Better Military Traffic Engineering

2016

SDDCTEA Pamphlet 55-17

Military Surface Deployment and Distribution Command
Transportation Engineering Agency

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BETTER MILITARY TRAFFIC ENGINEERING
SDDCTEA PAMPHLET 55-17

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This version of Pamphlet 55-17 is an update to the 2011 version of SDDCTEA Pamphlet 55-17. This pamphlet also combines content from and supersedes SDDCTEA Pamphlet 55-14, dated 2011. Therefore, previous versions of SDDCTEA Pamphlet 55-17 and all versions of SDDCTEA Pamphlet 55-14 are voided and obsolete with the release of this document.

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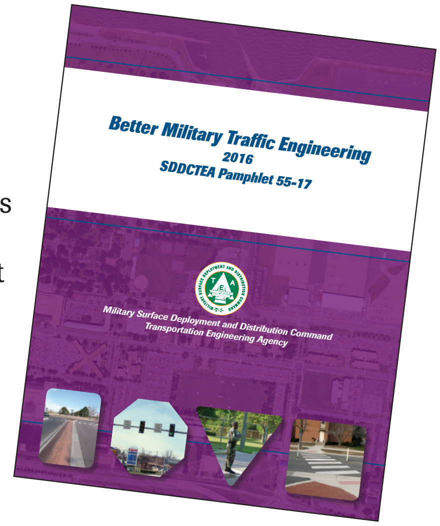
CHAPTER 1—INTRODUCTION

1.1. FORWARD

The *Better Military Traffic Engineering* pamphlet is intended for use by persons with responsibilities relating to traffic operations, roadway safety and/or roadway design. This pamphlet addresses traffic engineering principles, traffic operations, transportation planning, and traffic control (signing and striping) as they should be applied on military installations.



The text emphasizes general principles of traffic engineering. Case studies and problem-solving techniques are used to illustrate the practical application of these principles as they relate to the unique conditions that exist on military installations.

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By nature, traffic engineering is very complex and is built on the experience of others. Therefore, many of the standards in this text have been taken from other publications and are referenced within the text. In addition, the authors wish to acknowledge major contributions from publications of the following organizations: the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the Federal Highway Administration (FHWA).

1.2. WHO IS SDDCTEA?

The Military Surface Deployment and Distribution Command Transportation Engineering Agency, or SDDCTEA, executes the Department of Defense's (DoD) overall transportation engineering program on behalf of the military services.

SDDCTEA's mission is to improve highway safety and reduce traffic congestion on DoD installation roads and on routes providing access to installations. Our objectives are to save lives, decrease injuries, minimize lost time, and maintain readiness.

To achieve our mission and objectives, we focus our efforts into two key areas:

Training and Education—Includes the development of training and educational materials for distribution throughout the military. Materials include traffic engineering and highway safety bulletins, pamphlets, and software. The software includes the Better Military Traffic Engineering (BMTE) and the ACP/ECF SMART Decision Evaluator. These are discussed in Exhibit 1.1. It also includes hosting training seminars. This is an important part of training that leads to better project and master planning.

Engineering Services—Includes providing technical assistance and conducting traffic engineering studies in the areas of roadway planning, geometric design, road safety assessments, and traffic operations analysis.

1.2.1. Training and Education

As presented in Exhibit 1.1, SDDCTEA offers several forms of training and education.

Exhibit 1.1: SDDCTEA Training and Education

<table>
<tr><th>TRAINING AND EDUCATION PROGRAM</th><th>SUBJECT MATTER COVERED</th></tr>
<tr><td>

TRAFFIC ENGINEERING AND HIGHWAY SAFETY BULLETINS

Bulletins are published three to four times yearly and address a broad range of transportation and safety topics.

Bulletins are available online at: http://www.sddc.army.mil/sites/TEA/Functions/SpecialAssistant/TrafficEngineeringBranch/Pages/default.aspx

Sign up to receive bulletins at: http://www.sddc.army.mil/sites/TEA/Functions/SpecialAssistant/TrafficEngineeringBranch/Pages/default.aspx

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Sample bulletin topics include:

- ✓ *Access Management*
- ✓ *Pedestrian Safety*
- ✓ *Parking*
- ✓ *Gates Revisited*
- ✓ *Traffic Calming*
- ✓ *Safety Audits*
- ✓ *Speed Limits*
- ✓ *Traffic Signs*
- ✓ *Roadside Safety—A Forgiving Roadside*
- ✓ *Traffic Engineering For Better Gates*
- ✓ *Highway Safety Driver-Aid Treatments*
- ✓ *Safety Requirements of Active Vehicle Barriers*
- ✓ *Sign Retroreflectivity*
- ✓ *Intersection Control*

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PAMPHLETS

SDDCTEA has produced a variety of pamphlets and manuals on transportation issues. These materials provide specific, detailed engineering guidance on key issues.

Pamphlets and manuals are available online at: http://www.sddc.army.mil/sites/TEA/Functions/SpecialAssistant/TrafficEngineeringBranch/Pages/default.aspx

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- ✓ *SDDCTEA Pamphlet 55-8, Traffic Engineering Studies Reference*
- ✓ *SDDCTEA Pamphlet 55-15, Traffic and Safety Engineering for Better Entry Control Facilities*
- ✓ *SDDCTEA Pamphlet 55-17, Better Military* Traffic Engineering

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TRAFFIC ENGINEERING AND SAFETY (TES) SEMINARS

SDDCTEA TES Seminars are conducted three to four times a year at military installations within the continental United States (CONUS) and when possible at military installations outside CONUS (OCONUS).

The announcement flyer is available online at: http://www.sddc.army.mil/sites/TEA/Pages/default.aspx

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- ✓ *The purpose of these seminars is to provide guidance on traffic engineering and safety considerations along roadways, intersections, and at entry control facilities. Information is also provided on planning, design, and operations of entry control facilities, considering security, safety, and traffic requirements.*

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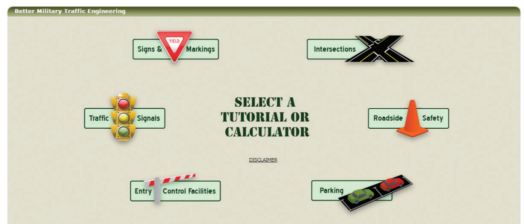
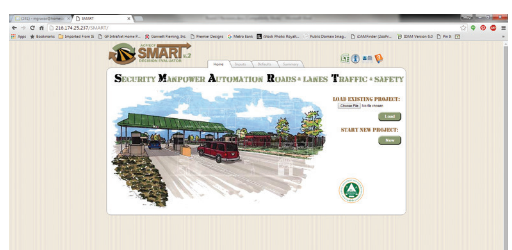
</table>

Exhibit 1.1: SDDCTEA Training and Education (Continued)

TRAINING AND EDUCATION PROGRAM	SUBJECT MATTER COVERED
TRAFFIC ENGINEERING TRAINING & CALCULATION SOFTWARE Originally released in 2002 as a CD ROM, SDDCTEA has developed an online version of the *Better Military Traffic Engineering* software to provide the military engineering community with state-of-the-art information regarding the proper use of traffic control and safety devices on military installations; and the proper design of parking areas, intersections, roadsides, and ECFs. There are two main tools: tutorials and calculators. The tutorials are an instructional tool to train installation personnel, and the calculators help with various commonly used traffic engineering calculations. Check it out on SDDC's webpage at: http://www.sddc.army.mil/sites/TEA/Functions/SpecialAssistant/TrafficEngineeringBranch/BMTE/Pages/default.aspx.	BMTE is divided into sections, each containing a different topic: ✓ *Signs & Markings* ✓ *Signals* ✓ *ECFs* ✓ *Parking* ✓ *Roadside Safety* ✓ *Intersections* *BMTE* also includes several traffic calculators for reference when planning a variety of traffic engineering projects. 
ENTRY CONTROL FACILITY SOFTWARE The purpose of the ACP/ECF SMART Decision Evaluator software is to help decide the best configuration for an ACP: to provide different scenarios that help to right-size the number of ID check lanes, with the optimal number of guards in order to minimize construction and operating costs, minimize risk, minimize environmental effects, obtain an acceptable maximum vehicle queue length, and obtain the greatest reasonable level of service in terms of overall delay to entering vehicles.	The ACP/ECF SMART Decision Evaluator software aims to assist ACP/ECF planners in assessing the impacts of their decisions by: ✓ Providing a comprehensive perspective of various ACP/ECF issues ✓ Providing the ramifications of different scenarios The ACP/ECF SMART Decision Evaluator software uses common engineering, security and economic principals and compares various metrics for different processing methods and ID check lanes. The purpose of the user guide is to outline and describe the capabilities and requirements of the ACP/ECF SMART Decision Evaluator software as well as the background calculations used. 

1.2.2. Engineering Services

KEY POINT

SDDCTEA offers on-site traffic engineering studies at no cost to the installations.

If your installation requires a study, SDDCTEA can assist by one of the methods shown in Exhibit 1.2. Our focus is to deliver a quality product to the installations in a timely manner. Study focus areas are identified in Exhibit 1.3.

SDDCTEA offers on-site engineering studies

SDDCTEA's services include the following:

Safety

- ✓ Crash Location Enhancement Studies (CrashLES)
- ✓ Fatal crash analysis
- ✓ Safety assessments
- ✓ Pedestrian studies
- ✓ Speed studies
- ✓ Traffic calming evaluations
- ✓ Sign retroreflectivity assessments
- ✓ Sign Management Studies

Transportation Engineering

- ✓ Traffic impact studies
- ✓ Signal warrant and operations evaluations
- ✓ Corridor evaluations
- ✓ Comprehensive transportation studies
- ✓ Roadway and intersection design/reviews
- ✓ Operational audit for traffic signal sustainability
- ✓ Parking Studies
- ✓ Desktop plan/study reviews

Force Protection and Installation Access

- ✓ Gate (ECF/ACP) studies and assessments
- ✓ Conceptual gate designs
- ✓ Access roads studies
- ✓ Active vehicle barrier location assessment and safety schemes

Exhibit 1.2: Delivery Methods for SDDCTEA Traffic Engineering Services

STUDY TYPE	DURATION
IN HOUSE These studies are of limited scope where the installation advises of their most pressing problem locations. Recommendations are provided to correct deficiencies, and generally include low-cost improvements that are within installation funding capabilities.	✓ The studies are typically performed in one week. ✓ A draft report containing recommendations is provided at the end of the week, along with an outbrief to installation personnel. ✓ A final report, incorporating comments from the outbrief meeting, is delivered in the weeks that follow.
COMPREHENSIVE **(USING CONTRACT SUPPORT)** Typically studies may address 10 or more intersections, as well as ECFs, access roadways, master planning issues, speed limits, pedestrian safety, and access management.	✓ The studies are typically performed over a several-month period. ✓ Following SDDCTEA's review and concurrence with the contents of the draft report, an outbrief meeting is held with installation personnel to report major deficiencies, address potential improvements, and solicit installation comments. ✓ Draft and final versions of a study report, with deficiencies and recommendations documented, are provided to installation personnel.
QUICK STUDIES **(USING CONTRACT SUPPORT)** These are studies of limited scope or with a quick duration that are performed with an existing task order between SDDCTEA and their engineer. These typically cover intersections, ECFs, safety, or pedestrian issues.	✓ The studies are typically performed over a several week period. ✓ Following SDDCTEA's review and concurrence with the contents in the report, a draft report is submitted to the installation. The report identifies major deficiencies and addresses potential improvements. The installation can provide review comments. ✓ A final version of the study report, with deficiencies and recommendations documented, is provided to installation personnel.

