

HANDBOOK FOR Designing Roadways for the **AGING POPULATION**





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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in ²	square inches	645.2	square millimeters	mm ²
ft ²	square feet	0.093	square meters	m ²
yd ²	square yard	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi ²	square miles	2.59	square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic	m ³
meters NOTE: volumes greater than 1000 L shall be				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m ²	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in ²	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000lb)	T
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	f
cd/m ²	candela/m ²	0.2919	foot-Lamberts	c
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in ²

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)



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CHAPTER 1

Introduction to the Desk Reference

Overview

This Desk Reference serves as a companion document to the *Handbook for Designing Roadways for the Aging Population* (the Handbook). It provides a quick reference to Part I of the Handbook and is ideal for use in the field or as an abbreviated information resource. While each design element from the Handbook is briefly described and illustrated in this desk reference, practitioners should refer to the corresponding section in the Handbook for more details and complete discussion.

This Desk Reference is organized in the following categories:

Chapter 2 — Intersections

Chapter 3 — Interchanges

Chapter 4 — Roadway Segments

Chapter 5 — Construction/Work Zones

Chapter 6 — Highway-Rail Grade Crossings

Within each chapter (category) is a list of the design elements that will be presented. For each design element, the Desk Reference illustrates the recommended treatments. After all of the numbered design elements are presented, then the “Promising Practice” treatments are provided. These are treatments that designers and engineers should consider, recognizing that they are currently being used by one or more agencies, and, although they have not been evaluated formally, are generally believed to benefit the aging population based on a subjective assessment by staff participating in the development of the Handbook.

Keep in mind that this Desk Reference is a condensed version of the corresponding material in the Handbook; practitioners should refer to the same treatment in the Handbook for additional details, examples, illustrations, and image sources.



Also note that the drawings included in this Desk Reference are for illustrative purposes only; they are not to scale and should not be used for design purposes.

Knowing When to Implement these Recommendations

Implementing the treatments in this Desk Reference will provide benefits for design challenges that disproportionately affect aging road users due to changes in functional ability experienced with normal aging. These may be most urgently needed where a crash problem with aging drivers or pedestrians has already been demonstrated; however, the greater benefit arguably lies in designing safer new roads and identifying and modifying problems with existing roads before statistics reveal a crash problem. Not only does this practice minimize the risk and severity of crashes, it minimizes the need for remedial works after construction, thus reducing the whole-life cost of projects.

The engineering enhancements described in this document should benefit all road users. Special justification may be required for implementation of Handbook practices. To this end, below is a three-step procedure outlining responses plus brief written comments to support engineering judgment. Please refer to the Handbook for a set of optional worksheets for documenting each step.

Step 1: Problem Identification [see Project Review Worksheet on page 7 of the Handbook]

During the planning stage for each project, practitioners are asked to determine whether a problem with the safe use of the facility by aging road users currently exists or may reasonably be expected based on current and projected use patterns. Using the work sheet that appears on page 7 of the Handbook, problem identification can be accomplished by answering YES or NO to the following four questions:



INTRODUCTION TO THE DESK REFERENCE

- Q1. "Is there a demonstrated crash problem with aging road users?"
- Q2. "Has any aspect of design or operations at the project location been associated with complaints to local, municipal, or county-level officials from aging road users or are you aware of a potential safety concern for aging road users at this location, either through observation, agency documentation, or engineering judgment?"
- Q3. "Is this project located on a direct link to a travel origin or destination for which, in the judgment of local planning/zoning authorities or other local officials, aging persons constitute a significant proportion of current users?"
- Q4. "Is the project located in a census tract or zip code designation that has experienced an increase in the proportion of (non-institutionalized) residents age 65 and older, for the most recent period in which the population was sampled?"

To answer these questions, practitioners will need to obtain reliable crash data from the appropriate division or bureau of their departments of transportation. At least the three most recent years for which data are available should be examined, and the data should be sorted by age, at a minimum. Sources of information outside of the State DOT also may be required to answer the problem identification questions. Potential sources include, but are not limited to:

- Local government officials/Board of Supervisors/city council representatives.
- Local and State police.
- The (State) Department of Aging and/or county Area Agency on Aging.
- The (State) Department of Health and Human Services and Department of Public Welfare.
- The regional planning commission.



Step 2: Identification of Design Elements and Treatments [see worksheet on page 9 of the Handbook]

For each project where a practitioner has answered YES to one or more of the problem identification questions in Step 1, the next step is consider all categories (i.e., intersection, interchanges, roadway segments, construction/work zones, and highway-rail grade crossings) on the facility. Then, for each category, consider each design element and treatment that could be applied. For each one, the engineer should indicate whether the recommended practice differs from standard State or local practices, and if yes, what additional benefits are expected to result from implementing the applicable Handbook treatment(s). See the Handbook for a more in-depth discussion of the identification process.

Step 3: Implementation Decision [see worksheet on page 10 of the Handbook]

To begin Step 3, each Handbook treatment identified as a candidate for implementation in Step 2 should be properly referenced [e.g., 5D(1)]. Next, any factors relating to increased costs (for an enhanced treatment), added approvals that may be needed, or any other special considerations that impact implementation may be noted in separate columns on the worksheet. The final step is then to proceed to an implementation decision. This is recorded as a judgment by the engineer as to whether implementation of the candidate countermeasure is recommended. The engineer's judgment is indicated by a check in the space next to YES or NO in the last column on the worksheet, accompanied by his/her initials for verification. Additional comments should be entered as deemed appropriate.

Organization

Like the Handbook for Designing Roadways for the Aging Population (Handbook), this Desk Reference includes recommended treatments for 33 traffic control or geometric design elements divided among five categories. The five categories of treatment are as follows:

- Intersections,



INTRODUCTION TO THE DESK REFERENCE

- Interchanges,
- Roadway Segments,
- Construction/Work Zones, and
- Highway-Rail Grade Crossings.

These treatments are recommended because they have been shown through research to be a benefit to the aging road user. In addition, 18 “Promising Practice” treatments are included. These are treatments being utilized by transportation agencies that should benefit aging road users as determined by a subjective assessment by staff participating on the development of the original Handbook. Current trends indicate these practices have a positive impact on aging road user safety. These promising treatments are placed at the end of each category to which they apply.

The treatments for each design element are presented as shown in Figure 1 and consist of the following components:

Category — At the top of each page is a header showing the category of treatment (i.e., Intersections, Interchanges, Roadway Segments, Construction Work Zones, and Highway-Rail Grade Crossings).

Design Element — Each element has a unique number for quick reference to the Table of Contents.

Treatments — Each treatment within a design element is clearly identified by a unique letter, followed by a recommendation on how that treatment should be used.

Figure(s) — Many of the concepts described in the treatments are illustrated in figures—as photographs, figures extracted from the *Manual on Uniform Traffic Control Devices* (MUTCD) or other publications, or as drawings. The drawings are for illustrative purposes only; they are not to scale and should not be used for design purposes. It is important to note that the lettering styles, arrows, and symbols used in this Desk Reference are not always consistent with those prescribed in the MUTCD. When employing treatments included in this Desk Reference and Handbook, only MUTCD-approved lettering styles, arrows and symbols should be used.



Additionally, any highway agency wishing to implement a treatment that has not been included in the most recent edition of the MUTCD must request experimentation approval from the FHWA.

Handbook References — This Desk Reference contains references below each treatment that indicate where the rationale and supporting evidence for this treatment can be found. This includes references to those national design guides that practitioners often turn to for guidance on the use and implementation of the treatment.

Design Element – each design element is numbered consistently with those in the Handbook to allow for quick reference.

Treatment – each recommended treatment is identified with a letter for quick reference.

References – Each practice refers back to the page in the Handbook where greater detail can be found.

Category – identifies the current section of the guide.

Figures – figures are used throughout the guide to illustrate the recommendations. They are numbered for easy reference.

Handbook for Designing Roadways for the Aging Population

INTERSECTIONS

PROVEN PRACTICES

1 **Intersecting Angle (Skew)**
Intersection skew angle in degrees is the absolute value of the difference between 90 degrees and the actual intersection angle.

A. Unrestricted Right-of-Way
Where right-of-way is not restricted, all intersecting roadways should meet at a 90-degree angle (as indicated in Figure 3).

B. Restricted Right-of-Way
Where right-of-way is restricted, intersecting roadways should meet at an angle of not less than 75 degrees (as indicated in Figure 4).

C. Skewed Signalized Intersections
At skewed signalized intersections where the approach leg to the left intersects the driver's approach leg at an angle of less than 75 degrees, prohibit right turn on red (RTOR) (see Figure 5).

The rationale and supporting evidence for these treatments begins on page 96 of the Handbook.

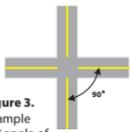


Figure 3. Example 90° angle of intersection

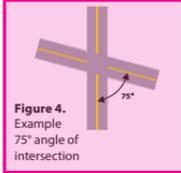


Figure 4. Example 75° angle of intersection

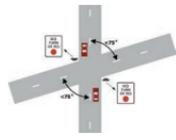


Figure 5. Skewed signalized intersection with prohibition of right turn on red

1

Note – Numbers are consistent with the complete Handbook for easy cross-reference.



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CHAPTER 2

Intersections

This section of the Desk Reference illustrates treatments for 16 different design elements in order to accommodate the needs and enhance the performance of road users with age-related diminished capabilities as they approach and negotiate intersections. Following these proven practices, eight additional promising practices are addressed.

PROVEN PRACTICES

1. Intersecting Angle (Skew)
2. Receiving Lane (Throat) Width
3. Channelization
4. Intersection Sight Distance
5. Offset Left-Turn Lanes
6. Delineation of Edge Lines and Curbs
7. Curb Radius
8. Left-Turn Traffic Control for Signalized Intersections
9. Right-Turn Traffic Control for Signalized Intersections
10. Street Name Signs
11. Stop and Yield Signs
12. Lane Assignment on Intersection Approach
13. Traffic Signals
14. Intersection Lighting
15. Pedestrian Crossings
16. Roundabouts

PROMISING PRACTICES

17. Right Turn Channelization Design
18. Combination Lane-Use/Destination Overhead Guide Signs
19. Signal Head Visibility
20. High Visibility Crosswalks
21. Supplemental Pavement Markings for Stop and Yield Signs
22. Reduced Left-Turn-Conflict Intersections
23. Accessible Pedestrian Signal (APS) Treatments
24. Flashing Yellow Arrow



PROVEN PRACTICES

1 Intersecting Angle (Skew)

Intersection skew angle in degrees is the absolute value of the difference between 90 degrees and the actual intersection angle.

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The rationale and supporting evidence for these treatments begins on page 96 of the Handbook.

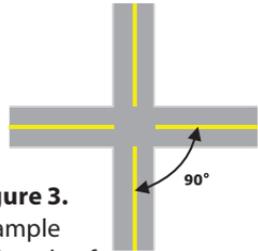


Figure 3.
Example
90° angle of
intersection

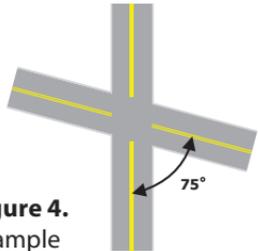


Figure 4.
Example
75° angle of
intersection

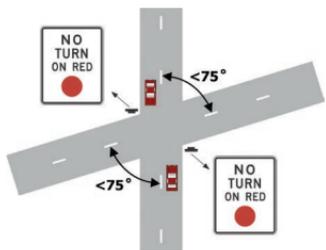


Figure 5. Skewed
signalized intersection
with prohibition of right
turn on red



2 Receiving Lane (Throat) Width

A. Minimum Width

Wherever practical, a minimum receiving throat width of 16 ft is recommended. The total width may include a travel lane of 11 to 12 ft and a paved shoulder or bicycle lane of 4 to 5 ft as shown in Figure 6.

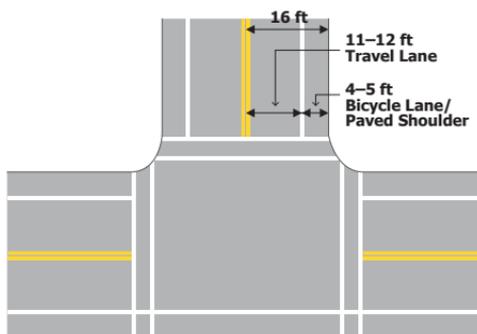


Figure 6. Recommended receiving lane width

The rationale and supporting evidence for this treatment begins on page 99 of the Handbook.

3 Channelization

A. Left- and Right-Turn Lanes

Raised channelization with sloping curbs (see Figure 7) is recommended instead of pavement markings alone for turn lane treatments on all roadways with operating speeds of less than 45 mph.

B. Retroreflective Markings

Where raised channelization is implemented at intersections (see Figure 7) the median and island curb sides and curb horizontal surfaces should be treated with retroreflectorized markings, such as edge lines, painted curbs, or raised pavement markers, and be maintained at a minimum luminance contrast level* as follows:

B-1. With overhead lighting, a contrast of at least 2.0.

B-2. Without overhead lighting, a contrast of at least 3.0.



INTERSECTIONS

Contrast should be calculated according to this formula:

$$\text{Luminance contrast (C)} = \frac{\text{Luminance}_{\text{stripe}} - \text{Luminance}_{\text{pavement}}}{\text{Luminance}_{\text{pavement}}}$$

* Luminance is the amount of light reflected from an object. This is different from retroreflectivity, which is a property of a material. While increasing retroreflectivity generally results in higher luminance, (often described as brightness)—especially at night—this may vary greatly for the same object or marking depending upon such factors as the location and intensity of the source of illumination, and the angle at which a driver views it.

C. Acceleration Lane

If right-turn channelization is present, an acceleration lane providing for the acceleration characteristics of passenger cars as delineated in AASHTO (2011) specifications is recommended for operating speeds of 45 mph or greater.

