabout; and

- the location and specific movement required to exit the roundabout on a given street or route.

First, it may be concluded that older drivers are likely to benefit from advance warning signs that include additional information beyond what is provided by the W2-6. On each approach leg, augmenting the W2-6 with a symbol representing the central island of the roundabout is recommended; this adds context and clarifies the meaning of the circular arrows on the sign. Use of the redundant plaque bearing the legend "ROUNDABOUT" is similarly recommended, during at least the initial maintenance cycle after installation of the facility. The addition of an advisory speed panel is also recommended, wherever warranted by engineering judgment. See the example in Figure 7.1.

Figure 7.1 Proposed Advance Warning Sign

The Phase II results further indicate that older drivers could benefit from advance warning about the number of lanes in the roundabout, with lane assignment information keyed to the available exits in the facility. For each approach on multiple-lane facilities, it is recommended that the lane control sign proposed in the *MUTCD* (FHWA 2003) be supplemented with text specifying which lane(s) is(are) to be used for which movements. For either single- or multiple-lane facilities, it is also recommended that the lane control sign be augmented with the central island symbol, for consistency with the enhanced W2-6 design. See the example in Figure 7.2.

Figure 7.2 Proposed Roundabout Guide Sign

A strong conclusion that can be drawn from this research is that older motorists will benefit from additional information that reinforces their understanding of the direction of traffic movement within a roundabout. The posting of one-way (R6-1) signs on the central island that are clearly visible to drivers entering on each leg of the roundabout is recommended. While the optimal placement of these signs may be determined by engineering judgment, use of an oversize panel should be considered when sign conspicuity is reduced due to a complex visual background or when the sign support is partially obscured (e.g., by vegetation). See the example in Figure 7.3.

Figure 7.3 Proposed Directional Sign

Conclusions from Phase II regarding the hypothesized benefits from alternative yield treatments at the entry points to roundabouts are mixed, with seniors appearing to benefit from a treatment that provides a specific reference for this general message, i.e., "to traffic in circle," but not realizing any clear benefit from—perhaps even being confused by—the inverted triangle pavement markings arrayed across the full width of the approach lane(s). Thus, it is recommended that a supplemental panel bearing the legend "TO TRAFFIC IN CIRCLE" be placed immediately below the R1-2 "YIELD" signs on both sides of the road at the entrance to a roundabout. However, pending further study, a dashed line marking the perimeter of the roundabout where it is joined by each intersecting leg appears to provide sufficient information to drivers about where they must exercise yield control over their vehicles. See the example in Figure 7.4.

Figure 7.4 Proposed Yield Treatment

The remaining conclusions to be drawn from Phase II data collection pertain to the recognition of roundabout exit locations and associated vehicle movements; older drivers' understanding of exit operations appeared to be greatly enhanced as a result of one of the tested countermeasures. Accordingly, it is recommended that the name of each intersecting leg on a roundabout be labeled with a sign panel placed on the splitter island for that intersection, facing toward approaching traffic in the roundabout, and that a directional arrow pointing toward the exit leg accompany the street name on the panel.

This recommendation does not rule out the use of an exit name sign placed upstream of the exit gore, i.e., between intersecting streets; indeed, this advance information should be especially helpful to older motorists. But if a single exit name sign is employed, the splitter island placement and design noted above is clearly preferable. See the example in Figure 7.5.

Figure 7.5 Proposed Exit Treatment

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, in naturalistic observations would of course be extremely valuable.

The preceding conclusions and recommendations suggest that there are a number of practical steps engineers can take to increase the perceived comfort and safety of the use of roundabouts by seniors. At the same time, the responses of the older drivers in this research acknowledge an enduring preference for conventional intersections with protected left-turn signal phasing. They also show a troubling perception that left turns at conventional intersections with permissive phasing are as safe as left turns at a roundabout. These findings suggest that information and education about roundabouts,

delivered at a broader, community level, will be necessary to realize potential safety benefits, especially in communities where roundabouts have not previously been used.

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APPENDIX A
FOCUS GROUPS MATERIAL

- Consent form
- Demographics questionnaire
- Script for focus groups*
- DVD of roundabout video clips used during the focus groups

*PowerPoint presentations containing still photos of various roundabouts' layouts, signage, and pavement markings were used as visual aids during the focus groups. These pictures have been inserted directly into the script for the purpose of this report.

PHASE I: CONSENT FORM

INFORMED CONSENT

I have been invited to participate in a group survey concerning the use of roundabouts (also known as traffic circles) at intersections. No prior knowledge or use of these facilities is required to be included in this study. The session is taking place in the offices of the Texas Transportation Institute or other predetermined venues located in Texas. A total of 40 participants will be interviewed in this study. I am being selected as a possible participant because I am aged 65 and older, I possess a valid driver's license, and I have no apparent limitations impeding my ability to drive. I have been instructed to read this form and ask any questions I may have before agreeing to participate in the study

Background Information: The purpose of this study is to understand how older drivers view the use of roundabouts and which design elements could be improved to facilitate their use.

