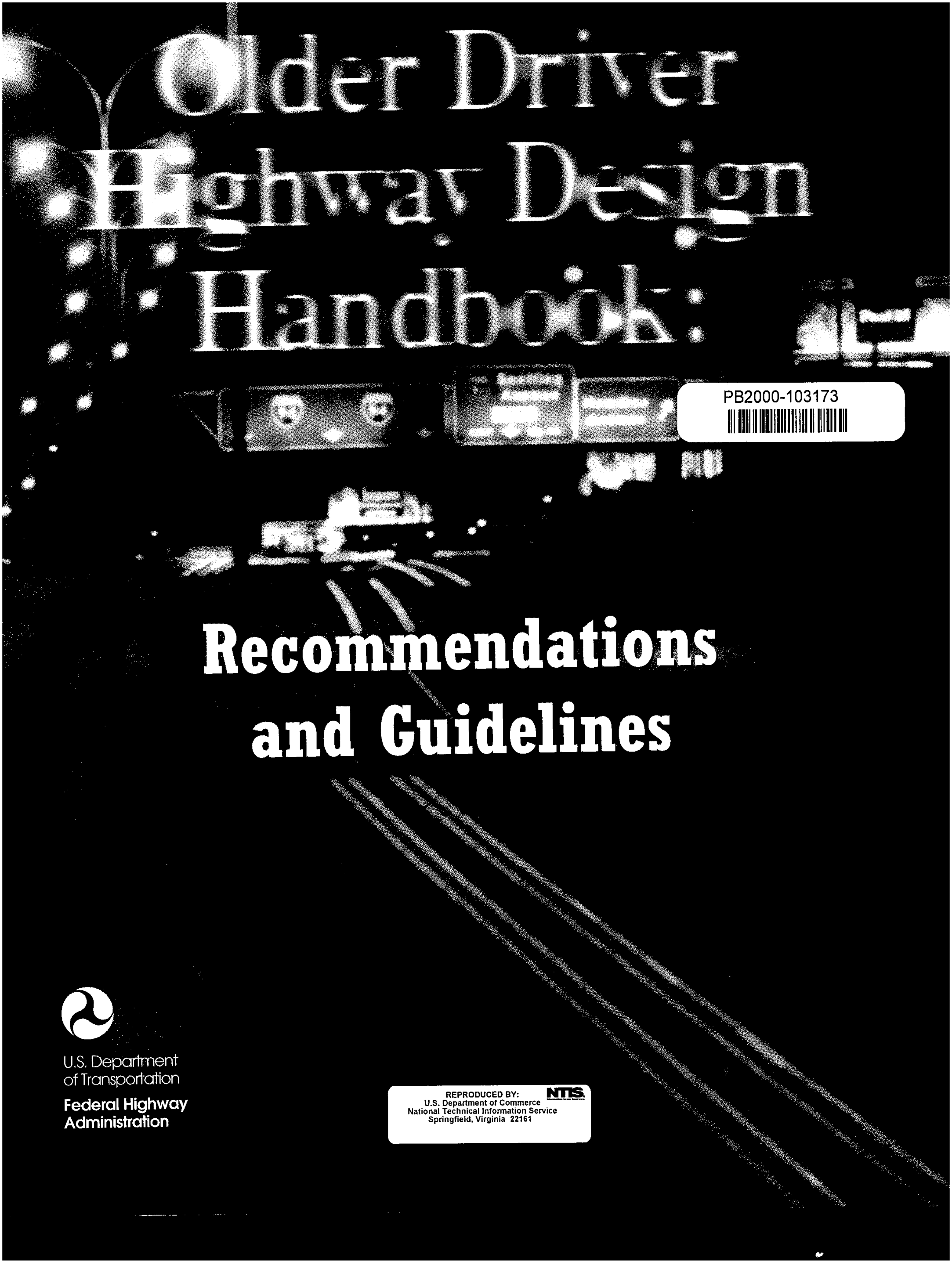


Older Driver Highway Design Handbook:

Recommendations and Guidelines

U.S. Department of Transportation

Federal Highway Administration

INTRODUCTION

The increasing numbers and percentages of older drivers using the nation's highways in the decades ahead will pose many challenges to transportation engineers, who must ensure system safety while increasing operational efficiency. The 65 and older age group, numbered 33.5 million in the United States in 1995, will grow to more than 36 million by 2005, and will exceed 50 million by 2020, accounting for roughly one-fifth of the population of driving age in this country. In effect, if design is controlled by even 85th percentile performance requirements, the "design driver" of the early 21st century will be an individual over the age of 65.

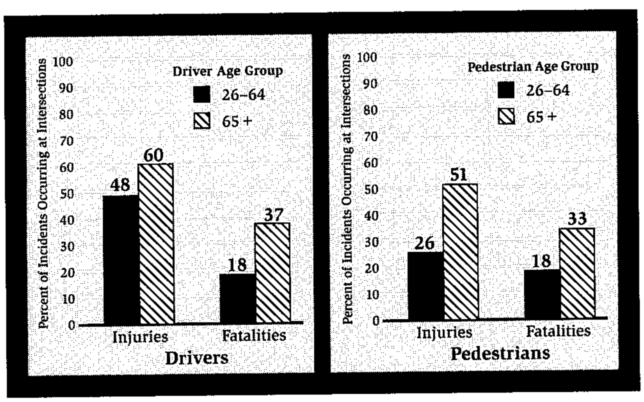
This report contains highway design information that will help accommodate the needs and capability of older road users. Specifically, it contains the recommendations sections of a larger report titled Older Driver Highway Design Handbook *(FHWA-RD-97-135). The full report also includes extensive sections covering the rationale and supporting evidence for each recommendation.*

These recommendations do not constitute a new standard of required practice. When and where to apply each recommendation remains at your disretion as the expert practitioner. The recommendations provide guidance that is firmly grounded in an understanding of older drivers' needs and capabilities, and can significantly enhance the safety and ease of use of the highway system for older drivers in particular, and for the driving population as a whole.

I. INTERSECTIONS
(AT-GRADE)

Background and Scope of Handbook *Recommendations*

The single greatest concern in accommodating older road users, both drivers and pedestrians, is the ability of these persons to safely maneuver through intersections. The findings of one widely cited analysis of nationwide accident data (Hauer, 1988), illustrated below, reveal the relationship between injuries and fatalities at intersections during the period 1983–85 in the United States, as a function of age and road user type (driver or pedestrian).



For drivers age 80 and over, *more than half* of fatal accidents occur at intersections, compared with 24 percent or less for drivers up to age 50 (Insurance Institute for Highway Safety, 1993). These findings reinforce a long-standing recognition that driving situations involving complex speed-distance judgments under time constraints—the typical scenario for intersection operations—are more problematic for older drivers and pedestrians than for their younger counterparts (Waller, House, and Stewart, 1977). Other studies within the large body of evidence showing dramatic increases in intersection accident involvements as driver age increases have revealed detailed patterns of data associating specific accident types and vehicle movements with particular age groups, and in some cases have linked such patterns to the driving task demands in a given maneuver situation (see Campbell, 1993; Council and Zegeer, 1992; Staplin and Lyles, 1991).

Another approach to characterizing older driver problems at intersections was employed by Brainin (1980), who used in-car observations of driving behavior with 17 drivers ages 25–44, 81 drivers ages 60–69, and 18 drivers age 70 and older, on a standardized test route. The two older age groups showed more difficulty making right and left turns at intersections and negotiating traffic signals. The left-turn problems resulted from a lack of sufficient caution and poor positioning on the road during the turn. Right-turn difficulties were primarily a result of failing to signal. Errors demonstrated at STOP signs included failing to make complete stops, poor vehicle positioning at STOP signs, and jerky and abrupt stops. Errors demonstrated at traffic signals included stops that were either jerky and abrupt, failure to stop when required, and failure to show sufficient caution during the intersection approach.

Complementing accident analyses and observational studies with subjective reports of intersection driving difficulties, a statewide survey of 664 senior drivers by

Benekohal, Resende, Shim, Michaels, and Weeks (1992) found that the following activities become more difficult for drivers as they grow older (with proportion of drivers responding in parentheses):

- Reading street signs in town (27 percent).
- Driving across an intersection (21 percent).
- Finding the beginning of a left-turn lane at an intersection (20 percent).
- Making a left turn at an intersection (19 percent).
- Following pavement markings (17 percent).
- Responding to traffic signals (12 percent).