D. Sloping vs. Vertical Curbs

The use of sloping curbs rather than vertical curbs (see Figure 7) for channelization is recommended, except where the curbs surround a pedestrian refuge area or are being used for access control. Vertical curbs should also not be used for channelization on high-speed (i.e., 45 mph or greater) roadways.



E. Pedestrian Refuge Island

If right-turn channelization is present and pedestrian traffic may be expected based on surrounding land use, it is recommended that an adjacent pedestrian refuge island, conforming to MUTCD (2009) and AASHTO (2011) specifications, be provided.



Figure 7. Vertical curb (top), sloping curb (bottom)



F. Median Channelization

To reduce unexpected midblock conflicts with opposing vehicles, the use of channelized left-turn lanes in combination with continuous raised-curb medians is recommended instead of center, two-way, left-turn lanes (TWLTL) for new construction or reconstruction where average daily traffic volumes exceed 20,000 vehicles per day, or for remediation where there is a demonstrated crash problem, or wherever a need is demonstrated through engineering study.

The rationale and supporting evidence for these treatments begins on page 102 of the Handbook.

4 Intersection Sight Distance

A. Gap Value

It is recommended that a gap of no less than 8.0 s, plus 0.5 s for each additional lane crossed, be used in intersection sight distance (ISD) calculations to accommodate the slower decision-making and maneuver times of aging drivers for the following cases, as defined in the AASHTO Green Book (2011):

- Cases B1, B2, and B3 – stop-control on the minor road,
- Cases C1 and C2 – yield control on the minor road,
- Case D – signalized with permissive left-turn phases and/or where RTOR is permitted and/or which are placed on flashing operations at night, and
- Case F – left turns from a major roadway.

The rationale and supporting evidence for these treatments begins on page 107 of the Handbook.



5 Offset Left-Turn Lanes

A. Full Offset – Opposing Cars

Left-turn lanes should be positively offset (as shown in Figure 8) at least 4 ft to the left of the opposing left-turn lane to achieve the desired sight distance for the left-turning driver.

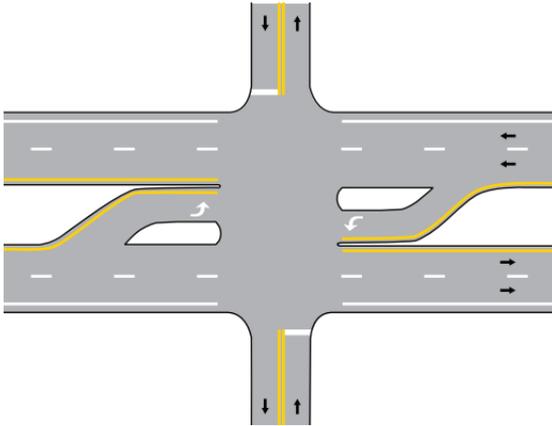


Figure 8. Left-turn lanes with positive offset

B. Full Offset – Opposing Heavy Trucks

At intersections where engineering judgment indicates a high probability of heavy trucks as the opposing left-turning vehicles, the positive offset is recommended to be 5.5 ft to achieve the desired sight distance.

C. Minimum Offset

At locations where the full offset distances cannot be obtained, it is recommended that the minimum offset distances shown in Table 6 be provided to achieve minimum required sight distances according to design speed. It is recommended that the “Opposing Truck” values be used where the opposing left-turn traffic includes a moderate to heavy volume of large trucks.



INTERSECTIONS

Table 6. Minimum offset distances for left-turn lanes.

Design Speed (mph)	Minimum Offset(ft)	
	Opposing Car	Opposing Truck
≤ 30	0.8	3.0
35	1.4	3.5
40	1.8	3.8
45	2.1	4.1
50	2.4	4.2
55	2.6	4.4
60	2.7	4.5
65	2.8	4.6
70	2.9	4.7

1 ft = 0.305 m**D. Signs and Markings**

At intersections where the left-turn lane treatment results in channelized offset left-turn lanes, the following countermeasures (see Figure 9) are recommended to reduce the potential for wrong-way maneuvers by drivers turning left from a stop-controlled intersecting minor roadway:

- D-1. Largest practical sign sizes as specified in the MUTCD (2009) for DIVIDED HIGHWAY CROSSING, WRONG WAY, DO NOT ENTER, KEEP RIGHT, and ONE WAY signs.
- D-2. For the signs listed above, use prismatic retroreflective sheeting, to provide increased sign conspicuity and legibility for older drivers.
- D-3. Retroreflective lane-use arrows.
- D-4. Retroreflective pavement marking extensions of the center line that scribe a path through the turn, except where extensions for opposing movements cross.



INTERSECTIONS

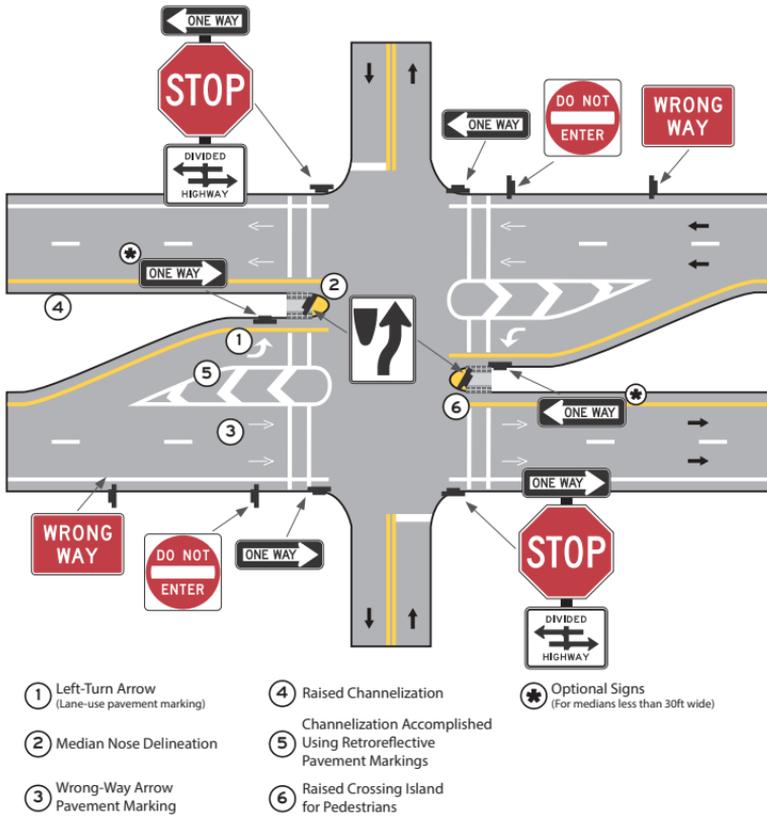


Figure 9. Recommended signs and markings for intersections with channelized offset left-turn lanes

D-5. Placement of 23.5-ft-long retroreflective wrong-way arrows in the through lanes at locations determined to have a special need, as specified in the MUTCD (2009), Sections 3B.19 and 2E-50.

D-6. Delineation of median noses using retroreflective treatments to increase their visibility and improve driver understanding of the intersection design and function.



E. Pedestrian Accommodations

At intersections where there are high pedestrian volumes, and the offset left-turn treatment results in a crossing width that would require a pedestrian walking at 3.0 s to cross in two stages, the following is recommended to create a pedestrian crossing island (or refuge area), as shown in Figure 10:

- E-1. Flush (painted) channelization to separate the left-turn lane and adjacent through lanes.
- E-2. Raised channelization with a vertical curb and a minimum width of 6 ft to separate the left-turn lane from opposing travel lanes.

The rationale and supporting evidence for these treatments begins on page 122 of the Handbook.

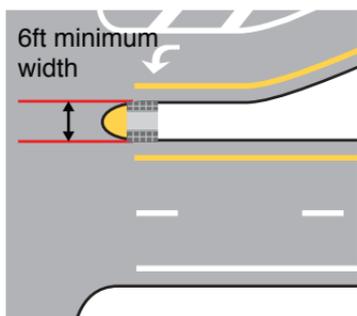


Figure 10. Pedestrian Crossing Island (or Refuge Area)

6 Delineation of Edge Lines and Curbs

A. Visibility

A minimum in-service luminance contrast level between the marked edge of the roadway and the road surface should be maintained as follows:

- A-1. At intersections with overhead lighting, a contrast of 2.0 or higher.



- A-2. At intersections without overhead lighting, a contrast of 3.0 or higher.

Contrast should be calculated according to the formula shown for Treatment 3: Channelization on page 10.

B. Intersection Curbs

Curbs at intersections (including median islands and other raised channelization) should be delineated on their vertical face and at least a portion of the top surface, in addition to the provision of a marked edge line on the road surface (see Figure 11).



Figure 11. Raised median island with yellow marking on the vertical face and top surface

The use of a Keep Right (R4-7 Series) or a Double Arrow (W12-1) sign with the addition of a low-mounted Type 1 Object Marker (OM1-1) near the median and channelizing island noses, respectively, could also be helpful to aging road users. These signs are optional and can be used if they are warranted. Since markings primarily supplement signing, this treatment should be placed in addition to the signing.

The rationale and supporting evidence for these treatments begins on page 129 of the Handbook.



7 Curb Radius

A. Simple Radius

Where roadways intersect at 90 degrees and are joined with a simple radius curve, a corner curb radius between 25 and 30 ft is recommended to: (a) facilitate vehicle turning movements, (b) moderate the speed of turning vehicles, and (c) avoid unnecessary lengthening of pedestrian crossing distances (see Simple Curve in Figure 12).

B. Accommodation of Heavy Vehicles

When it is necessary to accommodate turning movements by large trucks, the use of offsets, tapers, and compound curves is recommended in place of larger simple radii (e.g., 75 ft or more) to minimize pedestrian crossing distances (see Figure 12).

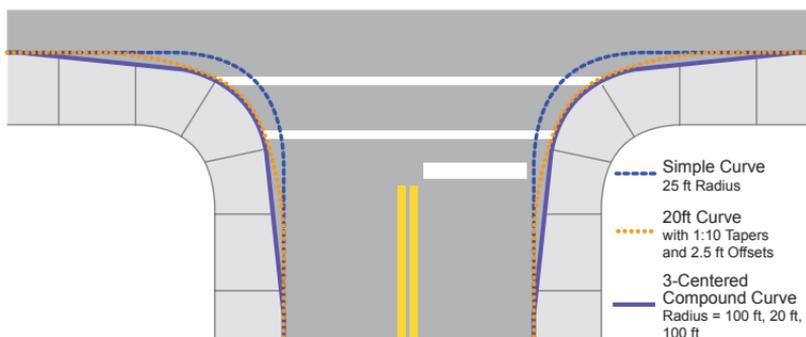


Figure 12. Comparison of curb radii

The rationale and supporting evidence for these treatments begins on page 132 of the Handbook.



8 Left-Turn Traffic Control for Signalized Intersections

A. Protected-Only Left-Turn Phasing

The use of protected-only left-turn operations is recommended for all left-turning movements, whenever appropriate. In particular, protected-only left-turn phasing should be considered where minimum intersection sight distance requirements are not achieved through the use of offset left-turn lanes (see Design Element 5) or other geometric design features, or where a pattern of permissive left-turn crashes occurs.

B. Permissive Left-Turn Signing

If circular green is used as the permissive indication of a protected/permissive left-turn, consistent use of the MUTCD R10-12 sign, (LEFT TURN YIELD ON GREEN) is recommended, with overhead placement preferred at the intersection adjacent to the left-turn signal face (see Figure 13).



Figure 13. MUTCD R10-12 sign adjacent to left-turn signal face

C. Advance Signing

Where practical, an additional R10-12 sign should be placed in advance of the intersection to advise left-turning drivers of permissive signal operation.



Figure 14. (MUTCD R10-31P)

The sign should be displayed at a 3 s preview distance before the intersection, or at the beginning of the left-turn lane, as per engineering judgment, accompanied by an AT SIGNAL (R10-31P) supplemental plaque as shown in Figure 14. [See time-speed-distance table on page 5 of the Handbook.]



D. Lead versus Lag Phasing

A leading protected left-turn phase is recommended wherever protected left-turn signal operation is implemented (as opposed to a lagging protected left-turn phase).

The rationale and supporting evidence for these treatments begins on page 135 of the Handbook.

9 Right-Turn Traffic Control for Signalized Intersections

A Turn Prohibition

At signalized intersections where a right turn on red is prohibited, a supplemental NO TURN ON RED sign, using the MUTCD R10-11 design as shown in Figure 15, should be placed at a location on either the near or opposite side of the intersection where, per engineering judgment, it will be most conspicuous. This supplemental NO TURN ON RED sign is in addition to the MUTCD recommended practice of installing an R10-11 series sign near the appropriate signal head.



Figure 15. (MUTCD R10-11)

B. Skewed Signalized Intersections

As discussed in Treatment 1: Intersecting Angle (Skew), at skewed signalized intersections where the approach leg to the left intersects the driver's approach leg at an angle of less than 75 degrees (as illustrated in Figure 4), prohibit right turn on red (RTOR).



C. Pedestrian Protection

Posting MUTCD standard R10-15 signs, Turning Vehicles Yield to Pedestrians (shown in Figure 17) is recommended wherever engineering judgment indicates a clear potential for right-turning vehicles to come into conflict with crossing pedestrians. (Note that a yellow background color may be used instead of fluorescent yellow-green for this sign.)



Figure 17. (MUTCD R10-15)

The rationale and supporting evidence for these treatments begins on page 148 of the Handbook.

10 Street Name Signs

A. Letter Heights and Sign Border

Minimum letter heights of 6 in for uppercase letters and 4.5 in for lowercase letters are recommended for use on ground-mounted street-name signs



Figure 18. (MUTCD D3-1)

(MUTCD D3-1, as shown in Figure 18) on all roads where the posted speed limit is at or below 25 mph. On all roads where the posted speed limit is greater than 25 mph, letter heights of 8 in for uppercase letters and 6 in for lowercase letters should be used.

The use of overhead-mounted street-name signs is recommended at major intersections as a supplement to ground-mounted street-name signs. Minimum letter heights of 12 in for uppercase letters and 9 in for lowercase letters are recommended by the MUTCD.



