Pedestrian Access to Modern Roundabouts: Design and Operational Issues for Pedestrians who are Blind

Figure 1. Chief Okemos Roundabout (Okemos, Michigan)
Photo courtesy of Dave Sonnenberg, Director of Traffic and Safety, Ingham County, Michigan Road Commission

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BACKGROUND

Roundabouts are replacing traditional intersections in many parts of the U.S. This trend has led to concerns about the accessibility of these free-flowing intersections to pedestrians who are blind and visually impaired. Most pedestrians who cross streets at roundabouts use their vision to identify a ‘crossable’ gap between vehicles. While crossing, they visually monitor the movements of approaching traffic and take evasive action when necessary. Blind pedestrians rely primarily on auditory information to make judgments about when it is appropriate to begin crossing a street. Little research has been conducted about the usefulness of such non-visual information for crossing streets at roundabouts. Recent research sponsored by the Access Board, the National Eye Institute, and the American Council of the Blind suggests that some roundabouts can present significant accessibility challenges and risks to the blind user (for a link to an abstract of this research, see the Resources section).
section at the end of this document). This bulletin:

- summarizes orientation and mobility techniques used by pedestrians who are blind in traveling independently across streets;
- highlights key differences between roundabouts and traditional intersections with respect to these techniques;
- suggests approaches that may improve the accessibility of roundabouts to blind pedestrians; and
- encourages transportation engineers and planners to implement and test design features to improve roundabout accessibility.

MODERN ROUNDABOUTS

There are an estimated 40,000 modern roundabouts worldwide, and more than 200 have been constructed in the United States. Most of these have been built within the last 5 years. Many jurisdictions are now considering roundabouts to improve vehicle safety, increase roadway capacity and efficiency, reduce vehicular delay and concomitant emissions, provide traffic-calming effects, and mark community gateways.

A typical modern roundabout (Figures 1 and 2) is an unsignalized intersection with a circular central island and a circulatory roadway around the island. Vehicles entering the roundabout yield to vehicles already on the circulatory roadway. A dashed yield line for vehicles is painted at the outside edge of the circulating roadway at each entering street. The dashed line defines the boundary of the circulatory roadway (not to be confused with a conventional 'stop bar,' since there is not requirement to stop prior to entering the roundabout).

![Figure 1. Typical modern roundabout](image1.png)

![Figure 2. Typical urban double-lane roundabout](image2.png)

Roundabouts have raised or painted splitter islands at each approach that separate the entry and exit lanes of a street. These splitter islands are designed to deflect traffic and thus reduce vehicle speed. Splitter islands also provide a pedestrian refuge between the inbound and outbound traffic lanes.
Roundabout design in the U.S. has not yet been standardized, although several types have been defined in industry publications. Engineers use a variety of design techniques, mostly geometric, to slow vehicles as they approach or exit a roundabout. Differing design practices in Europe and in Australia continue to influence U.S. engineers as they refine design approaches for application in urban, suburban, and rural areas.

Studies conducted in western Europe, where roundabouts are common, and in the U.S. have generally found that roundabouts result in less severe vehicular crashes than more traditional intersections. This reduction in the rate of serious vehicular crashes is the most compelling reason cited by transportation engineers for the installation of roundabouts. Roundabouts increase vehicular safety for two main reasons: 1) they reduce or eliminate the risk arising at signalized intersections when motorists misjudge gaps in oncoming traffic and turn across the path of an approaching vehicle; and 2) they eliminate the often-serious crashes that occur when vehicles are hit broadside by vehicles on the opposing street that have run a red light or stop/yield sign.

The research findings on pedestrian safety at roundabouts are less clear. There have been relatively few studies, mostly conducted in Europe, concerning pedestrians and roundabouts. Pedestrian-vehicle crashes, the most commonly used dependent measure in pedestrian safety studies, tend to occur infrequently both before and after an intersection is converted to a roundabout. As a result, it is difficult to draw firm conclusions from the literature regarding pedestrian safety and roundabouts. One issue that is often not considered in pedestrian research is the degree to which pedestrian volume changes when intersections with signal or stop-sign control are converted to roundabouts. There is a need for research on this topic as well as a broad range of other pedestrian-related concerns at roundabouts. Little is known about the effect of roundabouts on older pedestrians, children, and pedestrians with disabilities. Anecdotal evidence indicates that many Australian engineers (who have extensive experience with roundabouts) consider these intersections to be unsuitable if large numbers of pedestrians are present.

