PLANNING AND DESIGN PROCESS

Complete Streets planning processes usually begin with an assessment of the community context and the type of road users expected along a corridor. An analysis is conducted of the gaps in the system for different users—such as a lack of sidewalks. Planners and roadway designers then seek to make improvements that increase mobility and accessibility for all anticipated roadway users. See Figure 10.

By definition, a Complete Streets planning process should also address the needs of people in different stages of life and at different levels of ability. The need to expand transportation options has particular relevance for older Americans who need alternatives to driving. An AARP survey of Americans over 50 conducted in part for this study found that almost 40 percent of those polled reported inadequate sidewalks in their neighborhoods, while 55 percent do not have bike lanes or paths, and 48 percent say there is not a comfortable place to wait for the bus. Most sobering, almost half (47 percent) of poll responders say they cannot cross the main roads in their community safely. Half of those who reported such problems said they would walk, bicycle, or take the bus more if these problems were fixed (Skufca, 2008).

A Complete Streets approach should also balance the needs of older drivers with those of older pedestrians. The wide lanes and gentle curves that may make travel easier for older drivers can make crossing the street a much bigger challenge for older pedestrians. Complete Streets planning processes should help transportation planners take the needs of both constituencies into account, consistent with the community’s vision for the mobility outcomes it wishes to achieve.
As discussed in the section on the effects of physical limitations on mobility, the issues that commonly affect the safety and comfort of older drivers and pedestrians include declining vision, decreased physical fitness and flexibility, decreased ability to focus attention, and increased reaction time. Strategies to address these core issues can be organized around three basic planning and design principles explained below: Slow Down, Make it Easy, and Enjoy the View. Together these principles can aid designers in simplifying the road environment and increase its safety for all users. They can be applied to transportation project improvements at all stages, from initial planning to final design and construction, as noted below.

**Slow Down**

Reduce vehicle travel speeds in areas where vehicles and pedestrians interact and where older drivers and pedestrians need more time to make decisions and execute changes.

As discussed earlier, pedestrian injuries and deaths increase with increasing vehicular speed. In addition, older drivers who need more time to absorb information and make decisions may feel pressured in high-speed environments. This is especially true at intersections where 41 percent of fatal crashes involving drivers over the age of 64 take place (Eby, 2009). Older pedestrian deaths are also more likely to take place at intersections than are those involving pedestrians under the age of 65.9

To apply this principle in the planning realm, agencies and policy makers can establish goals and performance measures that seek to achieve optimal vehicle throughput at speeds that accommodate the needs of older drivers and pedestrians. For example, a traditional response to congestion problems along a suburban corridor is to maintain or increase vehicle capacity (measured principally by LOS and travel time or intersection delay) by widening the roadway or adding turn lanes. This can lead to increased vehicular speed.

An alternative approach would be to maintain or reduce overall corridor travel times and congestion levels while improving vehicle and pedestrian safety through strategies that aid in maintaining a desired target speed. These strategies include visual cues or physical changes that reduce real or perceived lane widths, in conjunction with improving operational efficiency through strategies such as access management and signal coordination.

Planning strategies such as these could be further strengthened by roadway design techniques aimed at keeping intersection size to a minimum and allowing sufficient signal timing for pedestrians to cross the street. Tighter curb radii at intersections require all drivers to navigate turns more slowly and serve to shorten pedestrian crossing

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9 Calculated using 2006 FARS Encyclopedia.
Networks designed for proximity better accommodate older drivers and pedestrians who have lost some of their dexterity.

Planning and design principles that can support better maneuverability focus on integrating transportation plans with land use policies and urban design standards in order to provide interconnected roadway networks, offering travelers a variety of multimodal routes to key destinations. Many of today’s transportation networks, particularly in suburban areas, funnel virtually all travelers—drivers and pedestrians—onto a few large-scale arterials, which are typically designed for large vehicles moving at relatively high speeds. In addition to improving the design of these larger roadways in order to support the needs of older drivers and pedestrians, adding complementary grid networks of local streets provides travelers the option of lower-speed routes with smaller intersections that are easier to maneuver. These networks also shorten walking distances. See Figure 11.

Design treatments that improve maneuverability for pedestrians include strategies such as placing two curb ramps at each corner that lead directly into the crosswalks instead of one ramp in the middle that leads directly into the street. The latter design requires
people using wheelchairs, walkers, or strollers to quickly “zig-zag” over to the crosswalk after entering the street.

Another strategy is to avoid channelized free-flow right-turn lanes and/or use tighter angles for right turns in order to improve maneuverability for older drivers who have difficulty turning their heads. While more generous curb radii assist an older driver with limited upper body dexterity, slower intersection speed resulting from tighter curb radii benefits older drivers, while at the same time providing benefits to pedestrians as described above. The avoidance of channelized free-flow right-turn lanes allows older drivers with stiff necks from looking over their shoulders at an uncomfortable angle.

**Enjoy the View**

*Make it easy for older drivers and pedestrians to notice, read, understand, and respond to visual cues and information.*

Planners and policy makers can improve roadway visibility by adopting corridor design standards that reduce visual “clutter,” such as oversized store signs and landscaping that make it hard for drivers to see important elements such as directional signs and pedestrians entering the roadway. They can also establish economic development policies and programs that support streetscape improvements such as burying overhead utility lines, further improving intersection visibility. Access management is another policy strategy that can improve corridor visibility by reducing the number of driveways and roadway signs that drivers and pedestrians must monitor.

Large-sized pedestrian countdown signals that can be seen easily from across the intersection or the median refuge improve visibility for pedestrians. For older drivers, visibility improvements can include retro-reflective signs, curb markings, and improved intersection signage and sight distance (both at and in advance of the intersection). Crosswalks painted with zebra stripes make pedestrians more noticeable to drivers.

Enriching Complete Streets policies and roadway planning and design methods to more specifically address these principles of speed, ease of navigation, and visibility will advance safety and mobility not only for older drivers and pedestrians, but for roadway users of all ages and travel modes. In addition, by adopting policies and practices that address these elements at each stage of project development—from policy to planning and design—the multitude of agencies and individuals involved in the process can communicate more clearly and consistently, so that the improvements envisioned in the plan are ultimately realized on the ground.
KEY DESIGN ELEMENTS FOR OLDER DRIVER AND PEDESTRIAN SAFETY

Older Drivers

*Vertical and Horizontal Alignment*

Vertical curvature can impede a driver’s ability to see in the distance. Horizontal curvature can reduce a driver’s peripheral vision. Roadway designers should avoid creating situations in which drivers may suddenly come upon a pedestrian or turning driver at the bottom or the crest of a steep hill (vertical alignment) or after rounding a sharp curve (horizontal alignment).

*Pavement Markings*

All drivers, but especially older drivers, can have trouble seeing poorly designed or maintained pavement markings, especially at night or in wet or foggy conditions. Longitudinal pavement markings that delineate the edge of the lane should be six to eight inches, rather than the four inch minimum. Retroreflective treatments, enhanced with other technologies such as oversized glass beads or raised pavement markings, improve wet-night recognition on edge and centerline markings. These treatments are is especially important for poorly lit and fast roads. The front and sides of median curb islands should be treated with retroreflective paint and/or reflectors.