INTERSECTIONS

B. Advance Street-Name Plaque

Wherever an advance intersection warning sign is installed (MUTCD W2 series) it should be accompanied by an advance street name plaque (W16-8P or W16-8aP) using minimum letter heights of 6 in for uppercase letters and 4.5 in for lowercase letters (see Figure 19). Where an advance traffic control sign (MUTCD W3 series) is installed on a multi-lane approach, an advance street name plaque (W16-8P or W16-8aP), using the same minimum letter heights described above, should be considered.



Figure 19. Intersection Warning W2-1 Sign and W16-8P Supplemental Advance Street Name Plaque

C. Advance Street-Name Sign

In the absence of an advance intersection warning sign or advance traffic control sign (with accompanying advance street-name plaque), the use of advance street-name signs (MUTCD D3-2) for major intersections is recommended, with turn bays being used to provide adequate preparation time for any lane change and/or turning maneuvers (see Figure 20).



Figure 20. (MUTCD D3-2)



D. Directional Street-Name Sign

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 advance and intersection street-name signs, as shown in Figure 20.

E. Retroreflectivity

Foreground-mounted street-name signs installed at intersections in areas of intensive land use, complex design features, and heavy traffic, prismatic retroreflective sheeting that provides for high retroreflectivity should be used to provide increased sign conspicuity and legibility for aging drivers.

The rationale and supporting evidence for these treatments begins on page 152 of the Handbook.

11 Stop and Yield Signs

A. Sign Size

The minimum sign size required by the 2009 MUTCD for STOP (R1-1) and YIELD (R1-2) signs is as follows:

- 30 in for single-lane applications and 36 in for multi-lane applications of STOP signs.
- 36 in for single-lane applications, 48 in for multi-lane applications, and 60 in for freeway applications of YIELD signs.

Larger R1-1 (36-in for single-lane applications, or 48-in in any location) signs may be used where engineering judgment indicates that greater emphasis or visibility is required.



B. Retroreflectivity

A minimum sign background (red area) retroreflectivity level (i.e., coefficient of retroreflection [RA]) for STOP (R1-1) and YIELD (R1-2) signs is as follows:

- B-1. 12 cd/lux/m² for roads with operating speeds lower than 40 mph.
- B-2. 24 cd/lux/m² for roads with operating speeds of 40 mph or higher. Signs with an RA below these levels should be replaced.

C. Supplemental Warning Sign

The use of a 30-in x 18-in supplemental warning sign panel (MUTCD W4-4P) as illustrated in Figure 21, mounted below the STOP (R1-1) sign, is recommended for two-way stop-controlled intersection sites selected on the basis of crash experience, where the sight triangle is restricted, and wherever a conversion from four-way stop to two-way stop operations is implemented.

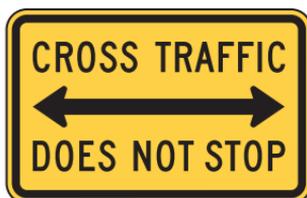


Figure 21. (MUTCD W4-4P)

D. Location of Stop Ahead Sign

A STOP AHEAD sign (MUTCD W3-1, as shown in Figure 22) should 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. [See time-speed-distance table on page 5 of the Handbook.]



Figure 22. (MUTCD W3-1)



E. Transverse Treatments and Supplemental Pavement Markings

Utilize supplemental pavement markings on approaches to stop-controlled or yield-controlled intersections where engineering judgment indicates a special need due to sight restrictions, high approach speeds, or a history of ran-stop-sign crashes. "STOP AHEAD" pavement markings to supplement STOP AHEAD signs and triangular pavement markings to supplement YIELD AHEAD signs are described in MUTCD Section 3B.20 and Figure 32. Transverse pavement striping or rumble strips may also be considered where high approach speeds are a concern.

The rationale and supporting evidence for these treatments begins on page 160 of the Handbook.

12 Lane Assignment on Intersection Approach

A. Lane-Use Control Signs

The consistent overhead placement of lane-use control signs (MUTCD R3-5 and R3-6 series) at intersections on a signal mast arm or span wire is recommended, as illustrated in Figure 23.



Figure 23. Mast-arm mounted lane-use control signs



B. Advance Signs and Markings

The consistent posting of lane-use control signs (MUTCD R3 series) 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. [See time-speed-distance table on page 5 of the Handbook.] R3-5 and R3-6 series signs should be mounted overhead wherever practical.

The rationale and supporting evidence for these treatments begins on page 170 of the Handbook.

13 Traffic Signals

A. Visibility

To ensure visibility and conspicuity of the traffic signal, the following is recommended:

- A-1. A maintained performance level of 200 cd for peak intensity for both 8-in and 12-in signals.
- A-2. Use of 12-in signals in all cases except the few limited situations in which the MUTCD allows the use of 8-in signals.

B. All-Red Clearance Interval

To accommodate age differences in perception-reaction time, an all-red clearance interval should be consistently implemented, with length determined according to the Institute of Transportation Engineers (2013) expressions given below:

- B-1. Where pedestrian traffic is prohibited, or no pedestrian crossing facilities are provided, use:



$$r = \frac{W + L}{1.47V}$$

B-2. Where pedestrian crossing facilities are provided, use:

$$r = \frac{P + L}{1.47V}$$

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 = approach speed of the vehicle (mph).

C. Backplates

Use backplates with traffic signals on all roads with operating speeds of 40 mph or higher. The use of backplates with signals is also recommended on roads with operating speeds lower than 40 mph where engineering judgment indicates a need due to the potential for sun glare problems, site history, or other variables. Yellow retroreflective borders, shown in Figure 24, may be used as an option to improve visibility of the illuminated face of the signal.

Details on dimensions of reflective strips are provided in the Handbook on page 36.

The rationale and supporting evidence for these treatments begins on page 173 of the Handbook.



Figure 24. Yellow retroreflective backplates

14 Intersection Lighting

A. Fixed Installations

Wherever feasible, fixed lighting installations are recommended as follows:

- A-1. Where the potential for wrong-way movements is indicated through crash experience or engineering judgment.
- A-2. Where twilight or nighttime pedestrian volumes are high.
- A-3. Where shifting lane alignment, turn-only lane assignment, or a pavement-width transition forces a path-following adjustment at or near the intersection.

B. Maintenance

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.

The rationale and supporting evidence for these treatments begins on page 181 of the Handbook.



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- C-1. For single stage crossings, use MUTCD R10-3b, R10-3c, R10-3e, R10-3f, R10-3g, or R10-3i. Examples of R10-3e, R10-3f are shown in Figure 26; other examples are shown in the Handbook.
- C-2. For two-stage crossings using a pedestrian refuge island, use MUTCD R10-3d or R10-3h on the corners of the intersection and the placards defined above the the median refuge island.

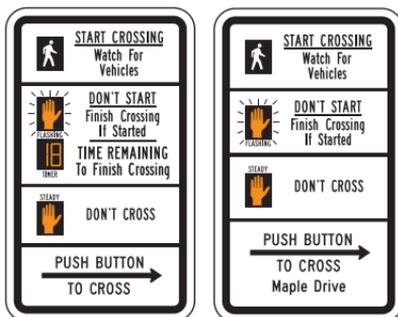


Figure 26. (MUTCD R10-3 Series)
R10-3e, R10-3f

D. Turning Vehicles Yield to Pedestrians Sign

The posting of the MUTCD R10-15 sign (see Figure 27) is recommended wherever engineering judgment indicates a clear potential for right-turning vehicles to come into conflict with crossing pedestrians.

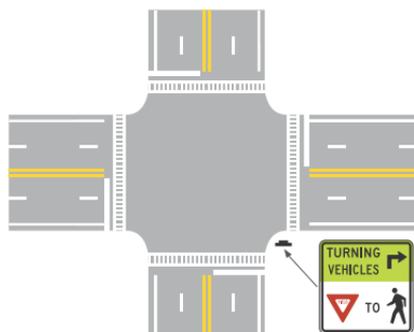


Figure 27. Recommended placement of MUTCD R10-15 sign

E. Leading Pedestrian Interval

At intersections with high turning-vehicle volumes and no turn on red (NTOR) control for traffic moving parallel to a marked crosswalk, a leading pedestrian interval (LPI) timed to allow slower walkers to cross at least one moving lane of traffic is recommended to reduce conflicts between pedestrians and turning vehicles. The length of the LPI, which should be at least 3.0 s, may be calculated using the formula:



$$\text{LPI} = (\text{ML} + \text{PL} + 6.0) / 3.0$$

where:

LPI = seconds between onset of the WALK signal for pedestrians and the green indicator for vehicles.

ML = width of moving lane in ft.

PL = width of parking lane (if any) in ft.

6.0 = distance in ft back from the edge of the curb to the assumed starting location for pedestrians.

3.0 = walking speed in ft/s.

F. Countdown Signal

Countdown pedestrian signals (see Figure 28) should be installed at all signalized intersections where pedestrian signals are warranted. The 2009 MUTCD requires the use of countdown pedestrian signals when the pedestrian change interval is greater than 7.0 s.



Figure 28. Countdown pedestrian signal

The rationale and supporting evidence for these treatments begins on page 185 of the Handbook.

16 Roundabouts

Roundabouts should be considered as part of the engineering study in the design of new intersections and the redesign of existing intersections. When a State or local highway authority has determined through an engineering study to install a modern roundabout, include the following (see Figure 29):



INTERSECTIONS

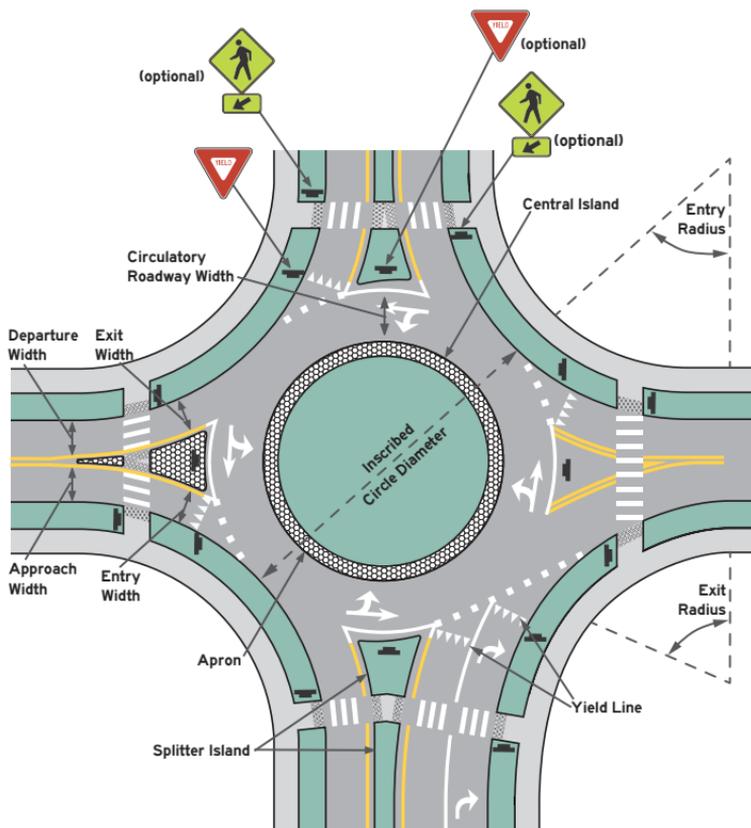


Figure 29. Key geometric design elements and traffic control devices for roundabouts

A. Number of Lanes

Unless required by operational needs, it is recommended that roundabout installations be limited to one-lane entrances and exits and one lane of circulating traffic.

B. Pedestrian Crossings

Pedestrian crossings at single-lane roundabouts should be set back a minimum of 25 ft from the yield lines and include a crossing island of at least 6 ft in width.



C. Splitter Islands

Raised splitter islands, as opposed to pavement markings, should be used to delineate the channelization. The pedestrian crosswalk area should be designed at street level (crosswalk cut through a splitter island).

D. Conspicuity

The sides and tops of curbs on the splitter islands and the central island should be treated with retroreflective markings, and be maintained at a minimum luminance contrast level as follows:

D-1. At roundabouts with overhead lighting, a contrast of 2.0 or higher.

D-2. At roundabouts without overhead lighting, a contrast of 3.0 or higher. Contrast should be calculated according to the formula shown for Treatment 3: Channelization on page 10.

E. Advance Warning Sign

The use of an advance roundabout warning sign (W2-6), as shown in Figure 30, is recommended on all approaches to a roundabout.



F. Directional Signs

Figure 30. (MUTCD W2-6)

The use of a Roundabout Directional Arrow sign (R6-4 series) is recommended to direct traffic counter-clockwise around the central island. This sign display should be placed on the central island in direct view of a driver's entry point, as shown in Figure 31, (if different than at the centerline of the approaching roadway).



INTERSECTIONS

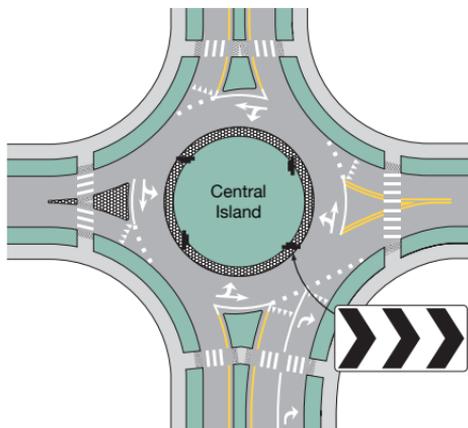


Figure 31. Roundabout directional arrow sign

G. Roundabout Circulation Plaque

The Roundabout Circulation Plaque (R6-5P) should be placed immediately below the R1-2 Yield sign on both sides of the road at each entrance to a roundabout (see Figure 32).