The differences between modern roundabouts and traditional intersections controlled by traffic signals and stop signs have important implications for blind pedestrians. While some of these implications are not yet well understood, they must be considered by any transportation engineer or planner whose goal is to create an accessible pedestrian environment.

### Improvements for wayfinding

- well-defined walkway edges
- separated walkways, with landscaping at street edge to preclude prohibited crossings to center island
- tactile markings across sidewalk to identify crossing locations
- bollards or architectural features to indicate crossing locations
- detectable warnings (separate at splitter islands) at street edge
- perpendicular crossings; where angled, use curbing for alignment cues
- high-contrast markings
- pedestrian lighting
CROSSING AT TRADITIONAL INTERSECTIONS

The techniques and cues used by blind pedestrians crossing at traditional intersections are diverse and vary by location and individual. Many blind pedestrians have received instruction in using these techniques from orientation and mobility (O&M) professionals. In the most common technique for crossing at fixed-time signalized intersections, pedestrians who are blind use traffic sounds to align themselves properly for crossing and then begin to cross when there is a surge of through traffic next to and parallel to them. This occurs at the onset of the walk interval, when the traffic signal changes in the pedestrian’s favor. Cues that can be used for identifying that a street is just ahead, and for determining when to cross, include traffic sounds, the orientation and slope of curb ramps, textural differences between the street and sidewalk, detectable warnings underfoot, locator tones at pedestrian pushbuttons, and audible or vibrotactile information from accessible pedestrian signals (APS).

Key street-crossing tasks for the blind pedestrian include:

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

When traffic sound cues are absent (e.g., when there are no cars on the street parallel to the pedestrian’s line of travel, and thus no auditory cue that the signal has changed) or unpredictable (e.g., when the intersection is of a major and minor street, and traffic signals are actuated by vehicles), information may be insufficient for determining the onset of the walk interval. In such situations, APS systems may be necessary. New guidance on the use of APS appears in the 2000 edition of the Manual of Uniform Traffic Control Devices (MUTCD).

CROSSING AT ROUNDABOUTS

Orientation and mobility techniques used by blind individuals at traditional intersections rely heavily on traffic sounds. When traffic signals and stop signs regulate traffic movements at intersections, the resulting breaks in traffic flow provide identifiable and predictable periods – gaps – during which pedestrians can cross. Such predictable breaks do not usually occur at roundabouts, and so pedestrians must make judgments about the speed and travel paths of approaching vehicles (and the duration of gaps between vehicles). It appears that sighted adults are generally able to safely make such judgments, although some pedestrians (e.g., those with cognitive impairments, children -- see Figure 3) may have difficulty doing so. Research suggests that the selection of appropriate gaps at roundabouts is problematic for blind pedestrians at some roundabouts.
Traffic sounds at roundabouts can provide ambiguous cues. Circulating vehicles can mask the sounds of entering and exiting traffic, making it difficult to identify an appropriate time to cross. At exit legs, auditory information may not be adequate to reliably convey whether circulating vehicles will exit or continue around the roadway.

At entry legs, it may not be clear from auditory information whether a driver intends to yield to a waiting pedestrian.

While research has shown that driver-yielding rates increase at low speeds, many drivers do not yield to blind pedestrians at crosswalks (see Figure 4) and yielding behavior may be difficult to detect.
The curvilinear layout of roundabouts poses several challenges to blind pedestrians. One challenge is obtaining information about the location and direction of the crosswalk. Sidewalks at roundabouts often curve in large arcs and, unlike traditional intersections, rarely lead directly to crosswalks. Instead, crosswalks are typically to the pedestrian’s side (see Figure 5) and must be located using different strategies and sources of information than those used at traditional intersections.