Exhibit 1.3: Study Focus Areas

STUDY TYPE	STUDY CHARACTERISTICS
ACCESS CONTROL POINT/ENTRY CONTROL FACILITY (ACP/ECF) STUDIES	This type of study identifies lane requirements for an ACP/ECF, and also focuses on safety (of the guards and the motorists) and efficiency of traffic flow. Additionally, the study provides conceptual drawings, to include roadway, passive barriers, proper placement of active vehicle barrier(s), suggested location of facilities, visitor control center sizing, commercial vehicle storage and preliminary cost estimates.
CRASH ANALYSIS	This is the study of a high crash or problem location. The analysis examines available crash data, roadway data, and traffic data to develop recommendations for improvements. These studies are generally considered confidential and would not be distributed without permission from the installation.
SAFETY ASSESSMENTS	Safety assessments involve a procedural approach to evaluating roadway safety for specific corridors. Safety assessments can focus on pedestrian accommodations, traffic signals, signing and pavement markings, drainage, and roadside hazards.
PEDESTRIAN STUDIES	Pedestrian studies involve the evaluation of pedestrian facilities and related activity including crosswalks, overpasses, sidewalks, pedestrian signing, school walking routes, and the proposed Public Rights-of-Way Accessibility Guidelines (PROWAG) requirements.
SPEED STUDIES	Speed studies usually involve the collection and assessment of speed data, stopping sight distances, assess points, crash history, roadway cross section, and pedestrian activities, for the purpose of establishing appropriate speed limits on installation roadways.
TRAFFIC CALMING EVALUATIONS	This study assesses the need for and appropriate application of the use of physical measures to address speeding and excess cut through traffic on neighborhood streets.
SIGN RETROREFLECTIVITY ASSESSMENTS	This type of study involves the inspection of installation signing to ensure that minimum retroreflectivity requirements are met for nighttime driving and to identify those signs that need replacement.
TRAFFIC IMPACT STUDIES	Traffic impact studies typically involve identifying impacts and roadway or intersection improvement needs resulting from development or an increase in population. The study involves estimating the number of additional trips to be generated by the proposed development and conducting capacity analyses to assess existing and future operations.

Exhibit 1.3: Study Focus Areas (Continued)

STUDY TYPE	STUDY CHARACTERISTICS
SIGNAL WARRANT AND OPERATIONS ANALYSES	This type of analysis involves conducting capacity analyses to identify operational conditions and comparing traffic volumes to the warrants set forth in the *Manual on Uniform Traffic Control Devices* (*MUTCD*) to determine if signalization should be considered. Operations analyses may include signal timing and phasing recommendations.
CORRIDOR EVALUATIONS	Corridor Evaluations involve the analysis of a group of intersections along a specific roadway corridor, and may include the identification of improvements to improve traffic flow and safety of the corridor.
ROADWAY AND INTERSECTION DESIGN REVIEWS	This service involves the review of design plans prepared by others to ensure consistency with national and local standards. This primarily involves a review of roadway geometry, but may also include a review of supporting data utilized in the design process.
PARKING EVALUATIONS	Parking Evaluations include identifying existing parking shortages, projecting future parking demand, and developing conceptual parking improvement schemes.
TRAFFIC SIGNAL INSPECTIONS & OPERATIONAL AUDITS	Traffic signal inspections include an inspection of traffic signal equipment (including mast arms, signal heads, controllers, loop detectors, etc.) to determine if improvements/updates are necessary. Operational audits include the analysis of parameters such as phasing, detectors, and timing to reduce motorist delay. Measures of Effectiveness reports can be provided to convey the savings in fuel, emissions, and driver delay.

1.3. SDDCTEA PAMPHLET 55-17

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This document was developed using reference sources such as: 2009 *MUTCD* with Revisions 1 and 2; 2011 *AASHTO Green Book*, 2015 DoD Supplement to the *MUTCD*, among others. Users of this pamphlet should be aware that as reference sources are updated, material referenced in the development of this pamphlet can become obsolete. Therefore, as this pamphlet is intended to be accurate based on reference material cited, it may become obsolete over time due to updates to referenced material.

SDDCTEA's DoD Supplement to the *MUTCD* is intended to provide DoD-specific traffic control requirements to include traffic conditions specific to DoD installations.

1.4. COMMON ACRONYMS

This pamphlet uses many different acronyms throughout the document. For ease of reference, Exhibit 1.4 summarizes commonly used acronyms.

Exhibit 1.4: Commonly Used Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ABA	Architectural Barriers Act
ACP	Access Control Point
ADT	Average Daily Traffic
AIE	Automated Installation Entry
AT	Antiterrorism
ATR	Automatic Traffic Recorder
AVB	Active Vehicle Barrier
AWDT	Average Work Day Traffic; i.e., the number of vehicles in a 24-hour period during a typical workday
BMTE	Better Military Traffic Engineering
CCTV	Closed Circuit Television
CrashLES	Crash Location Enhancement Study
CRI	Color Rendering Index
DMS	Dynamic Message Signs (also commonly referred to as VMS, Variable Message Signs)
DoD	Department of Defense
DOT	Department of Transportation
ECF	Entry Control Facility
FC	Foot-candle
FHWA	Federal Highway Administration
FPCON	Force Protection Condition
ft	Feet/Foot
HAR	Highway Advisory Radio
HCS	Highway Capacity Software
HID	High Intensity Discharge
HOV	High Occupancy Vehicle
IESNA	Illuminating Engineering Society of North America
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
LED	Light Emitting Diode
LOS	Level of Service

Exhibit 1.4: Commonly Used Acronyms (Continued)

mph	Miles per Hour
MUTCD	Manual on Uniform Traffic Control Devices
MVIS	Mobile Vehicle Inspection System
NCHRP	National Cooperative Highway Research Program
OCONUS	Outside Continental United States
POV	Privately Owned Vehicle*
PRT	Perception-Response Time (this is identical to the older “PIEV” term; i.e., perception, identification, emotion, and volition)
PROWAG	Public Rights-of-Way Accessibility Guidelines
PT	Physical Training
RPM	Raised Pavement Marker
RRPM	Retroreflective Raised Pavement Marker
RSA	Roadway Safety Assessment
SDDCTEA	Surface Deployment and Distribution Command Transportation Engineering Agency
SHSM	Standard Highway Signs and Markings Book
TMC	Turning Movement Count
TRB	Transportation Research Board
TTC	Temporary Traffic Control
UFC	Unified Facilities Criteria

**This pamphlet uses the term POV to refer to any non truck, commercial, or heavy vehicle, which may be government owned in addition to privately owned.*

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CHAPTER 2—BASEWIDE TRANSPORTATION PLANNING

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CHAPTER 2—BASEWIDE TRANSPORTATION PLANNING

Basewide planning involves evaluating the overall transportation-related needs of an installation considering future changes to population and land use. Frequently, changes to population and land use occur on bases, without consideration to the transportation needs. If long-term transportation needs are not considered, traffic problems will develop as missions increase, and more traffic is added to an already overburdened transportation system. Development should occur hand-in-hand with increases to the roadway network's capacity. This section will discuss how this can occur.

In addition to development, planning also includes accommodating overall areas of need that may or may not be the result of development.

2.1. CONGESTION MITIGATION

It is not uncommon for installations to experience large amounts of growth. To support existing and future demands, installations must not only identify capacity enhancements but also consider capacity management (or operations) and demand management strategies.

2.1.1. What is Congestion

Congestion is relatively easy to recognize—roads filled with cars, trucks, and buses; sidewalks filled with pedestrians. The definitions of the term congestion mention such words as "clog," "impede," and "excessive fullness."

In general, the cause of congestion is that the number of vehicles transporting travelers and goods exceeds the roadway capacity. The resulting effects are delays, increased travel time, increased costs, driver frustration, and unsafe driving practices.

There are four components of congestion:

Duration—This is the length of time during which congestion affects the travel system.

Extent—This is described by estimating the number of people or vehicles affected by congestion and by the geographic distribution of congestion.

Intensity—The severity of congestion that affects travel is a measure from an individual traveler's perspective. In concept, it is measured as the difference between the desired condition and the conditions being analyzed.

Variation—This key component describes the change in the other three elements. Recurring delay (the regular, daily delay that occurs due to high traffic volumes) is relatively stable. Delay that occurs due to incidents is more difficult to predict.

2.1.2. Causes of Congestion

As illustrated in Exhibit 2.1, congestion is the result of several root causes, often interacting with one another.

Congested Conditions

Exhibit 2.1: Causes of Congestion

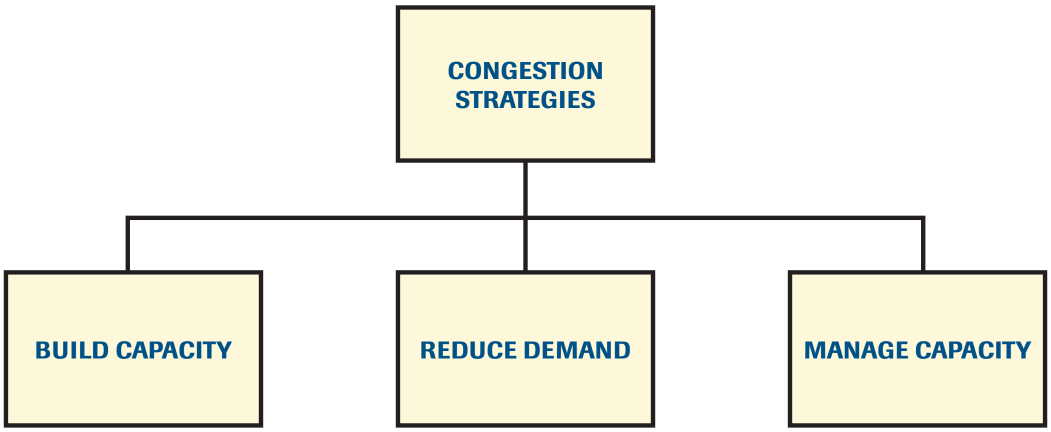
CAUSES OF CONGESTION	COMMON EXISTING CONDITIONS	COMMON FUTURE CONDITIONS WITHOUT IMPROVEMENTS
Physical Bottlenecks ("Capacity")– Capacity is the maximum amount of traffic capable of being handled by a given highway section. Capacity is determined by a number of factors: the number and width of lanes and shoulders; merge areas at interchanges; and roadway alignment (grades and curves).	✓ Bottlenecks occur at key intersections due to a lack of turning lanes	✓ Traffic impacts have been considered in new development areas; however, basewide needs are often not fully considered. ✓ ECFs are not widened to accommodate additional growth.

Exhibit 2.1: Causes of Congestion (Continued)

CAUSES OF CONGESTION	COMMON EXISTING CONDITIONS	COMMON FUTURE CONDITIONS WITHOUT IMPROVEMENTS
Traffic Incidents—Events that disrupt the normal flow of traffic, usually by physical impedance in the travel lanes. Events such as vehicular crashes, breakdowns, and debris in travel lanes are the most common form of incidents.	✓ Some crash history at key intersections and existing ECFs	✓ Crash rates generally increase without capacity and safety related improvements
Work Zones—Construction activities on the roadway that result in physical changes to the highway environment. These changes may include a reduction in the number or width of travel lanes, lane "shifts," lane diversions, reduction, or elimination of shoulders, and even temporary roadway closures.	✓ Delays on roadways in areas of work zones	✓ Additional delays expected due to construction activities.
Weather—Environmental conditions can lead to changes in driver behavior that affect traffic flow.	✓ Minor cause of congestion	✓ Minor cause of congestion
Traffic Control Devices—Intermittent disruption of traffic flow by control devices such as railroad grade crossings and poorly timed signals also contribute to congestion and travel time variability.	✓ Major cause of congestion can be due to traffic signals in poor operational condition ✓ Grade crossings across busy railroad tracks can be major causes of congestion	✓ Congestion increases with no improvements
Special Events—Are a special case of demand fluctuations whereby traffic flow in the vicinity of the event will be radically different from "typical" patterns. Special events occasionally cause "surges" in traffic demand that overwhelm the system.	✓ Major cause during special events and deployments	✓ Will continue to be a major cause without improvements
Lack of Access Management—When driveways and accesses are located too frequently and closely together, the unpredictable movement of traffic into and out of these access points can slow traffic and cause congestion.	✓ Many land uses along a corridor have their own driveways. They do not share one common larger access points.	✓ Congestion increases and continues to impact traffic on the major roadway

2.1.3. Congestion Mitigation Techniques

FHWA has also identified numerous mitigation techniques associated with each category. In reality, the most successful approach may be to implement a combination of appropriate strategies from all three categories.