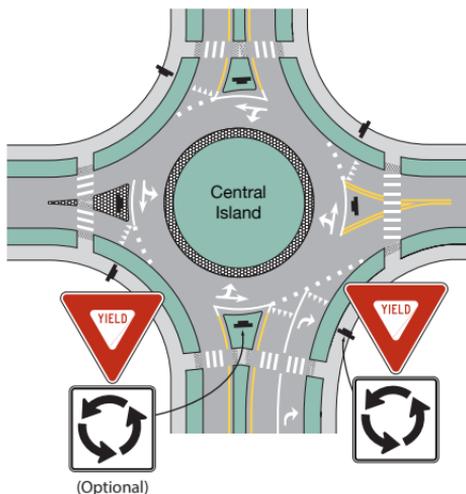


Figure 32. Placement of Roundabout Circulation Plaques

The rationale and supporting evidence for these treatments begins on page 197 of the Handbook.



PROMISING PRACTICES

17 Right-Turn Channelization Design

Consider right-turn channelization with tighter turning radii to reduce turning speeds to approximately 17 to 18 mph, decrease pedestrian crossing distances, and optimize the right-turning motorists' line of sight, as shown in the Preferred example on the right of Figure 33. Traffic control devices at the end of the channelization should be visible to vehicles entering the channelized lane.

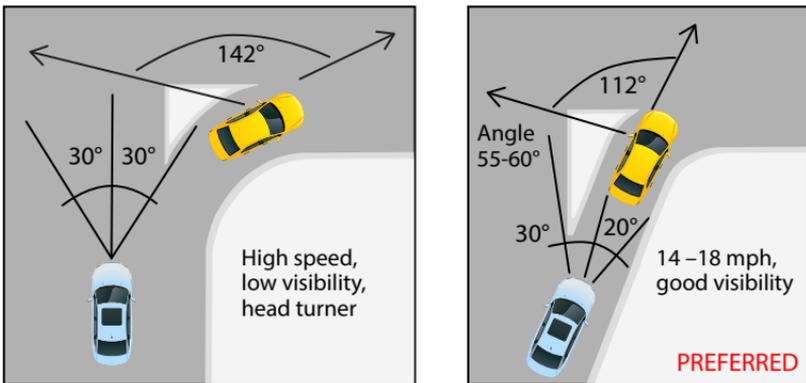


Figure 33. Right-Turn Channelization Design

The rationale and supporting evidence for these treatments can be found beginning on page 215 of the Handbook.

18 Combination Lane-Use/Destination Overhead Guide Signs

At intersections where complex design features or heavy traffic is present, and specific guidance advising roadway users which lane is necessary for their intended destination, combination lane use/destination signs (D15-1) should be used. These signs are typically



INTERSECTIONS

used as overhead combination lane use destination guide signs and are described in Section 2D.33 of the 2009 MUTCD (see Figure 34).

The rationale and supporting evidence for these treatments can be found beginning on page 215 of the Handbook.



Figure 34. Combination Lane Use/Destination Guide Sign (MUTCD D15-1)

19 Signal Head Visibility

Place all required signal heads overhead and centered over each lane instead of placing them on pedestal poles (see Figure 35). Supplemental signal heads may be placed on pedestal posts as needed.



Figure 35. Example Of One Signal Head Per Lane

The rationale and supporting evidence for these treatments can be found beginning on page 216 of the Handbook.



20 High-Visibility Crosswalks

To allow drivers to more easily see pedestrians in a marked crosswalk, high-visibility crosswalk marking patterns should be utilized. Two examples of such markings include white diagonal lines at a 45 degree angle to the crosswalk or the "ladder" crosswalk design shown in Figure 36.



Figure 36. High-Visibility ("Ladder") Crosswalk

The rationale and supporting evidence for these treatments can be found beginning on page 216 of the Handbook.

21 Supplemental Pavement Marking for Stop and Yield Signs

Use the "STOP AHEAD" pavement marking to supplement stop ahead signs (W3-1) and either the "YIELD AHEAD" pavement marking or the yield ahead triangle symbol pavement markings to supplement yield ahead signs (W3-2). See Section 3B.20 of the 2009 MUTCD and Figure 37.

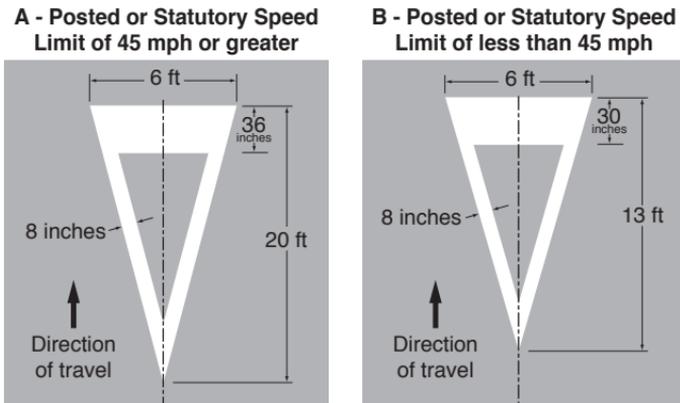


Figure 37. Yield Ahead Triangle Symbols

The rationale and supporting evidence for these treatments can be found beginning on page 217 of the Handbook.



22 Reduced Left-Turn-Conflict Intersections

A class of innovative intersection designs accommodate left turns in unique ways, which greatly reduce, if not eliminate, unprotected left turns at the intersection. Designs such as the median U-turn intersection (see Figure 38) and restricted-crossing U-turn (RCUT) intersection (see Figure 39) have features that minimize the operational delay and potential for crashes due to left turns. These innovative intersection designs should be considered for suitability during the engineering study for new and reconstructed intersections. Additional details are provided in the Handbook.

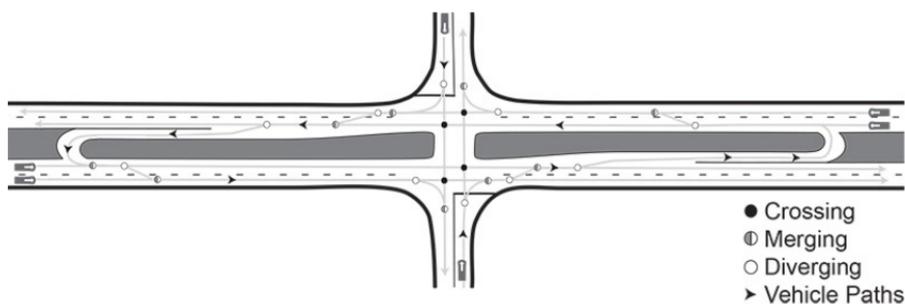


Figure 38. Diagram of Median U-Turn Intersection

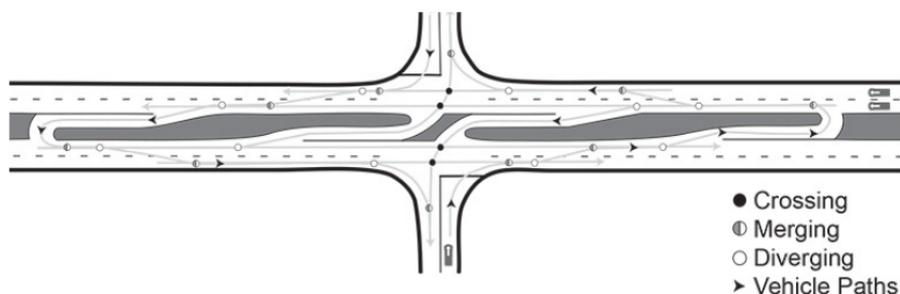


Figure 39. Diagram of Restricted Crossing U-Turn Intersection

The rationale and supporting evidence for these treatments can be found beginning on page 218 of the Handbook.



23 Accessible Pedestrian Signal (APS) Treatments

A. Pushbutton-Activated Extended Pedestrian Crossing Phase

At crosswalks frequently used by aging pedestrians, consider installing pushbutton-activated extension of the pedestrian crossing phase using the required signage described by the MUTCD, as shown in Figure 40.

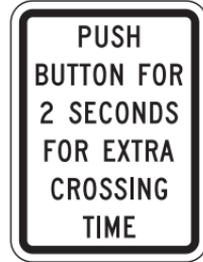


Figure 40.
(MUTCD R10-32P)

B. Passive Pedestrian Detection

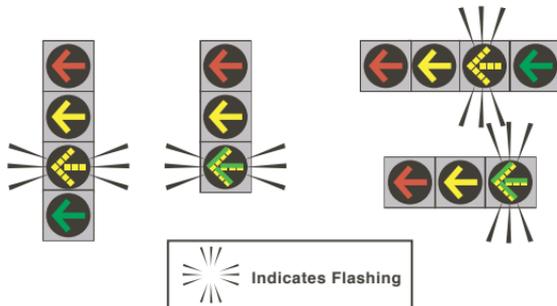
Use passive pedestrian detection to help aging pedestrians who have difficulty using the pushbutton or to detect pedestrians within the crosswalk that may need more time to complete the crossing maneuver.

The rationale and supporting evidence for these treatments can be found beginning on page 219 of the Handbook.

24 Flashing Yellow Arrow

The flashing yellow arrow (see Figure 41) is the recommended signal indication for permissive left-turn movements at signalized intersections.

Figure 41. Typical arrangements of signal faces with flashing yellow arrow indications for permissive left-turn movements



The rationale and supporting evidence for these treatments begins on page 220 of the Handbook.



Chapter 3. Interchanges

25. Exit Signs and Markings	40
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31. Advance Pavement (Route Shield) Markings at Major Freeway Junctions	49
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CHAPTER 3

Interchanges

This section of the Desk Reference focuses on treatments for highway design elements in six areas to enhance the performance of aging drivers at interchanges. After the last design element, two promising practice treatments are also presented.

PROVEN PRACTICES

25. Exit Signs and Markings
26. Freeway Entrance Traffic Control Devices
27. Delineation
28. Acceleration/Deceleration Lane Design
29. Interchange Lighting
30. Restricted or Prohibited Movements

PROMISING PRACTICES

31. Route Shield Markings at Major Freeway Junctions
32. Wrong-Way Driving Countermeasures



PROVEN PRACTICES

25 Exit Signs and Markings

A. Letter Size

Assume a minimum specific ratio of 1 inch of letter height per 30 feet of legibility distance for new or reconstructed installations and for sign replacement at interchanges and on their approaches.

B. Mixed-Case Lettering

It is required by the 2009 MUTCD that mixed-case lettering be used for destination and street names.

C. Overhead Arrow-per-Lane Sign

The MUTCD recommends Overhead Arrow-per-Lane guide signs to be used on all new or reconstructed freeways and expressways as described in MUTCD Sections 2E.20 and 2E.21, whereby the number of arrow shafts appearing on the sign matches the number of lanes on the roadway at the location of the sign (see Figure 42).



Figure 42. Example Overhead Arrow-per-Lane Sign



Freeway and expressway splits or multi-lane exit interchanges that contain an interior option lane in which traffic can either leave the route or remain on the route, or choose either destination at a split, from the same lane should use overhead arrow-per-lane guide signs rather than diagrammatic guide sign designs.

D. Retroreflective Sheeting

Microprismatic retroreflective sheeting should be used on overhead and ground-mounted guide signs.

The rationale and supporting evidence for these treatments can be found beginning on page 224 of the Handbook.

26 Freeway Entrance Traffic Control Devices

A. Guide Sign

A 48-in x 30-in guide sign panel with the legend Freeway Entrance (see Figure 43), using a minimum letter height of 8 in, should be consistently used in situations where freeway entrance and exit ramps are adjacent to one another (such as



Figure 43. (MUTCD D13-3)

at a partial cloverleaf interchange) and placed as described in Section 2D.46 and shown in Figure 2D-14 of the MUTCD.

B. Adjacent Entrance/Exit Ramps

Where adjacent entrance and exit ramps intersect with a crossroad, the use of a median separator, either painted or preferably raised, is recommended, with the nose of the separator delineated with yellow retroreflectorized markings and extending as close to the crossroad as practical without obstructing the turning path of vehicles (see Figure 44). Where



INTERCHANGES

engineering judgment determines the need for the median nose to be set back from the intersection, the setback distance should be treated by a 12 in or wider yellow stripe. In addition, a KEEP RIGHT (R4-7) sign should be posted on the median separator nose, if it is raised.

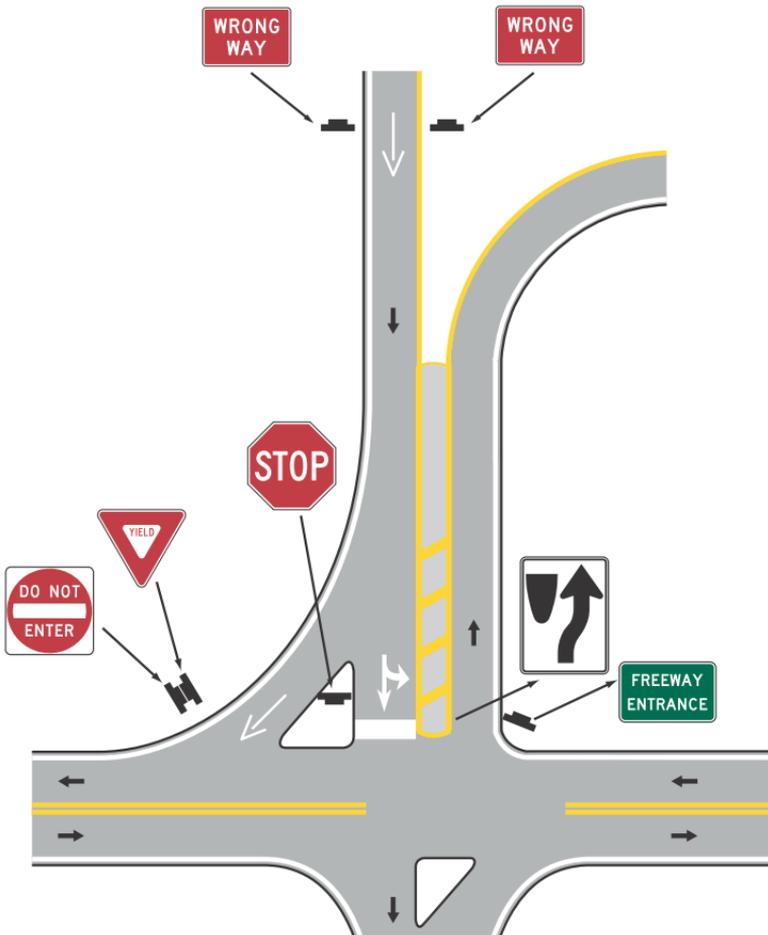


Figure 44. Recommended signs and markings for adjacent entrance/exit ramps at a crossroad intersection



INTERCHANGES

C. Diagrammatic Entrance Sign

For diagrammatic guide signs depicting lane use for entry to a freeway from an urban multi-lane arterial, maximum visibility is achieved through overhead sign placement. Where this is not feasible, two advance ground-mounted diagrammatic guide signs should be used, one placed at 0.5 mi and the second placed at 0.25 mi in advance of the interchange (see Figure 45).