Another challenge is aligning the body with the crosswalk prior to crossing (see Figure 6). At traditional intersections, a common nonvisual technique for accomplishing this is to use traffic sounds to line up to face parallel to the traffic to one’s side (i.e., one’s ‘parallel street’ traffic). This technique is probably not useful at roundabouts.

At some roundabouts, however, some of the nonvisual street-crossing methods used at traditional intersections may be appropriate. For example, it would appear to be appropriate to cross during the periods of ‘all quiet’ that occur at roundabouts where the traffic volume is very light (e.g., 1 lane roundabouts in residential areas) or where there are long periods during which there is no traffic (e.g., due to traffic signals at nearby intersections). However, as vehicles become quieter, this technique may be unsuitable at both traditional and roundabout intersections.

Roundabouts: An Informational Guide, published in 2000 by the Federal Highway Administration (FHWA), acknowledges the need for improvements in roundabout access for blind pedestrians.

“It is expected that a visually impaired pedestrian with good travel skills must be able to arrive at an unfamiliar intersection and cross it with pre-existing skills and without special, intersection-specific training. Roundabouts pose problems at several points in the street crossing experience, from the perspective of information access.

Unless these issues are addressed by design, the intersection is ‘inaccessible’ and may not be permissible under the ADA...[M]ore research is required to develop the information jurisdictions
Title II of the Americans with Disabilities Act (ADA) requires that new and altered facilities constructed by, on behalf of, or for the use of state and local government entities be designed to be readily accessible to and usable by people with disabilities (28 CFR 35.151).

**Improvements for speed control/yielding**
- single lane crossings at entrance and exit
- raised crossings, especially at exit
- ‘YIELD-TO-PED’ markings/driver signs/beacons; if pedbutton, need voice message to clarify not a RYG signal
- pedestrian lighting
- yield cameras

**IMPROVEMENTS WORTH INVESTIGATING**

Across the U.S., roundabouts are being designed and installed at a rapid pace. It is becoming increasingly clear that current roundabout design practices do not yield the same access to crossing information for blind and low vision pedestrians as for sighted pedestrians. An accessible roundabout will provide nonvisual information about crosswalk and splitter island location, crossing direction, and safe crossing opportunities.

An understanding of the auditory, tactile, and other cues used by blind individuals as they negotiate intersections will aid engineers and planners in designing and building accessible roundabouts. Orientation and mobility (O&M) specialists can aid transportation professionals in understanding the demands of non-visual travel and the strategies that blind people use to successfully meet these demands. Much research and development work is needed to improve the usability of modern roundabouts by persons with blindness and visual impairments. It is essential that transportation engineers and planners involve themselves in this R&D by working to devise, implement and test design features with potential for improving accessibility. Promising avenues for further investigation fall into four broad task categories:

1. **LOCATING THE CROSSWALK AND ESTABLISHING ALIGNMENT**
   - Landscaping, planters, pedestrian channelization, bollard-and-chain separation, railings, and other architectural features can delineate paths that lead to the crosswalk and prevent or discourage crossing at locations other than the crosswalk (see Figure 4 above).

   A distinctive edge, particularly paving-to-grass or a raised curb can provide orientation to the crossing direction.

   High-contrast markings and pedestrian routes that are well-lit at night will be useful to pedestrians who use residual vision to travel, the larger proportion of pedestrians who have vision impairments. Lighting will also enhance pedestrian visibility to drivers.
A standardized tactile paving is used in many foreign countries to mark the crossing location for pedestrians traveling along the sidewalk. For clarity of message, it should be a linear pattern that is distinguishable from the truncated dome pattern required in detectable warnings at the street edge (see Figure 7).