Crosswalk markings can be invisible to drivers moving quickly and/or people with declining vision. Crosswalks should be designed to correspond to vehicle speeds, and made highly visible by means such as retro-reflective paint. Zebra striping draws greater driver attention to the crosswalk than two parallel lines. Alternatively, a combination style crosswalk with no paint inside the parallel lines, but with zebra striping outside the parallel lines can be used. This type of crosswalk may lessen the chance of falling from paint that gets slippery in rainy conditions. See Figure 12.

*Visual Clutter*

Sign clutter is distracting and confusing to an older driver. A delayed or late reaction to an upcoming turn can be unsafe for all roadway users. Important directional signs and markings, particularly at decision points such as intersections, must be highly visible, not lost within a jumble of other signs or vegetation. Designers should create a visual clearance zone at intersections and near crosswalks, including only...
those signs necessary for traffic safety.

**Continuous Center-Turn Lanes**

Continuous center-turn lanes (colloquially referred to as “suicide lanes”) increase the chances for vehicular conflict among all drivers because turning movements become less predictable along the length of the roadway. While this issue affects drivers of all ages, older drivers are particularly challenged if they have lower visual acuity and increased reaction times. Confusion over their use can cause older drivers to stop in the through lane, leading to rear-end collisions. Roadway designers should limit vehicular turning movements to defined locations, using measures such as raised grassy medians to control these movements and increase roadway predictability. See **Figure 13**.

**Older Pedestrians**

**Pavement Maintenance and Materials**

Road designers need to be concerned not only with the risks to pedestrians from motor vehicles, but also from falls. For those aged 65 and older, falls are the leading cause of death from injuries among older persons (Kochera, 2002). Uneven pavement can be difficult to navigate in a wheelchair, with a walker, or with a walking aid. Declining physical fitness and flexibility can make a bump feel like a mountain. Roadway designers should select smooth, strong materials for sidewalks and crosswalks such as concrete or asphalt rather than textured materials such as cobblestones or bricks. Paint can be used to highlight pedestrian areas, rather than elevating them or using knobby textures. Sidewalks should be maintained to ensure uneven pavement does not pose a hazard to pedestrians. Street trees should be chosen from species whose roots will not lift or break the pavement.

**Curb Ramps**

ADA standards require that curb ramps be included at all intersections; however, the design of ramps can be accomplished in a variety of ways. A single central curb ramp at an intersection can “dump” the pedestrian into the center of the intersection and to
the side of either crosswalk. People using wheelchairs or walkers in these situations may have a particularly hard time navigating to the crosswalk quickly and can become stranded in the roadway. Designers should provide a separate curb ramp directly aligned with the crosswalk and sidewalk approach at each leg of the intersection. Alternatively, designers can choose a single, continuous ramp that wraps around the corner from one crosswalk to the other.

**Median Refuges**

Older pedestrians need more time to cross streets, which presents a particular challenge for crosswalks on multilane and/or wide-lane highways. Small or complex crossing signal icons are hard to read from across the entire roadway for those who suffer from declining vision. Designers should break up the crossing distance on wider roadways with one or more median refuge islands that allow pedestrians to cross a single direction of traffic at a time for increased predictability and safety. Simple, highly visible crosswalk signs should be placed within the median if necessary.

**Pedestrian Crossing Signals**

Pedestrian crossing signals are a useful part of a complete street network. However, signals placed across a wide roadway may not be visible to older pedestrians with declining vision. In addition, complex placards can be confusing. Designers should provide pedestrian countdown signals rather than placards. For wider crosswalks, visual signals should be combined with audible signals, and crossing signals in the median may be warranted. Regardless of the width of the intersection, designers should set the walk signal time for a crossing speed of 3.5\(\text{/second}\) plus 7 seconds to leave the curb, consistent with the proposed changes to the MUTCD.

**Other Pedestrian Amenities**

A lack of attention to streetscape detail discourages pedestrian activity and can even pose hazards to older travelers. Street lights scaled for automobiles can leave pedestrians in the shadows. A lack of benches and trees or awnings at transit stops can force pedestrians to stand for a long time in the hot sun. Narrow sidewalks with obstructions such as mailboxes, light posts, and fire hydrants leave no room for wheelchairs and walkers. Sidewalk amenities are important for all users; the following are especially critical for older people:

- Include pedestrian-scaled lighting to focus light onto the sidewalk, activating the sidewalk into the evening and improving visibility.

- Provide a wide sidewalk for wheelchair access and create room for outdoor cafes with awnings, benches, etc., transforming an uncomfortable, lonely pathway into a pleasant, visually interesting public plaza.

- Provide benches for sitting, resting, or gathering.
• Plant street trees for shade, enhanced aesthetics, and as a buffer between the sidewalk and roadway.

Balancing the Needs of Older Drivers and Pedestrians

Access Management

Strategies to consolidate multiple driveways into a few well-designed intersections address the needs of many different roadway users. Frequent driveways on main roads interrupt the pedestrian and bicycle network and create potential conflict points among turning vehicles, bicyclists, pedestrians, and oncoming traffic. Closing or limiting driveways along major roadways creates clearer pathways for all roadway users and less potential for conflict. Designers and planners should work together to create parallel access roads and shared driveways to improve access management.

Right Turn on Red

When a crossing signal reads “Walk,” pedestrians begin crossing the street with the belief that it is safe to cross. Vehicles making right turns on red, however, may place the pedestrian in sudden, unexpected danger. Where pedestrian activity is high, designers should prohibit right turns on red and/or consider a roundabout as an alternative. Roundabouts keep traffic moving at a consistent but low speed and provide pedestrians with crosswalks that are set back from turning vehicles.

Protected Left Turns

Left-turn movements without the benefit of a turn arrow can put all road users in danger. Older drivers as a group experience difficulties when making left turns, as they do not position themselves within the intersection before initiating a left turn and they have more difficulty judging the speed of oncoming traffic to find a safe gap (Staplin, 1998). When focused on judging gaps in oncoming traffic, drivers of any age may fail to notice pedestrians in the crosswalk. To reduce the risk to drivers and pedestrians, a protected left-turn phase should be provided.

Protected left turn arrows become even more important at intersections with a pedestrian refuge island or median. The median creates a negative offset—pushing the drivers’ line of site away from oncoming traffic and making it more difficult to judge gaps in traffic. See Figure 19, page 44.

Curb Radius

Curb radius describes the curvature of the curb between two legs of an intersection. Wide curb radii allow faster turning speeds and wider turning movements, lessening intersection congestion and facilitating vehicle mobility. However, higher speeds allow less time for drivers to look for other vehicles or pedestrians, and less time to make and execute decisions. These conditions are problematic for older drivers. Higher vehicle
speeds also increase the risk of serious injuries or fatalities to pedestrians, particularly among older adults. Wide curb radii also lengthen the crossing distance for pedestrians and make it more difficult to align the curb cut with the sidewalk approach. Roadway designers should use a 10′–15′ maximum curb radius wherever possible, particularly in urban and suburban locations. The addition of parallel parking and bike lanes can increase the effective turning radius.