Procedures: If I agree to be in this study, I am asked to observe a presentation consisting of short video clips and pictures of roundabouts. Throughout the presentation, I will be asked to engage in a discussion about the characteristics of the presentation. I will also be asked to complete a brief questionnaire about my driving habits. This session will take no longer than 2 hours. I understand that it is my right to stop participating in the study at any time for any reason without any repercussion. At the end of the interview, I will be paid $40 for my participation. If I ask to leave early, I will be paid adjusted to the portion of the scheduled 2 hours in which I participated.

Confidentiality: This session will be audio taped so that all comments can be captured. There may also be note takers present. I understand the records of this study will be kept confidential. In any sort of report that might be published, no information will be included which may make it possible to identify me. I understand the research records will be kept in a locked file, accessible only to the investigator. I will be asked to sign a form acknowledging payment for my participation. These forms are kept separate from this signed consent form and any other data that would identify me by name.

Voluntary Nature of the Study: My decision whether or not to participate will not affect my current or future relations with the Texas Transportation Institute, Texas A&M University, or the Centers for Disease Control and Prevention (CDC). If I decide to participate, I am free to withdraw at any time without affecting those relationships. A copy of this form will be given to me prior to my proceeding with the experiment if I request it.

Contacts and Questions: The researcher conducting this study is Dr. Dominique Lord of the Texas Transportation Institute. He can be reached at (979) 458-1218 or d-lord@tamu.edu. The Centers for Disease Control and Prevention is funding this project.

This research study has been reviewed and approved by the Institutional Review Board, Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, the Institutional Review Board may be contacted through the IRB Coordinator, Office of Vice President for Research and Associate Provost for Graduate Studies at (979) 845-1811.

Statement of Consent: *I have read and understand the explanation provided me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study. I have been provided a copy of this consent form if I so desire.*

_____ _____

Signature of Research Participant Date

_____ _____

Signature of Principal Investigator Date

PHASE I: DEMOGRAPHICS QUESTIONNAIRE

QUESTIONAIRE

Please circle the appropriate response.

DEMOGRAPHICS

Sex: Male Female

Age: _____ *Zip Code:* _____

Marital Status: Married Divorced Widowed Never Married

Racial Background: White African-American Asian or Pacific Islander

Hispanic Other

Current Employment: Retired Full-Time Part Time

Highest Level of Education Completed: Some High School High School Graduate

Some College or Vocational School College Graduate

Some graduate school Graduate degree

What type of area do you live in permanently? Large City Suburb

Small City Rural Area

DRIVING HISTORY

How many years have you been driving? 1-10 yrs 11-25 yrs 25+ yrs

How long have you lived in the state where you currently permanently reside?
_____ *years*

What other states have you lived in during the last twenty years? (List state and period lived there.)

_____

Do you own a vehicle? Yes No
*If yes, how many vehicles are in your household?*_____

PHASE I: DEMOGRAPHICS QUESTIONNAIRE

How often do you drive a motor vehicle?

_____A few times a year
_____A few times a month
_____A few times a week
_____Once a day
_____Several times a day

How often are you the "navigator" or co-pilot, that is, a passenger who is assisting the driver in reading signs and maps to navigate in an area?

_____A few times a year
_____Once a day
_____A few times a month
_____Several times a day
_____A few times a week

Please circle your primary mode of transportation; what is the most common way you get around town on a daily basis.

_____Drive my own vehicle
_____Take the bus
_____Take a taxi
_____Get a ride from a friend, neighbor, or co-worker
_____Get a ride from a family member

Do you find making left turns at intersections difficult? Yes No

If yes, what type of difficulty are you experiencing?

_____

Have you ever driven through a roundabout or traffic circle before? Yes No

If yes, please answer the questions below:

Where was this/these roundabout(s) located (country, county, city)?

_____

How many times?

_____

Did you understand how to maneuver inside a roundabout?

_____

Did you have difficulty maneuvering inside the roundabout?

_____

Do you find them more difficult than regular intersections?

_____

PHASE I: DEMOGRAPHICS QUESTIONNAIRE

What have you learned about roundabouts today?

After today's discussion, do you think roundabouts are a good idea?

COMMENTS ON TODAY'S STUDY ***Use this space to make any general comments on today's study.***

PHASE I: SCRIPT FOR FOCUS GROUPS

SCRIPT FOR ROUNDABOUT FOCUS GROUPS

INTRODUCTION

Thank you for coming today. My name is Sue Chrysler, and I am a research scientist at the Texas Transportation Institute at Texas A&M University in College Station. We are conducting four focus groups like this one with drivers over the age of 65 to get their thoughts on a new type of roadway intersection called a roundabout. The Centers for Disease Control and Prevention is funding this research in their Injury Prevention area. As a group, older drivers have more of their traffic crashes at intersections than anywhere else. Now, there are many reasons for this, but the CDC feels that if there are traffic engineering improvements which could be made to intersections, there could be fewer crashes involving older drivers. You were selected for participation in today's focus group because you are licensed drivers and are still driving at least three times a week. We want to talk to you because you represent the average driver, and we want to build roads that serve you, the average driver. We will take the results of these focus groups to develop a more scientific test of drivers' understanding of and preference for specific roadway features associated with roundabouts. This test will be conducted later this spring.

Today's session will last approximately two hours, and we will have a short break about halfway through. I have a few ground rules. (ON POWERPOINT)
1) Everyone must participate (and if you don't I will call on you).
2) There are no wrong answers (we want to know when drivers may be confused).
3) One person speaks at a time (for the sake of the tape).