![Figure 7. Australian use of bar tiles across sidewalk to indicate crossing location](image)

When alignment using traffic sounds is not possible, other sources of alignment information must be available. Curb ramps with returned edges aligned with crosswalk direction offer useful cues for establishing a line of travel. It is probably also the case that when curb ramp slope is sufficiently steep to be detected underfoot, additional information for alignment can be provided by aligning the slope of the ramp with the crosswalk. However, the usefulness of slope information for alignment is an unresolved research question, and it raises issues where non-standard crosswalk location (e.g., diagonal or apex ramps) may give misleading information that can result in crossings outside the legal or marked crosswalk.

2. DETECTING WHEN IT IS APPROPRIATE TO CROSS

Designing roundabouts that provide pedestrians with nonvisual information about the appropriate time to initiate a street crossing appears to be the greatest challenge facing transportation engineers at roundabouts. Key issues include:

- First, to cross streets safely at roundabouts, there must be gaps in traffic that are long enough to permit pedestrians to cross to the splitter island (or from the splitter to the destination curb). As the traffic volume increases, the number of 'crossable' gaps decreases.

- Second, pedestrians must distinguish 'crossable' gaps from those that are too short to cross. They must make crossing decisions quickly, before approaching vehicles are too close. Longer gaps are needed to cross multi-lane roads than roads with only one lane in each direction.

- Third, instead of accepting a gap in moving traffic, pedestrians will sometimes cross in front of vehicles that have stopped for them (effectively creating a gap). When (if) vehicles stop, pedestrians who are blind must use their hearing to detect the presence of the stopped vehicle, and they must then decide whether it is safe to walk in front of the vehicle.

As noted earlier, the speed of vehicles influences the likelihood that drivers will stop for pedestrians. Traffic calming measures (e.g., pedestrian signage, flashing beacons, raised crosswalks, narrow lanes, neckdowns) should be considered to maintain low speeds at the crosswalk.

It is more difficult – and dangerous – to cross in front of stopped vehicles if the pedestrian is crossing more than one
lane. Vehicles in the lane nearest the pedestrian stop but vehicles in other lanes (moving in the same direction) may not. To facilitate crossing in front of stopped vehicles, consideration should be given to locating crosswalks before the point where two-lane roads are flared to accommodate multiple-lane entries and exits.

Research is currently underway to determine the likelihood that vehicles will yield to pedestrians traveling with dog guides and long canes. Preliminary results about driver yielding behavior collected at 3 crosswalks suggest that most drivers do not yield to blind pedestrians waiting at a crosswalk. This is particularly a problem at exit lanes.

When vehicles do stop, they are sometimes not detected. This is typically the case when vehicles stop several car lengths away from the pedestrian, when the vehicle is relatively quiet (e.g., hybrid gas/electric vehicles), and/or when the sounds of other vehicles mask the sounds of the yielding vehicle. However, the strategy of crossing in front of a stopped vehicle should work where some vehicles stop and are detectable.

Some designers have incorporated stop bars and LED in-roadway warning lights (MUTCD, Chapter 4L) to encourage vehicles to yield to pedestrians at crosswalks. The use of 'YIELD TO PEDESTRIAN' signage at yield lines may also be effective. Recommendations from a roundabouts summit sponsored by ITE and FHWA in December 2002 included raised crossings, particularly on exit legs to discourage driver acceleration. Testing of the effectiveness of 'rumble strips' or similar sound-generating pavings before entry and exit has also been proposed. Research is needed to determine if pedestrians can gain useful information on approaching and yielding vehicles from such cues.

Jurisdictions are also experimenting with ‘smart’ intersections that can sense and signal pedestrian presence. In situations where there are few ‘crossable’ gaps and where vehicles do not stop for pedestrians waiting to cross (or, because of multiple lanes, it is unsafe to cross in front of a stopped vehicle), specially-designed pedestrian signals -- models include 'HAWK' and 'TOUCAN' schemes that blink in amber unless activated. Pre-emption signals utilized for emergency vehicles and trains may also have some application to provide street-crossing opportunities for pedestrians who are blind. Research is needed to determine how to optimize such signalization for both pedestrians and drivers. Continuing advocacy for signalization can be expected until effective alternatives are developed. Roundabouts with multiple lane entrances and exits, where signalization is more necessary to provide crossable (and detectable) gaps for pedestrians, would experience greater delays from signalization.