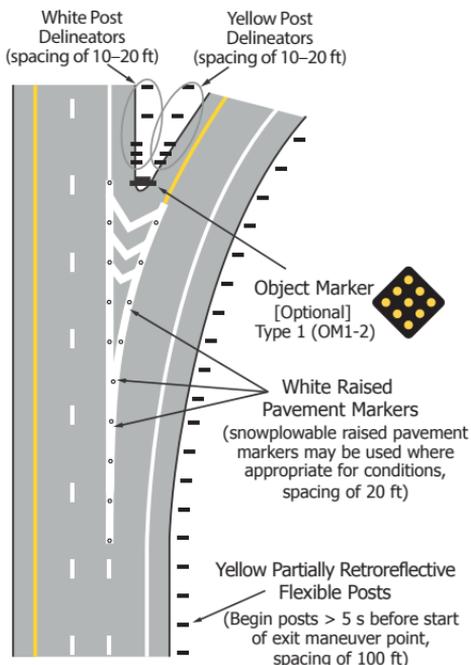
Figure 45. Advance ground-mounted diagrammatic sign

The rationale and supporting evidence for these treatments can be found beginning on page 235 of the Handbook.

27 Delineation**A. Delineators/Raised Pavement Markers**

Delineation in the vicinity of the exit gore at non-illuminated and partially illuminated interchanges should include, as a minimum, raised pavement markers and retroreflective post-mounted delineators as shown in Figure 46.

Figure 46. Recommended raised pavement markers and post-mounted delineators at an exit gore





B. Object Marker

Where engineering judgment has identified a hazardous gore area (e.g., containing a ditch) or other special visibility need, the minimum treatments described above should be supplemented by adding Type 1 object markers to the exit gore sign post as illustrated in Figure 46.

C. Chevrons / Post-Mounted Delineators

Post-mounted delineators and/or chevrons should be applied to delineate the controlling curvature on exit ramps, as illustrated in Figure 47.

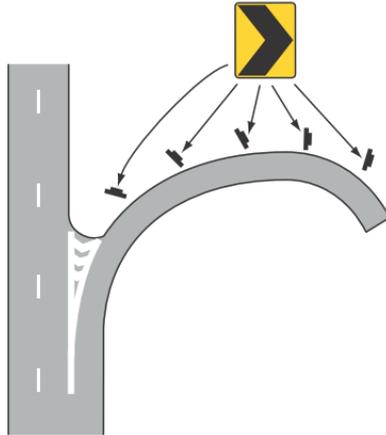


Figure 47. Placement of chevrons on the controlling curve of an exit ramp

The rationale and supporting evidence for these treatments can be found beginning on page 238 of the Handbook.

28 Acceleration/Deceleration Lane Design

A. Entrance Ramp Geometry

A parallel (rather than a taper) design for entrance ramp geometry is recommended, as shown in Figure 48. A parallel style entrance lane length of at least 1,200 ft, plus a taper, is desirable.

B. Location of Exit Ramps

The AASHTO (2011) decision sight distance values (instead of stopping sight distance) should be consistently applied in



INTERCHANGES

locating ramp exits downstream from sight-restricting vertical or horizontal curvature on the mainline.

The rationale and supporting evidence for these treatments can be found beginning on page 243 of the Handbook.

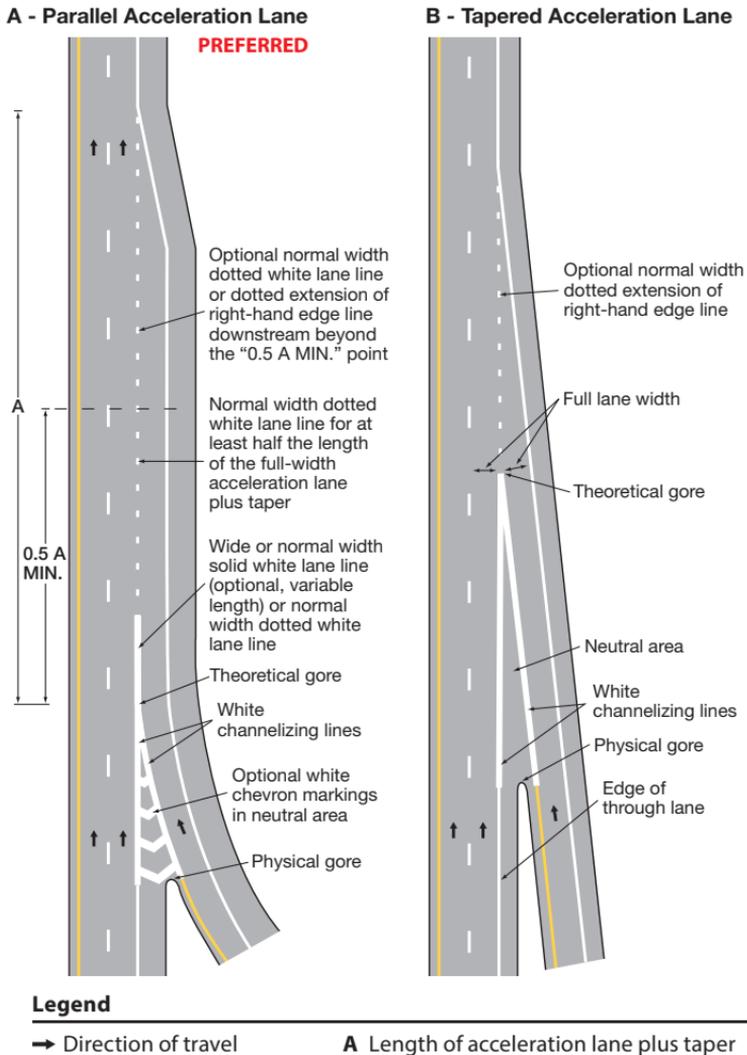


Figure 48. Recommended markings for acceleration lanes from entrance ramps onto freeways



29 Interchange Lighting

A. Complete versus Partial Lighting

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 (e.g., 60- to 150-ft-high structures with 3 to 12 luminaires per structure) per ramp is recommended, with one fixture located on the inner ramp curve near the gore, and one fixture located on the outer curve of the ramp, midway through the controlling curvature.

The rationale and supporting evidence for this treatment can be found beginning on page 248 of the Handbook.

30 Restricted or Prohibited Movements

A. Signing Practices

The following countermeasures should be used where DO NOT ENTER (R5-1) and WRONG WAY (R5-1a) signs are used:

- A-1. For enhanced conspicuity of DO NOT ENTER (R5-1) and WRONG WAY (R5-1a) signs placed on freeway ramps, use larger than minimum MUTCD sizes for freeway applications with corresponding increases in letter size.
- A-2. To provide increased sign conspicuity and legibility for aging drivers, use retroreflective fluorescent red sheeting materials that provide for high retroreflectance overall.
- A-3. Where engineering judgment indicates an exaggerated risk of wrong-way movement crashes, both the R5-1 and R5-1a signs should be installed on both sides of the ramp, placed in accordance with the MUTCD (see Figure 49).



INTERCHANGES

- A-4. Where all other engineering options have been tried or considered, lowering sign height to maximize brightness under low-beam headlight illumination is recommended by mounting the signs 36 in above the pavement (measured from the road surface to the bottom of the sign), or the lowest value above 36 in that is practical when the presence of snow, vegetation, or other obstructions is taken into consideration.

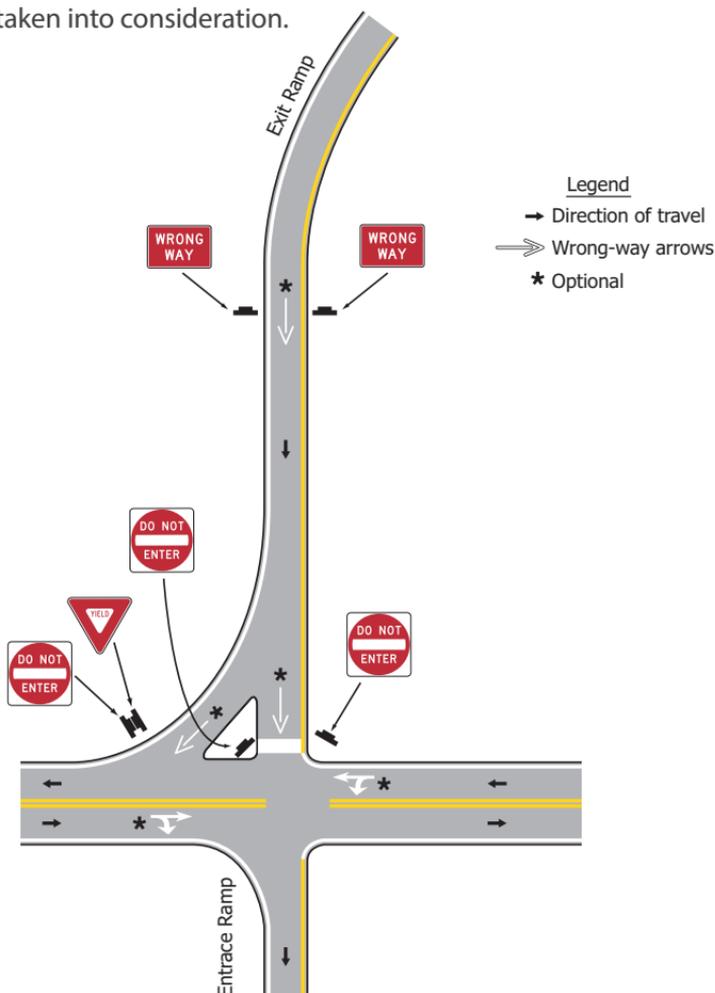


Figure 49. Recommended signing for restricted movements on an exit ramp



B. Pavement Markings

- B-1. The application of 23.5-ft long wrong-way arrow pavement markings near the terminus on all exit ramps is recommended (see Figure 49).

- B-2. Where engineering judgment indicates a need for increased conspicuity, wrong-way arrow pavement markings should be supplemented with red/white bidirectional retroreflective raised pavement markers.

The rationale and supporting evidence for these treatments can be found beginning on page 252 of the Handbook.



PROMISING PRACTICES

31 Advance Pavement (Route Shield) Markings at Major Freeway Junctions

At major freeway interchanges and route splits, route shield markings should be used in the lanes approaching the split to guide drivers to the correct approach lane (see Figure 50). The placement of this type of marking should be just prior to the location of the advance guide signs.



Figure 50. Route Shield Markings At Freeway Junctions

The rationale and supporting evidence for these treatments can be found beginning on page 257 of the Handbook.



32 Wrong-Way Driving Countermeasures

Additional treatments to counter wrong-way driving by aging drivers (e.g., improved lighting, channelization, signs and markings in addition to those in Treatment 30) should be considered where exit ramps intersect with surface streets. Those treatments include:

- Conducting a Road Safety Audit (RSA) to examine the performance of the interchange and determine appropriate countermeasures to employ.
- Using the Wrong-Way Driving (WWD) Prompt list to focus specific attention on wrong-way driving issues and contributing factors.
- Referring to American Traffic Safety Services Association publication that describes promising practices in wrong-way driving countermeasures (ATSSA, 2012); a review of that document should be included during the consideration of potential WWD treatments to implement.

The rationale and supporting evidence for these treatments can be found beginning on page 257 of the Handbook.



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CHAPTER 4

Roadway Segments

This section of the Desk Reference illustrates treatments designed to facilitate the safety of aging drivers on specific types of roadway segments. It contains four proven practices and six treatments that promise to support the needs of aging drivers.

PROVEN PRACTICES

33. Horizontal Curves
34. Vertical Curves
35. Passing Zones
36. Lane Control Devices

PROMISING PRACTICES

37. Lane Drop Markings
38. Contrast Markings on Concrete Pavement
39. Utilize Highly Retroreflective Marking Material
40. Curve Warning Markings
41. Road Diets
42. High Friction Surface Treatments



PROVEN PRACTICES

33 Horizontal Curves

A. Edge Lines

White edge lines on horizontal curves (see Figure 51) are to be maintained at the following in-service contrast levels:

- A-1. On highways without median separation of opposing directions of traffic, the recommended minimum in-service contrast level for edgelines on horizontal curves is 5.0.
- A-2. On highways where median barriers effectively block the drivers' view of oncoming headlights or where median width exceeds 50 ft, the recommended minimum in-service contrast level for edgelines on horizontal curves is 3.75.

Contrast should be calculated according to the formula shown for Treatment 3: Channelization on page 10.



Figure 51. White edge lines, centerline RPMs, and chevrons on a horizontal curve



B. Retroreflective Pavement Markers

- B-1. For curves with radii greater than 1,640 ft and less than 3,280 ft, it is recommended that standard centerline markings be supplemented with RPMs installed at standard spacing (i.e., 40 ft apart), and that they be applied for a distance of 5 s of driving time (at 85th percentile speed) on the approach to the curve and continued throughout the length of the curve. [See time-speed-distance table on page 5 of the Handbook.]
- B-2. Where engineering judgment indicates that nighttime wet pavement visibility for surface delineation treatments is a priority for safe operations, regardless of curve radius, the use of RPMs is recommended.