Capacity Enhancements can include new roadways and roadway widening for additional vehicle lanes, but may also include minor geometric enhancements and the elimination of bottlenecks. Large-scale capacity enhancements are typically the last measures transportation professionals consider, because they are often the most expensive and can have adverse impacts, such as environmental and right-of-way impacts. Large-scale capacity enhancements can also have the effect of inducing additional travel, which may result in the roadway becoming congested again in the future. However, strategic capacity enhancements can alleviate existing congestion and may accommodate some future growth if properly considered.

Operational Improvements are geared toward improving the "supply side" of the transportation system. These efforts are intended to enhance the operation of the transportation system and make it as efficient as possible. Operational Improvements include things such as intersection upgrades, access management, reversible lanes, traffic signal improvements, and Intelligent Transportation Systems. Operations represent technologies and institutional arrangements that allow transportation systems to operate more closely to their maximum design intent.

Demand Management programs attempt to address congestion at the root of the problem by reducing the number of vehicles on the road. These initiatives work to modify driver behavior by encouraging people to make fewer single-occupancy trips, travel in off-peak hours when possible, and support land use policies that reduce the demand for automobile transportation.

2.1.4. U.S. Department of Transportation Congestion Initiative

In May 2006, the U.S. Department of Transportation (U.S. DOT) announced the National Strategy to Reduce Congestion of America's Transportation Network (otherwise known as the Congestion Initiative). This initiative is focused on making meaningful and near-term reductions in congestion. Because of this initiative, the Department set a goal that calls for reducing congestion, not just reducing the rate of growth of congestion.

Since then, the Department has worked to advance low-cost operational and technological improvements aimed at congestion reduction. It is encouraging and supporting state efforts to:

- ✓ Provide real-time traffic information to all users;
- ✓ Deploy incident management strategies such as the formation of roving response teams and quick clearance and "move it" laws;
- ✓ Improve traffic signal timing;
- ✓ Improve work zone safety and mobility; and
- ✓ Deploy quick fix operational and low-cost construction strategies to address congestion.[1]

2.2. PERFORMANCE BASED PLANNING

Performance based planning refers to the ability to measure traffic components (individually or combined) to determine how well the transportation network is functioning within the military installation. Identifying quantifiable performance measures that can be tracked over time can help to meet established operational goals and determine if and where improvements are necessary. A performance measure is a data element used to quantify a particular aspect of transportation service and used to describe its quality of service. Performance measures focus attention on the operating performance of the transportation system from both the agency and user perspective, and increase the awareness of maintenance and operation approaches within the planning process. Tracking specific performance measures can be beneficial in the evaluation of a variety of transportation system components including:

- ✓ Safety
- ✓ Infrastructure condition
- ✓ Congestion
- ✓ System reliability and efficiency
- ✓ Mobility
- ✓ Air quality

There are many performance measures related to transportation systems, i.e. roadway and bridge condition ratings; vehicle, pedestrian, and bicycle travel speed; number of crashes; travel time delay; Level of service; and transit passenger perception. Reliable traffic data is required to evaluate these measures. Traffic studies can provide the data for a specific performance measure needed to periodically assess the user quality of an intersection, gate access, or roadway segment within the installation.

1 *Traffic Bottlenecks: A Primer—Focus on Low Cost Operational Improvements, FHWA, 2008*

Conducting before and after traffic studies can help determine the effectiveness of an individual or system-wide improvement. Typically, performance is measured on a quarterly, annual or multi-year period depending on the specific type of system component. For example, traffic volume can be measured every year to show an annual trend line and help estimate future volumes. However, traffic crashes may be measured over multiple year periods to establish a baseline from which to determine improvement needs. Examples of performance measures that focus on system maintenance and operations include:

- ✓ Average hours of incident related delay
- ✓ Consistency of peak and off-peak travel times
- ✓ Meeting both short-term and long-term performance targets
- ✓ Transit on-time performance
- ✓ System user perspective
- ✓ link project priorities with funding availability

The goal of performance planning is to develop measures that will help installation planners to objectively evaluate the transportation network and develop a process for prioritizing transportation projects and improvements. Exhibit 2.2 provides example performance measures for evaluating various transportation system components:

Exhibit 2.2: Example Performance Measures

PERFORMANCE	PERFORMANCE MEASURE	OBJECTIVE
SAFETY	✓ Total Crashes ✓ Fatalities ✓ Injury Crashes ✓ Bike/Ped Crashes	✓ Reduce all types of crashes ✓ Improve signal timing and incorporate appropriate signs and pavement markings
INFRASTRUCTURE CONDITION	Roadways: International Roughness Index (IRI) Intersections: Travel time Delay Transit: ✓ On-time Performance ✓ Passenger Satisfaction ✓ Ridership	✓ Reduce high IRI levels ✓ Reduce Delay ✓ Improve on-time schedules, ✓ Improve satisfaction ✓ Increase commuter usage
CONGESTION	✓ Level of Service (LOS) ✓ Entrance/Exit Gate Delay	✓ Increase LOS ✓ Increase throughput
SYSTEM RELIABILITY, EFFICIENCY AND MOBILITY	Travel Time Delay	✓ Reduce delay
ENVIRONMENT	Air Quality	✓ Decrease traffic delay and congestion

Performance measures are referenced where appropriate within the various traffic analyses and studies throughout the pamphlets. Additional performance measures can be identified and incorporated providing the supporting data is measurable, reliable and quantifiable. Identifying performance targets for instance, decreasing delay by a particular percent, or decreasing crashes by a certain amount over a given time frame, can be useful to provide improvement objectives and to help maintain a consistent practice of measuring the installation's transportation system performance.

2.3. MILITARY BASE APPLICATION

In the civilian world, private developers often are required to provide additional roadway capacity when they build a development in order to accommodate the additional traffic that the development would generate. Developers are required to perform whatever improvements are necessary to the external roadway network such that the amount of delay per motorist does not worsen. Depending on the size of the development, improvements are often required far offsite, as far as at least a mile away to key intersections.

In the military world, it is very common to construct facilities that generate a large amount of traffic, and make no roadway improvements. Development may only consist of the building itself, and a parking lot outside of the building. The facility will then open, and the roadways accessing it will be over capacity with no plan for improvements. Entry control facilities will be over capacity if the development draws additional traffic through an ECF.

When development is in the planning stage, ensure that all appropriate personnel are involved in plan reviews. This includes the following:

- ✓ Master planners
- ✓ Traffic engineers
- ✓ Security forces
- ✓ Safety

Master planners should review plans for opportunities to upgrade roadways when projects occur. If a project occurs on a roadway corridor on which long-term plans exist to widen to provide more lanes, the project in the area of the building could include widening a portion of this roadway. On a smaller scale, if plans exist to upgrade sidewalks throughout the base, a project could include upgrading sidewalks in the area of the development.

Traffic engineers should review plans to ensure that projects incorporate improvements to handle additional traffic. This could include:

- ✓ Turn lanes at access points
- ✓ Traffic signal retiming and upgrades
- ✓ Additional traffic signals at nearby intersections
- ✓ Additional turn lanes at nearby intersections
- ✓ Additional roadways to link development to roadway networks
- ✓ Impacts to ECFs

Security forces should work with traffic engineers to ensure that additional traffic to ECFs is accommodated. This includes short-term manning at ECFs, and long-term improvements to ECFs.

It is important that traffic impacts be considered when adding development to an installation. When reviewing a plan for development, a reviewer should think of the different aspects, as discussed in Exhibit 2.3.

Exhibit 2.3: Roadway Development Considerations

✓ Turn lanes at access points	• Are there left-turn lanes into the driveways so as to not delay through traffic? • Are right-turn lanes needed? • Are separate turning lanes exiting the development needed?
✓ Traffic signal retiming and upgrades	• Are nearby traffic signals going to see a change in traffic volumes, requiring retiming? • Are nearby traffic signals in need of upgrades to detection, operations, phasing, and equipment? • Is existing traffic signal equipment sufficient to accommodate roadway widening? • Does existing traffic signal equipment need pedestrian accommodations?
✓ Additional traffic signals at nearby intersections	• Do any nearby intersections have deficient levels of service, existing or with projected traffic added to the intersection? • Are there any nearby unsignalized intersections that will warrant signalization with new development? • Are traffic signals the most appropriate form of traffic control, or would roundabouts be better?
✓ Additional turn lanes at nearby intersections	• Will intersections away from the development get additional turning traffic; thereby requiring turn lanes? • Will existing turn lanes need to be lengthened?
✓ Additional roadways to link development to roadway networks	• Are multiple driveways needed to alleviate traffic to and from the development? • Even if there is a driveway to an existing roadway, is there another roadway nearby that a second access can be built to, such that the traffic can be split over multiple existing roadways?
✓ Impacts to ECFs	• Are any ECFs currently under capacity? • Are all ECFs nearby adequately-sized to accommodate development-related traffic? • Are processing techniques appropriate for long-term conditions?

2.4. AREAS OF NEED

Accommodating overall areas of need is critical for acceptable traffic operations on an installation. This can include several different aspects at a master planning level. For the most part, it includes mitigation of existing traffic problems, or planning for upgrades to the transportation system hand-in-hand with upgrades to land use. In addition to vehicular traffic, consider accommodating alternate modes. When reviewing installation-wide areas of need, consider some of the following questions:

- ✓ Are there any missing roadway links that should be provided to make a continuous corridor?
- ✓ Is there a better location for an entry control facility?
- ✓ Do roadways have sidewalks if pedestrian demand is expected?
- ✓ Is there room for adding jogging trails for PT to avoid using roads for PT?
- ✓ Are bike trails provided?
- ✓ Are commissaries and exchanges located close enough to employment centers to allow workers to walk to lunch?
- ✓ Is there an opportunity to make a loop-style roadway around the busier areas of a cantonment area to keep traffic in the periphery to allow for more pedestrian-friendly areas within major employment centers?
- ✓ Is development located such that access points will not impact nearby intersections?

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CHAPTER 3—TRAFFIC ENGINEERING STUDIES

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CHAPTER 3—TRAFFIC ENGINEERING STUDIES

The first step in transportation planning is to clearly identify traffic problems of the area being studied. The term "traffic problem" is defined as any situation that impairs the safe and efficient flow of traffic.

In the identification of traffic problems, relativity must be considered. Traffic problems vary across different areas of the country. For example, a five-minute delay in New York City is considered negligible, while the same delay in a remote area would be extremely frustrating to motorists. Therefore, remember that traffic problems are relative to the location being studied.

3.1. PROBLEM IDENTIFICATION

KEY POINT

Traffic engineering studies are the basis for formulating solutions to traffic problem areas.

On a one-mile free-flowing roadway with a 30-mph speed limit, three stops of 30 seconds each will result in an increase of about 90 percent in total running costs of the car. The value of a motorist's time is far more difficult to measure. However, evidence shows that, given a choice, motorists will forfeit operating economy to save time.

There are two major sources of traffic-related problems on roadway networks: congestion and crashes. Congestion wastes motorists' time and money. Crashes result in property damage, injuries, and fatalities.

Congestion

Motorists mainly dislike traffic congestion because of wasted time and the resulting increased vehicle operating costs. Excessive operating costs can be measured with a fair degree of precision.

Crashes

Crashes can have the most severe consequences of all traffic problems. Nationally, in 2014, there were 32,675 traffic related fatalities. Of these, 17,791 fatalities were a result of road departure; 9,967 fatalities were alcohol-related; and 4,884 were pedestrians. Even though alcohol-related crashes may not necessarily be directly related to the roadway itself, the number of fatalities not related to alcohol indicate that there are opportunities for improvement to our roadway system.

Several means are available for identifying safety and operational problems on military bases. Crash analyses, roadway or intersection capacity studies, and field observation can be used in this identification process.

Crashes should be studied in an attempt to reduce the crash rate on an installation. The basic procedures in a crash study are: collection of crash data, identification of high crash locations, analysis of available data, and improvement identification. Information gained from the crash history may be used to identify necessary improvements to help mitigate future crashes. Crashes may be prevented by application of traffic control devices, law enforcement, driver education, and safety-oriented traffic engineering.

Crash reports should be collected and summarized in an orderly fashion. They are usually filed at the installation security or safety offices.