3. REMAINING IN THE CROSSWALK

Several design approaches may be used to provide directional information in the crossing. Jurisdictions have experimented with ultra-high contrast markings and crosswalk lighting (useful for pedestrians who have low vision); raised crosswalks to provide a boundary, and providing a raised guidestrip at the centerline of the crosswalk. By using the constant-contact cane technique, a blind pedestrian can identify and use tactile surface cues that provide information about the direction of the crosswalk.

4. DETECTING THE DESTINATION SIDEWALK OR SPLITTER ISLAND

Detectable warnings at splitter islands and destination curb ramps signal one’s arrival at a pedestrian refuge. Splitter islands should be demarcated with detectable warnings at each street/sidewalk edge, separated by a width of untextured sidewalk surface. Because detectable warnings mark the beginning and/or end of a safe pedestrian area, they should be applied in pairs, separated by standard sidewalk surfacing. Research indicates that 24 inches of detectable warning surface is needed for underfoot detection while walking.

The use of similar design features across roundabouts will enhance their accessibility to persons who are blind. Consistency in the location of crosswalks, in the design of splitter islands, in the use of bollards and pedestrian channelizing devices, separators, and edging, and in the use of landscaping features can provide effective non-visual cues for negotiating roundabouts.

When a roundabout is introduced to a community through newspaper and TV stories, be sure to emphasize that pedestrians are expected to cross there. Show photos and film of drivers yielding to pedestrians.
RESEARCH IN PROGRESS

Empirical research about the accessibility of modern roundabouts is in its infancy. In 1999, a program of research on roundabout accessibility was initiated by Western Michigan University and Vanderbilt University. Conducted at three modern roundabouts in metropolitan Baltimore, Maryland, the study provides information about the ability to use vision and hearing to distinguish ‘crossable’ gaps in traffic from gaps that are too short to afford safe crossing. ‘Crossable gaps’ were defined as those that would have allowed pedestrians sufficient time to cross from a curb to a splitter island before the arrival of the next vehicle at the crosswalk. The results of the study suggest that there are significant differences in the ability of blind and sighted pedestrians to determine whether it is safe to initiate a crossing at some roundabouts, presumably because of differences in the way information is obtained to make decisions about crossings.

The Western Michigan/Vanderbilt team also conducted a comparable study at three roundabouts in the greater Tampa, Florida area with similar results. A principal finding of this research was that the ability to judge whether gaps are crossable or not is strongly affected by vehicle volume. For example, the judgements of blind and sighted pedestrians were similar at a single-lane roundabout at mid-day, but blind pedestrians were significantly disadvantaged at rush hour.

The team is currently studying the behavior of blind and sighted pedestrians as they cross at roundabouts and the behavior of drivers as they approach blind pedestrians waiting at uncontrolled crosswalks (both at roundabouts and mid-block crosswalks). Preliminary analysis suggests that few drivers yield, although this varies widely from crosswalk to crosswalk. While such research has begun to address several of the key issues cited earlier in this bulletin, it is clear that much more work remains to be done.

Improvements for gap creation

- pedestrian-actuated crossing signals (HAWK, puffin, or similar)
- upstream /downleg signals
- signal metering (as at freeway ramps)
- pre-emption

Improvements for gap identification/notification

- ITS technologies with APS or other audible output
- sound surfaces on entrance/exit legs

Note: avoid masking vehicle sounds with water features in central island or nearby
FEDERAL RESEARCH INITIATIVES