We will be audio taping today's session so that we can transcribe it later. If we report any of your comments, they will be reported anonymously, like "a 72-year-old male driver from Central Texas." If I repeat your comment or identify you by name, that's just so we know who was saying what when we transcribe it.

Any questions about the procedures?

Let's take a moment and introduce ourselves. Please tell us your first name, where you live, and how long you've lived there.

Let's look at some photos of roundabouts and let me explain a little bit. Then we're going to begin today's session by watching a 10-minute video produced by the Washington State Department of Transportation.

SHOW OVERVIEW PHOTOS (PowerPoint presentation)

PHASE I: SCRIPT FOR FOCUS GROUPS

Roundabouts can be:

- single or double lane
- not used where there is high traffic (e.g., Holleman and Anderson)
- not used where there is an imbalance in traffic on one leg

This video will explain what roundabouts are and how you are supposed to drive on them. If you think of a comment or question while watching the video, please jot it down on your notepad, and we will discuss it when the video is complete.

SHOW INSTRUCTIONAL VIDEO (DVD)

Can everyone hear?

OK, so did anyone have any questions or comments they thought of while watching the video?

Do you think roundabouts sound like a good idea?

Do you think the video did a good job of explaining the benefits of roundabouts?

Do you think the video did a good job of explaining how to safely drive a roundabout?

Do you think you would know how to drive a roundabout if you had not seen the video? (Use a board with a simple roundabout diagram if necessary.)

Has anyone driven a roundabout like this?

- Where was it?
- What was your experience?

INFORMATION NEEDS QUESTIONS—START GENERAL ASKING ABOUT COMFORT, RIGHT OF WAY, SPEED, AND LANE ASSIGNMENT

For the rest of today's session we will watch a series of videos of actual roundabouts in use which were filmed in Washington state. I'll ask you to discuss your understanding and comfort with roundabouts in general, and then later we'll talk about some specific roadway features like signs and curbs.

First we'll look at some simple roundabouts like you'd find in a residential area. All the video was shot from a car driver's perspective. We'll see two different intersections. For each intersection, the first pass will show you going straight through, and the second pass will show a left turn. As you watch these I just want you to put yourself in the role of the driver and watch how the other traffic behaves in the roundabout. Feel free to jot down your impressions which we'll discuss after we've watched all of them. I'm especially interested in hearing your opinion on items that may make you feel unsafe or uncomfortable if you were driving through these intersections.

Show Videos 10/11 and 32/33 (These are all single-lane entrance and single lanes in circle.)

PHASE I: SCRIPT FOR FOCUS GROUPS

Take note of other traffic in the circle.

Does anyone have any comments?
Make sure they address:

- comfort in use
- right of way
- speed choice
- left-turn movement

What was the first thing you noticed that clued you in that there was a roundabout coming up?

CHECK: Is everyone contributing? Is one person dominating? Does tape need to be changed?

Now let's watch some videotape from some larger roundabouts and talk about those. Again, jot down any comments and impressions you think of while watching the tapes.

Show Videos 23, 24, 25, 26 (These are all two-lane approach and two lanes in circle.)

Notice where the vehicle places itself at the entry.
Think about how this compares to the single-lane roundabouts we just saw.

Does anyone have any comments?
Make sure they address:

- comfort in use
- right of way
- speed choice
- lane choice in circle
- lane choice on two-lane approaches
- left-turn movement

Was there anything about the scene that made you feel unsafe or uncomfortable?

What about the other drivers may make you feel uncomfortable?

Can you imagine what they may look like at night? What would make you feel comfortable at night?

What would help you feel more comfortable?

OK, good. Now I will show some shorter video clips to address some specific items in the scene. You may have noticed some differences among the various roundabouts we showed you in terms of landscaping, pavement type, curbs, road stripes, and signs. These are all things that can be designed and selected by traffic engineers. As I show you the next series of video clips, I will ask you to focus your attention on specific items.

PHASE I: SCRIPT FOR FOCUS GROUPS

CENTRAL ISLAND
In the first series of runs, I want you to pay attention to the central island area of the different roundabouts shown. Notice the materials used in the central island, the curb area, the road striping around it, and the landscaping in it. By curb, I mean the raised concrete perimeter around the central island. We will talk about signs later. Some of these video clips are from roundabouts you've seen already, and some are new.

SHOW 26 (bare, roundabout 3)
19 (tall landscape, roundabout 10)

HAVE POWERPOINT READY WITH CENTRAL ISLAND FILE

What did you notice about the central islands?
Make sure they address:

- size of circle
- landscaping
  - Does landscaping help identify that there's a roundabout up ahead while you're approaching it?
  - What other landscaping or objects would you like to see placed in that central island? **(SHOW PHOTOS)**

  - Do you think those would improve or hurt the safety of the intersection? Address visibility and obscuration.
- contrasting pavement and curb
  - Does the contrasting brick help you see the edge of the circle?

PHASE I: SCRIPT FOR FOCUS GROUPS

SPLITTER ISLAND/APPROACH GORE

Now let's concentrate on the approach to the roundabout. In this next series pay attention to how traffic is diverted as it approaches the entrance to the roundabout. You'll notice some different road striping, some different curb types, and some landscaping. Again, we'll talk about signs later. For now focus your attention on the roadway and curb area.