The following data should be included in the crash report:

- ✓ Location
- ✓ Day of the week, time of day, and weather conditions
- ✓ Severity
- ✓ Types of vehicles
- ✓ Collision paths of vehicles
- ✓ Probable cause

Stakeholder involvement is very beneficial when studying crashes. Military police who investigate crashes have an awareness of individual crashes and the problems at locations throughout the base. Installation safety personnel can help identify safety-related concerns at crash locations. DPW personnel can inform of recent and planned engineering improvements, as well as constraints in the area that may hinder improvement opportunities. Outside expertise can be beneficial to provide a fresh set of eyes on a problem area.

Refer to SDDCTEA Pamphlet 55-08 for procedures on identifying high crash locations and additional information regarding crash studies. Once high crash locations are identified, the reasons why the location is crash prone must be determined. These reasons must be thoroughly evaluated to determine if any of the reasons are related to design features or related to traffic control. The procedure to perform this evaluation is identified below.

- ✓ Assemble crash reports for the location under study. Typically, the most current five-year period is used; however, a one-year period is acceptable if that is the only data available.
- ✓ Prepare a crash diagram, showing patterns or similarities in crashes. Each crash is plotted to show direction of approach; type, severity, date, and time of crash; and weather conditions at the time of the crash.
- ✓ Prepare a condition diagram, which is a scale drawing of the location showing all physical conditions that may influence driver behavior. The drawing should show all features such as curbs, driveways, markings, traffic control devices, and so forth.
- ✓ Assemble necessary data related to traffic volumes, approach speeds, intersection delay, parking conditions, and traffic control devices.
- ✓ Analyze problem to define primary and secondary contributing factors.

Once contributory factors are identified, a safety assessment can be performed for the intersection or roadway corridor. A safety assessment is a procedural approach to evaluating roadway safety. Roadway corridors are reviewed with the focus on the following:

- ✓ Pedestrian accommodations
- ✓ Signing and pavement markings
- ✓ Drainage
- ✓ Roadside hazards
- ✓ Geometric deficiencies
- ✓ Adequate sight distance

The following photos show a location before and after a safety assessment was performed. The recommendations focused on signing and pavement marking changes, which resulted in more logical traffic flow patterns.

Safety assessments focus on improving roadway safety, often through low-cost improvements

3.2. TRAFFIC DATA COLLECTION

KEY POINT

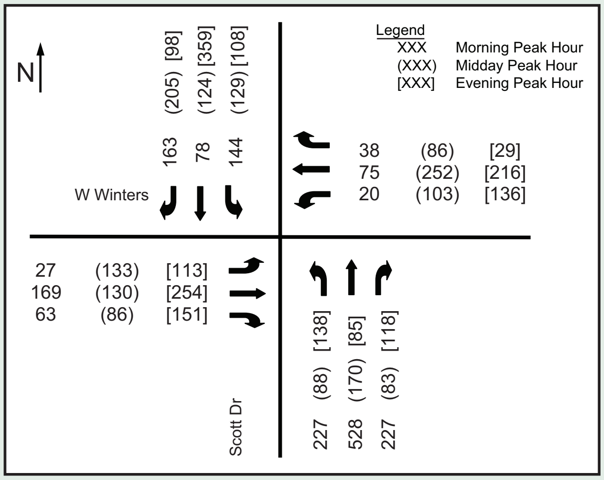
Traffic volume information is crucial to developing traffic-related improvements.

Typical turning movement counter

Intersection turning movement counts (TMC) are taken to obtain data on the movement of vehicles through an intersection or along a roadway. All approaching vehicles that travel through an intersection are recorded in 15-minute increments according to their movements—either left-turn, straight, or right-turn. Electronic count boards are commonly used but, in the absence of equipment, people can manually tally vehicles. Typically, TMCs are performed in the morning peak period (0600-0900), midday peak period (1100-1300), and afternoon peak period (1500-1800). When more targeted time periods are known based on installation-specific information, the counting time periods can be reduced.

If the data is being summarized manually, convert it into a usable form. To obtain a peak hour volume, for each peak period studied, add all turning movement count volumes within each 15-minute interval. The four highest consecutive 15-minute interval totals represent the peak hour volume. Add the four

TYPICAL TURNING MOVEMENT COUNT SUMMARY



15-minute interval counts for each individual movement within the peak hour. These movements represent the peak hour turning movement volumes for the intersection. When peak hour turning movements are obtained for each peak period, the movements can be summarized on a turning-movement diagram, as shown to the left.

More commonly, though, software is used in lieu of manually creating turning movement diagrams.

The diagram can also show pedestrian, bicycle, or other classification data as necessary.

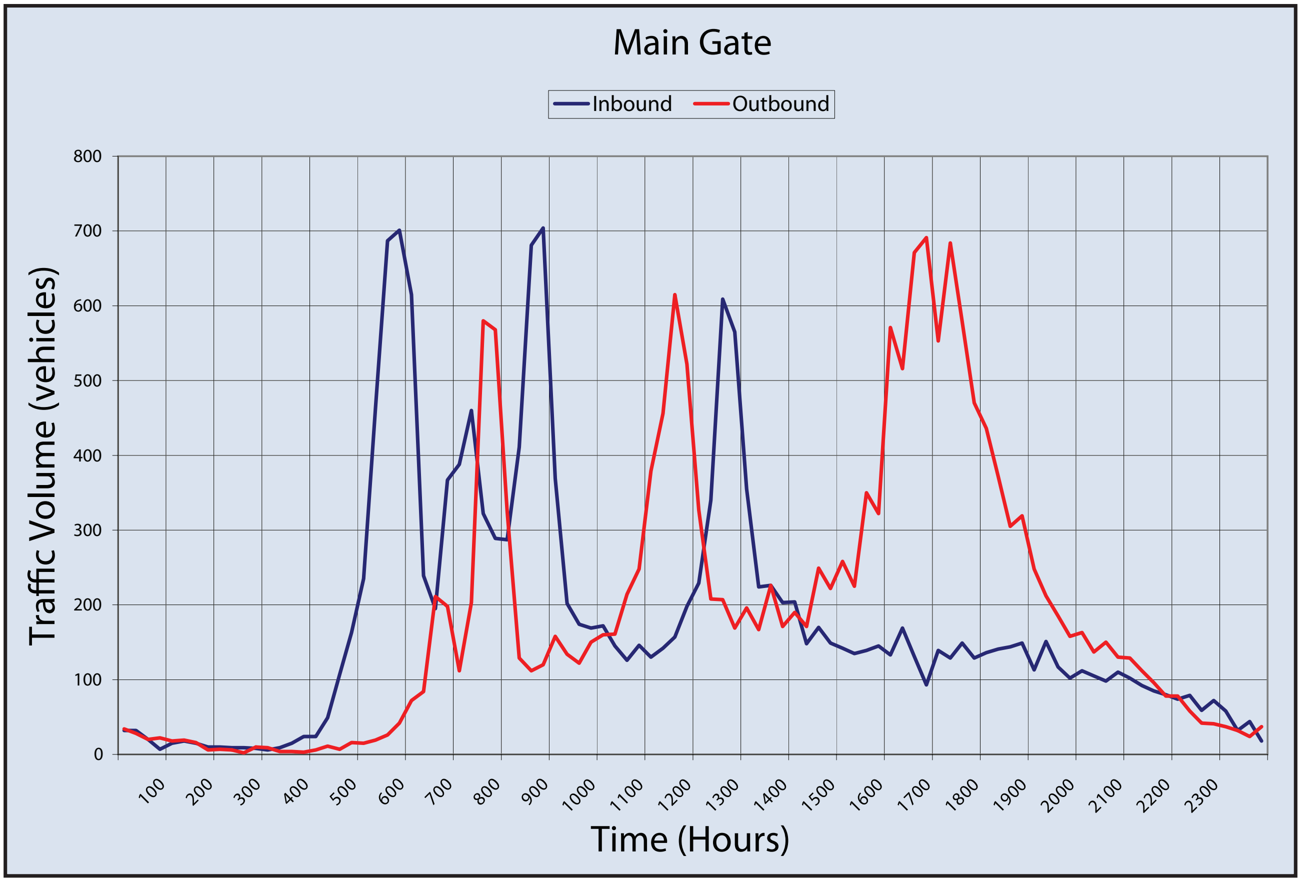
Automatic traffic recorders (ATR) are commonly used to obtain 24-hour count data. Common ATRs include tubes across the road or in-lane card counters. The total volume from a 24-hour count is commonly referred to as the average daily traffic (ADT).

Many ATRs provide other useful information such as speed and vehicle classification data. Speed data is valuable in identifying the appropriate speed limit of a roadway. Vehicle classification data is necessary for determining pavement design, and identifying routes that trucks may prefer to use.

Tube-style ATR

In-lane card counter

Traffic volume profiles from 24-hour ATR data help identify peak time periods, as is visible on the example profile shown on the following page. This data can be useful in several different types of applications, such as determining appropriate hours for separate traffic signal timing plans and ECF operations. See *SDDCTEA Pamphlet 55-8* for more information on traffic data collection.



Example 24-hour traffic volume profile

3.3. ANALYSIS AND LEVELS OF SERVICE

Level of service (LOS) is a measure of intersection performance based on the amount of delay through an intersection or roadway corridor. Levels of service are calculated using peak hour traffic volumes for the morning, midday, and evening peak hours from an average day. Methodologies for calculating LOS are provided in the *Highway Capacity Manual*. Software, such as *Synchro* and *Highway Capacity Software (HCS)*, is available to calculate levels of service. An example of a road network analyzed in Synchro and the output for one of the intersections in the network is shown on the following page.

There are six LOS classifications, "A" through "F." "A" represents the best; "F" represents the worst. LOS "A" and "B" are considered to be good. LOS "C" and "D" are considered to be acceptable. LOS "E" and "F" are considered to be unacceptable. LOS is summarized in Exhibit 3.1. When designing a new intersection or improving an existing intersection, designing for a LOS C or better is often desirable for future traffic volumes; but LOS D is acceptable.

Typically, at conventional intersections, deficient LOS can be improved by adding turning lanes or by improving traffic signal phasing and timing. Typically intersections along a corridor govern operations and LOS. When this is not the case, and if a roadway corridor has deficient LOS, it may need additional through lanes to attain an acceptable LOS.

NOTE: Synchro Studio 9 (including the Synchro, SimTraffic, and 3D Viewer applications) has an Army Certificate of Networthiness (CON). The CON ID is 17333 and currently expires on 9/2/2017.