C. Post-Mounted Delineators

In addition to the installation of chevron alignment signs (W1-8) as specified in the MUTCD, roadside post-mounted delineators should be installed on horizontal curves with approximate uniform spacing as shown in Table 7.

Table 7. Recommended spacing for post-mounted delineators.

Radius of Curve (Feet)	Approximate Spacing (Feet)
< 600	40
700	75
800	80
900	85
> 1000	90

Note: Spacing for curves greater than 600 ft based on the following formula from the MUTCD (Table 3D-1):

$$\text{English: } S = 3(R-50)^{0.5}$$

Where: S = approximate spacing on curve (ft), R = radius (ft)



D. Pavement Width

On two-lane rural roads, the combined (lane plus shoulder) paved width in one direction should be at least 18 ft throughout the length of the curve for a horizontal curve with a radius less than 1,900 ft.

The rationale and supporting evidence for this treatment can be found beginning on page 260 of the Handbook.

34 Vertical Curves

A. Perception-Reaction Time

Strict adherence to a perception-reaction time (PRT) of at least 2.5 s for a roadway hazard obscured by vertical curvature should be used in the design of new and reconstructed facilities.

B. Passive Warning Sign

Where a need has been determined for installation or replacement of a device to warn motorists that sight distance is restricted by a crest vertical curve, use the 30-in x 30-in HILL BLOCKS VIEW sign (MUTCD W7-6) with an Advisory Speed plaque (MUTCD W13-1P) as shown in Figure 52.

C. Active Warning Sign

If a signalized intersection is obscured by vertical curvature in a manner that the signal becomes visible at a preview distance of 8 s or less (at operating speed), then it is recommended that, in addition to the standard advance signal warning sign (MUTCD W3-3), a BE PREPARED TO STOP warning sign (MUTCD W3-4) and WHEN FLASHING plaque (MUTCD W16-13) be used along with a warning beacon



Figure 52. (MUTCD W7-6 and W13-1P)



ROADWAY SEGMENTS

interconnected with the traffic signal controller (see Figure 53). The yellow warning beacon should be activated at a sufficient interval prior to the onset of the yellow signal phase and sustained after the onset of the green signal phase to take into account the end of queues experienced during peak traffic conditions, as determined through engineering study. [See time-speed-distance table on page 5 of the Handbook.]



Figure 53. (MUTCD W3-4 and W16-13)

The rationale and supporting evidence for these treatments can be found beginning on page 272 of the Handbook.

35 Passing Zones

A. Passing Sight Distance

To accommodate age-related difficulties in judging gaps and longer decision making and reaction times exhibited by aging drivers, use the most conservative minimum required passing sight distance (PSD) values from the 2009 MUTCD, Table 3B-1 (see Table 8.)

Table 8. Minimum passing sight distances for no-passing zone markings.

85th-Percentile or Posted or Minimum Passing	Statutory Speed Limit Sight Distance
25 mph	450 feet
30 mph	500 feet
35 mph	550 feet
40 mph	600 feet
45 mph	700 feet
50 mph	800 feet
55 mph	900 feet
60 mph	1,000 feet
65 mph	1,100 feet
70 mph	1,200 feet



B. Pennant

The MUTCD oversized (48-in x 64-in x 64-in) NO PASSING ZONE pennant (W14-3), or the standard size (36 in x 48 in x 48 in) pennant using fluorescent yellow retroreflective sheeting, is recommended as a high-conspicuity supplement to conventional centerline pavement markings at the beginning of no passing zones (see Figure 54).



Figure 54.
(MUTCD W14-3)

C. Passing Lanes

To the extent feasible for new or reconstructed two-lane facilities, the implementation of passing/overtaking lanes (in each direction) at intervals of no more than 3.1 mi is recommended.

The rationale and supporting evidence for these treatments can be found beginning on page 277 of the Handbook.

36 Lane Control Devices

A. Pixel Specifications

To increase the legibility distance of overhead lane-control signal indications for prohibited movements (red X), use a double-stroke arrangement of pixels that are small (approximating 0.15 in diameter) and closely spaced (approximating 0.70 in center-to-center), as shown in Figure 55.

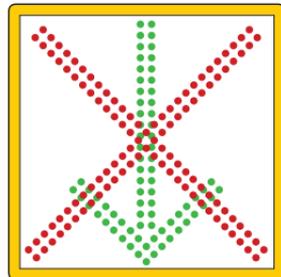


Figure 55. Lane control signal (adapted from Ullman et al. 1996)

The rationale and supporting evidence for these treatments can be found beginning on page 281 of the Handbook.



PROMISING PRACTICES

37 Lane Drop Markings

Where a through lane becomes a mandatory turn lane at an intersection or becomes a mandatory exit lane at an interchange, a “dotted” lane line should be used to separate the continuing through lane from the mandatory turn or mandatory exit lane, as described in Section 3B.04 of the 2009 MUTCD and as shown in Figure 56.

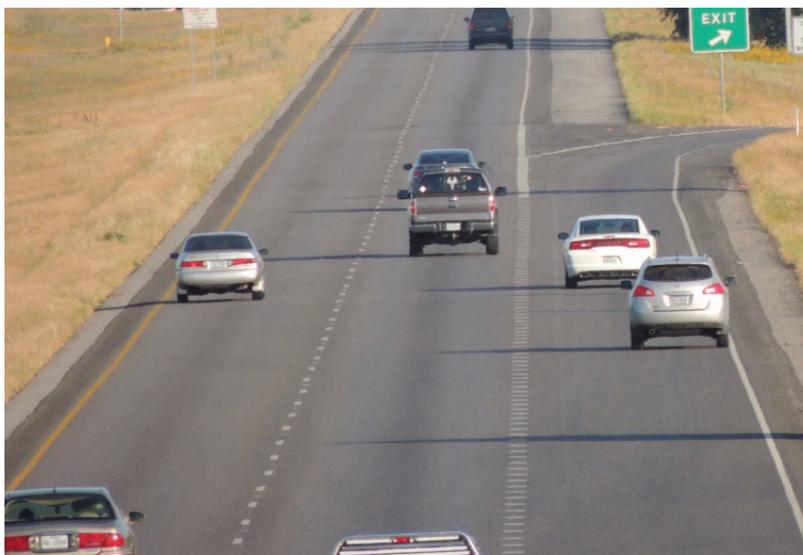


Figure 56. Dotted lane line markings at freeway lane drop

The rationale and supporting evidence for these treatments can be found beginning on page 284 of the Handbook.



38 Contrast Markings on Concrete Pavement

Contrast markings should be used wherever the pavement color is light to increase visibility of pavement markings (see MUTCD Section 3A.05 and Figure 57).



Figure 57. Contrast markings on light colored pavement

The rationale and supporting evidence for these treatments can be found beginning on page 284 of the Handbook.

39 Utilize Highly Retroreflective Marking Material

To maintain visibility under adverse driving conditions, use highly retroreflective marking material.

The rationale and supporting evidence for these treatments can be found beginning on page 285 of the Handbook.



40 Curve Warning Markings

Curve warning pavement markings, such as shown in Figure 58, should be considered as a supplement to curve warning signs at horizontal curves identified as a safety problem.



Figure 58. Curve warning markings (MUTCD:5)

The rationale and supporting evidence for these treatments can be found beginning on page 285 of the Handbook.

41 Road Diets

When performing an evaluation or road safety audit of a roadway segment that may be redesigned or reconstructed, a road diet should be included among the options to be considered. An example of a completed road diet is shown in Figure 59.

The rationale and supporting evidence for these treatments can be found beginning on page 286 of the Handbook.



Figure 59. Example of road diet

42 High Friction Surface Treatments

High friction surface treatments (HFST) are recommended on horizontal and vertical curves (such as the example shown in Figure 60), at intersections, at on and off-ramps, on bridge decks, locations prone to frequent rain, snow, or ice, or where additional side friction is beneficial.

The rationale and supporting evidence for these treatments can be found beginning on page 287 of the Handbook.



Figure 60. High friction surface treatment on a horizontal curve



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CHAPTER 5

Construction/Work Zones

This section of the Desk Reference examines treatments to enhance the performance of aging drivers as they approach and travel through construction/work zones. It addresses five specific proven design elements and two promising practices.

PROVEN PRACTICES

43. Signing and Advance Warning
44. Portable Changeable (Variable) Message Signs
45. Channelization (Path Guidance)
46. Delineation of Crossovers/Alternate Travel Paths
47. Temporary Pavement Markings

PROMISING PRACTICES

48. Increased Letter Height for Temporary Work Zone Signs
49. Work Zone Road Safety Audit (WZRSA)



PROVEN PRACTICES

43 Signing and Advance Warning

A. Flashing Yellow Arrow Panel

At construction/maintenance work zones on high-speed roadways (where the posted speed limit is 45 mph or greater) and divided highways, the consistent use of a flashing arrow panel located at the taper for each lane closure is recommended as shown in Figure 61.

B. Lane Closure Advance Signing

In implementing advance signing for lane closures as per MUTCD Part 6, it is recommended that:

A supplemental (portable) changeable message sign (CMS) displaying the one-page (phase) message LEFT (RIGHT, CENTER) LANE CLOSED should be placed 0.5 to 1.0 mile upstream of the lane closure taper (see Figure 62).

OR

Redundant static signs should be used, with a minimum letter height of 8 in and fluorescent orange retroreflective sheeting, where both the first upstream sign (e.g., W20-1) and the second sign (e.g., W20-5) encountered by the driver

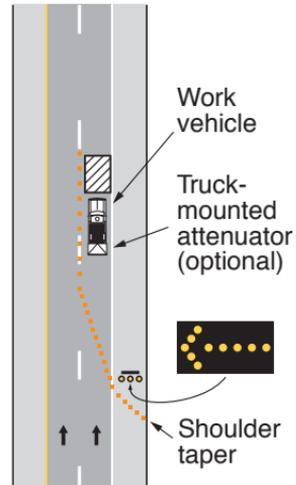


Figure 61. Flashing arrow panel at lane closure taper

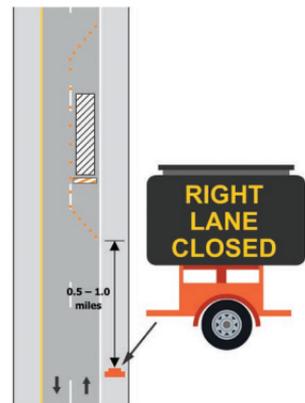


Figure 62. Changeable message sign upstream of lane closure taper

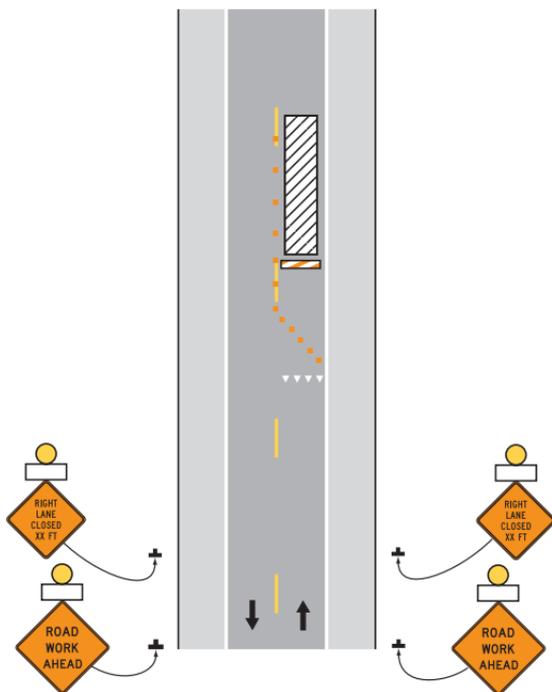


Figure 63. Redundant static signs upstream of lane closure taper

are equipped with flashing warning lights throughout the entire time period of the lane closure (see Figure 63).

C. Sign Sheeting

To increase the legibility distance of ground-mounted work-zone signs, the use of fluorescent orange is recommended over the use of beaded high-intensity orange sheeting.

D. Legibility Distance

A minimum specific ratio of 1 inch of letter height per 30 feet of legibility distance should be used.

The rationale and supporting evidence for these treatments can be found beginning on page 290 of the Handbook.



44 Portable Changeable (Variable) Message Signs

A. Number of Phases

The MUTCD requires that no more than two phases be used on a changeable message sign (CMS). If a message cannot be conveyed in two phases, multiple CMSs and/or a supplemental highway advisory radio message should be used; alternatively, the action statement only may be presented on a single page/phase.

B. Display Time

Each phase of a CMS message should be displayed for a minimum of 3 s.

C. Units of Information

C-1. It is recommended that no more than one unit of information be displayed on a single line on a CMS, and no more than three units should be displayed for any single phase.

C-2. For CMS messages split into two phases, a total of no more than four unique units of information should be presented.



Figure 64. Phase 1 (Top) and Phase 2 (Bottom)



Figure 65. Use of approved abbreviation in one-phase message



D. Sign Content

When a CMS 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, as illustrated in Figure 64.

If legibility distance restrictions rule out a two-phase display, the use of abbreviations [as specified in the MUTCD (FHWA, 2007)] plus elimination of the problem statement is the recommended strategy to allow for the presentation of the entire message in one phase, as illustrated in Figure 65.

E. Legibility

For superior legibility:

- E-1. Only single-stroke lettering should be used for displays of alphanumeric characters on portable CMSs with the conventional 5- x 7-pixel matrix.
- E-2. As new portable CMSs are procured by a highway agency, the performance specifications of such devices should include a minimum character width-to-height ratio of 0.7 (complete character) and a maximum stroke width-to-height ratio of 0.13.

F. Sign Height

Portable changeable message signs should be elevated to a height sufficient to be seen across multiple lanes of (same-direction) traffic by approaching passenger car drivers.

The rationale and supporting evidence for these treatments can be found beginning on page 300 of the Handbook.