The dearth of research addressing the negotiation of roundabouts by blind pedestrians has prompted Federal funding of several projects on this topic. The first, funded by the National Eye Institute of the National Institutes of Health, was awarded in 2000 to a consortium led by Western Michigan University. This project emphasizes the identification of variables affecting blind pedestrians’ safety while crossing streets at roundabouts and treatments to enhance this safety. The second project, funded by the National Institute on Disability and Rehabilitation Research, was awarded in 2001 to a consortium led by the Sendero Group, LLC. This project emphasizes the identification of wayfinding information needed by blind pedestrians at roundabouts (e.g., crosswalk location, intersection geometry) and ways to convey this information to the pedestrian. A third project, focused specifically on the usability of roundabouts and slip lanes by pedestrians who have vision impairments, will be awarded in 2004 by the National Cooperative Highway Research Program (a prior NCHRP study still underway will identify "geometric, traffic, and other characteristics that are expected to affect the safety and operation of all roundabout users, including bicycles, pedestrians, and pedestrians with disabilities" and to "refine geometric and traffic control design criteria used for roundabouts, including....treatments for bicycles and pedestrians (including pedestrians with disabilities and including the impact of accessible pedestrian signals on pedestrian access and vehicle operations)..."). The Turner-Fairbanks Research Center of the Federal Highway Administration/DOT has a human factors study newly underway that will test several potential improvements to roundabout usability by pedestrians who have vision impairments.

Collectively, these and other projects should significantly enhance engineers’ and planners’ access to information about how to build roundabouts that can be negotiated safely and efficiently by blind pedestrians.

PUBLIC RIGHTS-OF-WAY ACCESS ADVISORY COMMITTEE RECOMMENDATIONS

The U.S. Access Board is an independent Federal agency that develops accessibility guidelines for buildings, facilities, transportation vehicles, and communications technologies and electronic devices covered by the ADA and other laws. In 1999, the Board established a Public Rights-of-Way Access Advisory Committee (PROWAAC) to make recommendations on accessibility guidelines for public rights-of-way. The 33 members of PROWAAC represented Federal agencies, traffic engineering organizations, public works agencies, transportation departments, traffic consultants, standard-setting organizations, disability organizations, and others. On January 10, 2001, the PROWAAC submitted its report to the Board recommending a new national set of guidelines for accessible sidewalks, street crossings, and related pedestrian facilities. The report includes several recommendations regarding access to roundabouts. In particular, the report recommends:

- barriers (landscaping, railings, bollards with chains) where pedestrian crossings are prohibited;
- cues (locator tones, detectable warnings, other) to identify crossing locations; and
- pedestrian-activated traffic signals at crossings.

The Access Board will consider Committee recommendations in developing a Notice of Proposed Rulemaking (NPRM) on guidelines for public rights-of-way for publication in the Federal Register. The NPRM will seek public input and comment on the proposed guidelines before a rule is finalized. Further information on the status of this rulemaking is provided on this website.

RESOURCES
A summary of roundabouts research concerning access by individuals who are blind is also available on this website.

Additional resources on public rights-of-way accessibility available from the Board include:

**Building a True Community**, a report from the Public Rights-of-Way Access Advisory Committee submitted to the Board in January 2001. (Also available in PDF format).

**Accessible Rights-of-Way: A Design Guide**, a guide the Board developed in cooperation with the Federal Highway Administration to provide advisory information until guidelines for public rights-of-way are developed (also available in PDF format).

**Accessible Pedestrian Signals**, a Board report that provides a synthesis on current technology in accessible pedestrian signals, including a listing of devices and manufacturers in the U.S. and abroad, and a matrix comparing the features of each device. (Also available in PDF format). Note: A more recent synthesis of accessible pedestrian signal technologies developed through the National Cooperative Highway Research Program (NCHRP) is available at www.walkinginfo.org/aps/.

**Detectable Warnings: Synthesis of U.S. and International Practice**, a Board-sponsored study on detectable warnings that surveys the state-of-the-art in the U.S. and abroad and summarizes the installation and effectiveness of various designs. (Also available in PDF format).

Resources available from the Federal Highway Administration include:

**Roundabouts: An Informational Guide**, a comprehensive overview of roundabouts.

**Manual of Uniform Traffic Control Devices**, which contains standards for the application and installation of traffic signals, signs and pavement markings that regulate, warn, and guide the vehicle and pedestrian users of the public right of way. The MUTCD promotes the uniformity of traffic control devices nationwide.

Project List | Research