AN ASSESSMENT OF FHWA DESIGN RECOMMENDATIONS

One of the objectives of this research project was to review the FHWA’s Highway Design Handbook for Older Drivers and Pedestrians through the lens of Complete Streets. The FHWA Handbook presents cost-effective solutions backed up by human factors and highway safety research. Given the increasing funding difficulties faced by state DOTs, the FHWA Handbook’s emphasis is on providing solutions for new construction and reconstruction that have measurable safety results, rather than a systemwide retrofit. This is a positive and pragmatic approach.

The FHWA Handbook’s design solutions go beyond mere policy. They offer engineers detailed recommendations that can be incorporated to “real-life” roadway design problems. The FHWA Handbook also offers a process for engineers to use in prioritizing strategies, based on safety issues specific to the community and relative cost benefit.

The great majority of the 31 recommendations in the FHWA Handbook are mode neutral. If states wholeheartedly implemented the mode-neutral recommendations, the safety of the U.S. road system would be greatly enhanced—for drivers in particular, yet without detriment to other road users. Thus, it is not the objective of this research to discard the FHWA Handbook recommendations, but to examine them through the lens of Complete Streets and offer refinements to better address the simultaneous needs of all road users.

General Issues and Opportunities for Refinement

Focusing Equally on Pedestrians and Drivers

While the FHWA Handbook is titled Highway Design Handbook for Older Drivers and Pedestrians, the discussions and recommendations are primarily focused on the older driver. For example, the introduction provides only one mention of the older pedestrian compared to 18 references made to the driver. The preponderance of research on drivers versus pedestrians dictates this outcome, because the FHWA Handbook presents only empirically based recommendations. Still, while it may not be possible to give equal weight to pedestrians throughout the FHWA Handbook, more discussion about the design considerations for the older pedestrian would greatly enhance the document.10

10 The FHWA Handbook bases its recommendations on a solid understanding of the available
The scope of the FHWA Handbook does not permit discussion of the growing debates among research, planning, and engineering communities on how to design roads for safety. Increasingly, planners and engineers challenge traditional highway design practice that tends to promote suburban roadways designed to provide mobility for the personal vehicle, often at the expense of other road users. The human cost of this traditional roadway engineering approach is significant. It exacerbates the social and physical isolation of nondrivers, not to mention the dangers imposed upon pedestrians and bicyclists.

Addressing Different Land Use Contexts

Understanding land use context is critical to balancing the needs of different users. Many suburban communities, small towns, and cities are seeking to build walkable, mixed-use places modeled upon the traditional city streetscape, and to expand public transportation options by creating a safe and comfortable walking environment around transit stops. Communities such as these would need to carefully consider whether the FHWA Handbook recommendations are appropriate for their situation. For example, the FHWA Handbook’s recommendation to build acceleration lanes when applying channelization treatments (discussed below) may be appropriate for rural highways, but not for urban and suburban roadways with a mix of modes.

This emphasis on context, central to new approaches such as Context Sensitive Solutions and Complete Streets, is largely absent from the FHWA Handbook. Readers should understand that the FHWA Handbook’s recommendations are appropriate primarily for rural highways and new, suburban higher-speed roads.

In a few instances the FHWA Handbook mentions the need to consider the surrounding land use when designing for improved mobility of older adults, but there is room for much more information on this topic. For example, adding several design iterations for each of the intersection recommendations could demonstrate ways in which the needs of older drivers and pedestrians can be addressed, given the functional classification of the road (residential, collector, arterial) as well as the land use context (urban, suburban, rural). The CSS framework could serve as a structure to present the FHWA Handbook recommendations.

Considering the Effects of Vehicle Speed

Research on human factors and highway safety. Unfortunately, there is much less research on older pedestrians and other road users than on older drivers, and most studies lack a multimodal analysis of safety. Furthermore, the current practice of highway safety research is largely based on the use of safety surrogates rather than actual observances of safety outcomes, such as crash frequency and severity (Hauer, 2007). When field or laboratory studies of driver behavior were not available, the research referenced in the FHWA Handbook relied upon these surrogates (driver reporting of comfort levels, observations of curb and lane encroachment, change in speed, etc.). This weakness in the current state of road safety research makes it difficult to fully consider the interrelated issues of older drivers and pedestrians.
Guidelines for many roadway design elements, from lane widths to intersection treatments, vary depending upon the assumed design speed. Traditional engineering practice is to establish a design speed of 5–10 mph above the intended posted speed. Yet, research has shown that the speed at which traffic is moving has a significant impact on pedestrian safety. The risks of fatalities and severe injuries, particularly for older pedestrians, rise exponentially with driver speeds. The literature on context sensitive solutions emphasizes the importance—and the difficulty—of establishing design speeds that balance pedestrian safety with driver mobility in different land use contexts.

The FHWA Handbook recommendations do not indicate an assumed design speed, and the supporting research in the appendix does not clearly address the question of whether treatments apply equally to roads designed for varying speeds. This lack of information indicates a need for more research on this topic. In the meantime, the FHWA Handbook could benefit from discussions and, where appropriate, design iterations to address a variety of design speeds.

**Intersection Design Assessment**

Intersections are complex locations that pose many safety risks, particularly for older drivers and pedestrians. Different road users must make many individual decisions rapidly at intersections, while simultaneously anticipating or reacting to the decisions of others. These decisions are harder to make with reduced visual acuity, physical dexterity, and reaction times.

The FHWA Handbook recommendations on interchanges, roadway curvature, and passing zones (presumably for rural highways); construction/work zones; and highway-rail grade crossings present comparatively few potential conflicts among bicyclists, pedestrians, and older road users. In many cases, the recommended treatments to aid older drivers, such as larger sign fonts and retro-reflectivity, can benefit all travelers.

However, a few of the intersection recommendations could have the unintended consequence of benefiting one type of roadway user at the expense of others. For example, wide lanes and sweeping curves may make it easier for older drivers to navigate an intersection. But the increased crossing widths and potentially higher vehicle speeds associated with these types of design treatments can make conditions more difficult for older pedestrians.

These design conflicts are not unique to the FHWA Handbook. An energetic debate has been going on for some time among planners and engineers on how to balance the needs for roadway capacity and vehicle mobility with the needs of nonmotorized road users at intersections, specifically when designing elements such as lane widths and curb radii.

The following analysis identifies five types of potential older driver/pedestrian conflicts presented by the FHWA Handbook’s “Intersection Design Element” recommendations, and offers supplemental urban and suburban intersection refinements intended to reduce
these conflicts and achieve greater compatibility with Complete Streets goals. The design assessment elements described in this section are as follows:

- Receiving lane (throat) width for turning operations
- Channelization
- Offset (single) left-turn lane geometry, signing, and delineation
- Curb radius
- Pedestrian crossing design, operations, and control

### Receiving Lane (Throat) Width for Turning Operations

**FHWA Recommendation**

A minimum receiving lane width of 3.6 m (12’) is recommended, accompanied, wherever practical, by a shoulder of 1.2 m (4’) minimum width.