Discuss:

- island size
- curb type
- landscaping
- striping

SHOW 17 (roundabout 9, average-sized splitter with pedestrian crossing)
8 (roundabout 4, long gore with small splitter)
24 (roundabout 2, long splitter with bushes)

HAVE POWERPOINT READY WITH PHOTOS

What did you think of those?
Do you think one would be more effective in slowing driver down as they approached the roundabout?

What other designs of paint or curbs do you think would make you feel safe and comfortable approaching a roundabout?

SHOW PHOTOS IF NECESSARY

PHASE I: SCRIPT FOR FOCUS GROUPS

Which treatment did you like the best? Why?

Make sure they address:

- landscaping
  - curb color
  - amount and style of gore striping
  - longitudinal length of gore markings
- splitter island
  - splitter island size
  - splitter island color
- yield bars
  - Do you think they helped?

PROBABLY TIME FOR A BREAK HERE

APPROACH SIGNS, WARNING AND GUIDE

On this next set of passes I want you to pay attention to the signs. I know that it's difficult to see some of the signs in the video. After we're done watching them, we'll talk about what kinds of information you'd like in a sign as you approach a roundabout. I've got some examples of signs in blown-up photos that I can show you. Again, make notes during the tape if you need to.

SHOW 32 (roundabout 7, yield ahead and roundabout ahead)
36 (roundabout 9, rectangular sign)

Let's say you were a block away from a roundabout. What kind of information would you like to have before you got there?

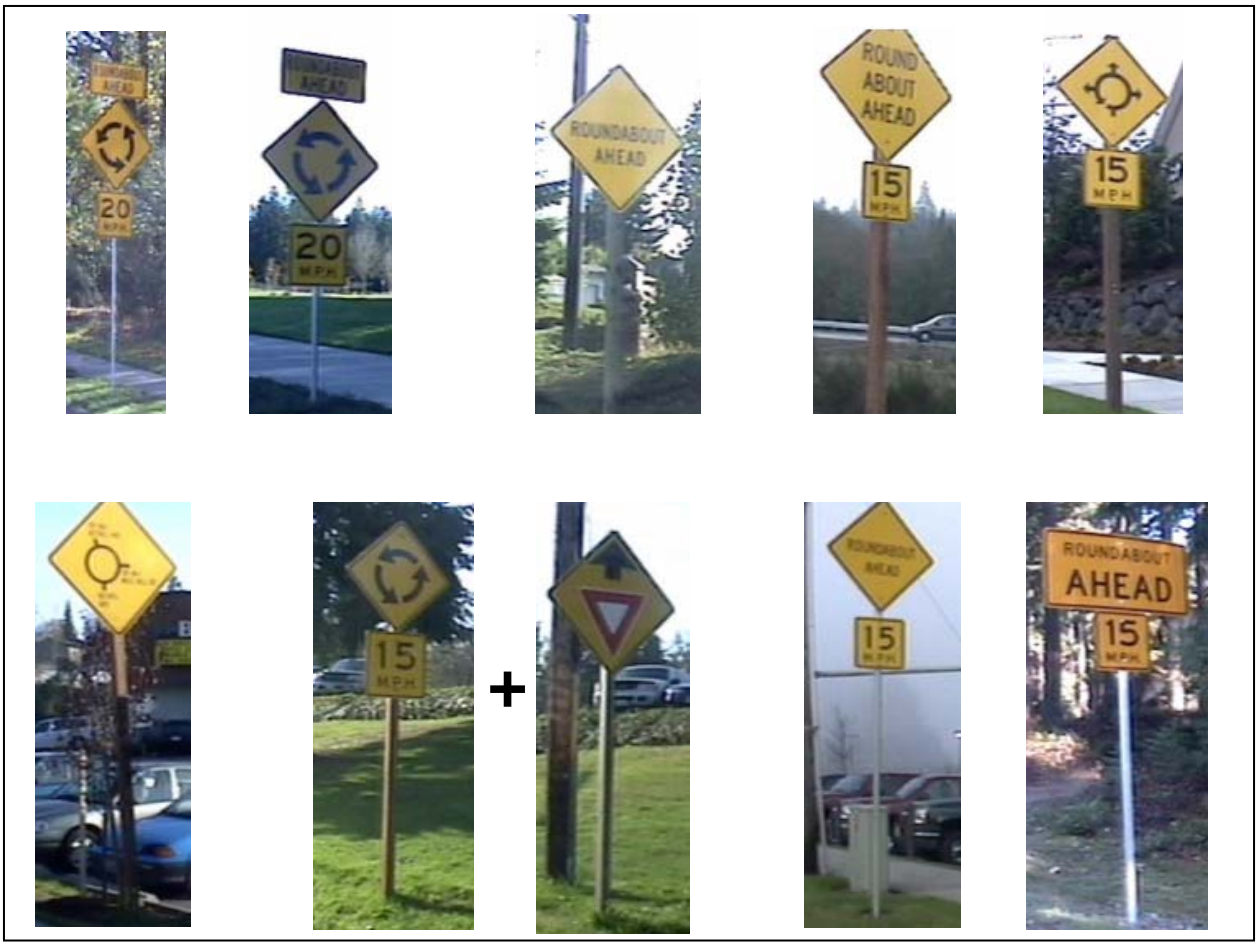
If you had to put a single sign up, what would it be?
(Give them an opportunity to draw on the flip chart, trying to see if they think warning or guide is more important.)