Benekohal et al. (1992) also found that the following highway features become more important to drivers as they age (with proportion of drivers responding in parentheses):

- Lighting at intersections (62 percent).
- Pavement markings at intersections (57 percent).
- Number of left-turn lanes at an intersection (55 percent).
- Width of travel lanes (51 percent).
- Concrete lane guides (raised channelization) for turns at intersections (47 percent).
- Size of traffic signals at intersections (42 percent).

Comparisons of responses from drivers ages 66–68 versus those age 77 and older showed that the older group had more difficulty following pavement markings, finding the beginning of the left-turn lane, and driving across intersections. Similarly, the level of difficulty for reading street signs and making left turns at intersections increased with increasing senior driver age. Turning left at intersections was perceived as a complex driving task. This was made more difficult when raised channelization providing visual cues was absent, and only pavement markings designated which were through versus turning lanes ahead. For the oldest age group, pavement markings at intersections were the most important item, followed by the number of left-turn lanes, concrete guides, and intersection lighting. A study of older road users completed in 1996 provides evidence that the single most challenging aspect of intersection negotiation for this group is perf`*ming left turns during the permitted (green ball) signal phase (Staplin, Harkey, Lococo, and Tarawneh, 1997).

During focus group discussions conducted by Benekohal et al. (1992), older drivers reported that intersections with too many islands are confusing, that raised curbs that are unpainted are difficult to see, and that textured pavements (rumble strips) are of value as a warning of upcoming raised medians, approaches to (hidden or flashing red) signals, and the roadway edge/shoulder lane boundary. Regarding traffic signals, study subjects indicated a clear preference to turn left on a protected arrow phase, rather than making "permitted phase" turns. When turning during a permitted phase (green ball) signal operation, they reported waiting for a large gap before making a turn, which frustrates following drivers and causes the following drivers to go around them or blow their horns at the older drivers. A general finding here was the need for more time to react.

Additional insight into the problems older drivers experience at intersections was provided by focus group responses from 81 older drivers in the Staplin et al. study (1997). The most commonly reported problems are:

- Difficulty in turning head at skewed (non-90-degree) angles to view intersecting traffic.
- Difficulty in smoothly performing turning movements at tight corners.
- Hitting raised concrete barriers such as channelizing islands in the rain and at night due to poor visibility.
- Finding oneself positioned in the wrong lane—especially a "turn only" lane—during an intersection approach, due to poor visibility (maintenance) of pavement markings or the obstruction of roadside signs designed to inform drivers of intersection traffic patterns.
- Difficulty at the end of an auxiliary (right) turn lane in seeing potential conflicts well and quickly enough to smoothly merge with adjacent-lane traffic.
- Merging with adjacent-lane traffic after crossing an intersection, when a lane drop occurs near the intersection (e.g., when two lanes merge into one lane within 150 m [500 ft] after crossing the intersection).

Although these problems are by no means unique to older drivers, the various functional deficits associated with aging result in exaggerated levels of difficulty for this user group.

Finally, the analysis by Council and Zegeer (1992) included an examination of pedestrian accidents and the collision types in which older pedestrians were overinvolved. The results showed older pedestrians to be overrepresented in both right- and left-turn accidents. The young-elderly (ages 65–74) were most likely to be struck by a vehicle turning right, whereas the old-elderly (age 75 and older) were more likely to be struck by a left-turning vehicle.

This section provides recommendations to enhance the performance of diminished-capacity drivers as they approach and travel through intersections, for 16 different design elements:

- intersecting angle (skew);
- receiving lane (throat) width for turning operations;
- channelization;
- intersection sight distance (sight triangle);
- opposite (single) left-turn lane geometry, signing, and delineation;
- edge treatments/delineation of curbs, medians, and obstacles;
- curb radius;
- traffic control for left-turn movements at signalized intersections;
- traffic control for right-turn/right-turn-on-red (RTOR) movements at signalized intersections;
- street-name signage;
- one-way/wrong-way signage;
- stop- and yield-controlled intersection signage;
- devices for lane assignment on intersection approach;
- traffic signal performance issues;
- fixed lighting installations; and
- pedestrian control devices.

A. Intersecting Angle (Skew)

(1) In the design of new facilities where right-of-way is not restricted, all intersecting roadways should meet at a 90-degree angle.

(2) In the design of new facilities or redesign of existing facilities where right-of-way is restricted, intersecting roadways should meet at an angle of not less than 75 degrees.

B. Receiving Lane (Throat) Width for Turning Operations

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

C. Channelization

(1) At intersections with high pedestrian volumes, it is recommended that right-turn channelization *not* be implemented without the provision of an adjacent pedestrian refuge island conforming to MUTCD (Federal Highway Administration, 1988) and AASHTO (1994) specifications.

(2) If right-turn channelization is present at an intersection, an acceleration lane providing for the acceleration characteristics of passenger cars as per AASHTO (1994) is recommended.

(3) Raised channelization (sloping curbed medians) is recommended over painted channelization for left- and right-turn lane treatments at intersections, with island curb sides and curb surfaces treated with reflectorized paint and maintained at a minimum luminance contrast level of 3.0 or higher under low beam (passenger vehicle) headlight illumination.

D. Intersection Sight Distance (Sight Triangle)

(1) For Cases I through IV, as described below, it is recommended that perception-reaction time (PRT) for intersection sight distance (ISD) be no less than 2.5 s to accommodate the slower decision times exhibited by, and the larger gap sizes desired, by older drivers.

Case I: No Control

Case II: Yield Control

Case IIIA: Stop Control—Crossing

Case IIIB: Stop Control—Left Turn

Case IIIC: Stop Control—Right Turn

Case IV: Signal Control

(2) For ISD Case V (Stop Control—Vehicle Turning Left From Major Highway), unrestricted sight distances and corresponding left-turn lane offsets are recommended whenever possible in the design of opposite left-turn lanes at intersections.

(2a) At intersections where there are large percentages of left-turning trucks, the offsets required to provide unrestricted sight distance for opposing left-turn trucks should be used.

(2b) Where the provision of unrestricted sight distance is not feasible, ISD values for left-turning traffic that must yield to opposing traffic on the major roadway (ISD Case V) should be computed using the modified AASHTO model, as follows:

$$ISD = 1.47\ V\ (J + t_a) \quad \text{English}$$

$$ISD = 0.278\ V\ (J + t_a) \quad \text{Metric}$$

where:

ISD = intersection sight distance (feet for English equation; meters for metric equation).

V = major roadway operating speed (mi/h for English equation; km/h for metric equation).

J = time to search for oncoming vehicles, to perceive that there is sufficient time to make the left turn, and to shift gears, if necessary, prior to starting (modified to 2.5 s).

t_a = time required to accelerate and traverse the distance to clear traffic in the approaching lane(s); obtained from Figure IX-33 in the AASHTO Green Book.

E. Opposite (Single) Left-Turn Lane Geometry, Signing,and Delineation

(1) To provide a margin of safety for older drivers, who, as a group, do not position themselves within the intersection before initiating a left turn, unrestricted sight distance achieved through positive offset of opposite left-turn lanes is recommended whenever possible, for new or reconstructed facilities.

(2) At intersections where engineering judgment indicates a high probability of heavy trucks as the opposing turn vehicles during normal operations, the offsets required to provide unrestricted sight distance for opposing left-turn trucks should be used, for new or reconstructed facilities.

(3) Where the provision of unrestricted sight distance is not feasible, ISD values for left-turning traffic that must yield to opposing traffic on the major roadway (ISD Case V) should be computed using the modified AASHTO model, as follows:

$$ISD = 1.47\ V\ (J + t_a) \quad \text{English}$$

$$ISD = 0.278\ V\ (J + t_a) \quad \text{Metric}$$

where:

ISD = intersection sight distance (feet for English equation; meters for metric equation).

V = major roadway operating speed (mi/h for English equation; km/h for metric equation).

J = time to search for oncoming vehicles, to perceive that there is sufficient time to make the left turn, and to shift gears, if necessary, prior to starting (modified to 2.5 s).

t_a = time required to accelerate and traverse the distance to clear traffic in the approaching lane(s); obtained from Figure IX-33 in the AASHTO Green Book (1994).

(4) At intersections where the left-turn lane treatment results in channelized offset left-turn lanes (e.g., a parallel or tapered left-turn lane between two medians) the following countermeasures are recommended to reduce the potential for wrong-way maneuvers by drivers turning left from a stop-controlled, intersecting minor roadway:

(4a) In the implementation of (advance) DIVIDED HIGHWAY CROSSING signs, and WRONG WAY, DO NOT ENTER, and ONE WAY signs at the intersection, as per MUTCD (Federal Highway Administration, 1988) specifications, sign sizes larger than MUTCD standard sizes (e.g., MUTCD expressway size for DO NOT ENTER [900 x 900 mm] and MUTCD special size for WRONG WAY [1050 x 750 mm]) are recommended, as is high-intensity sheeting.