As explained in the FHWA Handbook, older drivers have more difficulties maneuvering their vehicles through smaller areas. Narrow (10’–11’) receiving lanes with no shoulder could provide insufficient width for turning vehicles, causing conflicts as left-turning vehicles cut the corner of the turn lane on the receiving street. At the same time, the FHWA Handbook acknowledges that lane widths beyond 12’ may result in “unacceptable increases in older pedestrian crossing times.” The recommendation (minimum receiving lane width of 12’ with a 4’ shoulder) is intended as a compromise to accommodate the needs of older drivers and pedestrians, as well as larger turning vehicles. *See Figure 14.*

### Discussion

The AASHTO Green Book provides substantial flexibility on whether lane widths narrower than 12’ are appropriate for urban and suburban arterials. While narrow lanes...
A wide receiving lane and shoulder increase pedestrian crossing distance and may encourage faster driving

Figure 14. Authors’ Illustration of Enhanced FHWA Handbook Recommendation

(less than 12’) may be difficult for the older driver to maneuver in some cases, they are ideal for pedestrians, especially older pedestrians. Not only do they reduce crossing distance, they also tend to encourage drivers to drive more slowly and carefully.\textsuperscript{14}

Conversely, studies show that the safety benefit of wider lanes effectively stops once lanes reach a width of 11’; after that point, crash rates increase on lanes that approach or exceed the more common 12’ standard.\textsuperscript{15}

Narrower lanes are one element of roadway design that can contribute to lower speeds. Other factors such as roadway markings and landscaping can change the drivers’ perception of their maneuvering area, causing them to feel as if they are traveling faster than they actually are and slowing down as a result (Massachusetts Highway Department Project Development and Design Guide [MassSAFE], 2004).

\begin{itemize}
\item \textsuperscript{14} As pointed out by Ewing (1999), narrow streets contribute to calmer traffic and less aggressive driving because drivers sense that there is a greater risk of traveling outside the lane and colliding with objects on either boundary of the lane. Several studies have found that reduced lane widths lower vehicular speeds. Yagar and Van Aerde “found a reduction in speed of 1.1 mph for every foot of reduction in lane width beyond 13 feet” (cited in Martens et al., 1997). Heimbach and colleagues found that on four-lane undivided urban roadways, during off-peak hours a foot reduction in lane width would result in traffic moving 0.6 mph slower. A 1.0 mph reduction in speed would occur during peak hours (Heimbach et al., 1983). Another study, titled “Design Factors that Affect Driver Speed on Suburban Arterials,” suggested that on four-lane urban arterials for every foot the width of a travel lane increased, traffic traveled 2.9 mph faster (Fitzpatrick et al., 2000).
\item \textsuperscript{15} Recent studies indicate that increased lane widths and overall street widths are linked to increased crash rates and severity (Dumbaugh, 2005; King, 2003; Swift, 2006). Dumbaugh (2005) references Hauer (1999), whose examination of the literature found that there was “little evidence to support the assertion that widening lanes beyond 11 feet enhances safety. Instead, the literature has almost uniformly reported that the safety benefit of widening lanes stops once lanes reach a width of roughly 11 feet, with crash frequencies increasing as lanes approach and exceed the more common 12-foot standard.” Similarly Potts and colleagues (2007) concluded that there is “no indication of an increase in crash frequencies as lane width decreased for arterial roadway segments or arterial intersection approaches.”
\end{itemize}
Suggested Refinements

In most urban areas, the FHWA recommendation to widen the receiving lane can be accomplished through the provision of bike lanes. Additional travel lanes also provide the indirect benefit of additional throat width for a left-turning vehicle. In these areas, the FHWA Handbook standard should be refined to accommodate a 10’–11’ receiving lane, ideally with an adjacent 5’ bicycle lane. Bike lanes can increase the effective maneuvering space while still keeping speeds down, as drivers will adjust to the marked lane width. See Figure 15.

At intersections where it is necessary to accommodate heavy vehicles or other vehicles with a wider turning radius, it may be appropriate to move the stop bar on the receiving side back to accommodate a wider radius, as long as the recommended sight distance is not compromised.

It may also be useful for the FHWA Handbook to specify that the 12’ receiving lane with 4’ shoulder recommendation is a rural standard and may be accompanied by “share the road” signage where bicycle activity is expected. Lanes of 12’ or greater should be applied, if necessary, on parkways, rural highways, and other types of throughways where traffic movement is the primary objective of the roadway.

Channelization

FHWA Recommendation

The FHWA Handbook does not endorse channelization but, rather, describes how it should be designed. For right-turn channelization where pedestrian traffic may be expected based on surrounding land use, it is recommended that an adjacent pedestrian refuge island conforming to the MUTCD and AASHTO design guidelines be provided. The crosswalk should be located as close as possible to the approach leg to maximize the visibility of pedestrians before drivers are focused on scanning for gaps in traffic on the
intersecting roadway. The channel should be raised and treated with retro-reflectorized marking and maintained at a minimum luminance contrast level. The FHWA Handbook also discussed the need to provide an acceleration lane providing for the acceleration characteristics of passenger cars as delineated in AASHTO specifications.

**Discussion**

Channelization is used to separate and define travel paths. It directs drivers and pedestrians to the correct location when they are navigating through traffic medians or pavement markings. By providing a protected turning area with a large radius, channelized right turns allow all vehicles to turn more quickly and large vehicles to turn more easily. Some channelized right turns exit into a dedicated acceleration lane before having to merge into traffic (free right turn), while others require the merge to occur when exiting the turn itself.

The study team does not have concerns with the content of FHWA Handbook recommendation but, instead, with the issues left unstated. The FHWA Handbook does not discuss the physical fitness issues that may be at play for older drivers when they navigate channelized right turns. Furthermore, it fails to caution designers against using right-turn channelization in urban and suburban areas where pedestrians are present.

The FHWA Handbook discusses the decline of older driver’s head and neck mobility and the difficulty in seeing and judging oncoming traffic at skewed intersections (Design Element A) but it does not discuss limited range of motion in the context of channelization. A channelized right turn requires a larger range of motion for a driver’s head and neck, for which older drivers may be unable to compensate.17

In addition, since channelized turns are designed to keep traffic moving quickly around a curve, they present a short window of time for drivers to make merging or yielding decisions when exiting the channelized turn, which can be an issue for older drivers with slowed reaction times. As the angle at which the two roads intersect diverges from 90 degrees, the sight distance for turns diminishes, making it increasingly difficult for persons with reduced neck mobility to identify gaps. ITE’s recent publication on context sensitive solutions (2006) justifies a low-angle turn to “slow down the speed of right-turning vehicles and improve driver visibility of pedestrians within and approaching the crosswalk.” 18 While the FHWA Handbook does cite research pointing to increased

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17 The movement of neck rotation used to perform turns at skewed intersections is similar to the motion required for navigating a channelized right turn. In a study by Staplin and colleagues (1997) to determine whether older drivers used outside mirrors to help perform a right turn on red at a skewed intersection, 30 percent of drivers ages 25–45 and 65–74 used their mirrors, and none of the drivers over 75 used outside mirrors to help (FHWA, 2001). Channelization could be problematic for older drivers who are less physically capable of looking over their shoulder, and arguably less likely to use outside mirrors.