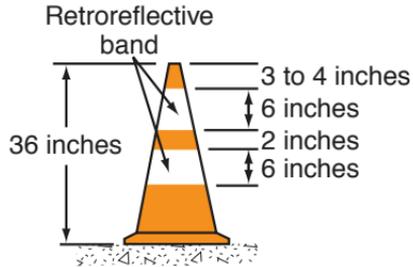
45 Channelization (Path Guidance)

A. Device Dimensions

The following minimum dimensions or properties for channelizing devices used in highway work zones are recommended to accommodate the needs of aging drivers:

A-1. Traffic cones—36 in high, with two bands of retroreflective material totaling at least 12 in wide for nighttime operations. (see Figure 66).

A-2. Tubular markers—42 in high, with a single band of retroreflective material at least 12 in wide for nighttime operations.



A-3. Vertical (striped) panels—12 in wide.

Figure 66. Traffic cone for nighttime work zone operations

A-4. Barricades—12 in x 36 in minimum dimension.

A-5. Drums—18 in x 36 in, with high-brightness sheeting for the orange and white retroreflective stripes (as per MUTCD guidelines).

B. Device Spacing

Channelizing devices through work zones (in non-crossover applications) should be spaced at no more than a distance in feet equal to the speed limit through the work zone in miles per hour (e.g., in 40-mph work zone, channelizing devices should be spaced no farther apart than 40 ft). Where engineering judgment indicates a special need for speed reduction where there is horizontal curvature or through the taper for a lane closure, spacing of channelizing devices at a distance in feet



equal to no more than half of the speed limit in miles per hour is recommended (e.g., in a 40-mph zone, space the devices no farther apart than 20 ft).

C. Reflectors

The use of side reflectors with cube-corner lenses or reflectors (facing the driver) mounted on top of concrete safety-shaped barriers and related temporary channelizing barriers is recommended, spaced (in feet) at no more than the construction zone speed limit (in miles per hour) through a work zone.

The rationale and supporting evidence for these treatments can be found beginning on page 313 of the Handbook.

46 Delineation of Crossovers/ Alternate Travel Paths

A. Positive Barriers

Use positive barriers in transition zones and positive separation (channelization) between opposing two-lane traffic throughout a crossover, for intermediate- and long-term work zones, for all roadway classes except residential.

B. Device Spacing

A maximum 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).

C. Reflectors

Use side reflectors with cube-corner lenses spaced (in feet) at no 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).



D. Screens

It is recommended for construction/work zones on high-volume roadways that glare-control screens be mounted on top of temporary traffic barriers that separate two-way motor vehicle traffic, when used in transition and crossover areas, at a spacing of not more than 24 in.

The rationale and supporting evidence for these treatments can be found beginning on page 318 of the Handbook.

47 Temporary Pavement Markings

A. Raised Pavement Markers

Where temporary pavement markings shorter than the 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.

The rationale and supporting evidence for this treatment can be found beginning on page 323 of the Handbook.



PROMISING PRACTICES

48 Increased Letter Height for Temporary Work Zone Signs

It is recommended that some “action” words on temporary work zone signs on portable sign stands have a minimum letter height of 8 in. (see Figure 67).

The rationale and supporting evidence for these treatments can be found beginning on page 328 of the Handbook.



Figure 67. Temporary work zone sign with increased letter height

49 Work Zone Road Safety Audit (WZRSA)

Work Zone Road Safety Audit Guidelines and Prompt Lists include guidance on conducting Road Safety Audits (RSA) at all phases of work zone planning, design and deployment, and considerations for each project phase. The guidelines and prompt lists explain the importance of the Work Zone RSA and navigate the practitioner through the RSA process.

The rationale and supporting evidence for these treatments can be found beginning on page 329 of the Handbook.



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CHAPTER 6

Highway-Rail Grade Crossing

This section of the Desk Reference highlights two specific treatments that have proven to enhance the performance of aging drivers at highway-rail grade crossings.

PROVEN PRACTICES

- 50. Passive Traffic Control Devices
- 51. Lighting



51 Lighting

A. Luminaire Type/Alignment

Illumination may be effective under the following conditions:

- Nighttime train operations.
- Low train speeds.
- Blockage of crossings for long periods at night.
- Collision history indicating that motorists often fail to detect trains or traffic control devices at night.
- Horizontal and/or vertical alignment of highway approach such that vehicle headlight beam does not fall on the train until the vehicle has passed the safe stopping distance.
- Long dark trains, such as unit coal trains.
- Restricted sight or stopping distance in rural areas.
- Humped crossings where oncoming vehicle headlights are visible under trains.
- Low ambient light levels.
- A highly reliable source of power.

Luminaires may provide a low-cost alternative to active traffic control devices on industrial or mine tracks where switching operations are carried out at night.

Luminaire supports should be placed in accordance with the principles in the Roadside Design Guide and NCHRP Report 350. If they are placed in the clear zone on a high-speed road, they should be breakaway.

The rationale and supporting evidence for these treatments can be found beginning on page 343 of the Handbook.



Glossary



Glossary

AAAFTS. American Automobile Association Foundation for Traffic Safety.

AAADT. Annual Average Daily Traffic.

AASHTO. American Association of State and Highway Transportation Officials.

Ambient conditions. The visual background or surrounding atmospheric and visibility conditions.

Angular motion sensitivity. The ability of an observer to detect changes in the apparent distance and direction of movement of an object as a function of the change in the angular size of the visual stimulus on the observer's retina.

Angular velocity threshold. The rate of change in angular size of a visual stimulus that is necessary for an observer to discern that an object's motion has increased or decreased.

Annual average daily traffic (AADT). The total volume passing a point or segment of a highway facility in both directions for 1 year divided by the number of days in the year.

Apron. The mountable portion of the central island of a roundabout that is adjacent to the circulatory roadway. An apron is generally required on smaller roundabouts to accommodate the wheel tracking of large vehicles.

ASTM. American Society for Testing and Materials.

ATSSA. American Traffic Safety Services Association.

Attraction signing. Information/supplemental signs featuring logos or verbal messages pointing out places to visit or food, gas, and rest stop locations.

Barnes Dance timing. Type of exclusive signal timing phase where pedestrians may also cross diagonally in addition to crossing either street. Also referred to as scramble timing.



Brake reaction time. The interval between the instant that the driver recognizes the presence of an object or hazard on the roadway ahead and the instant that the driver actually applies the brakes.

Brightness. A term that refers to human perception of luminance. Whereas luminance is a photometrically measured quantity, brightness describes how intense a light source or lighted surface appears to the human eye.

Buttonhook ramp. J-shaped ramp that connects to a parallel or diagonal street or frontage road, which is often well removed from the interchange structure and other ramps.

Candela (cd). A measure of luminous intensity.

Central island. The raised area in the center of a roundabout around which traffic circulates.

Changeable message sign (CMS). Sometimes called portable changeable or variable message sign. This traffic control device has the flexibility to display a variety of messages to fit the needs of the traffic and highway situation.

Channelization. The separation or regulation of conflicting traffic movement into definite paths of travel by the use of pavement markings, raised islands, or other suitable means, to facilitate the safe and orderly movement of both vehicles and pedestrians.

Chevron signs. A chevron symbol (sideways “V”) in black, against standard yellow background, on a vertical rectangle. Used as an alternate or supplement to standard delineators and to large arrow signs.

CIE. Commission Internationale de l’Éclairage (International Commission on Street/ Highway Lighting).

Circulatory roadway. The curved path used by vehicles to travel in a counterclockwise fashion around the central island of a roundabout.

Circulatory roadway width. The width between the outer edge of the circulatory roadway and the central island, not including the width of any apron.



Cloverleaf interchange. A form of interchange that provides indirect right-turn movements in all four quadrants by means of loops. Generally used where the turning and weaving volumes are relatively low. This type of interchange eliminates all crossing conflicts found in a diamond interchange but requires more area. The cloverleaf type of interchange can have one or two points of entry and exit on each through roadway.

Coefficient of luminous intensity (RI). The ratio of the luminous intensity (I) of a retroreflectometer in the direction of observation to the illuminance E at the retroreflectometer on a plane perpendicular to the direction of the incident light, expressed in candelas per lux.

Coefficient of retroreflected luminance (RL). A measure of retroreflection most often used to describe the retroreflectivity of pavement markings. Coefficient of retroreflected luminance is defined as the coefficient of luminous intensity per unit area.

Coefficient of retroreflection (RA). A measure of retroreflection used more often to refer to the retroreflectivity of highway signs. Coefficient of retroreflection is defined as the ratio of the coefficient of luminous intensity (RI) of a plane retroreflecting surface to its area (A), expressed in candelas per lux per square meter.

Complete interchange lighting (CIL). Includes lighting in the interchange area on both the acceleration and deceleration areas plus the ramps through the terminus.

Composite photometry. Light measurement applied to a high-mast lighting system that employs a counterbeam arrangement, to take advantage of the efficiency with which pavement luminance can be increased with light directed upstream, while enhancing positive contrast through additivity of vehicle headlighting with the light directed downstream.

Concrete safety-shaped barrier (CSSB). A tapered concrete barrier used as a highway divider in narrow medians to prevent vehicle crossovers into oncoming traffic. It is referred to as a Jersey Barrier in some jurisdictions, as its first application was on the New Jersey Turnpike. CSSB's can be either permanent barriers or temporary portable barriers used in work zone applications.



Conspicuity. A measure of the likelihood that a driver will notice a certain target at a given distance against a certain background.

Contrast. See luminance contrast.

Contrast sensitivity. Ability to perceive a lightness or brightness difference between two areas. Frequently measured for a range of target patterns differing in value along some dimension such as pattern element size and portrayed graphically in a contrast sensitivity function in which the reciprocal of contrast threshold is plotted against pattern spatial frequency or against visual angle subtended at the eye by pattern elements (such as bars).

Critical gap. The gap (distance to nearest vehicle) in oncoming or cross traffic that a driver will accept to initiate a turning or crossing maneuver 50 percent of the time it is presented, typically measured in seconds.

Crossbuck. White X-shaped retroreflectorized highway-rail grade crossing sign with the words RAILROAD CROSSING in black lettering, located alongside the highway at the railroad tracks. At multiple track crossings a sign indicating the number of tracks will be on the post of the Crossbuck.

Cutoff. A luminaire light distribution is designed as cutoff when the candlepower per 1,000 lamp lumens does not numerically exceed 25 (2.5 percent) at an angle of 90 degrees above nadir (horizontal); and 100 (10 percent) at a vertical angle of 80 degrees above nadir. This applies to any lateral angle around the luminaire.

Dark adaptation. Adjustment of the eye to low levels of illumination, which results in increased sensitivity to light.

Decision sight distance (DSD). The distance required for a driver to detect an unexpected or otherwise difficult-to-perceive information source or hazard in a roadway environment that may be visually cluttered, recognize the hazard or its threat potential, select an appropriate speed and path, and initiate and complete the required safety maneuver safely and efficiently.



Deflection. The change in trajectory of a vehicle imposed by geometric features of the roadway.

Depth perception. The ability to distinguish the relative distance of objects in visual space, used to interpret their motion over multiple observations.

Diamond interchange. The simplest and perhaps most common type of interchange. This type of interchange contains a one-way diagonal-type ramp in one or more of the quadrants. The diamond interchange provides for all movements to and from the intersecting road.

Diverge steering (DS) zone. Used with interchange/ramp exit models, it is the distance upstream from the exit gore at which a driver begins to diverge from the freeway.

Divided attention. The ability of a driver to allocate attention among tasks or stimuli in the roadway environment, where more than one task or stimulus is perceived to be important to safe performance at a given time.

Divided highway. Roadway that is separated by a median.

Downstream. The direction toward which traffic is flowing.

Dynamic visual acuity. Acuteness or clarity of vision for an object that has angular movement relative to the observer. Acuity depends on sharpness of retinal focus, sensitivity of nervous elements, oculomotor coordination, interpretative faculty of the brain, and contextual variables.

Edgeline visibility. The detection/recognition of painted pavement surface delineation along roadway edges demarcating the outside edge of the travel lane.

Entry width. The width of the entry to a roundabout, where it meets the inscribed circle, measured perpendicularly from the right edge of the entry to the intersection point of the left edge line and the inscribed circle.



Exit gore area. The area located immediately between the left edge of a ramp pavement and the right edge of the mainline roadway pavement at a merge or diverge area.

Flared approach. The widening of an approach at a roundabout, resulting in multiple lanes at entry to provide additional capacity at the yield line and storage.

FARS. Fatal Analysis Reporting System.

FHWA. Federal Highway Administration.

Footcandle. The English system's unit of illuminance. One footcandle is the illuminance on a surface that is everywhere one foot from a uniform point source of light of one candle and equal to one lumen per square foot. One footcandle equals 10.76 lux.

Footlambert. A unit of luminance equivalent to 1 lumen per square foot.

Full diamond interchange. Interchange with a one-way diagonal-type ramp in each quadrant.

Gap acceptance. The decision by a driver that there is sufficient time and/or distance ahead of an approaching vehicle to allow safe performance of a desired crossing or merging maneuver.

Gap judgments. The judgment of a driver of the time and/or distance ahead of an approaching vehicle traveling in a lane that the driver wishes to turn across or merge into.

Gap search and acceptance (GSA) zone. Used with interchange/ramp entry models, it is the zone in which the driver searches, evaluates, and accepts or rejects the available lags or gaps in the traffic stream for execution of a merging maneuver.

Guard (guide) rail. Protective barrier along a roadway to prevent vehicles from leaving the roadway.

Half-diamond interchange. An interchange with a one-way diagonal-type ramp in two adjacent quadrants. This type of interchange is appropriate to situations in which traffic demand is predominantly in one direction.



High-mast lighting. Illumination of a large area by means of a cluster of 3 to 12 luminaires which are designed to be mounted in fixed orientation at the top of a high mast (generally 18 to 46+ m [80 to 150+ ft] or higher).

High-spatial-frequency stimulus. A visual target characterized by fine detail.