(4b) Lane-use arrows for channelized left-turn lanes are recommended, and reflectorized treatments should be used wherever practical; otherwise, white painted pavement markings should be used.

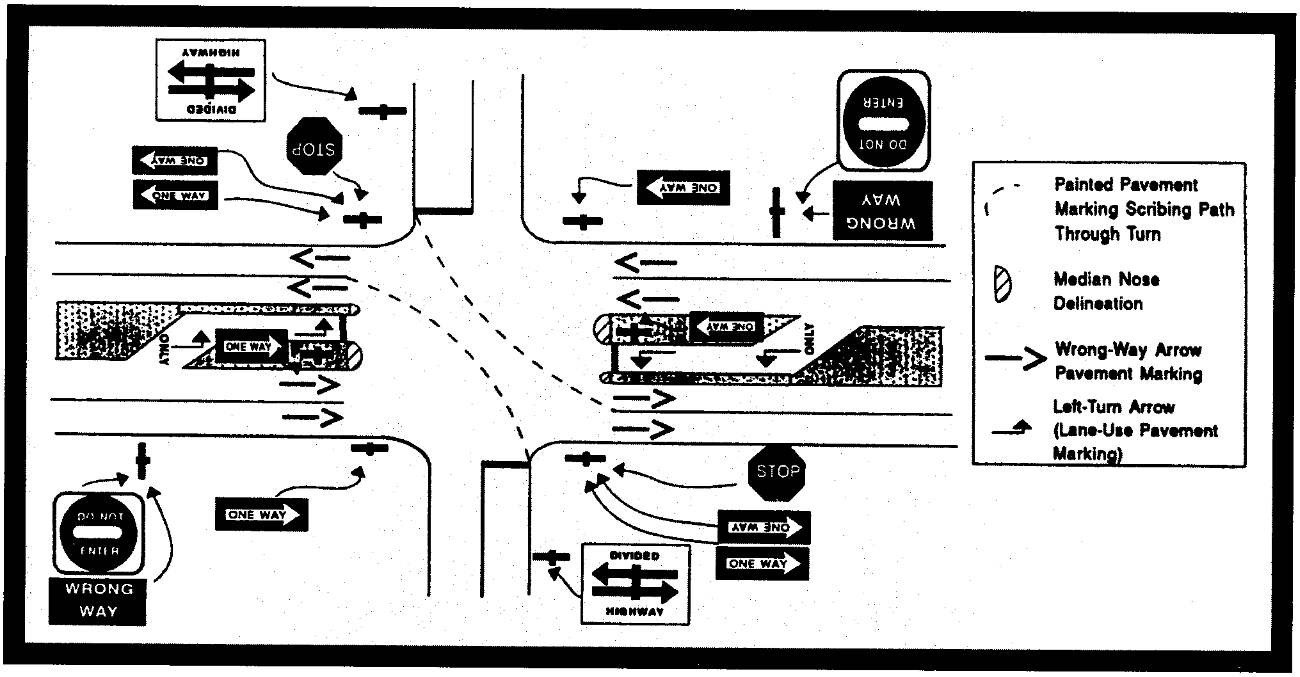
(4c) Pavement markings which scribe a path through the turn are recommended to reduce the likelihood for the wrong-way movement.

(4d) The use of a white stop bar 600 mm (24 in) in width is recommended at the end of the channelized left-turn lane as a countermeasure to aid in preventing a potential wrong-way movement.

(4e) Placement of 7-m (23.5-ft) wrong-way arrows in the through lanes is recommended for wrong-way traffic control at locations determined to have a special need, as specified in the MUTCD, section 2E-40.

(4f) Delineation of median noses using reflectorized paint and other treatments to increase their visibility and improve driver understanding of the intersection design and function is recommended.

The diagram presented below illustrates the countermeasures recommended in E(4a)–(4f).



Recommended signing and delineation treatments for intersections with medians 9 m (30 ft) wide or wider, and medians with channelized left-turn lanes, to reduce the potential for wrong-way movements for drivers turning left from the minor roadway.

F. Edge Treatments/Delineation of Curbs, Medians, and Obstacles

(1) A minimum in-service contrast level of 2.0 is recommended between the painted edge of the roadway and the road surface for intersections with overhead lighting, where:

$$\text{luminance (L) contrast} = \frac{L_{stripe} - L_{pavement}}{L_{pavement}}$$

(2) A minimum in-service contrast level of 3.0 is recommended between the painted edge of the roadway and the road surface for intersections without overhead lighting.

(3) It is recommended that all curbs at intersections (including median islands and other raised channelization) be delineated on their vertical face and at least a portion of the top surface, in addition to the provision of a painted edgeline on the road surface.

(4) It is recommended that a "preview" of vertical surfaces be provided using cross-hatched pavement markings, as specified in the MUTCD (Federal Highway Administration, 1988), section 3B-13 "Approach to an Obstruction."

G. Curb Radius

(1) Except where precluded by high volumes of heavy vehicles, a corner curb radius of 9 m (30 ft) is recommended as a tradeoff to (a) facilitate vehicle turning movements, (b) moderate the speed of turning vehicles, and (c) avoid unnecessary lengthening of pedestrian crossing distances.

H. Traffic Control for Left-Turn Movements at Signalized Intersections

(1) The use of protected-only operations is recommended, except when, based on engineering judgment, an unacceptable reduction in capacity will result.

(2) To reduce confusion during an intersection approach, the use of a separate signal to control movements in each lane of traffic is recommended.

(3) Consistent use of a common sign throughout the United States advising drivers of the correct response to a steady green ball during protected-permitted operations (R10-12, "LEFT TURN YIELD ON GREEN ●") is recommended, with overhead placement preferred at the intersection.

(4) A leading protected left-turn phase is recommended wherever protected left-turn signal operation is implemented.

(5) To reduce confusion with the meaning of the red arrow indication, it is recommended that the steady green arrow for protected-only left-turn operations time out to a yellow arrow, then a steady red ball.

(6) The use of redundant upstream signing (R10-12) that advises left-turning drivers of permitted signal operation, affording at least a 3-s preview (at operating speeds in the left-turn lane) before the intersection, is recommended, using either overhead or median sign placement.

(7) Where the required (minimum) sight distance as calculated using a modified AASHTO intersection sight distance (ISD) model with a 2.5-s perception-reaction time (PRT) is not practical to achieve through geometric redesign/reconstruction, the following operational changes are recommended:

(7a) If programmable signal control capability exists, restrict permitted left-turn operations to low-volume (off-peak) conditions.

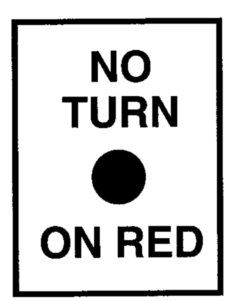
(7b) Where a pattern of permitted left-turn accidents occurs, eliminate permitted left turns and implement protected-only left-turn operations.

I. Traffic Control for Right-Turn/RTOR Movements at Signalized Intersections

(1) To reduce confusion with the meaning of the (right-turn) red arrow, it is recommended that a steady red ball be used at signalized intersections where a right turn is prohibited, supplemented by the NO TURN ON RED sign depicted in Recommendation 3 below.

(2) The prohibition of right turn on red (RTOR) at skewed intersections (angle less than 75 degrees or greater than 105 degrees) is recommended.

(3) The signing of prohibited RTOR movements using the novel design (as shown) is recommended, with sign placement on the overhead mast arm and on the opposite corner of the intersection.



(4) Where RTOR is permitted and a pedestrian crosswalk is delineated on the intersecting roadway, the posting of signs with the legend TURNING TRAFFIC MUST YIELD TO PEDESTRIANS is recommended, in an overhead or roadside location that is easily visible to the motorist prior to initiating the turning maneuver.

J. Street-Name Signage

(1) To accommodate the reduction in visual acuity associated with increasing age, a minimum letter height of 150 mm (6 in) is recommended for use on post-mounted street-name signs (D3).

(2) The use of overhead-mounted street-name signs with minimum letter heights of 200 mm (8 in) is recommended at major intersections.

(3) Wherever an advance intersection warning sign is erected (e.g., W2-1, W2-2, W2-3, W2-4), it is recommended that it be accompanied by a supplemental street-name sign.