Timings
27: 761st Tank Battalion Ave & Hood Rd

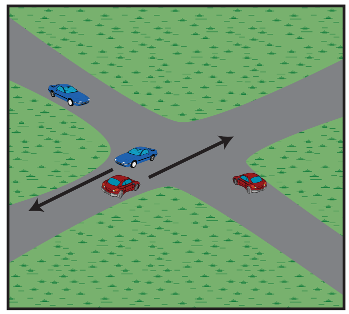
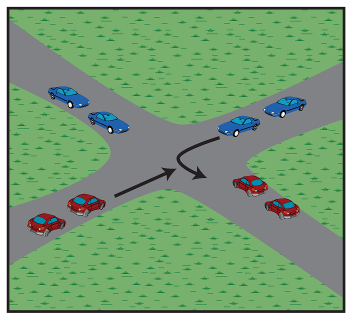
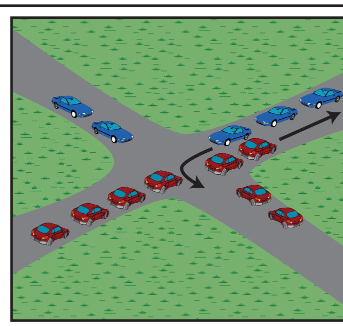
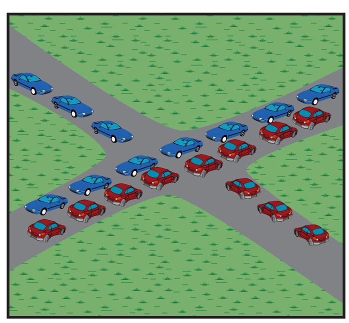
Lane Group	EBL	EBT	EBR	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations									
Volume (vph)	192	129	88	121	106	97	911	122	882
Turn Type	pm+pt		Perm	pm+pt		pm+pt		pm+pt	
Protected Phases	3	8		7	4	1	6	5	2
Permitted Phases	8		8	4		6		2	
Detector Phase	3	8	8	7	4	1	6	5	2
Switch Phase									
Minimum Initial (s)	7.0	10.0	10.0	7.0	10.0	7.0	10.0	7.0	10.0
Minimum Split (s)	13.5	22.5	22.5	13.5	22.5	13.5	22.5	13.5	22.5
Total Split (s)	14.0	22.8	22.8	13.8	22.6	13.6	39.8	13.6	39.8
Total Split (%)	15.6%	25.3%	25.3%	15.3%	25.1%	15.1%	44.2%	15.1%	44.2%
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Lost Time Adjust (s)	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Lead/Lag	Lead	Lag	Lag	Lead	Lag	Lead	Lag	Lead	Lag
Lead-Lag Optimize?									
Recall Mode	None	None	None	None	None	None	Min	None	Min
Act Effct Green (s)	25.2	15.2	15.2	24.8	15.0	44.6	35.0	45.4	37.9
Actuated g/C Ratio	0.29	0.18	0.18	0.29	0.18	0.52	0.41	0.53	0.44
v/c Ratio	0.79	0.35	0.42	0.53	0.57	0.38	0.84	0.59	0.81
Control Delay	43.1	32.7	8.2	27.3	19.0	13.9	29.5	23.6	27.2
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	43.1	32.7	8.2	27.3	19.0	13.9	29.5	23.6	27.2
LOS	D	C	A	C	B	B	C	C	C
Approach Delay		29.8			21.8		28.3		26.8
Approach LOS		C			C		C		C

Splits and Phases: 27: 761st Tank Battalion Ave & Hood Rd

Image provided courtesy of Trafficware

Example of Synchro Network

Exhibit 3.1: Level of Service Definitions

<table>
<tr><th rowspan="2">LOS</th><th colspan="3">INTERSECTIONS</th></tr>
<tr><th>SIGNALIZED</th><th></th><th>UNSIGNALIZED</th></tr>
<tr><td>A</td><td>✓ Very low delay, average less than 10.0 seconds per vehicle (spv)
✓ Most vehicles arrive during green phase
✓ Most vehicles do not need to stop</td><td rowspan="2"></td><td>✓ Average delays less than 10.0 spv
✓ Little or no delay to minor street traffic</td></tr>
<tr><td>B</td><td>✓ Average delay in the range of 10.1-20.0 spv
✓ More vehicles stop than LOS A</td><td>✓ Average delay in the range of 10.1-15.0 spv
✓ Short traffic delays to minor street traffic</td></tr>
<tr><td>C</td><td>✓ Average delay in the range of 20.1-35.0 spv
✓ Number of vehicles stopping is significant
✓ Cycle failures may begin to appear</td><td></td><td>✓ Average delay in the range of 15.1-25.0 spv
✓ Average traffic delays to minor street traffic</td></tr>
<tr><td>D</td><td>✓ Average delay in the range of 35.1-55.0 spv
✓ Congestion more noticeable
✓ Many vehicles stop
✓ Cycle failures noticeable</td><td></td><td>✓ Average delay in the range of 25.1-35.0 spv
✓ Long traffic delays to minor street traffic</td></tr>
<tr><td>E</td><td>✓ Average delay in the range of 55.1-80.0 spv
✓ Cycle failures frequent</td><td rowspan="2"></td><td>✓ Average delay in the range of 35.1-50.0 spv
✓ Very long delays to minor street traffic</td></tr>
<tr><td>F</td><td>✓ Average delay in excess of 80.0 spv
✓ Delay unacceptable to most drivers
✓ Many cycle failures</td><td>✓ Average delay in excess of 50.0 spv
✓ Extreme delays with queuing
✓ Congestion affects other intersections
✓ Warrants improvement to intersection</td></tr>
</table>

3.4. APPLICATION

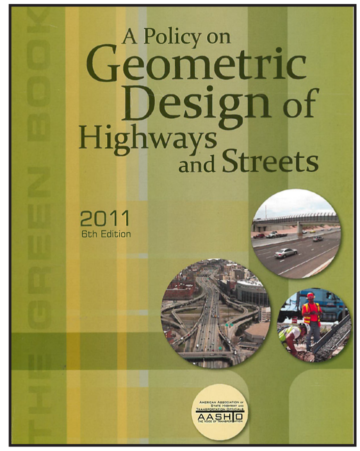
Traffic volume data is used with other types of data to support all traffic-improvement decisions. Volumes are typically used to:

- ✓ Justify installation (or removal) of a traffic signal by comparing with traffic signal warrants.
- ✓ Determine appropriate traffic signal timing and phasing.
- ✓ Indicate the need for traffic control signs according to the requirements stated in the *MUTCD*.
- ✓ Evaluate crash data and study the relationship of turning movements with crashes and congestion.
- ✓ Compare day and night traffic volumes with their associated crash rates to determine the need for street lighting.
- ✓ Assist in the development of a street-classification system such as arterial, collector, and local streets.
- ✓ Evaluate the need for intersection or roadway corridor improvements.
- ✓ Indicate long-term growth trends for vehicle usage and for traffic volumes in general.
- ✓ Assist in establishing construction and maintenance priorities.
- ✓ Assist in establishing road pavement markings and in determining the required frequency for repainting traffic-worn lines.
- ✓ Assist in analyzing parking demands and in assessing the impact of new traffic generators on the surrounding streets.

CHAPTER 4—GEOMETRIC DESIGN BASICS

CHAPTER 4—GEOMETRIC DESIGN BASICS

Roadway features such as design speed, roadway classification, design vehicle, land use, and traffic volumes are considered in determining the design criteria for a project. Design criteria can be divided into three categories: cross section, horizontal alignment, and vertical alignment. Additional areas of concern are intersection design, pavement design, and drainage design.



The primary "how-to" book on geometric design published by *AASHTO*, is titled *A Policy on Geometric Design of Highways and Streets*, commonly called the *Green Book*. The *Green Book* has design criteria on all areas of roadway and highway design. In addition to design criteria in the *Green Book*, several state departments of transportation have also developed state-specific guidelines. There may be cases where state criteria exceeds *AASHTO*; therefore, it is important to verify state criteria when developing a design.

4.1. ROADWAY FEATURES

Several factors such as design speed, roadway classification, and design vehicle, influence the geometric design of a roadway. Also, the availability of land and traffic volume may impact design. This section provides basic guidance on general design features.

Design criteria provide a measure of consistency and quality when used by different engineers. Design criteria can be classified into three areas: cross section features; horizontal alignment; and vertical alignment and clearances. Many design guidelines document minimum design criteria. Whenever possible, minimum design criteria should be exceeded in order to promote safe operations and to enhance roadway operations.

4.1.1. Design Speed

> **KEY POINT**
>
> Design speed is used to determine the various geometric features of a roadway.

Design speed is used to determine the various geometric features of a roadway. The design speed should be a logical speed considering the anticipated operating speed, adjacent land use, and functional classification of the roadway. *AASHTO* defines the design speed as the maximum safe speed that can be maintained over a specified section of roadway when conditions are so favorable that the design features of the roadway govern.

The selection of design speed should be based on the *AASHTO* definition of design speed. In no case should the posted speed limit exceed the design speed. In general, a good rule-of-thumb is to set the posted speed limit five miles per hour below the design speed.

4.1.2. Roadway Classification

Roadways can be classified in one of four categories: principal arterial, minor arterial, collector, and local, as shown in Exhibit 4.1.

Exhibit 4.1: Roadway Classifications

CLASSIFICATION		FEATURES	USAGE
PRINCIPAL ARTERIAL (INTERSTATES, FREEWAYS, AND EXPRESSWAYS)		✓ Controlled access by interchanges or other grade-separated facilities ✓ No cross traffic movements provided ✓ Wide or barrier medians provided ✓ Wide shoulders and long acceleration and deceleration lanes	✓ High traffic volumes ✓ Speeds above 55 miles per hour (mph) ✓ Connect urban areas ✓ Provide efficient movement between points of origin
MINOR ARTERIAL		✓ At-grade intersections (mostly signalized) ✓ Limited access points ✓ Driveway spacing at large intervals ✓ Cross traffic movement discouraged ✓ Shoulders or curb and gutter provided	✓ High traffic volumes ✓ Speeds of 35-55 mph ✓ Provides connection to major points within an area ✓ Provides connection to controlled access
COLLECTOR		✓ At-grade intersections (mix between signalized and unsignalized intersections) ✓ Access points spaced at smaller intervals ✓ Cross traffic frequent ✓ Small shoulder or curb and gutter provided	✓ Lower traffic volumes than arterials or controlled access ✓ Speeds of 25-40 mph ✓ Connect local facilities ✓ Access abutting land uses ✓ Contribute to arterial volumes
LOCAL		✓ Narrow lanes that are sometimes unstriped ✓ At-grade intersections (mostly unsignalized) ✓ Access points spaced at irregular intervals ✓ Mostly curb and gutter provided	✓ Low traffic volumes ✓ Speeds of 25 mph ✓ Access specific land uses or developments

Source: ITE, Traffic Engineering Handbook

4.1.3. Design Vehicle

KEY POINT

The design vehicle is defined as the largest vehicle likely to use the facility with considerable frequency.

The design team must determine what design vehicle is appropriate for designing a roadway with respect to the expected roadway users. Design vehicles have critical dimensions and operating conditions such that they influence or control the design of one or more roadway elements. The design vehicle is the largest vehicle likely to use the facility with considerable frequency. The design vehicle is used to establish critical geometric features such as turning radii, lane widths, and vertical clearances.

Typically, a design vehicle WB-67 should be used in areas that accommodate trucks. A single unit truck (SU) or a bus (school, transit, or other) may be the appropriate design vehicle at locations where trucks are not permitted.

Vehicle turning templates are shown in the *AASHTO Green Book*. Many states also have turning templates that can be used for design. Larger design vehicles have larger turning radius requirements. Turning templates are used to evaluate the turning path of a vehicle as it completes a turn. Examples of turns include roadway sections through curves (for lane widening), for designing radius returns at intersections, for designing intersection geometrics (such as median noses) and for stop line placement at intersections.

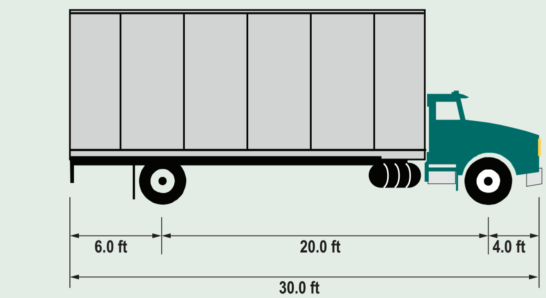
When using design vehicle turning templates or software programs, it is generally considered unacceptable for vehicles to significantly overtrack into adjacent lanes. Minor encroachment could occur if necessary, but should be avoided. If a vehicle larger than the design vehicle encroaches into an adjacent lane, it is acceptable especially when traffic volumes are lower because the frequency will be less. At intersections or roadways with tight curves, the design vehicle should remain in its lane.

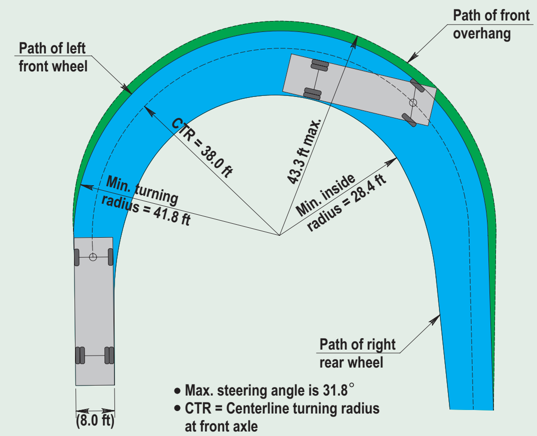
Encroachment into the adjacent lane may result in a sideswipe crash. Generally, encroachment can be minimized by widening the lane. Recommended lane widths for sharper curves are summarized in the *AASHTO Green Book*, Table 3-26b. For example, with curve radii less than 200 feet, and larger design vehicles, the lane width may exceed 20 feet.