18 The AASHTO Green Book design calculations for sight distance are relevant for intersections.
Channelized intersections designed for high speed place pedestrians outside the driver’s cone of vision.

*Figure 16. Illustration Showing the Challenges Faced by Pedestrians at Channelized Intersections.*

older driver comfort with channelized right turns when acceleration lanes are provided, these lanes are undesirable for pedestrians as they increase pedestrian crossing distance and facilitate increased vehicle speed.

The FHWA Handbook references the benefits of the pedestrian refuge, as well as the fact that channelization can help clarify an ambiguous or complex intersection. However, it also notes that the presence of islands is unlikely to offset the pedestrian disadvantage at a large intersection (Hauer, 1988).

It also references studies that indicate vehicles move faster, are less likely to stop, and exhibit higher crash rates at channelized intersections with longer curb radii.19 As the risk of pedestrian death in crashes with motor vehicles rises with speed, it can be assumed that higher vehicle crash rates and longer pedestrian crossing distances also contribute to a more dangerous situation for pedestrians.

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19 A study by Staplin and colleagues (1997) found that higher turn speeds (3–5 mi/h) are common among younger drivers on intersection approaches with channelized right-turn lanes. The study also indicated that younger drivers were less likely to stop before making a right turn on red at channelized intersections. Additional recent research indicates that vehicle turning speed increases as the turn radius increases and, in most cases, vehicular crash rates are higher at channelized right turns than at right turns without channelization (Bauer, 2000; Fitzpatrick, 2005).
A tighter turn makes it easier for drivers with stiff necks to merge with traffic

Figure 17. Illustration of Authors’ Refinement Showing Pedestrian and Driver Improvements at Channelized Intersections.

Unmarked or improperly marked paths for pedestrians crossing from the curb to the channelized island refuge can cause dangerous situations. See Figure 16. Pedestrians at channelized intersections must cross from the curb to the island and then cross the lanes of traffic.

Research shows that poorer contrast sensitivity makes the painted channel marking less visible to older drivers. Without a visibly marked crossing path, drivers may not be aware of the presence of pedestrians at the intersection. Drivers may be unable to stop for pedestrians who cross too close to the approach, and are less likely to see pedestrians who cross too close to the receiving side. A clearly marked crossing alerts drivers to the possibility of pedestrians, and provides pedestrians with a clear safe path to follow. Advance warning signs would also remind drivers to be aware of crossing pedestrians. Installing “Yield to Pedestrian” signs reduces pedestrian crashes by 10 percent (ITE, 2004).

Suggested Refinements

As with all suggested refinements in this report, the first priority is to make sure the design treatment is appropriate for the context of the road and surrounding area. Channelization in urban and suburban settings should be discouraged, because of the potentially dangerous obstacles it can present to pedestrians. A non-channelized, 90-degree intersection accompanied by a prohibition of right turn on red (RTOR) is suggested to reduce conflicts between motorized vehicles and pedestrians and bicyclists. If RTOR
prohibitions are not used, yield to pedestrian signs should be used.

Where channelization is warranted, the older driver’s cone of vision should be considered in designing the angle of a channelized turn. Pedestrian visibility to drivers should be the top priority. Tighter turn angles can reduce driver speeds and open the driver’s vision to the potential presence of a crossing pedestrian. In addition, tighter angled channelized turns reduce the degree to which the driver’s head must turn left in order to look for oncoming traffic. These attributes are particularly important for older drivers, who may have stiff neck issues. See Figure 17. Minimizing the curb radius can help increase pedestrian safety while reducing the width of the approach lane for the channelized turn can help reduce vehicle speed.

Crosswalks should be located 15’–20’ behind the merge point of the channelized island to allow adequate space for a vehicle to stop and look left for oncoming traffic without blocking the path of pedestrians. This placement also enables drivers to scan the intersection for the presence of pedestrians in advance of needing to merge with traffic.

Landscaping treatments such as low prickly shrubs along the curb will confine pedestrians to crossing at the safest location. Other treatments such as rumble strips and raised crosswalks help to slow traffic and improve pedestrian safety. Signalizing the channelized right turn with an actuated pedestrian button further increases pedestrian safety, as right-turning vehicles are stopped by a red light while pedestrians are crossing.

As recommended by FHWA, if a channelized right turn is present in a pedestrian-oriented area, a raised curb is recommended with an at-grade crosswalk to provide refuge for crossing pedestrians, rather than demarcating the channel with surface paint alone. Contrast paint should be added to the curb side to make it more visible at all times of the day and under all driving conditions. The surface and sides of the median refuge should also be reflectively painted to increase visibility.

Participants in the online survey and the Innovation Roundtable assembled for this study mostly agreed with these suggested refinements. In general, survey participants discouraged channelization, encouraged raised islands especially in pedestrian-heavy areas,
supported a tighter angle for easier perception of approaching traffic, and opposed free-flow turns. To further improve the safety of pedestrians at intersections, Roundtable attendees recommended that right-turn channelization be replaced by right-angle turns in combination with a right turn on red (RTOR) prohibition. When a RTOR crash occurs, a pedestrian or bicyclist is frequently involved, and these types of crashes usually result in injury (Compton & Milton, 1994).

**Offset (Single) Left-Turn Lane Geometry, Signing, and Delineation**

*FHWA Recommendation*

Unrestricted sight distance (achieved through positive offset of opposing left-turn lanes) is recommended whenever possible, for new or reconstructed facilities. See Figure 18. This will provide a margin of safety for older drivers who, as a group, do not position themselves within the intersection before initiating a left turn.

**Discussion**

Older drivers are overrepresented in left-turn crashes where failure to yield to the right-of-way is the movement violation. Typical underlying causes of these crashes include the misjudgment of oncoming vehicle speed, misjudgment of available gap, assuming the oncoming vehicle was going to stop or turn, and simply not seeing the other vehicle (Council & Zegeer, 1992, as discussed in FHWA Handbook, 2001). Older drivers as a group experience inordinate difficulties when making left turns, as they do not position themselves within the intersection before initiating a left turn. This can block the sight line to oncoming traffic for drivers waiting to make left turns from the opposite direction.

Attempting to make a left turn at an intersection where there is no protected phase can be difficult and dangerous to the older driver. Making a left turn during a permissive (unprotected) phase requires the driver to judge the speed of oncoming through traffic, identify an adequate gap, and execute the turn within the space allowed by the gap. When the oncoming traffic consists of two or more lanes, judging the speed and identifying a gap becomes considerably more difficult. In areas with pedestrian activity, left-turning drivers must also make sure that there are no pedestrians in the crosswalk that would block the vehicle from finishing the turn and proceeding safely out of the way of opposing through vehicles. Attendees at AARP’s Innovation Roundtable asserted that permissive left turns with two or more lanes of oncoming traffic have very high pedestrian crash rates, and that permissive-only left turns are one of the leading causes for crashes in urban areas.