What colors should these signs be?
What shape should these signs be?

PHASE I: SCRIPT FOR FOCUS GROUPS

What side of the road should these signs be on?
Should they be repeated more than once?

SHOW EXAMPLES OF "ROUNDABOUT AHEAD" SIGN



Do you think this sign is necessary?
What action would you take if you saw this sign?
Did you like the speed advisory plaque?
Which one do you like best?
Can you think of a different sign that would convey this message?

PHASE I: SCRIPT FOR FOCUS GROUPS

SHOW EXAMPLES OF ADVANCE GUIDE

Do you think this type of sign is necessary?
What action would you take if you saw this sign?
Which one do you like best?
Why?
Could you read each sign?
Can you think of a different sign that would convey this message?

In some of these photos, there were signs and markings for where there are **two lanes** leading up to the roundabout

Did you see a sign or road marking in any of the videos or photos that was trying to tell you which lane to be in?

What information do you need as you approach this kind of roundabout?

Do you remember which lane you're supposed to be in if you want to turn left?

Can you draw that sign or road marking that explains this?

Can you think of a new sign or marking that could be used at these two-lane entrances?

PHASE I: SCRIPT FOR FOCUS GROUPS

What do you think of these signs?

SHOW STILL PHOTOS OF ADVANCE LANE ASSIGNMENT, INCLUDE PHOTO OF PAVEMENT MARKINGS

Which one do you like best?
Why?
Can you think of a different sign that would convey this message?
Do you think you need both signs and road markings? Would one alone be enough?

What would help you feel more comfortable?

ENTRANCE AREA SIGNS AND MARKINGS

In the next set of video clips, I want you to pay attention to the entrance area (point to board with drawing). Look for the signs in the vicinity of the entrance. Remember to make any notes as you watch the video.

PHASE I: SCRIPT FOR FOCUS GROUPS

SHOW VIDEO OF APPROACH AND INITIAL TURN INTO CIRCLE. I DON'T THINK WE NEED TO SHOW THE WHOLE PASS.

SHOW 8 (Roundabout 4, no yield bar)
10 (Roundabout 5, pedestrian sign, contrast brick)

What kinds of information do you need as you are entering a roundabout?
Make sure they address:

- no left turn
- one way
- speed
- yield
- lane assignment

Do you think the roundabouts in the video provided all this information?

SHOW PHOTOS OF ROUNDABOUT ENTRANCES

PHASE I: SCRIPT FOR FOCUS GROUPS

Was there a particular sign or marking that did a really good or really bad job?

Do you think we need two yield signs?

Where at the entrance should the yield signs be placed?

SHOW STILL PHOTOS OF ONE WAY/CHEVRON

PHASE I: SCRIPT FOR FOCUS GROUPS

Where in the road do you think one-way signs should be placed (use diagram on board)?

Do you think we need both one-way signs and chevrons?

EXIT SIGNS

In this next group of video clips, I want you to pay attention to the signs which mark the exits. These include street name signs with and without arrows. I want you to note where they are placed, how they are designed, and how legible they are. Like before, you'll get a chance to see some still photographs of some of them after we've talked for a bit.

SHOW 1 (roundabout 1, freeway)
25 (roundabout 3, SNS)
27 (roundabout 4, route shield)

What street name or exit information do drivers need?

What else would help you know where and when to exit?

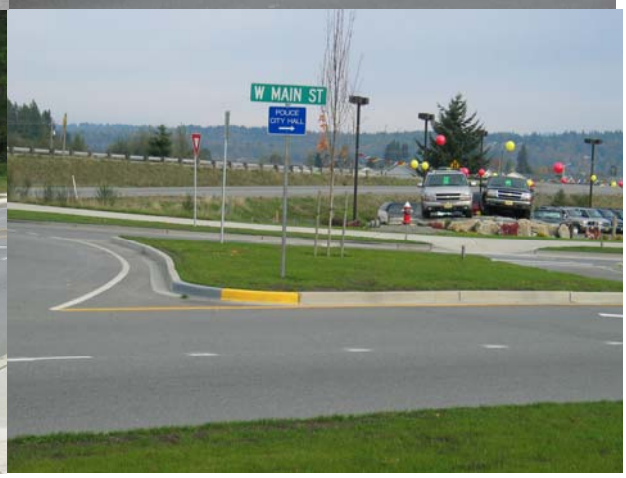
What did you think of the placement of these signs?
Make sure they address:

- splitter versus corner
- height

If we have street name signs on each leg of the roundabout, do we still need the advance sign that shows the name of each street as you're approaching the intersection?

PHASE I: SCRIPT FOR FOCUS GROUPS

SHOW PHOTOS OF SIGNS



PHASE I: SCRIPT FOR FOCUS GROUPS

Which one of these do you like the best?

What do you think of this one that has an arrow built in? Do you think you'd notice that little arrow while driving through the roundabout?