Examples of AASHTO design vehicles, along with their accompanying turning template, are shown in the following figure.

DESIGN VEHICLE EXAMPLES FROM *AASHTO GREEN BOOK*

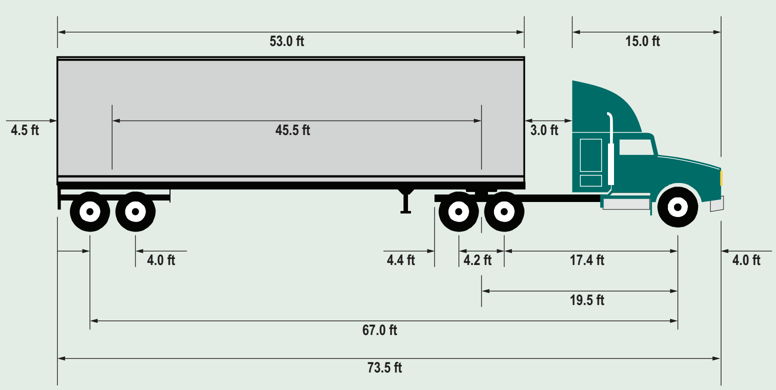
SINGLE-UNIT TRUCK (SU-30)

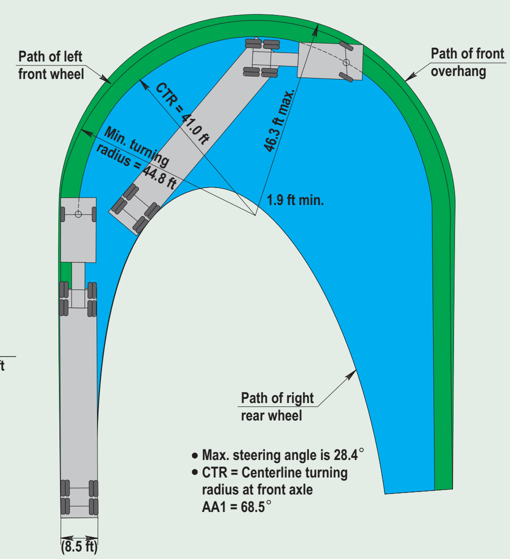




AASHTO Exhibit 2-2 Minimum Turning Path for Single-Unit Truck (SU-30)
Design Vehicle from AASHTO Green Book

INTERSTATE SEMITRAILER (WB-67)



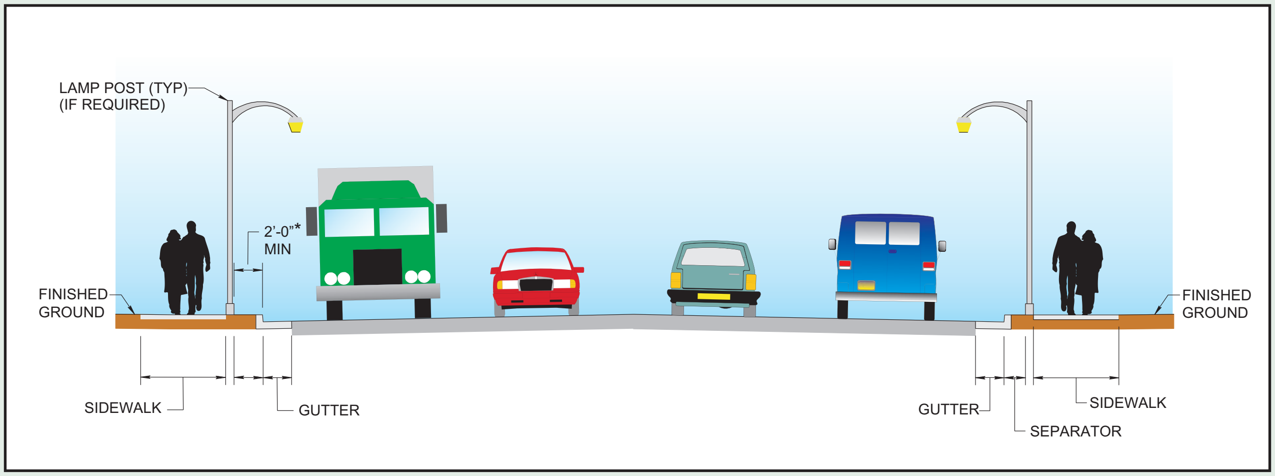


AASHTO Exhibit 2-15 Minimum Turning Path for Interstate Semitrailer (WB-67)
Design Vehicle from AASHTO Green Book

4.2. CROSS SECTIONS

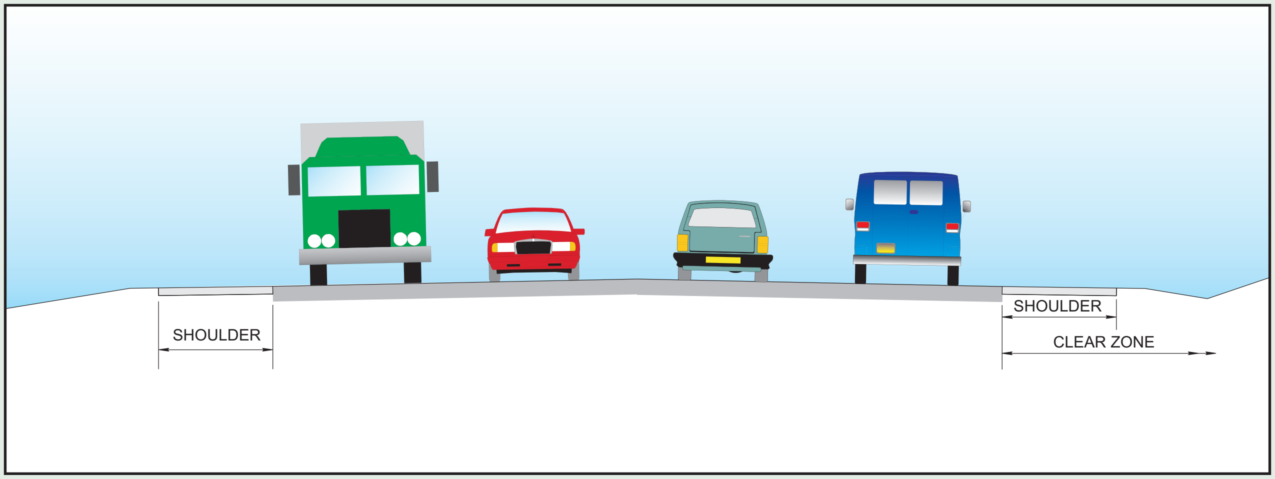
The cross section of a roadway and associated features is the width available for use by vehicles, pedestrians, drainage, and other roadway features. The preferred width of a travel lane is 12 feet. When necessary, the minimum lane width can be reduced to 10 feet, and the maximum width can be 16 feet. When extra pavement width is present, consider striping an edge line to designate a 12-foot wide travel lane and utilizing the remaining pavement width as shoulder.

ROADWAY TYPICAL SECTION (URBAN)



*Meet clear zone requirements for fixed objects, if possible.

ROADWAY TYPICAL SECTION (RURAL)

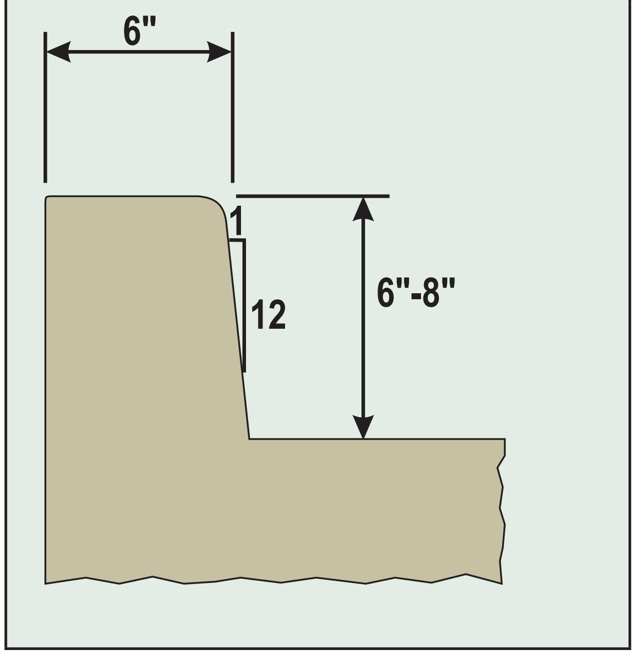


4.2.1. Curb and Gutter

KEY POINT

Combination curb and gutter sections are used to control drainage and channel it longitudinally to drainage inlets.

Roadways typically utilize a gutter section from 1 to 2 feet wide. A gutter should not be considered part of the travel lane width.



4.2.2. Shoulders

KEY POINT

Roadway shoulders support a variety of functions.

The shoulder is the part of the roadway immediately contiguous to the traveled way. It is intended for several functions, including:

- ✓ To provide a recoverable area outside the traveled way for drivers forced to take evasive action or experiencing temporary loss of control
- ✓ To store a disabled or parked vehicle safely out of the traveled way
- ✓ To support law enforcement activities
- ✓ To provide for certain maintenance functions
- ✓ To provide a temporary travel way during major maintenance and reconstruction
- ✓ To enable a safe travel path outside of higher speed traffic for bicycles

The recommended shoulder width depends upon the type of roadway and traffic volumes, as given in the *AASHTO Green Book* and as shown in Exhibit 4.2. As a minimum, all fixed objects (such as signs, fence posts, structures, and trees) should be at least 6 feet from the shoulder or meet *AASHTO Roadside Design Guide* clear zone requirements, whichever provides the greater clearance from the lane edge.

Exhibit 4.2: Roadway Classification Shoulder Width

<table>
<tr><th rowspan="2">ROADWAY CLASSIFICATION</th><th colspan="4">AVERAGE DAILY TRAFFIC (ADT)</th></tr>
<tr><th><400 VEHICLES</th><th>400-1,499 VEHICLES</th><th>1,500-2,000 VEHICLES</th><th>>2,000 VEHICLES</th></tr>
<tr><td>ARTERIALS</td><td>4 ft.</td><td>6 ft.</td><td rowspan="3">6 ft.</td><td rowspan="3">8 ft.</td></tr>
<tr><td>COLLECTORS</td><td rowspan="2">2 ft.</td><td rowspan="2">5 ft.</td></tr>
<tr><td>LOCAL</td></tr>
</table>

Source: AASHTO, Green Book

Shoulders should be pitched to drain away from the road surface, but not so much as to make their use hazardous. Their design should be a compromise between slope needs and drivability. Shoulder width should be consistent and continuous. Where transition is made from a shouldered roadway to a curbed, unshouldered roadway (such as entering an urban area from a rural area or an approach to an ECF), the curb should not be abruptly introduced in place of the shoulder. Rather, a transition zone, with a 10:1 minimum taper, should be used to give a driver time to react, especially at night. This taper length is shown in Exhibit 4.3. When a new lane is added on the right, the shoulder should continue at full width through the transition; otherwise, the new lane may appear to be a continuation of the shoulder.

4.2.3. Clear Zone

A clear zone is the total roadside border area from the edge of the travel way that is available for safe use by errant drivers. Adequate clear zones can enhance roadway safety by providing motorists with certain levels of expectation. Clear zones are discussed more in Section 11.2.

4.2.4. Medians

KEY POINT

Medians separate opposing directions of travel.

Medians separate opposing directions of travel and can provide control for left turns. Raised median islands are often used on urban arterials. Medians are often used to plant vegetation, and wide medians provide a refuge area for pedestrians and left-turn traffic. When plantings are provided in a median, consult the *AASHTO Roadside Design Guide* for information on obstructions adjacent to the travel way. Additionally, plantings should not obstruct the view of crossing/turning vehicles, and crossing pedestrians. Typically, medians should not be less than 4 feet wide.