Obstructed lines of sight caused by queued vehicles in opposing left-turn lanes (i.e., negative offsets) can pose safety and capacity deficiencies for all drivers, particularly for those making unprotected left-turn movements. Older drivers may experience additional difficulties in completing left turns as a result of diminished ability to properly perceive
depth and speed of oncoming traffic.\textsuperscript{20} Positive offsets are associated with larger sight distances (Joshua & Saka, 1992), which helps older drivers to judge gaps in opposing traffic, and they are associated with a reduction in crashes relative to permissive left turns without a positive offset.\textsuperscript{21}

Positive offset treatments can, however, pose problems for pedestrians. Ideally, multilane roads would provide a median refuge for pedestrians unable to cross in the allotted signal time. However, this median introduces a negative offset, and an attempt to compensate for this by providing a positive offset for left-turning drivers creates an awkward location for a pedestrian to wait and is especially disorienting for visually impaired persons. \textit{See Figures 19 and 20.}

The additional space needed to provide the median also increases the total pedestrian crossing distance and required green time. Respondents to the online survey remarked that a pedestrian refuge must be at least 6’ wide, which requires more right-of-way and increases crossing distance, while also failing to provide accommodations for bicycles.

Instead of addressing problems of restricted sight distance through geometric changes, a more affordable solution may be to make operational improvements such as traffic

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\textsuperscript{20} Older drivers are found to require double the angle of stereopsis to perceive depth than is required for younger drivers (Staplin et al., 1993, as discussed in FHWA Handbook 2001). Additionally, older drivers require twice the rate of movement to perceive approaching objects as compared to younger drivers (Hills, 1975, as discussed in FHWA Handbook, 2001). These factors result in difficulty perceiving oncoming traffic and judging its speed while completing left turns.

\textsuperscript{21} Perception reaction time (PRT) also diminishes with age, which is an important factor in considering intersection sight-distance requirements for turning vehicles. Conclusions from several studies cited in the AASHTO Green Book report reaction times of 0.2 to 0.3 seconds for drivers under alerted conditions and 1.5 seconds under normal conditions (AASHTO, 2004b). To account for complexities beyond laboratory and road tests, AASHTO recommends a reaction time of 2.5 seconds, which is the minimum perception reaction time recommended by the FHWA Handbook. This amount of time is recommended in addition to the typical time needed to stop based on the road design speed.
signals with a protected left-turn phase (oncoming traffic is stopped, denoted by a green arrow). Left-turning drivers are protected from opposing drivers who are stopped at a red light, and from opposing pedestrians who have a “Don’t Walk” light during the protected phase. When left turns are only allowed during a protected phase (thus prohibited during the general green phase), pedestrians are protected as they will not conflict with left-

This attempt to balance older driver and pedestrian needs by providing both a pedestrian refuge median and negative offset was rejected by engineers and planners.

![Diagram of intersection with negative offset and pedestrian refuge median](image)

Figure 20. Intersection showing both a negative offset and pedestrian refuge median.

A protected-only mode works best when the average daily traffic (ADT) is heavy, the use of through lanes is heavy, and the permissive left turn would result in a high frequency of crashes. The protected-only mode reduces left-turn crashes by 63–70 percent and has a particular safety benefit to the older driver (ITE, 2004).

In spite of the safety benefits of protected-only left-turn phases, they present some drawbacks that can discourage an agency from universally implementing them. Providing protected phases requires green time from other phases that could decrease intersection capacity, especially on wide roads with long pedestrian crossing distances. In addition, protected-only left turns can frustrate left-turning drivers who are forced to wait even when there is no oncoming traffic.

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22 Basha (2007) found collision rates at intersections with lagging left-turn arrows to be less than those at intersections with leading left-turn arrows. Left-turn head-on (LTHO) collisions make up 33 percent of all collisions at intersections in a city with leading left-turn arrows, while 21 percent of collisions are LTHO collisions in a city with lagging left-turn arrows (Basha, 2007).
Employing a phasing plan with a permissive left turn during the general phase and a lagging protected left-turn phase (solid green light, followed by a green arrow) is a comprehensive solution in most cases. Allowing left turns to process during the permitted phase reduces the queue of vehicles during the protected phase, which can give green time back to other movements. For older drivers who are less likely to position themselves within an intersection, a protected lag phase allows them time to execute the turn during the green arrow, while drivers behind them, who may normally become impatient, will have the opportunity to turn at the end of the general phase.\textsuperscript{23}

\textit{Suggested Refinements}

Depending upon the context of the intersection, a signal phasing plan with a protected left-turn lag phase will often provide more comprehensive benefits to older drivers and pedestrians than positive offset for the left-turn lane. This strategy provides an exclusive phase for drivers to make a left turn without risking conflicts with opposing traffic or pedestrians. It requires no additional pavement and does not increase pedestrian crossing distances.

Generally, if opposing through vehicular traffic is heavy, or if opposing pedestrian volumes are high, it may be best to restrict left turns to the protected-only phase. The presence of marked crosswalks between all quadrants of the intersection becomes more essential if a lagging left-turn phase is permitted in order to draw the attention of turning drivers to the possible presence of pedestrians in the intersection.

In urban and suburban settings, which warrant a median refuge of 6’ between directions of traffic, it becomes more important to limit the turn to a protected left-turn phase, as the refuge creates a negative offset and reduces the line of sight for drivers turning left.

As with any change in intersection design and operation, it is of utmost importance to consider the context of the road and the character of the surrounding area when deciding if a design treatment or phasing change is appropriate. The design presented here is most appropriate for urban and suburban roadways. The wider offset recommended by the FHWA Handbook may be more appropriate in limited rural settings where pedestrian traffic is not expected.

\textsuperscript{23} It should be noted that older drivers have more difficulty understanding left turn signal relative to younger drivers. Ullman (1993) found the protected left-turn signal to be the best understood while the protected/permissive the least (Eby, 2009).
Curb Radius

**FHWA Recommendation**

(1) Where roadways intersect at 90 degrees and are joined with a simple radius curve, a corner curb radius in the range of 7.5 m to 9 m (25’–30’) is recommended as a trade-off to (a) facilitate vehicle turning movements, (b) moderate the speed of turning vehicles, and (c) avoid unnecessary lengthening of pedestrian crossing distances, except where precluded by high volumes of heavy vehicles. *See Figure 21.*

(2) When it is necessary to accommodate turning movements by heavy vehicles, the use of offsets, tapers, and compound curves is recommended to minimize pedestrian crossing distances.