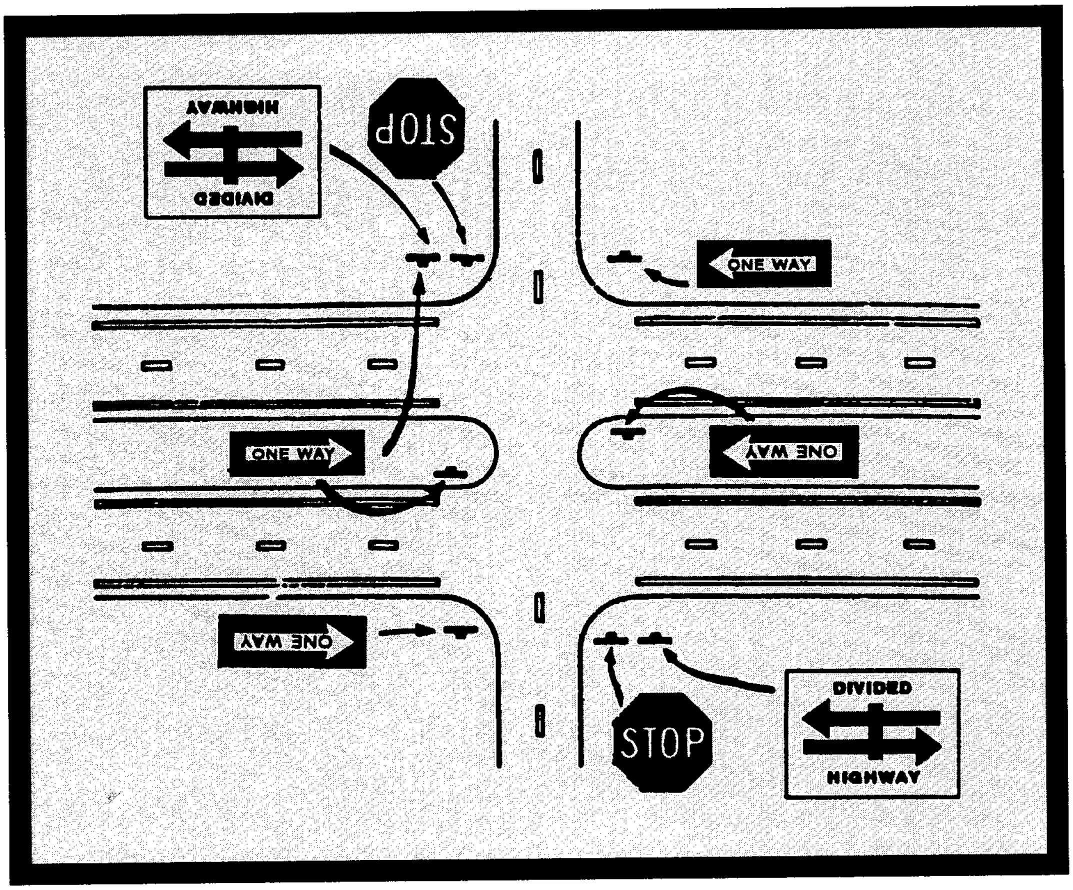
(4) The use of redundant street-name signing for major intersections is recommended, with an advance street-name sign placed upstream of the intersection at a midblock location, and an overhead-mounted street-name sign posted at the intersection. Wherever practical, the midblock sign should be mounted overhead.

(5) When different street names are used for different directions of travel on a crossroad, the names should be separated and accompanied by directional arrows on both midblock and intersection street-name signs, as shown below:

K. One-Way/Wrong-Way Signage

(1) It is recommended that approaches to divided highways be consistently signed; use of the DIVIDED HIGHWAY CROSSING sign (R6-3) is the recommended current practice, but this sign may be replaced or supplemented with new treatments that are demonstrated through research to provide improved comprehensibility to motorists.

(2) For divided highways with medians of 9 m (30 ft) and under, the use of four ONE WAY signs is recommended, in the configuration diagrammed below.



Recommended signing configuration for medians less than or equal to 9 m (30 ft).

(3) For medians over 9 m (30 ft) the use of eight ONE WAY signs is recommended, as diagrammed on page 8 under "Opposite (single) Left-Turn Lane Geometry, Signing, and Delineation".

(4) For T-intersections, the use of a near-right side ONE WAY sign and a far side ONE WAY sign is recommended; the preferred placement for the far side sign is opposite the extended centerline of the approach leg as shown in MUTCD Figure 2-4 (Federal Highway Administration, 1988). Where the preferred far side location is not feasible because of blockage, distracting far side land use, excessively wide approach leg, etc., engineering judgment should be applied to select the most conspicuous alternate location for a driver who has not yet initiated the wrong-way turning maneuver.

(5) For four-way intersections (i.e., the intersection of a one-way street with a two-way street), ONE WAY signs placed at the near right/far left locations are recommended, regardless of whether there is left-to-right or right-to-left traffic.

(6) As a general practice, the use of DO NOT ENTER and WRONG WAY signs is recommended at locations where the median width is 6 m (20 ft) and greater; consideration should also be given to the use of these signs for median widths narrower than 6 m (20 ft), where engineering judgment indicates a special need.

L. Stop- and Yield-Controlled Intersection Signage

System-wide recommendations* to improve the safe use of intersections by older drivers, where the need for stop control or yield control has already been determined, include the following:

(1) The use of standard size (750 mm [30 in]) STOP (R1-1) and standard size (900 mm [36 in]) YIELD (R1-2) signs, as a minimum, is recommended wherever these devices are implemented.

(2) A minimum in-service sign background (red area) retroreflectivity level of 12 cd/m /lux for roads with operating speeds under 64 km/h (40 mi/h), and 24 cd/m /lux for roads with operating speeds of 64 km/h (40 mi/h) or higher, is recommended for STOP (R1-1) and YIELD (R1-2) signs.

(3) The use of a supplemental warning sign panel mounted below the STOP (R1-1) sign, as illustrated, is recommended for two-way stop-controlled intersection sites selected on the basis of accident experience; where the sight triangle is restricted; and wherever a conversion from four-way stop to two-way stop operations is implemented.

CROSS TRAFFIC
DOES NOT STOP

(4) It is recommended that a STOP AHEAD sign (W3-1a) be used where the distance at which the STOP sign is visible is less than the AASHTO stopping sight distance (SSD) at the operating speed, plus an added preview distance of at least 2.5 s. Consideration should also be given to the use of transverse pavement striping or rumble strips upstream of stop-controlled intersections where engineering judgment indicates a special need due to sight restrictions, high approach speeds, or other geometric or operational characteristics likely to violate driver expectancy.

***These broad recommendations may not address all of the diverse and varying problems occurring at any unique location. Engineering study may be needed to identify specific additional measures or combinations of measures to modify problem driver behaviors.**

M. Devices for Lane Assignment on Intersection Approach

(1) The consistent placement of lane-use control signs (R3-5, R3-6) overhead on the signal mast arm at intersections is recommended, as a supplement to pavement markings and shoulder- and/or median-mounted signage.

(2) The consistent posting of lane-use control signs plus application of lane-use arrow pavement markings at a preview distance of at least 5 s (at operating speed) in advance of a signalized intersection is recommended, regardless of the specific lighting, channelization, or delineation treatments implemented at the intersection. Signs should be mounted overhead wherever practical, but they may be shoulder- and/or median-mounted in other cases.

N. Traffic Signal Performance Issues

(1) To accommodate the increased optical density (reduced ocular transmittance) of the older driver's eye, and to improve availability of signal information under divided attention conditions during an intersection approach, it is recommended for all over-the-road signals that the Commission Internationale de l'Éclairage (CIE) 1980 standard for vertical intensity distribution (percent of peak) for a 300-mm (12-in) signal be adhered to in the United States, as given below:

Vertical Angle (degrees)	Intensity (% of Peak)	
	Backplate	No Backplate
0 - 1.5	100	100
1.5 - 2.0	67	95
2.0 - 3.0	33	90
3.0 - 4.0	25	80
4.0 - 5.0	17	60
5.0 - 10.0	8	30

(2) To accommodate age differences in perception-reaction time (PRT), it is recommended that an all-red clearance interval be consistently implemented, with length determined according to the Institute of Transportation Engineers (1992) expressions given below.

When there is no pedestrian traffic, use:

$$r = \frac{W + L}{V}$$

Where there is the probability of pedestrian crossings, use the greater of:

$$r = \frac{P + L}{V} \quad \text{or} \quad r = \frac{P}{V}$$

Where there is significant pedestrian traffic or pedestrian signals protect the crosswalk, use:

$$r = \frac{P + L}{V}$$

where:

- r = length of red clearance interval, to the nearest 0.1 s.
- W = width of intersection (ft), measured from the near-side stop line to the far edge of the conflicting traffic lane along the actual vehicle path.
- P = width of intersection (ft), measured from the near-side stop line to the far side of the farthest conflicting pedestrian crosswalk along the actual vehicle path.
- L = length of vehicle, recommended as 20 ft.
- V = speed of the vehicle through the intersection (ft/s).