Should the letters be all uppercase or mixed case?

Can anyone think of a different design which may be better? Would this new design be just for roundabouts or would it be better at regular intersections too?

IF TIME, ASK

PAVEMENT MARKINGS IN CIRCLE FOR TWO LANE

Now I'm going to show you some video of driving through a two-lane roundabout. I want you to pay attention to the road markings.

SHOW 1 (roundabout 1, right turn lane marked)
25 (little marking)

PHASE I: SCRIPT FOR FOCUS GROUPS

What information do you need while you are driving in the circle?

How can we make it clear when it is safe and legal to change lanes?

Do you think most drivers will pay attention to these road markings?

What other types of striping could we use to communicate to drivers?

PEDESTRIAN FACILITIES

Lastly, let's talk about pedestrian crossings at roundabouts. In this next set of videos pay attention to the pedestrian crossing areas both at the entrance and the exit.

First, let me ask, do you think it's safe to have pedestrians trying to cross the street in these areas? Why or why not?

SHOW VIDEO WITH VARIOUS CROSSWALK TREATMENTS INCLUDING CONTRASTING BRICK. ALSO FLASHING BEACON.

Which pedestrian crosswalk do you think would help alert you as a driver that there may be a pedestrian?

Make sure they address:

- landscaping hiding pedestrians
- flashing beacon
- pedestrian crossing signs at exits

Do you think there should be traffic lights to stop traffic for pedestrians, where the pedestrian would push a button to activate a red light?

PHASE I: DVD OF ROUNDABOUT VIDEO CLIPS

Folder: DVD of Roundabout Video Clips Used During the Focus Groups

APPENDIX B
STRUCTURED INTERVIEWS MATERIAL

- Consent form
- Questionnaire for Stage 1
- Questionnaire for Stage 2
- Questionnaire for Stage 3
- Demographic questionnaire
- PowerPoint slide presentation used for the structured interviews

*PowerPoint presentations containing still photos of various roundabouts' layouts, signage, and pavement markings were used as visual aids during the focus groups. These pictures have been inserted directly into the script for the purpose of this report.

PHASE II: CONSENT FORM

Participant #_____

INFORMED CONSENT

I have been invited to participate in a survey concerning the use of roundabouts (also known as traffic circles) at intersections. No prior knowledge or use of these facilities is required to be included in this study. The session is taking place in the offices of the Texas Transportation Institute or other predetermined venues located in Texas. A total of 30 participants will be interviewed in this study. I am being selected as a possible participant because I am aged 65 and older, I possess a valid driver's license, and I have no apparent limitations impeding my ability to drive. I have been instructed to read this form and ask any questions I may have before agreeing to participate in the study

Background Information: The purpose of this study is to understand how older drivers view the use of roundabouts and which design elements could be improved to facilitate their use.

Procedures: If I agree to be in this study, I am asked to observe a presentation consisting of short video clips and pictures of roundabouts. Throughout the presentation, I will be asked to complete an opinion survey and rating scale about the video. I will also be asked to complete a brief questionnaire about my driving habits. This session will take no longer than 90 minutes. I understand that it is my right to stop participating in the study at any time for any reason without any repercussion. At the end of the interview, I will be paid $40 for my participation. If I ask to leave early, I will be paid adjusted to the portion of the scheduled 2 hours in which I participated.

Confidentiality: This session will be audio taped so that all comments can be captured. There may also be note takers present. I understand the records of this study will be kept private. In any sort of report that might be published, no information will be included which may make it possible to identify me. I understand the research records will be kept in a locked file, accessible only to the investigator. I will be asked to sign a form acknowledging payment for my participation. These forms are kept separate from this signed consent form and any other data that would identify me by name.

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This research study has been reviewed and approved by the Institutional Review Board, Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, the Institutional Review Board may be contacted through the IRB Coordinator, Office of Vice President for Research and Associate Provost for Graduate Studies at (979) 845-1811.

Statement of Consent: *I have read and understand the explanation provided me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study. I have been provided a copy of this consent form if I so desire.*

_____ _____

Signature of Research Participant Date

_____ _____

Signature of Principal Investigator Date

PHASE II: QUESTIONNAIRE FOR STAGE 1

Participant #_____

Form A

Use this scale of 1 to 7 to answer each question below.

1	2	3	4	5	6	7
It would be *significantly lower* with Drive 1	It would be *a lot lower* with Drive 1	It would be *a little bit lower* with Drive 1	It would be *the same—no change* with Drive 1	It would be *a little bit higher* with Drive 1	It would be *a lot higher* with Drive 1	It would be *significantly higher* with Drive 1

_____ Compared to the first drive, how would your level of **comfort** change, if at all, based on the new feature included in the second drive?

_____ Compared to the first drive, how would your level of **confidence** that you are using the roundabout correctly change, if at all, based on the new feature included in the second drive?

_____ Compared to the first drive, how would your **feeling of safety** change, if at all, based on the new feature included in the second drive?

****

Thinking about 10 average drivers your age, how many do you think will feel comfortable when they see the sign or marking that is shown

in the first drive _____ out of 10 drivers will feel comfortable.

in the second drive _____ out of 10 drivers will feel comfortable.