Highway-rail grade crossing. The general area where a highway and a railroad's right-of-way cross at the same level, including the railroad tracks, highway, and traffic control devices for highway traffic traversing the area.

Horizontal alignment. The linear (tangent) character or specific degree of curvature describing the geometry of a defined section of highway in plain view.

IHS. Insurance Institute for Highway Safety.

Illuminance. The density of luminous flux (rate of emission of luminous energy flow of a light source in all directions) incident on a surface; the quotient of the flux divided by the area of the surface, when the surface is uniformly illuminated.

Illumination. The amount of light falling onto a surface.

Initial acceleration (IA) zone. Used with interchange/ramp entry models, it is the zone in which the driver accelerates to reduce the speed differential between the ramp vehicle and the freeway vehicles to an acceptable level for completing the merge process.

Inscribed circle diameter. The basic parameter used to define the size of a roundabout, measured between the outer edges of the circulatory roadway. It is the diameter of the largest circle that can be inscribed within the outline of the intersection.

In-service brightness level (ISBL). The brightness level of a delineation treatment at an intermediate point in its anticipated service life; this value varies by type of delineator, type of wear (traffic level), and environmental conditions.



Interchange (grade separation). A system of interconnecting roadways that provides for the movement of traffic between two or more highways on different levels.

Intersecting angle (skew). The angle formed by the intersection of two roadways (other than a 90-degree angle).

Intersection (at grade). The general area where two or more highways join or cross without grade separation, including the roadway and roadside facilities for traffic movements within it.

Intersection sight distance (ISD). The unobstructed view of an entire (at-grade) intersection and sufficient lengths of the intersecting highway to permit control of the vehicle to avoid collisions during through and turning movements.

ISTEA. Intermodal Surface Transportation Efficiency Act.

TEH. Institute of Transportation Engineers.

Joint flexibility. An aspect of the physical condition of the driver that can be assessed to determine whether the driver has sufficient strength to turn the steering wheel, apply the brakes, and generally control the vehicle.

Lane control signals. Special overhead signals that permit or prohibit the use of specific lanes of a street or highway or that indicate the impending prohibition of their use.

Leading pedestrian interval (LPI). Also known as, “pedestrian head start,” and “delayed vehicle green,” an LPI allows pedestrians to begin crossing an intersection a few seconds before the vehicular green interval begins. This allows pedestrians to establish their presence in the crosswalk before the turning vehicles, thereby enhancing the pedestrian right of way.

Legibility index (LI). Used to describe the relative legibility of different letter styles, it is calculated from the distance at which a character, word, or message is legible divided by the size of the letters on the sign.



Limited sight distance. A restricted preview of the traveled way downstream due to a crest vertical curve or horizontal curvature of the roadway, or to blockage or obstruction by a natural or manmade roadway feature or by (an)other vehicle(s).

Luminaire. A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

Luminance. The luminous intensity or brightness of any surface in a given direction, per unit of projected area of the surface as viewed from that direction, independent of viewing distance. The SI unit is the candela per square meter.

Luminance contrast. The difference between the luminance of a target area and a surrounding background area, divided by the background luminance alone (e.g., lane marking minus lane pavement surface, divided by pavement surface.)

Lux. The metric unit of illuminance. One lux is equal to the illuminance corresponding to a luminous flux density of one lumen per square meter.

Measures of effectiveness (MOE's). Descriptions of driver or traffic behavior which quantify the level of safety or the quality of service provided by a facility or treatment to drivers, passengers, or pedestrians; examples include vehicle speed, trajectory, delay, and similar measures, especially crashes, plus indices of performance such as reaction time. In research studies, the MOE's are the dependent measures (e.g., the effects/behaviors resulting from introduction of a treatment or countermeasure).

Median barriers. A longitudinal system of physical barriers used to prevent an errant vehicle from crossing the portion of a divided highway separating traffic moving in opposite directions.

Merge steering control (MSC) zone. Used with interchange/ramp entry models, it is the zone in which the driver enters the freeway and positions the vehicle in the nearest lane on the mainline.



Minimum required visibility distance (MRVD). The distance necessary to permit detection and comprehension, plus driver decision-making, response selection, and completion of a vehicle maneuver, if necessary.

Mountable. Geometric features (e.g., curbs) that can be driven upon by vehicles without damage, but not intended to be in the normal path of traffic.

MUTCD. Manual on Uniform Traffic Control Devices for Streets and Highways.

NCHRP. National Cooperative Highway Research Program.

Nearside priority. Priority given to drivers entering the circle of a roundabout.

Negative offset. A term used to describe the alignment of opposing left-turn lanes at an intersection; this geometry exists when the left boundary of one left-turn lane, when extended across the intersection, falls to the right of the right-facing boundary of the opposite left-turn lane.

NHTSA. National Highway Traffic Safety Administration.

Non-cutoff. The luminaire light distribution category when there is no candlepower limitation in the zone above maximum candlepower.

No turn on red (NTOR). This message on signs is used to indicate that a right turn on red (or left turn on red for one-way streets) is not permitted at an intersection.

NTSB. National Transportation Safety Board.

Ocular media. The internal structure of the eye, including the aqueous, through which light entering through the cornea must be transmitted before reaching the photosensitive retina.

Ocular transmittance. The amount of light reaching the retina relative to the amount incident upon the cornea.



Offside priority. Priority given to traffic already in the circle of a roundabout.

Osteoarthritis. A degenerative form of arthritis.

Parclo loop ramp. A (partial cloverleaf) interchange with loops in advance of the minor road with direction of travel on the freeway; and in the same interchange area, an interchange with loops beyond the minor road.

Partial interchange lighting (PIL). Lighting on an interchange that consists of a few luminaires located in the general areas where entrance and exit ramps connect with the through traffic lanes of a freeway (between the entry gore and the end of the acceleration ramp or exit gore and the beginning of the deceleration ramp).

Passive crossing control devices. Non-activated traffic control devices, including signs, pavement markings, and other devices located at or in advance of crossings to indicate the presence of a crossing and the possibility of a train.

Peak intensity. The maximum strength of a traffic signal maintained through a defined viewing angle; measured in candelas.

Pedestrian control device. A special type of device (including pedestrian signal indications and sign panels) intended for the exclusive purpose of controlling pedestrian traffic in crosswalks.

Pedestrian crosswalk. An extension of a sidewalk across an intersection or across a roadway at a midblock location to accommodate pedestrian movement.

Pedestrian refuge. An at-grade opening within a median island that allows pedestrians to safely wait for an acceptable gap in traffic.

Perception-reaction time (PRT). The interval between a driver's detection of a target stimulus or event and the initiation of a vehicle control movement in response to the stimulus or event.



Positive offset. A term used to describe the alignment of opposing left-turn lanes at an intersection; this geometry exists when the left boundary of one left-turn lane, when extended across the intersection, falls to the left of the right-facing boundary of the opposite left-turn lane.

Post-mounted delineators (PMD's). Retroreflective devices located in a series at the side of a roadway to indicate alignment. Each delineator consists of a flat reflecting surface, typically a vertical rectangle, mounted on a supporting post.

Raised. Geometric features (e.g., curbs) with a sharp elevation change that are not intended to be driven upon by vehicles at any time.

Raised pavement markers (RPM's). Used as positioning guides and/or as supplements or substitutes for other types of markings, these markers conform to the color of the marking for which they serve as a positioning guide, can be mono- or bi-directional, and are fastened into the pavement with the reflector surface visible above the road surface.

Reaction time (RT). The time from the onset of a stimulus to the beginning of a driver's (or pedestrian's) response to the stimulus, by a simple movement of a limb or other body part.

Retroreflective. Capable of returning light to its source.

Rheumatoid arthritis. A usually chronic disease of unknown cause characterized by pain, stiffness, inflammation, swelling, and sometimes destruction of joints. Drivers with this condition sometimes require compensatory equipment for their vehicle. In acute conditions, individuals should not drive because of weakness and extreme tenderness in the joints of the wrists and hands.

Right turn on red (RTOR). Unless otherwise specified by traffic signal control signing, this practice permits a driver to proceed with a right turn on a red signal after stopping at signalized intersections. It provides increased capacity and operational efficiency at a low cost.



Roundabouts. Circular intersections with specific design and traffic control features that include yield control of entering traffic, channelized approaches, and appropriate geometric curvature to ensure that travel speeds on the circulating roadway are typically less than 50 km/h (30 mph).

Route marker reassurance assembly. Consists of a cardinal direction marker (i.e., east, west, north, and south) and a route marker.

Saccadic movement. A change in visual fixation from one point to another by means of a quick, abrupt movement of the eye.

Scissors off-ramp. A condition where one-way traffic streams cross by merging and diverging maneuvers onto exit ramps. Drivers tend to go straight ahead onto an off-ramp instead of turning left.

Selective attention. The ability, on an ongoing moment-to-moment basis while driving, to identify and allocate attention to the most relevant information, especially embedded when within a visually complex scene and in the presence of a number of distractors.

Senile miosis. An aging characteristic involving an excessive smallness or contraction of the pupil of the eye.

Short range delineation. Delineation that is useful to the driver for tracking the roadway at night under poor visibility conditions.

Sight distance. The length of highway visible to the driver.

Sight triangle. In plan view, the area defined by the point of intersection of two roadways, and by the driver's line of sight from the point of approach along one leg of the intersection, to the farthest unobstructed location on another leg of the intersection.

Situational awareness. The selective attention to and perception of environmental elements within a specified space and time envelope, the comprehension of their meaning, and the projection of their status in the near future.

Slip ramp. A diagonal ramp, more properly called a cross connection, which connects with a parallel frontage road.



Small target visibility (STV). A proposed criterion for roadway lighting. The concept assumes that increased target visibility results in both increased nighttime safety and improved nighttime driver performance, a surrogate for reduced crash risk.

Speed-change lane (SCL). Used in interchange/ramp exit models, it refers to the speed-change maneuver on deceleration lanes segmented components.

Splitter island. A raised or painted area on an approach to a roundabout used to separate entering from exiting traffic, deflect and slow entering traffic, and provide storage space for pedestrians crossing the road in two stages. It is also referred to as a median island or separator island.

Steering control (SC) zone. Used with interchange/ramp entry models, it is the zone where positioning of the vehicle along a path from the controlling ramp curvature onto the speed-change lane is accomplished.

Stereopsis. Binocular visual perception of three-dimensional space based on retinal disparity.

Stopping sight distance (SSD). The sight distance required to permit drivers to see an obstacle soon enough to stop for it under a defined set of reasonable worst-case conditions, without the performance of any avoidance maneuver or change in travel path; the calculation of SSD depends upon speed, gradient, road surface and tire conditions, and assumptions about the perception-reaction time of the driver.

Temporary pavement marking treatment. This treatment primarily involves the application of paint or tape striping and has been shown to be important for effective vehicle guidance at highway work sites.

Threshold contrast. The minimum difference in luminance of a target and luminance of that target's background at which the target is visible. Also defined as the luminance contrast detectable during some specific fraction of the times it is presented to an observer, usually 50 percent.



T-intersection. An intersection that involves three legs, where one leg is perpendicular to the other two legs. There are several types of this intersection, such as plain, with turning lanes, and channelized.

Traffic control device (TCD). The prime, and often the only, means of communicating with the driving public. These devices (e.g., signs, markings, signals, islands) must be used discriminately, uniformly, and effectively to ensure correct driver interpretation and response.

Transient adaptation factor. A reduction in target contrast caused by the process of transient visual adaptation.

Transient visual adaptation (TVA). The process in which the (driver's) eye fixates upon roadway locations or surrounding environments at different luminance levels, continuously adapting to higher and lower levels; this process temporarily reduces contrast sensitivity.

TRB. Transportation Research Board.

Trumpet interchange. A three-leg interchange where a connecting highway terminates and where only a small amount of traffic moves between the terminating highway and one of the two legs of the freeway. The trumpet is laid out so that this minor traffic moves via a 200-degree loop.

Two-quadrant cloverleaf interchange. A type of partial cloverleaf where most traffic leaving one highway turns to the same leg of the intersecting highway.

TWLT. Two-way, left-turn lane.

Two-way stop-control. Stop signs are present on the approaches of the minor street and drivers on the minor street (or a driver turning left from the major street) must wait for a gap in the major-street traffic to complete a maneuver.

Upstream. The direction from which traffic is flowing.



Useful field of view. Also known as the “functional field of view,” or “attentional window,” this area refers to a subset of the total field of view where stimuli can not only be detected, but can be recognized and understood sufficiently to permit a timely driver response. As such, this term represents an aspect of visual information processing, rather than a measure of visual sensitivity.

Variable message sign (VMS). See changeable message sign.

Veiling glare. Stray light entering the eye that reduces the contrast of a target upon which the driver has fixated; this may result from the driver’s direct view of light sources, such as opposing headlights or roadway luminaires, or from light reflected from surfaces near the target’s location.

Vertical curve. The parabolic curve connecting the two approach grades on either side of a hill.

Visual accommodation. The process by which the eye changes focus from one distance to another

Visual acuity. The ability of an observer to resolve fine pattern detail. Acuity is usually specified in terms of decimal acuity, defined as the reciprocal of the smallest resolvable pattern detail in minutes of arc of visual angle. “Normal” or average acuity is considered to be 1.0 (a resolution of 1-min arc).

Visual adaptation. The process by which the retina becomes accustomed to more or less light than it was exposed to during an immediately preceding period. It results in a change in the sensitivity of the eye to light.

Visual clear (VC) zone. Used with interchange/ramp entry models, this refers to the zone that provides a buffer between the driver and the end of the acceleration lane, where the driver can either merge onto the freeway in a forced maneuver or abort the merge and begin to decelerate at a reasonable rate.



Yield line. A pavement marking used to mark the point of entry from an approach into the circulatory roadway of a roundabout, and is generally marked along the inscribed circle. Entering vehicles must yield to any circulating traffic coming from the left before crossing this line into the circulating roadway.

Zebra crossing. A crossing marked by transverse white stripes where vehicles are required to yield to pedestrians.



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