(3) Wherever practical, the use of a backplate with traffic signals on roads with operating speeds of 64 km/h (40 mi/h) or less is recommended.

(4) The consistent use of a backplate with traffic signals on roads with operating speeds over 64 km/h (40 mi/h) is recommended.

O. Fixed Lighting Installations

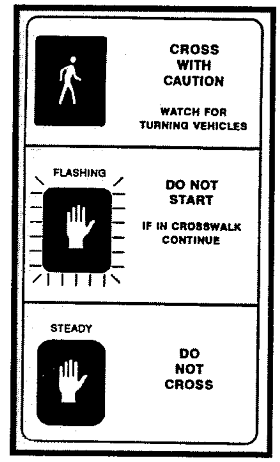
(1) Wherever feasible, fixed lighting installations are recommended (a) where the potential for wrong-way movements is indicated through accident experience or engineering judgment; (b) where pedestrian volumes are high; or (c) where shifting lane alignment, turn-only lane assignment, or a pavement-width transition forces a path- following adjustment at/near the intersection.

(2) Regular cleaning of lamp lenses and lamp replacement when output has degraded by 20 percent or more of peak performance (based on hours of service and manufacturer's specifications) are recommended for all fixed lighting installations at intersections.

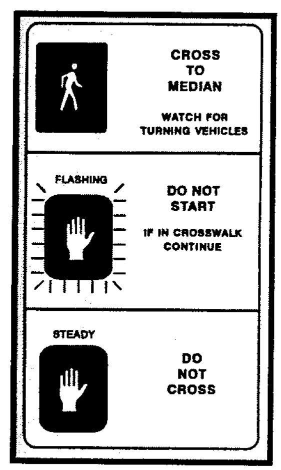
P. Pedestrian Control Devices

(1) 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/s (2.8 ft/s) is recommended.

(2) It is recommended that a placard explaining pedestrian control signal operations and presenting a warning to watch for turning vehicles be posted at the near corner of all intersections with a pedestrian crosswalk, using the design shown.



(3) It is recommended that at intersections where pedestrians cross in two stages using a median refuge island, the placard depicted above be placed on the median refuge island, and that a placard modified as shown below be placed on the near corner of the crosswalk.



II. INTERCHANGES

(GRADE SEPARATION)

Background and Scope of Handbook *Recommendations*

Overall, freeways are characterized by the highest safety level (lowest fatality rates) when compared with other types of highways in rural and urban areas (American Automobile Association Foundation for Traffic Safety, 1995). At the same time, freeway interchanges are design features that have been shown to result in significant safety and operational problems. Taylor and McGee (1973) reported over 20 years ago that erratic maneuvers are a common occurrence at freeway exit ramps and that the number of accidents in the vicinity of the exit ramp is four times greater than at any other freeway location. Two decades later, Lunenfeld (1993) reiterated that most freeway accidents and directional uncertainty occur in the vicinity of interchanges.

Distinct patterns in the occurrence of freeway interchange accidents emerge in studies that look specifically at driver age. Staplin and Lyles (1991) conducted a statewide (Michigan) analysis of the accident involvement ratios and violation types of drivers in the following age groups: age 76 and older; ages 56–75, ages 27–55, and age 26 and under. Using induced-exposure methods to gauge accident involvement levels, this analysis showed that drivers over age 75 were overrepresented as the driver at fault in merging and weaving accidents near interchange ramps. With respect to violation types, the older driver groups were cited most frequently for failing to yield and improper use of lanes. Similarly, Harkey, Huang, and Zegeer's (1996) study of the precrash maneuvers and contributing factors in older driver freeway accidents indicated that their failure to yield was the most common contributing factor. These data raise concerns about the use of freeway interchanges by older drivers, in light of evidence presented by Lerner and Ratté (1991) that a dramatic growth in older-driver freeway travel occurred between 1977 and 1988, with this trend expected to continue.

Age differences in interchange accidents and violations may be understood in terms of driving task demands and age-related diminished driver capabilities. The exit gore area is a transitional area that requires a major change in tracking. A driver (especially in an unfamiliar location) must process a large amount of directional information during a short period of time and at high speeds, while maintaining or modifying his/her position within the traffic stream. When drivers must perform guidance and navigation tasks in close proximity, the chances increase that a driver will become overloaded and commit errors (Lunenfeld, 1993). Erratic maneuvers resulting from driver indecisiveness in such situations include encroaching on the gore area, and even backing up on the ramp or the through lane. When weaving actions are required, the information-processing task demands for freeway interchange maneuvers—both entry and exit—are further magnified.

On a population basis, the age-related diminished capabilities that contribute most to older drivers' difficulties at freeway interchanges include losses in vision and information-processing ability, and decreased physical flexibility in the neck and upper body. Specifically, older adults show declines in static and dynamic acuity, increased sensitivity to glare, poor night vision, and reduced contrast sensitivity (McFarland, Domey, Warren, and Ward, 1960; Weymouth, 1960; Richards, 1972; Pitts, 1982; Sekuler, Kline, and Dismukes, 1982; Owsley, Sekuler, and Siemsen, 1983). These sensory losses are compounded by the following perceptual and cognitive deficits, the first two of which are recognized as being especially critical to safety: reduction in the ability to rapidly localize the most relevant stimuli in a driving scene, reduction in the ability to efficiently switch attention between multiple targets, reduction in working memory capacity, and reduction in processing speed (Avolio, Kroeck, and Panek, 1985; Plude and Hoyer, 1985; Ponds, Brouwer, and van Wolffelaar, 1988; Brouwer, Ickenroth, Ponds, and van Wolffelaar, 1990; Brouwer, Waterink, van Wolffelaar, and Rothengatter, 1991). The most important physical losses are reduced range of motion (head and neck), which impairs visual search, and slowed response time to execute a vehicle control movement, especially when a sequence of movements—such as braking, steering, accelerating to weave and then exit a freeway—are required (Smith and Sethi, 1975; Goggin, Stelmach, and Amrhein, 1989; Goggin and Stelmach, 1990; Hunter-Zaworski, 1990; Staplin, Lococo, and Sim, 1990; Ostrow, Shaffron, and McPherson, 1992).

One result of these age-related diminished capabilities is demonstrated by a driver who waits when merging and entering freeways at on-ramps until he/she is alongside traffic, then relies on mirror views of overtaking vehicles on the mainline to begin searching for an acceptable gap (McKnight and Stewart, 1990). Exclusive use of mirrors to check for gaps and slowing or stopping to look for a gap increase the likelihood of accidents and have a negative effect on traffic flow. Malfetti and Winter (1987), in a critical incident study of merging and yielding problems, reported that older drivers on freeway acceleration lanes merged so slowly that traffic was disrupted, or they stopped completely at the end of the ramp instead of attempting to approach the speed of the traffic flow before entering it. In Lerner and Ratté's (1991) research, older drivers in focus group discussions commented that they experienced difficulty maintaining vehicle headway because of slower reaction times, difficulty reading signs because of visual deficits, fatigue, mobility limitations, a tendency to panic or become disoriented, and loss of daring or confidence. Merging onto the freeway was the most difficult maneuver discussed during the focus group sessions. Needed improvements identified by these older drivers included the elimination of weaving sections and short merge areas, which would facilitate the negotiation of on-ramps at interchanges. Improvements identified to ease the exit process included better graphics, greater use of sign panels listing several upcoming exits, and other methods to improve advance signing for freeway exits.

This section provides recommendations for highway design elements in four areas to enhance the performance of diminished-capacity drivers at interchanges:

- exit signing and exit ramp gore delineation;
- acceleration/deceleration lane design features;
- fixed lighting installations; and
- traffic control devices for prohibited movements on freeway ramps.