**Discussion**

Curb radius is a measure of the sharpness of a corner: smaller radii equal sharper turns suitable for automobiles and pedestrians, while larger radii facilitate the turning of large trucks and buses. One of the common pedestrian crash types involves a pedestrian who is struck by a right-turning vehicle at an intersection. Therefore, the design of the curb radius is an important consideration at an intersection where the paths of turning cars and crossing pedestrians overlap.

When curb radii are too small, older drivers who have physical conditions that make it difficult for them to maneuver turns may attempt to increase their turning radius in order to decrease steering wheel rotation, which results in cutting the corner or encroaching into other lanes of traffic (Staplin et al., 1994, as discussed in FHWA Handbook, 2001). While large curb radii are preferred by older drivers, they...
pose significant challenges for all pedestrians. Studies have shown that wide turns at intersections extend the crossing distance and encourage higher speeds among turning vehicles, putting the pedestrian at greater risk of vehicular conflict even when a pedestrian refuge island is provided (Hauer, 1988; Fitzpatrick, 2005; Wolfe, 2000). See Figure 22. Participants at the AARP Innovation Roundtable also pointed out that a large radius creates difficulties with the geometry of lining up the sidewalk, crosswalk and curb ramp, a design detail of particular importance to people who use wheelchairs and those with visual impairments.

The FHWA Handbook recommends a corner curb radius between 25’ and 30’ at 90-degree intersections to assist with the challenge of steering wheel rotation needed for older drivers, but provides little discussion of the most appropriate context for the standard. This type of radius is appropriate on streets with high volumes of large vehicles, and it is often applied in auto-oriented suburban areas where less emphasis is placed on pedestrian activity and safety.

The AASHTO Green Book gives an acceptable range of 15’–25’ as the design curb radius for passenger vehicles, appropriate for streets with fewer turning trucks or buses. The book recommends a minimum of 25’ where space permits, but notes that urban areas can function with curb radii of 10’–15’ given space limitations, presence of pedestrians, and generally lower operating speeds (AASHTO, 2004b). ITE’s Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities recommends a curb radius of 10’–15’ in several situations: where pedestrian activity is expected, where occasional encroachment into the opposing lane is acceptable and/or it is possible for larger vehicles to encroach on the corner of a curb, or where bike lanes or on-street parking increase the effective turning radius. Even 5’ curb radii are common in older cities.

**Suggested Refinements**

In all cases, the context of the roadway and appropriate vehicle speed should be considered in determining the appropriate size of the curb radius for the particular condition where it is located. Smaller curb radii in the 10’–15’ range, combined with lower vehicle speeds, are useful traffic calming devices and are most appropriate in urbanized areas where there is a greater mixture of users sharing the roadway. This is true for small towns, suburban mixed-use areas, and any other places where communities wish to encourage pedestrian and bicycle travel.

ability, visibility of oncoming traffic, and likelihood of hitting a curb or median while completing a right turn (Staplin et al., 1997, as discussed in FHWA Handbook, 2001). Another study further supported these difficulties. For older persons who are more likely to suffer from rheumatoid arthritis or other arthritic conditions that make gripping and turning the steering wheel difficult and painful, these conditions result in less control over vehicle movement when completing turns (Roberts & Roberts, 1993, as discussed in FHWA Handbook, 2001).
The addition of bike lanes and parallel parking increases the effective radius making it easier for older drivers to turn.

Figure 23: Comparison of Actual and Effective Curb Radii

Crosswalks do not line up with curb cuts and sidewalks

Fig. 24: Illustration of how R2 in figure 23 would appear if it were the actual radius.

A 25’ curb radius may be appropriate, however, for urban boulevards, parkways, and less urbanized areas where the dominant form of mobility is the automobile, or where larger vehicles use the facility on a regular basis. In all cases, the designer should aim for the smallest curb radius possible with consideration given to the nearby land uses, design speed, and types of road users.

To ensure pedestrian safety, designers should aim for the smallest curb radius that works for the particular context, design speed, and vehicle. Smaller curb radii can both shorten the crossing distance and force drivers to slow down as they make a tighter radius turn. Participants at the Innovation Roundtable offered the following recommendations to make a tighter curb radius work in a variety of contexts:

- Choose the appropriate design vehicle. Curb radii should be designed to accommodate the largest vehicle type that will frequently turn the corner. For example, a bus may use a make a certain turn several times an hour, but a moving van, once or twice a year. Do not choose a larger design vehicle than necessary.

- Calculate the curb radius for each corner individually. Curb radius design is not a one-size-fits-all approach. For example, on one-way streets, a corner with
no turns can have a very tight (5’) radius, while another corner may require a longer radius.

- Calculate curb radii to reflect the “effective” turning radius of the corner. The effective turning radius takes into account the wheel tracking of the design vehicle utilizing the width of parking and bicycle lanes, and location of the stop bar. This allows a smaller curb return radius while retaining the ability to accommodate larger design vehicles.

- Allow trucks and other large vehicles to encroach into second lane at large signalized intersections.

- Use a lower-speed setting on truck-turning software. Occasional turns by vehicles that are larger than the design vehicle could be accomplished by turning more slowly.

Comments from the online survey varied on this design refinement. There was general consensus that 10’–15’ radii work well for pedestrians particularly in urban areas, as evidenced by the 80 percent approval that the suggested refinement resolved potential conflicts well or somewhat well as compared to the original FHWA Handbook design. Many respondents also acknowledged that small radii would be difficult for large trucks and buses, and may cause problems for pedestrians if the corner, curb, or sidewalk is damaged by heavy vehicles. These responses prove the importance of considering the context of the road, as different types of roadway users and activities will influence transportation needs and priorities.

Pedestrian Crossing Design, Operations, and Control

FHWA Recommendation

To accommodate the shorter stride and slower gait of less capable (15th percentile) older pedestrians, and their exaggerated start-up time before leaving the curb, pedestrian control-signal timing based on an assumed walking speed of 0.85 m/second (2.8’/second) is recommended.

Discussion

Assumed Walking Speeds - The walking speed set for signal operations is by far one of the most important design and operational parameters that can affect pedestrian-vehicular conflicts, pedestrian safety, and crashes at signalized intersections. Older pedestrians may have physical limitations that make it difficult to cross a street in the time allotted by a crossing signal. Additionally, older pedestrians may have physical or visual disabilities that impair their ability to safely navigate a crossing.

Current standards from the Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) base the length of the pedestrian clearance phase (the flashing
“Don’t Walk” segment) on the “normal” pedestrian walking speed of 4’ (1.2 m) per second. However, the length of time it takes to cross a street varies by an individual’s age, gender, physical abilities, etc. Nearly 90 percent of older pedestrians using walkers or canes would be unable to cross the street in the time allotted (Arango, 2008). Because of this, older pedestrians often find themselves caught in the right-of-way after the walking signal has already expired. To account for this discrepancy, the FHWA Handbook recommends that crossing signals be based on an assumed walking speed of 2.8’/second (Staplin et al., 2001).