****

PHASE II: QUESTIONNAIRE FOR STAGE 2

Participant #_____

Form B

Use this scale of 1 to 7 to answer each question below.

1	2	3	4	5	6	7
It would be *significantly lower* with Drive 1	It would be *a lot lower* with Drive 1	It would be *a little bit lower* with Drive 1	It would be *the same—no change*	It would be *a little bit higher* with Drive 1	It would be *a lot higher* with Drive 1	It would be *significantly higher* with Drive 1

_____ Compared to the first drive, how would your level of **comfort** change, if at all, based on the new feature included in the third drive?

_____ Compared to the first drive, how would your level of **confidence** that you are using the roundabout correctly change, if at all, based on the new feature included in the third drive?

_____ Compared to the first drive, how would your **feeling of safety** change, if at all, based on the new feature included in the third drive?

****

Thinking about 10 average drivers your age, how many do you think will feel comfortable when they see the sign or marking that is shown

in the first drive _____ out of 10 drivers will feel comfortable.

in the second drive _____ out of 10 drivers will feel comfortable.

****

PHASE II: QUESTIONNAIRE FOR STAGE 3

Participant #_____

Form C-1: Warning Sign

Looking at these three photos of the different signs you just saw, your ratings from before indicate that you liked this one (point to it) best.

Why do you like that one best?

Which one of these signs did you find the **easiest to understand**?

1	2	3

Was there one of these, or more, that you found **particularly difficult to understand w**hat it was trying to tell you?

1	2	3

Which sign do you think will do the best job of getting other drivers to become aware that **there is a roundabout ahead**?

1	2	3

Which sign do you think will do the best job of **getting other drivers to slow down as they approach the roundabout**?

1	2	3

* These highlighted sections will have to be changed for each design element.

PHASE II: QUESTIONNAIRE FOR STAGE 3

Participant #_____

Form C-2: Guide Sign

Looking at these three photos of the different signs you just saw, your ratings from before indicate that you liked this one (point to it) best.

Why do you like that one best?

Which one of these signs did you find the **easiest to understand**?

1	2	3

Was there one of these, or more, that you found **particularly difficult to understand** what it was trying to tell you?

1	2	3

Which sign do you think will do the best job of getting other drivers to **know which lane to travel in through the roundabout**?

1	2	3

Which sign do you think will do the best job of getting other drivers to **choose the correct lane based on their destination**?

1	2	3

PHASE II: QUESTIONNAIRE FOR STAGE 3

Participant #_____

Form C-3: Directional Sign

Looking at these three photos of the different signs you just saw, your ratings from before indicate that you liked this one (point to it) best.

Why do you like that one best?

Which one of these signs did you find the **easiest to understand**?

1	2	3

Was there one of these, or more, that you found **particularly difficult to understand** what it was trying to tell you?

1	2	3

Which sign do you think will do the best job of getting **other drivers to become aware of the direction that traffic is traveling around the roundabout**?

1	2	3

Which sign do you think will do the best job of getting **other drivers to look for conflicts with approaching traffic in the roundabout before entering**?

1	2	3

Which sign do you think will do the best job of **keeping people from turning the wrong way into the roundabout**?

1	2	3

PHASE II: QUESTIONNAIRE FOR STAGE 3

Participant #_____

Form C-4: Yield Treatment

Looking at these three photos of the different signs you just saw, your ratings from before indicate that you liked this one (point to it) best.

Why do you like that one best?

Which one of these signs did you find the **easiest to understand**?

1	2	3

Was there one of these, or more, that you found **particularly difficult to understand** what it was trying to tell you?

1	2	3

Which sign do you think will do the best job of getting other drivers to become aware **that traffic in the roundabout has right of way**?

1	2	3

Which sign do you think will do the best job of getting other drivers to **yield to traffic in the roundabout**?

1	2	3

* These highlighted sections will have to be changed for each design element.

PHASE II: QUESTIONNAIRE FOR STAGE 3

Participant #_____

Form C-5: Street Name Sign at Exit

Looking at these three photos of the different signs you just saw, your ratings from before indicate that you liked this one (point to it) best.

Why do you like that one best?

Which one of these signs did you find the **easiest to understand**?

1	2	3

Was there one of these, or more, that you found **particularly difficult to understand** what it was trying to tell you?

1	2	3

Which sign do you think will do the best job of getting **other drivers to become aware that the next exit is Jones Road**?

1	2	3

Which sign do you think will do the best job of getting **other drivers to make speed and lane adjustments early enough to safely exit the roundabout**?

1	2	3

* These highlighted sections will have to be changed for each design element.

PHASE II: QUESTIONNAIRE FOR STAGE 3

Participant #_____

Form D

(Line up the five photos representing their favorites for each design element.)

Let's pretend we've built the dream roundabout that has your favorite signs and markings.

Please indicate how strongly you agree or disagree with the following statements about these signs using this scale:

1	2	3	4	5	6
Very Strongly Disagree	Strongly Disagree	Slightly Disagree	Slightly Agree	Strongly Agree	Very Strongly Agree

_____ I would avoid this intersection whenever possible.

_____ I would come to a complete stop every time before entering the roundabout.

_____ I would stay in the outside lane of the roundabout all the time, no matter which exit I wanted to take.

Now, I want you to think about driving through this roundabout and <u>making a left turn</u>. Using this scale of 1 to 7, answer each question below.