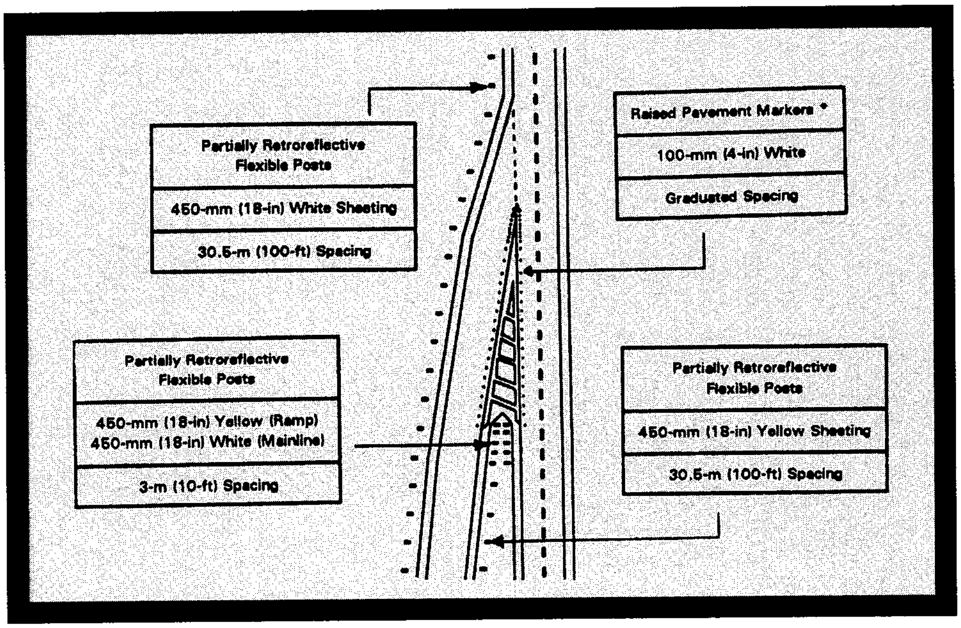
A. Exit Signing and Exit Ramp Gore Delineation

(1) The calculation of letter size requirements for exit signing based on an assumption of *not more than* 10 m (33 ft) of legibility distance for each 25 mm (1 in) of letter height is recommended, for new or reconstructed installations and at the time of sign replacement.

(2) It is recommended that the MUTCD (Federal Highway Administration, 1988) requirements for multiple advance signing upstream of major and intermediate interchanges (section 2E-26) be extended to minor interchanges as well.

(3) A modification of diagrammatic guide signing displayed in the MUTCD (Figure 2-30), such that the number of arrow shafts appearing on the sign matches the number of lanes on the roadway at the sign's location, is recommended for new or reconstructed installations.

(4) It is recommended that delineation in the vicinity of the exit gore at nonilluminated and partially illuminated interchanges include, *as a minimum*, the treatments illustrated in the figure below:



* **Snowplowable raised pavement markers may be used where appropriate for conditions.**

B. Acceleration/Deceleration Lane Design Features

(1) It is recommended that acceleration lane lengths be determined using the higher of AASHTO (1994) Table X-4 speed change lane criteria or NCHRP 3-35 (Reilly, Pfefer, Michaels, Polus, and Schoen, 1989) values for a given set of operational and geometric conditions, and assuming a 64 km/h (40 mi/h) ramp speed at the beginning of the gap search and acceptance process.

(2) A parallel versus a taper design for entrance ramp geometry is recommended.

(3) It is recommended that post-mounted delineators and/or chevrons be applied to delineate the controlling curvature on exit ramp deceleration lanes.

(4) It is recommended that AASHTO (1994) decision sight distance values be consistently applied in locating ramp exits downstream from sight-restricting vertical or horizontal curvature on the mainline (instead of locating ramps based on stopping sight distance [SSD] or modified SSD formulas).

C. Fixed Lighting Installations

(1) Complete interchange lighting (CIL) is the preferred practice, but where a CIL system is not feasible to implement, a partial interchange lighting (PIL) system comprised of two high-mast installations per ramp—one fixture on the inner ramp curve near the gore and one fixture on the outer curve of the ramp, midway through the controlling curvature—is recommended.

D. Traffic Control Devices for Prohibited Movements on Freeway Ramps

(1) The consistent use of 1,200 mm x 750 mm (48 in x 30 in) FREEWAY ENTRANCE signs for positive guidance as described as an option in section 2E-40 of the MUTCD (Federal Highway Administration, 1988), using a minimum letter height of 200 mm (8 in) with series D or wider font, is recommended.

(2) Where adjacent entrance and exit ramps intersect with a crossroad, the use of a median separator is recommended, with the nose of the separator delineated with yellow reflectorized paint and extending as close to the crossroad as practical without obstructing the turning path of vehicles. In addition, it is recommended that a KEEP RIGHT (R4-7a) sign be posted on the median separator nose.

(3) Where DO NOT ENTER (R5-1) and WRONG WAY (R5-9) signs are placed, in accordance with sections 2A-31 and 2E-40 of the MUTCD, a minimum size for R5-1 of 900 mm x 900 mm (36 in x 36 in) and for R5-9 of 1,200 mm x 800 mm (48 in x 32 in) is recommended, with corresponding increases in letter sizes, and the use of high-intensity sheeting. In addition, a mounting height (from the pavement to the bottom of the bottom sign) of between 450 mm and 900 mm (18 in and 36 in) is recommended, using the lowest value for this range that is practical when the presence of snow or other obstructions is taken into consideration.

(4) The application of 7.3-m (24-ft) wrong-way arrow pavement markings (see MUTCD section 2B-20) near the terminus on all exit ramps, accompanied by red raised pavement markers facing wrong-way traffic, is recommended.

III. ROADWAY CURVATURE AND PASSING ZONES

Background and Scope of Handbook *Recommendations*

Accidents on horizontal curves have been recognized as a considerable safety problem for many years. Accident studies indicate that roadway curves experience a higher accident rate than tangents, with rates ranging from one-and-a-half to three to four times higher than tangents (Glennon, Neuman, and Leisch, 1985; Zegeer, Stewart, Reinfurt, Council, Neuman, Hamilton, Miller, and Hunter, 1990; Neuman, 1992). Lerner and Sedney (1988) reported anecdotal evidence that horizontal curves present problems for older drivers. Also, Lyles' (1993) analyses of accident data in Michigan found that older drivers are much more likely to be involved in accident situations where the drivers were driving too fast for the curve or, more significantly, were surprised by the curved alignment. In a review of the literature aimed at modifying driver behavior on rural road curves, Johnston (1982) reported that horizontal curves that are below 600 m (1,968 ft) in radius on two-lane rural roads, and those requiring a substantial reduction in speed from that prevailing on the preceding tangent section, were disproportionately represented among accident sites.

Successful curve negotiation depends upon the choice of appropriate approach speed and adequate lateral positioning through the curve. Many studies have shown that loss-of-control accidents result from an inability to maintain lateral position through the curve because of excessive speed, with inadequate deceleration in the approach zone. These problems in turn stem from a combination of factors, including poor anticipation of vehicle control requirements, induced by the driver's prior speed, and inadequate perception of the demands of the curve.

Many studies report a relationship between horizontal curvature (and the degree of curvature) and the total percentage of accidents by geometric design feature on the highways. The reasons for these accidents are related to the following inadequate driving behaviors:

- Deficient skills in negotiating curves, especially those of more than 3 degrees (Eckhardt and Flanagan, 1956).
- Exceeding the design speed on the curve (Messer, Mounce, and Brackett, 1981).
- Exceeding the design of the vehicle path (Glennon and Weaver, 1971; Good, 1978).
- Failure to maintain appropriate lateral position in the curve (McDonald and Ellis, 1975).
- Incorrect anticipatory behavior of curve speed and alignment when approaching the curve (Messer et al., 1981; Johnston, 1982).
- Inadequate appreciation of the degree of hazard associated with a given curve (Johnston, 1982).

With respect to vertical curves, design policy is based on the need to provide drivers with adequate stopping sight distance (SSD). That is, enough sight distance must exist to permit drivers to see an obstacle soon enough to stop for it under some set of reasonable worst-case conditions. The parameters that determine sight distance on crest vertical curves include the change of grade, the length of the curve, the height above the ground of the driver's eye, and the height of the obstacle to be seen. SSD is determined by reaction time, speed of vehicle, and tire-pavement coefficient of friction. There is some concern with the validity of the SSD model that has been in use for over 50 years, however. Current practice assumes an obstacle height of 150 mm (6 in) and a locked-wheel, wet-pavement stop. Minimum lengths of crest vertical curves are based on sight distance and driver comfort. These criteria do *not* currently include adjustments for age-related effects in driving performance measures, which would suggest an even more conservative approach. At the same time, the general lack of empirical data demonstrating benefits for limited sight distance countermeasures has led some to propose liberalization of model criteria, such as obstacle height.