4.2.5. Bicycle Accommodations

Bicycles should be accommodated to the greatest extent possible in roadway design. In general, there are four major types of bicycle accommodations:

✓ **Shared Roadway, No Bicycle Designation:** Most bicycle travel is done on streets and highways without bicycle designations. With this type of accommodation, there are two subcategories. The street condition is fully adequate for efficient bicycle travel and additional signing and pavement markings is unneeded; or the roadway is not safe for bicycle travel and they should not be encouraged for bicycle travel. A roadway with a 4-foot minimum width shoulder is an example of the former, and a roadway with no shoulder is an example of the latter.

Roadway shoulder

- ✓ **Signed, Shared Roadway:** These are designated by bike route signs. In this case, the owning agency would determine that the route is suitable for a shared route, and will be maintained in a manner consistent with the needs of bicyclists. Signing also informs motorists that bicycles are present.
- ✓ **Bike Lane:** Bike lanes are established with appropriate pavement markings and signing along roadways where there is significant bicycle demand. The intent of this is to improve conditions for bicyclists on streets. Bike lanes delineate the right of way for bicyclists and motorists. Roadway improvements should be made to accommodate the needs for bicyclists, such as eliminating potholes, using bicycle-safe inlets, and ensuring that traffic signals are responsive to bicycles.
- ✓ **Shared Use Path:** When there are frequent bicyclists, shared paths should be provided where streets and other roadways are not adequate. Abandoned railroad right of way could be converted to a shared use path, or a shared use path can travel parallel to a major roadway or through a park area.

Bike Lane Example

4.3. TURNING MOVEMENTS

KEY POINT

AASHTO and *MUTCD* should be followed in design. Additionally, follow local DOT standards. There may be small differences in policy.

A decision that should be made early in the design process is which design vehicle to use. Different design vehicles have different turning radii. Turning radii influence several areas of design, including ECF, intersection, and parking lot design. Note that design vehicles vary with different areas of design. For example, the radius returns at an entrance to an exchange may be designed for a WB-67, but parking spaces for the exchange would be designed for a passenger car.

Turning Radii

Characteristics of a design vehicle include: minimum center line turning radius, out-to-out track width, wheelbase, and the path of the inner rear tire. When classifying the vehicles, *AASHTO* assumes the speed for determining the minimum turning radius is less than 10 mph.

As mentioned previously, in areas where trucks are expected, use the WB-67 as a minimum design vehicle. At other locations, the SU or bus design vehicle should be used, with accommodations for larger vehicles if necessary. Based on the selected design vehicle, use the appropriate turning template for the design vehicle as given in the *AASHTO Green Book*. The figure shown in Section 4.1.3 illustrates the minimum turning path for a single-unit truck (SU-30) and also for an interstate semitrailer (WB-67).

4.4. INTERSECTION DESIGN CONSIDERATIONS

KEY POINT

Geometric design and traffic control are the two critical components of intersection design.

The number, type, and spacing of intersections determine to a large degree the capacity, speed, and safety of most installation roadways. Proper geometric design and traffic control are usually based on accommodating traffic demand during the three peak periods: morning, midday, and evening.

Geometric design includes number and width of lanes, median design, channelization, and curb radii, for example. Traffic control includes devices such as traffic signals and use of STOP and YIELD signs. This section covers geometric design and physical aspects of intersections. Chapter 6 discusses intersection traffic control.

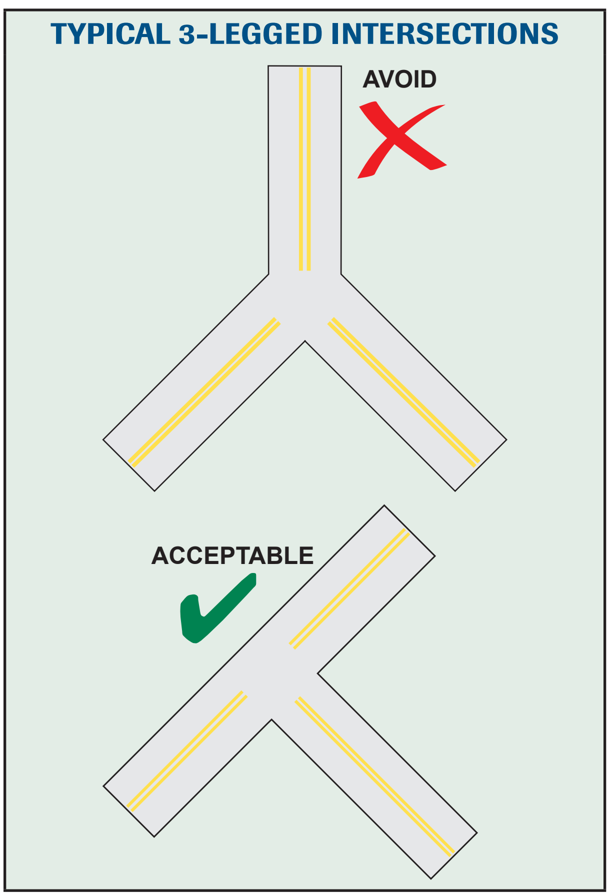
4.4.1. Intersection Types

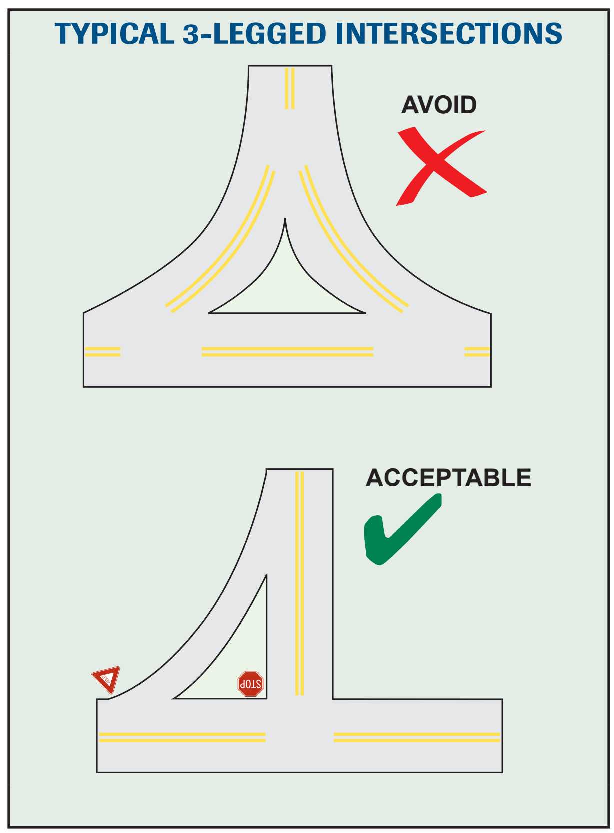
Basic types of intersections are determined by the number of intersecting legs; that is, three-legged, four-legged, or multi-legged. However, any one of the basic types can vary greatly in size, shape, and channelization. Once the type is established, a final geometric design can be selected simply by applying the design controls and elements discussed later.

Three-Legged

Generally, this design is used to terminate one roadway. The intersection may be flared or designed with turning roadways where turning movements are hazardous or where traffic volumes warrant their use. A Y-type design is undesirable and generally results in safety and operational problems.

An undesirable configuration of a three-legged intersection is one with two bidirectional segments off of the major roadway which lead to the side street. This type of intersection is generally not desired due to the conflict points through the intersection. It is generally desired to reconstruct these intersections to be three-leg intersections. If desired, a single-direction turning roadway could be used for right-turn traffic. These are shown in the illustration below.

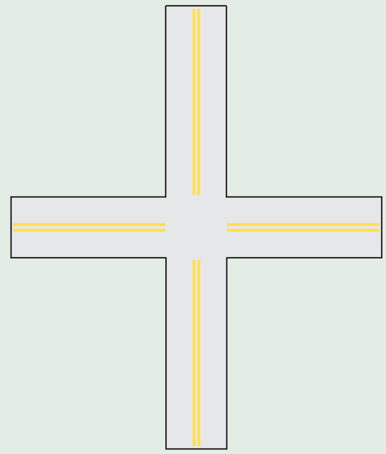




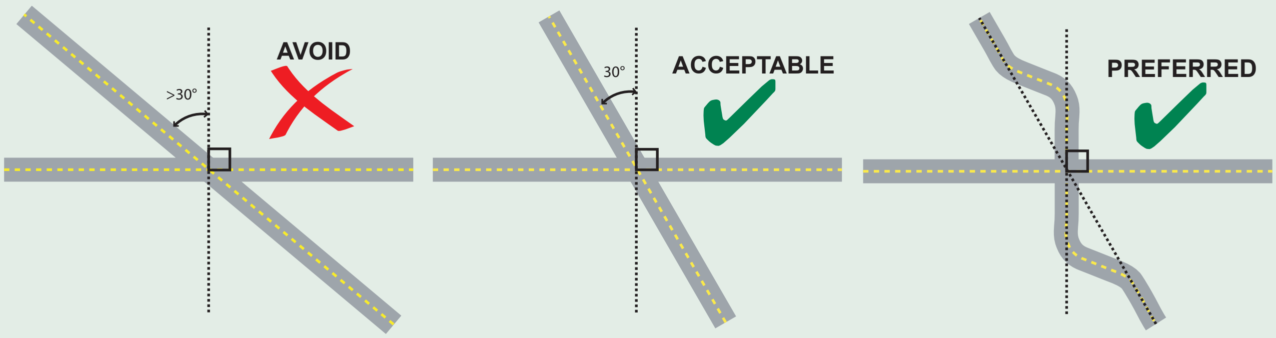
Four-Legged

A four-legged intersection allows for direct crossing movements. The four-legged intersection has many variations, which are based on operating conditions. The right-angle intersection is safest and easiest for drivers to traverse. When crossroads are not perpendicular, skewed intersections result. Skewed four-legged intersections create problems with visibility, pedestrian safety, and turning angles. Where skewed intersections must be used, try to keep the angle less than 30 degrees off perpendicular, or realign to form a perpendicular intersection, as shown. The *AASHTO Green Book* presents several realignment options.

TYPICAL 4-LEGGED INTERSECTION



SKEWED INTERSECTION CONFIGURATIONS



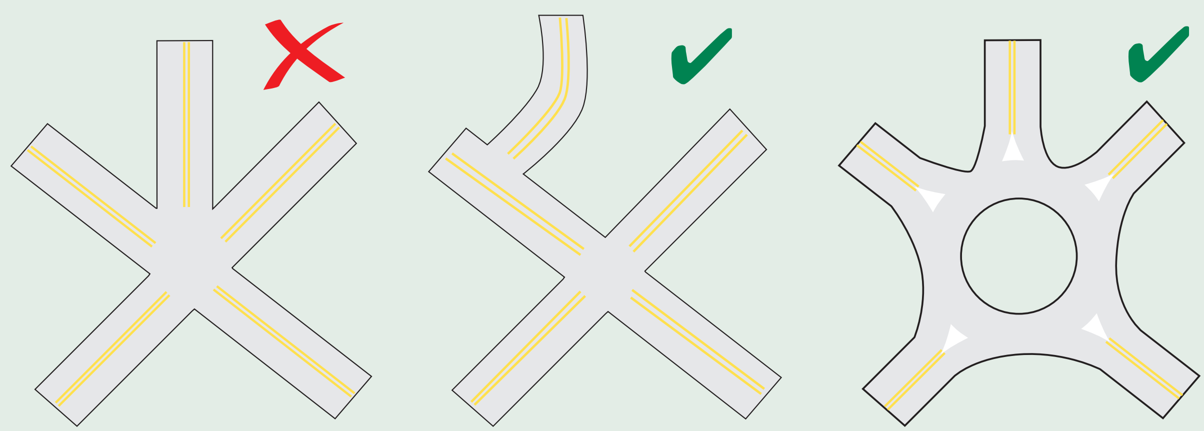
Multi-Legged

This type of intersection generally represents a total compromise of operational requirements. Generally, channelization and signalization should be used, or one leg of the intersection should be eliminated. A roundabout could also be used.

Roundabouts

Roundabouts are another type of intersection, where traffic flows through a circular roadway. Traffic yields on entry to the circular roadway. Roundabouts are further discussed in Chapter 10.