1	2	3	4	5	6	7
It would be *significantly lower* with the roundabout	It would be *a lot lower* with the roundabout	It would be *a little bit lower* with the roundabout	It would be *the same—no change*	It would be *a little bit higher* with the roundabout	It would be *a lot higher* with the roundabout	It would be *significantly higher* with the roundabout

_____Compare in your mind making a left turn in this roundabout to making a left turn at a regular intersection with a four-way stop sign. How would your feeling of safety change?

_____Compare in your mind making a left turn in this roundabout to making a left turn at a regular intersection with a traffic light but no turn arrow. How would your feeling of safety change?

_____Compare in your mind making a left turn in this roundabout to making a left turn at a regular intersection with a traffic light with a turn arrow. How would your feeling of safety change?

PHASE II: DEMOGRAPHICS QUESTIONNAIRE

Please circle the appropriate response.

DEMOGRAPHICS

Sex: Male Female

Age: _____ *Zip Code:* _____

Marital Status: Married Divorced Widowed Never Married

Racial Background: White African-American Asian or Pacific Islander

Hispanic Other

Current Employment: Retired Full Time Part Time

Highest Level of Education Completed: Some High School High School Graduate

Some College or Vocational School College Graduate

Some graduate school Graduate degree

What type of area do you live in permanently? Large City Suburb

Small City Rural Area

DRIVING HISTORY

How many years have you been driving? 1-10 yrs 11-25 yrs 25+ yrs

How long have you lived in the state where you currently permanently reside?
_____ *years*

What other states have you lived in during the last twenty years? (List state and period lived there.)

_____

Do you own a vehicle? Yes No
*If yes, how many vehicles are in your household?*_____

PHASE II: DEMOGRAPHICS QUESTIONNAIRE

How often do you drive a motor vehicle?

_____A few times a year
_____A few times a month
_____A few times a week
_____Once a day
_____Several times a day

How often are you the "navigator" or co-pilot, that is, a passenger who is assisting the driver in reading signs and maps to navigate in an area?

_____A few times a year
_____Once a day
_____A few times a month
_____Several times a day
_____A few times a week

Please circle your primary mode of transportation; what is the most common way you get around town on a daily basis.

_____Drive my own vehicle
_____Take the bus
_____Take a taxi
_____Get a ride from a friend, neighbor, or co-worker
_____Get a ride from a family member

Do you find making left turns at intersections difficult? Yes No

If yes, what type of difficulty are you experiencing?

_____

Have you ever driven through a roundabout or traffic circle before? Yes No

If yes, please answer the questions below:

Where was this (these) roundabout(s) located (country, county, city)?

_____

How many times?

_____

Did you understand how to maneuver inside a roundabout?

_____

Did you have difficulty maneuvering inside the roundabout?

_____

Do you find them more difficult than a regular intersection?

_____

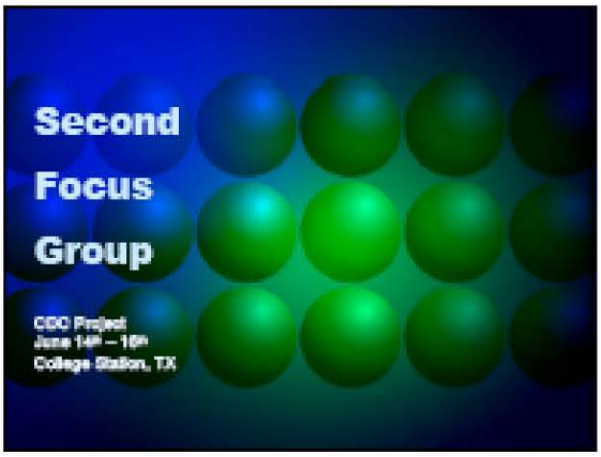
PHASE II: DEMOGRAPHICS QUESTIONNAIRE

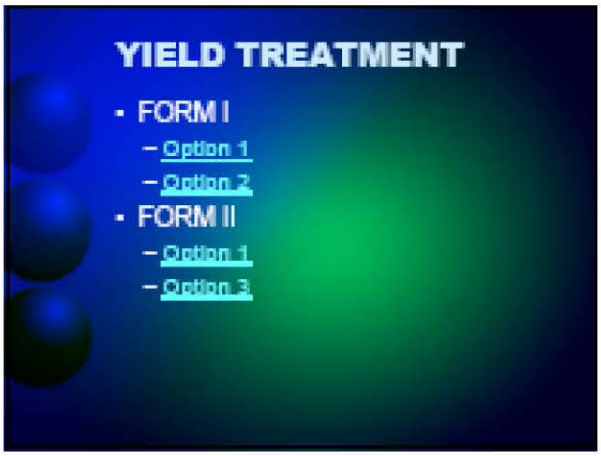
What have you learned about roundabouts today?

After today's discussion, do you think roundabouts are a good idea?

COMMENTS ON TODAY'S STUDY ***Use this space to make any general comments on today's study.***

PHASE II: POWERPOINT SLIDE PRESENTATION





PHASE II: POWERPOINT SLIDE PRESENTATION