Standards and criteria for sight distance, horizontal and vertical alignment, and associated traffic control devices are based on the following driver performance characteristics: detection and recognition time, perception-reaction time, decision and response time, time to perform brake and accelerator movements, maneuver time, and (if applicable) time to shift gears. However, these values have typically been based on driving performance (or surrogate driving measures) of the entire driving population, or have been formulated from research biased toward younger (college-age) as opposed to older driver groups. The models underlying these design standards and criteria therefore have not, as a rule, included variations to account for slower reaction time or other performance deficits consistently demonstrated in research on older driver response capabilities. In particular, diminished visual performance (reduced acuity and contrast sensitivity), physical capability (reduced strength to perform control movements and sensitivity to lateral force), cognitive performance (attentional deficits and declines in choice reaction time in responses to unpredictable stimuli), and perceptual abilities (reduced accuracy of processing speed-distance information as required for gap judgments) combine to make the task of negotiating the highway design elements addressed in this section more difficult and less forgiving for older drivers.

This section provides recommendations to enhance the performance of diminished capacity drivers as they negotiate roadway curvature and passing zones, focusing on four design elements:

- pavement markings and delineation on horizontal curves;
- pavement width on horizontal curves;
- crest vertical curve length and advance signing for sight-restricted locations; and
- passing zone length, passing sight distance, and passing/overtaking lanes on two-lane highways.

A. Pavement Markings and Delineation on Horizontal Curves

(1) The installation and maintenance of white edgelines of normal width (MUTCD [Federal Highway Administration, 1988]) on horizontal curves at an effective luminance (L) contrast level of at least 5.0 is recommended on all highways (including arterials) without median separation of opposing directions of traffic, where

$$\text{luminance contrast} = \frac{L_{stripe} - L_{pavement}}{L_{pavement}}$$

(2) A minimum in-service contrast value of 3.75 is recommended for pavement edgelines on horizontal curves where median barriers effectively block drivers' view of oncoming headlights or where median width exceeds 15 m (49 ft).

(3) The installation (at standard spacing) of centerline raised pavement markers beginning 5 s driving time (at 85th percentile speed) before, and continuing through the length of, all horizontal curves of radii under 1,000 m (3,281 ft) is recommended.

(4) The installation of roadside delineation devices at a maximum spacing (S) of 12 m (40 ft) on all horizontal curves with a radius (R) of 185 m (600 ft) or less, is recommended; for curves of radii over 185 m (600 ft), the standard/MUTCD formula (in feet) to define roadside delineator spacing intervals is recommended, where

$$S = 3\sqrt{R - 50}$$

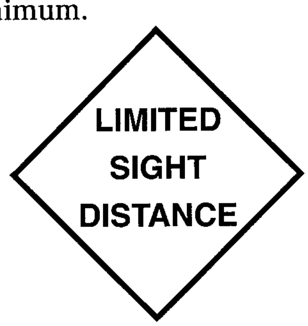
B. Pavement Width on Horizontal Curves

(1) A minimum lane-plus-paved shoulder width of 5.5 m (18 ft) through the length of arterial horizontal curves ≥ 3 degrees of curvature is recommended (assuming AASHTO [1994] design values for superelevation and coefficient of side friction).

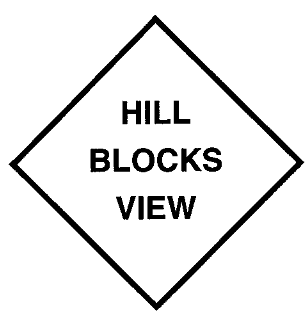
C. Crest Vertical Curve Length and Advance Signing for Sight-Restricted Locations

(1) To accommodate the exaggerated decline among older drivers in response to unexpected hazards, it is recommended that the present criterion of 150 mm (6 in) for obstacle height on crest vertical curves be preserved in the design of new and reconstructed facilities.

(2) Where a need has already been determined for installation or replacement of a LIMITED SIGHT DISTANCE (W14-4) sign, the alternate message HILL BLOCKS VIEW is recommended, using the special sign size of 900 mm x 900 mm (36 in x 36 in) cited in *Standard Highway Signs as Specified in the Manual on Uniform Traffic Control Devices* (Federal Highway Administration, 1979) as a minimum.



Not recommended



Recommended

(3) If a signalized intersection is obscured by vertical or horizontal curvature such that the signal condition becomes visible at a preview distance of 8 s or less (at operating speed), then the use of the advance warning sign PREPARE TO STOP, with a yellow flasher activated during the red signal phase, is recommended.

D. Passing Zone Length, Passing Sight Distance, and Passing/Overtaking Lanes on Two-Lane Highways

(1) A minimum passing zone length of 350 m (1,150 ft) is recommended for any facility with an operating speed of 64 km/h (40 mi/h) or greater.

(2) A minimum passing sight distance (MUTCD definition [Federal Highway Administration, 1988]) of 215 m (705 ft) is recommended for any facility with an operating speed of 64 km/h (40 mi/h) or greater.

(3) Use of special size (1,200 mm x 1,600 mm x 1,600 mm [48 in x 64 in x 64 in]) NO PASSING ZONE pennant (W14-3) as a high-conspicuity supplement to conventional centerline pavement markings at the beginning of no passing zones is recommended.

(4) To the extent feasible for new or reconstructed facilities, excepting those with low volume, the implementation of passing/overtaking lanes (each direction) at intervals of no more than 5 km (3.1 mi) is recommended.

IV. CONSTRUCTION/ WORK ZONES

Background and Scope of Handbook *Recommendations*

Highway construction and maintenance zones deserve special consideration with respect to older driver needs because of their strong potential to violate driver expectancy. Alexander and Lunenfeld (1986) properly emphasized that driver expectancy is a key factor affecting the safety and efficiency of all aspects of driving task performance. Consequently, it is understandable that accident analyses consistently show that more accidents occur on highway segments containing construction zones than on the same highway segments before the zones were implemented (Juergens, 1972; Graham, Paulsen, and Glennon, 1977; Lisle, 1978; Nemeth and Migletz, 1978; Paulsen, Harwood, and Glennon, 1978; Garber and Woo, 1990; Hawkins, Kacir, and Ogden, 1992).

Work zone traffic control must provide adequate notice to motorists describing the condition ahead, the location, and the required driver response. Once drivers reach a work zone, pavement markings, signing, and channelization must be conspicuous and unambiguous in providing guidance through the area. The National Transportation Safety Board (NTSB) believes that the MUTCD guidelines concerning signing and other work zone safety features provide more than adequate warning for a *vigilant* driver, but may be inadequate for an inattentive or otherwise impaired driver (NTSB, 1992). It is within this context that functional deficits associated with normal aging, as described below, may place older drivers at greater risk when negotiating work zones.

In an accident analysis at 20 case-study work zone locations, among the most frequently listed contributing factors were driver attention errors and failure to yield the right-of-way (Pigman and Agent, 1990). Older drivers are most likely to demonstrate these deficits. Research on selective attention has documented that older adults respond much more slowly to stimuli that are unexpected (Hoyer and Familant, 1987), suggesting that older adults could be particularly disadvantaged by changes in roadway geometry and operations characteristic of construction zones. There is also research indicating that older adults are more likely to respond to new traffic patterns in an "automatized" fashion, resulting in more frequent driver errors (Fisk, McGee, and Giambra, 1988). To respond in situations that require decisions among multiple and/or unfamiliar alternatives, with unexpected path-following cues, drivers' actions are described by *complex reaction times* that are longer than reaction times in simple situations with expected cues. In Mihal and Barrett's (1976) analysis relating simple, choice, and complex reaction time to crash involvement, only an increase in complex reaction time was associated with accidents. The relationship with driver age was most striking: the correlation between complex reaction time and accident involvement increased from 0.27 for the total analysis sample (all ages) to 0.52 when only older adults were included. Such data suggest that in situations where there is increased complexity in the information to be processed by drivers—such as work zones—the most relevant information must be communicated in a dramatic manner to ensure that it receives a high priority by older individuals.

Compounding their exaggerated difficulties in allocating attention to the most relevant aspects of novel driving situations, diminished visual capabilities among older drivers are well documented (McFarland, Domey, Warren, and Ward, 1960; Weymouth, 1960; Richards, 1972; Pitts, 1982; Sekuler, Kline, and Dismukes, 1982; Owsley, Sekuler, and Siemsen, 1983; Wood and Troutbeck, 1994). Deficits in static and dynamic acuity and contrast sensitivity, particularly under low luminance conditions, make it more difficult for them to detect and read traffic signs, to read variable message signs, and to detect pavement markings and downstream channelization devices. Olson (1988) determined that for a traffic sign to be noticed at night in a visually complex environment, its reflectivity must be increased by a factor of 10 to achieve the same level of conspicuity as in a low-complexity environment. Mace (1988) asserted that the minimum required visibility distance—the distance from a traffic sign required by drivers in order to detect, understand, make a decision, and complete a vehicle maneuver before reaching a sign—is increased significantly for older drivers due to their poorer visual acuity and contrast sensitivity, coupled with inadequate sign luminance and legend size. Other age-related deficits cited by Mace (1988) include lowered driver alertness, slower detection time in complex roadway scenes due to distraction from irrelevant stimuli, increased time to understand unclear messages such as symbols, and slower decision making.