In 2004, LaPlante and Kaeser summarized the research on pedestrian walking speeds, citing average crossing times for normal adults at 4.0’/second and crossing speeds for older adults ranging from 2.2’/second to 3.8’/second. Based on their research, they recommended a maximum walking speed of 3.5’/second be used to determine the pedestrian clearance interval (PCI) from curb to curb, and a maximum walking speed of 3.0’/second be used to determine the entire “Walk” plus PCI (considering signal phasing of the total crossing from the top of the ramp to the far curb).

More recent research from ITE and AAA supports these findings, recommending a 7-second walk signal, in addition to a pedestrian clearance interval based on a walking speed of 3.5’/second (Stollof, 2007). The recommendations also include options to increase or decrease the pedestrian walking speed based on specific pedestrian characteristics and available pedestrian signal hardware at intersections. In 2006, the National Committee on Uniform Traffic Control Devices (NCUTCD) Signals Technical Committee voted to recommend these changes for the next edition of MUTCD.

**Signal Design** - Another important crosswalk safety factor for older pedestrians is the design of the pedestrian crossing signal. Traditional pedestrian signals consist of illuminated symbols such as a walking person (symbolizing “Walk”), a flashing upraised hand during the pedestrian clearance interval (symbolizing that it is okay to continue walking if one has already begun crossing), and an upraised hand (symbolizing “Don’t Walk”). Research shows that such signals can be confusing to the pedestrian if used without any explanation (Stollof, 2007). The FHWA Handbook recommends a placard that explains pedestrian control-signal operations and presents a warning to watch for turning vehicles to be posted at the near corner of all intersections with a pedestrian crosswalk.

A tested strategy to reduce confusion at crosswalks is the use of pedestrian countdown (PCD) signals, which are more easily understood than the traditional pedestrian signal (Eccles, Tao, & Mangum, 2004; Mahach, Nedzesky, Atwater, & Saunders, 2002; Allsbrook, 1999; Chester & Hammond, 1998). One study recommended the use of PCD signals at intersections frequented by an older adult population because of the value of the added information about the time available for crossing (Huang & Zegeer, 2000). The proposed amendments for the next edition of the MUTCD require all new pedestrian signal heads to include a PCD, except on the narrowest of streets.
Curb Ramp Design - The 2005 draft Public Rights-of-Way Accessibility Guidelines (PROWAG) serves as the current best practice for accessible pedestrian design (as identified by the USDOT). It provides guidance on all types of public rights-of-way, and contains a useful summary of ADA and ADA Accessibility Guidelines (ADAAG) regulations as well as industry design practices on bus stops, curb ramps, pedestrian crossings, and street furniture relevant to bus stop accessibility. A whole chapter is dedicated to providing examples of curb ramp designs for 10’ and 30’ radius curb returns.

Suggested Refinements

Assumed Walking Speeds - The FHWA Handbook should recommend a 7-second walk signal, in addition to a pedestrian clearance interval based on a walking speed of 3.5'/second. According to the research conducted by ITE, reducing signal timing so that the PCI accommodates a walk speed of 3.5'/second would have minimal operational impacts in most cases. Increased vehicle delays would occur most often on the major street approaches, which tend to be wider and, thus, have longer crossing distances, requiring a longer PCI. A careful balance between the needs of pedestrians and drivers is necessary; attention to the context and operational capacity of the intersection is critical in determining pedestrian crossing time.

Signal Design - Pedestrian signals should be designed simply (without complex placards) and include a pedestrian countdown (PCD). The signals should be large enough to be clearly visible from the opposite side of the street and may be best when combined with an audible signal to assist pedestrians with visual impairments. The use of backplates surrounding the signal housing would further increase signal visibility to older drivers, especially where the lights are viewed against a bright sky or confusing background.25

Curb Ramps - The FHWA Handbook should include a section on ADA accessibility and compliance, referring to PROWAG for the design and layout of curb ramps. While there is no standard layout for a curb ramp, there are a number of factors that need to be achieved to construct a curb ramp that will be usable by all pedestrians. These include:

1. Curb ramp slope should be aligned with the sidewalk and crosswalk to help citizens with visual disabilities or those using a wheelchair to navigate safely.

2. Where a curb ramp is present on one side of a roadway, another curb cut or at-grade sidewalk must provided on the other side of the roadway.

3. So as not impede the progress or safety of pedestrians with disabilities, sidewalks should be designed with no more than a 2 percent cross-slope, which is sufficient for proper drainage of rainwater (and snowmelt).

25 The FHWA Handbook cites studies that show backplates can increase the intensity of the signal face by 33 percent. However, backplates increase wind loading on signal suspension systems and therefore are appropriate when used with wind-resistant suspension systems (Amparano, 2006).
ADDITIONAL RESEARCH NEEDED

Several issues were raised during the course of this study that could not be adequately addressed and are recommended for further research. These include the need for better multimodal safety research and the effects of speed on safety and urban roadway design.

Multimodal Safety Research

Current literature is deficient for fully understanding the safety implications of design on the pedestrian and bicyclist, especially the older pedestrian. More research projects need to be tailored to look at the effects of a particular treatment on more than one mode at the same time. For instance, research studies supporting the FHWA Handbook recommendations for curb radius reference focus groups of drivers, older and younger, where participants reported factors such as ease of turning, better maneuverability, and less chance of hitting the curb. Based on these studies and a desire to moderate the negative impact of a long radius on pedestrians, FHWA recommends a 25′ curb radius. More recent research to test the effectiveness of the FHWA guidelines uses kinematics measures such as acceleration forces, yaw, and speed as surrogates for safe driving performance (Classen, 2007). Older drivers’ ability to maintain their speed through the intersection is seen as a positive benefit of the FHWA Handbook treatment.

While the FHWA Handbook recognizes that wider radii would increase speed and compromise pedestrian safety, a 25′ radius is nonetheless challenged by many engineers as still too fast and wide to “Complete the Street” in many urban and suburban settings. More rigorous research should be done to test actual safety for different road users for varying curb radii. The same is true for testing other intersection design treatments. Safety surrogates provide an inconclusive basis for design guidelines.

Effects of Speed on Safety and Urban Roadway Design

Current research related to the effects of speed on the safety of all road users, including older adults, is inadequate. A better understanding of urban roadway design and driver behavior is needed. Gattis (2005) notes that current research predominantly focuses on rural or high-speed environments, which results in urban roadway engineers’ extrapolating from the principles learned in a rural highway environment to the urban environment. The current research on older driver safety fails to adequately address the effect of speed. Questions worth looking at would include:

- How could the effects of traffic calming impact the recommendations offered for older driver safety?
- What particular challenges does the older driver have in slow urban environments compared to fast rural or fast suburban environments? How would treatment recommendations vary under these different conditions?
- Treatments should be tested against the safety and traffic operations effects for each
mode. What is gained by lowering the speed? What is lost?

Road design is a both a science and an art. It requires designers to balance and prioritize the needs of diverse users. Planners, engineers, policy makers, developers, and all other stakeholders, including residents, must work together in support of a new paradigm. Approaching road planning and design through the lens of a Complete Streets framework offers designers the opportunity to assess community context and goals. The results of such an approach will never be perfect, but they will come closer to realizing solutions that work for everyone.


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