This section provides recommendations to enhance the performance of diminished-capacity drivers as they approach and travel through construction/work zones, keyed to five specific design elements:

- advance signing for lane closure(s);
- variable (changeable) message signing practices;
- channelization practices;
- delineation of crossovers/alternate travel paths; and
- temporary pavement markings.

A. Advance Signing for Lane Closure(s)

(1) At construction/maintenance work zones on high-speed and divided highways, the consistent use of a flashing arrow panel located at the taper for each lane closure is recommended.

(2) In implementing advance signing for lane closures as per MUTCD Part VI (Federal Highway Administration, 1988), it is recommended that a supplemental (portable) variable message sign displaying the one-page (phase) message LEFT (RIGHT, CENTER) LANE CLOSED be placed 800–1,600 m (2,625–5,250 ft) upstream of the lane closure taper.

or

Redundant static signing should be used, where both the first upstream sign (e.g., W20-1) and the second sign (e.g., W20-5) encountered by the driver are equipped with flashing warning lights throughout the entire period of the lane closure, and a minimum letter height of 200 mm (8 in) is used.

B. Variable (Changeable) Message Signing Practices

(1) It is recommended that no more than two phases be used on a variable message sign (VMS); if a message cannot be conveyed in two phases, multiple VMSs and/or a supplemental highway advisory radio message should be used.

(2) It is recommended that no more than one unit of information (defined in Rationale and Supporting Evidence text for this section) should be displayed on a single line on a VMS, and no more than three units should be displayed on any single phase.

(3) For nondiversion VMS messages split into two phases, a total of no more than four *unique* units of information should be presented.

(4) Generally, to display information about accidents, road construction, or environmental warnings on permanent variable message signs, line 1 should present the problem, line 2 the location or distance ahead, and line 3 a driver action. This is the standard for single-phase messages: *problem location (or distance ahead) action advised/required.*

(5) When a portable variable message sign is used to display a message in two phases, the problem and location statements should be displayed during phase 1 and the effect or action statement during phase 2. For example, phase 1 could read:

ROADWORK | NEXT | 2 MILES

while phase 2 could read:

LEFT | LANE | CLOSED

If legibility distance restrictions rule out a two-phase display, the use of abbreviations plus elimination of the problem statement is the recommended strategy to allow for the presentation of the entire message on one phase:

LFT LANE | CLOSED | NEXT 2 MI

(6) Where abbreviations are necessary in VMS operations, an adherence to the "acceptable," "not acceptable," and "acceptable with prompt" categories as shown on the next three pages is recommended.

"Acceptable" abbreviations for frequently used words.
Source: Dudek, Huchingson, Williams, and Koppa (1981).

Word	Abbreviation
Alternate	ALT
Avenue	AVE
Boulevard	BLVD
Can Not	CAN'T
Center	CNTR
Do Not	DON'T
Emergency	EMER
Entrance, Enter	ENT
Expressway	EXPWY
Freeway	FRWY, FWY
Highway	HWY
Information	INFO
It Is	IT'S
Junction	JCT
Left	LFT
Maintenance	MAINT
Normal	NORM
Parking	PKING
Road	RD
Service	SERV
Shoulder	SHLDR
Slippery	SLIP
Speed	SPD
Street	ST
Traffic	TRAF
Travelers	TRVLRS
Warning	WARN
Will Not	WON'T

Abbreviations that are "not acceptable."
Source: Dudek, Huchingson, Williams, and Koppa (1981).

Abbreviation	Intended Word	Common Misinterpretation
ACC	Accident	Access (Road)
CLRS	Clears	Colors
DLY	Delay	Daily
FDR	Feeder	Federal
L	Left	Lane (Merge)
LT	Light (Traffic)	Left
PARK	Parking	Park
POLL	Pollution (Index)	Poll
RED	Reduce	Red
STAD	Stadium	Standard
WRNG	Warning	Wrong

Abbreviations + that are "acceptable with a prompt."
Source: Dudek, Huchingson, Williams, and Koppa (1981).

Word	Abbreviation	Prompt
Access	ACCS	Road
Ahead	AHD	Fog*
Blocked	BLKD	Lane*
Bridge	BRDG	[Name]*
Condition	COND	Traffic*
Congested	CONG	Traffic*
Construction	CONST	Ahead
Downtown	DWNTN	Traffic*
Eastbound	E-BND	Traffic
Exit	EX, EXT	Next*
Express	EXP	Lane
Frontage	FRNTG	Road
Hazardous	HAZ	Driving
Interstate	I	[Number]
Local	LOC	Traffic
Major	MAJ	Accident
Mile	MI	[Number]*
Minor	MNR	Accident
Minute(s)	MIN	[Number]*
Northbound	N-BND	Traffic
Oversized	OVRSZ	Load
Prepare	PREP	To Stop
Pavement	PVMT	Wet*
Quality	QLTY	Air*
Roadwork	RDWK	Ahead [Distance]
Route	RT	Best*
Southbound	S-BND	Traffic
Temporary	TEMP	Route
Township	TWNSHP	Limits
Turnpike	TRNPK	[Name]*
Upper, Lower	UPR, LWR	Level
Vehicle	VEH	Stalled*
Westbound	W-BND	Traffic
Cardinal Directions	N, E, S, W	[Number]

* Prompt word should precede abbreviation.

\+ The words and abbreviations shown in normal type are understood by at least 85 percent of the driving population. Those shown in boldface type are understood by at least 75 percent of the driving population, and public education is recommended prior to their usage.

C. Channelization Practices

(1) The following minimum dimensions for channelizing devices used in highway work zones are recommended, to accommodate the needs of older drivers:

(1a) Traffic cones—900 mm (36 in) height (with at least a 300-mm [12-in] reflective collar for nighttime operations).

(1b) Traffic tubes—1050 mm (42 in) height (with at least a 300-mm [12-in] reflective band for nighttime operations).

(1c) Vertical panels—300 mm (12 in) width.

(1d) Barricades—300 mm x 900 mm (12 in x 36 in) minimum dimension.

(2) The use of a flashing arrow panel at the start of the taper at all right and left lane closures is recommended on all roadways with an operating speed of 72 km/h (45 mi/h) and above. On lower speed roadways *without an arrow panel*, it is recommended that the start of the taper for a lane closure be marked with a reflectorized plastic drum with steady-burn light, and accompanying chevrons, as a channelizing treatment.

(3) The spacing of channelizing devices (in feet) through a work zone and through taper and transition sections at not more than the speed limit (in miles per hour) is recommended, with spacing (in feet) through the taper for a lane closure at not more than one-half the speed limit (in miles per hour) where engineering judgment indicates a special need for speed reduction.

(4) The use of side reflectors with cube-corner lenses on Jersey barriers and related concrete channelizing devices spaced (in feet) at not more than the construction zone speed limit (in miles per hour) through a work zone is recommended.

D. Delineation of Crossovers/Alternate Travel Paths

(1) The use of positive barriers in transition zones, and positive separation (channelization) between opposing two-lane traffic throughout a crossover, is recommended for all roadway classes except residential.

(2) A minimum spacing (in feet) of one-half the construction zone speed limit (in miles per hour) for channelizing devices (other than concrete barriers) is recommended in transition areas, and through the length of the crossover and in the termination area downstream (where operations as existed prior to the crossover resume).

(3) The use of side reflectors with cube-corner lenses spaced (in feet) at not more than the construction zone speed limit (in miles per hour) on concrete channelizing barriers in crossovers (or alternately the use of retroreflective sheeting on plastic glare-control louvers [paddles] placed in crossovers) is recommended.

(4) It is recommended for construction/work zones on high-volume roadways that plastic glare-control louvers (paddles) be mounted on top of concrete channelizing barriers, when used in transition and crossover areas, at a spacing of not more than 600 mm (24 in).

E. Temporary Pavement Markings

(1) Where temporary pavement markings shorter than the 3 m (10 ft) standard length are implemented, it is recommended that a raised pavement marker be placed at the center of the gap between successive markings.

or, if deemed a more cost-effective alternative,

It is recommended that temporary pavement markings shorter than 3 m (10 ft) be supplemented with devices including cones, tubes, or barrels placed on the centerline between opposing lanes, spaced (in feet) and maintained at not more than the construction zone speed limit (in miles per hour) apart.

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