TYPICAL MULTI-LEGGED INTERSECTION

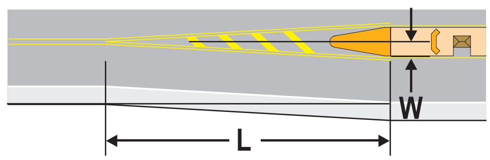
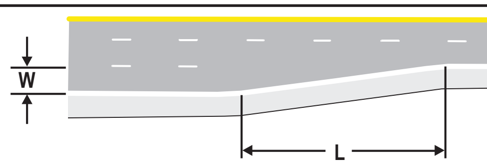
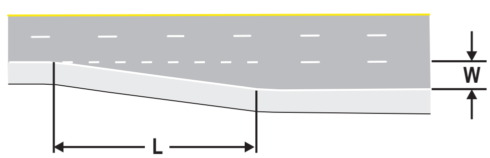
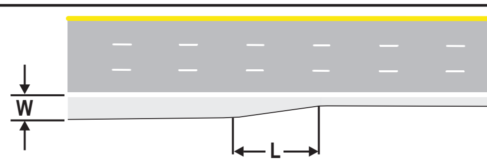


4.4.2. Lane Tapers and Transitions

Open Roadway/Non-intersection Locations

A taper is a lateral shift in roadway alignment. Properly constructed tapers enhance safety and efficient use of pavement. They allow drivers to recognize a change in conditions and to react accordingly. Tapers are typically based on calculations dependent on the width of the lateral shift and the design speed. In some cases, they are referenced in ratios of length of roadway to width of change. For example, 10:1 means that 10 feet of roadway length is needed for every 1-foot of lateral shift. Formulas for calculating roadway taper lengths are shown in Exhibit 4.3. This exhibit shows taper calculations for cases where travel lanes are redirected, where a lane reduction or addition occurs, or where a shoulder to curb transition occurs.

Exhibit 4.3: Transition Tapers

TYPE		CRITERIA
LANE REDIRECTED *Source:* MUTCD *Fig 3B-15*		✓ Speeds less than 45 mph: $L=\frac{WS^2}{60}$ ✓ Speeds of 45 mph or more: L = WS Minimum L = 100 feet in urban areas Minimum L = 200 feet in rural areas
LANE REDUCTION *Source:* MUTCD *Fig 3B-14 and AASHTO Green Book Equations 3-37 and 3-38*		✓ Speeds less than 45 mph: $L=\frac{WS^2}{60}$ ✓ Speeds of 45 mph or more: L = WS
LANE ADDED *Source: AASHTO Green Book Page 3-137*		✓ Speeds less than 45 mph: $L=\frac{WS^2}{90}$ Speeds of 45 mph or more: $L=\left(\frac{2}{3}\right)WS$ Minimum L = 100 feet in urban areas Minimum L = 200 feet in rural areas
SHOULDER-TO-CURB TRANSITION *Source: SDDCTEA*		✓ All speeds: L=10W (10:1 ratio) is recommended
W = Width of Lateral Shift (feet) S = Posted, 85th-percentile, or Statutory Speed (mph) L = Length of Taper (feet)		

Source: MUTCD *and AASHTO Green Book*

Intersection Locations

In intersection applications, tapers are frequently used in adding auxiliary lanes. Auxiliary lane components include deceleration length, approach taper, bay taper, and storage length.

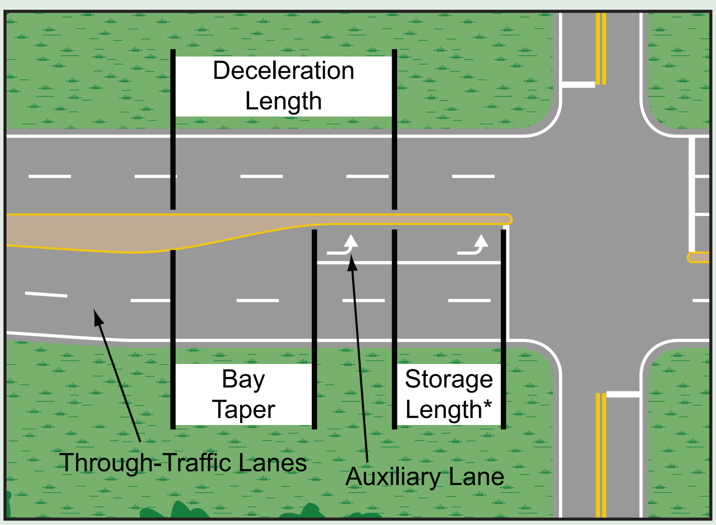
On high-speed roadways, it may be desirable to design turn lanes based on deceleration requirements rather than storage needs. This allows vehicles to gradually reduce their speed, thereby reducing the potential for rear-end collisions. Minimum deceleration lengths for lanes with an accompanying stop condition are shown in Exhibit 4.4.

Storage length is based upon the maximum number of vehicles that will accumulate at any one time. This length should be long enough to accommodate all turning vehicles so that traffic does not back up into through-traffic lanes.

Use a minimum storage length of 100 feet if the number of left turns per hour is 60 or less. Storage lengths may need to be increased based on deceleration requirements on high-speed highways.

Bay taper length is the transition length from through-traffic lanes to adjacent auxiliary lanes. Bay taper lengths are dependent on vehicle speeds and width of auxiliary lane. Installations should also check state DOT criteria to verify whether alternate criteria are used. For example, some states use different taper lengths for a section with a raised median versus a painted taper. Generally, bay taper rates of 8:1 should be used for design speeds up to 30 mph, and 15:1 for design speeds 50 mph and greater. The lengths typically range between 100 feet and 180 feet for a 12-foot wide lane.

LANE TAPERS AND TRANSITIONS



*Space for at least two passenger cars should be provided; with over 10% turning truck traffic, provisions should be made for at least one car and one truck, per AASHTO (pg 9-127)

Exhibit 4.4: Desirable Full Deceleration Lengths

SPEED (MPH)	DISTANCE (FEET)
20	70
30	160
40	275
50	425
60	605
70	820

Note: These values only apply for design when raised median islands are used.

Source: AASHTO Green Book, Chapter 9

4.4.3. Islands and Channelization

KEY POINT

Traffic islands provide channelization, division, and refuge.

Channelization is the design of traffic lanes and islands in a way that will provide definite paths for vehicles to follow through an intersection. Effective channelization reduces points of conflicting traffic movements and helps to separate traffic flow.

Curbed islands can be difficult to identify at night because of glare. When curbed islands are used, lighting should be installed at the intersection or curb top delineators should be installed. When islands are used in succession along a corridor, a common geometric design should be used.

Channelizing islands are commonly delineated by the following: pavement markings or buttons; raised or outlined curbs; textured or colored pavement areas; and delineators. As shown in Exhibit 4.5, traffic islands provide channelization, division, and refuge.

Exhibit 4.5: Types of Traffic Islands

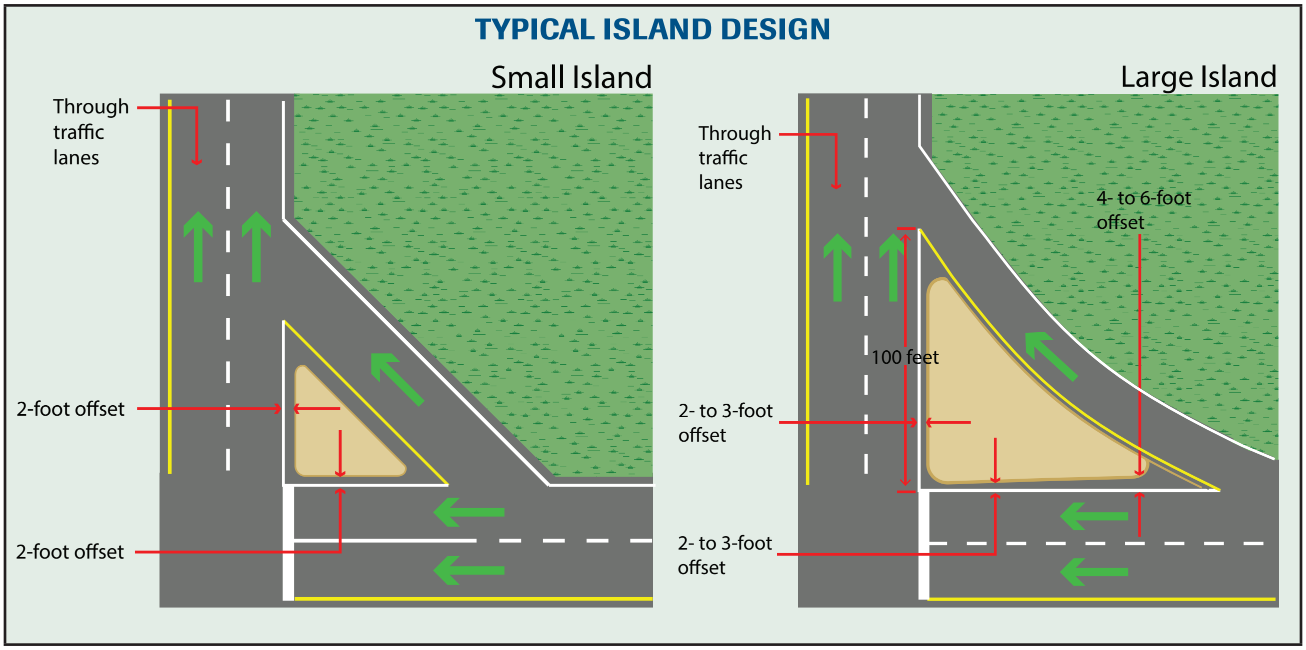
TRAFFIC ISLAND TYPE	FEATURES	GEOMETRICS	TYPICAL USAGE
CHANNELIZATION	Raised or flush	Normally triangular	When providing a free right-turn movement from one roadway to another
DIVISION	Raised or flush	Normally elongated	When a left-turn lane tapers away from the through lane
REFUGE	Raised	Triangular or elongated	When pedestrians need to cross a distance that they may not be able to complete in one signal cycle

Source: ITE, Traffic Engineering Handbook

Raised islands should not be in the natural path of vehicles and should be clearly visible. Major through-traffic flow should be favored and not restricted. Avoid small islands that a vehicle could easily drive over. Islands should not be less than 75 square feet. If islands must be small, provide adequate delineation such as pavement markings around the island or object markers on the island to warn motorists; or substitute a painted island for a raised island.

When area for an island becomes small, verify that an island is truly needed. Often small islands can be beneficial for sign or signal pole placement, but with small islands, these can become clear zone hazards. These hazards should be relocated beyond the edge of roadway, possibly eliminating the need for the island. A painted island can replace a raised island. With a small island, the turning traffic movement may not need its own traffic control since it often functions with the remaining movements on the approach.

Larger islands essentially form a separate turning roadway, thereby removing that movement's turning traffic from the intersection. The length of one of the sides of a larger island should be at least 100 feet. Larger islands are often sufficient to provide a proper clear zone for signs and signal poles. Larger islands also can benefit pedestrians. The location where traffic merges back onto the roadway after completing the turn often requires separate traffic control from the intersection, typically a STOP or YIELD sign. When performing a capacity analysis on a turning roadway, it should be analyzed as a separate intersection since the traffic control can differ from the adjacent intersection.



It is very important to properly sign raised channelization islands. Commonly used signs include: Divided Highway, KEEP RIGHT, and LEFT LANE MUST TURN LEFT.

Raised channelization islands should be a minimum of 2 feet from the travel lane. Larger islands can be offset 2 to 3 feet with a 4- to 6-foot taper from the inside lane approach. Islands should not reduce adjacent lane widths, as this may cause motorists to swerve to avoid hitting them.

Channelization islands are shown in the photo to the right.

4.5. SIGHT DISTANCE

There are several different types of sight distance for different scenarios. These include stopping and passing sight distance on horizontal and vertical curves, and intersection sight distance at 3- and 4-legged intersections.

4.5.1. Stopping Sight Distance

> **KEY POINT**
> The distance required to identify, react, and stop before hitting an object in the vehicle path is the stopping sight distance.

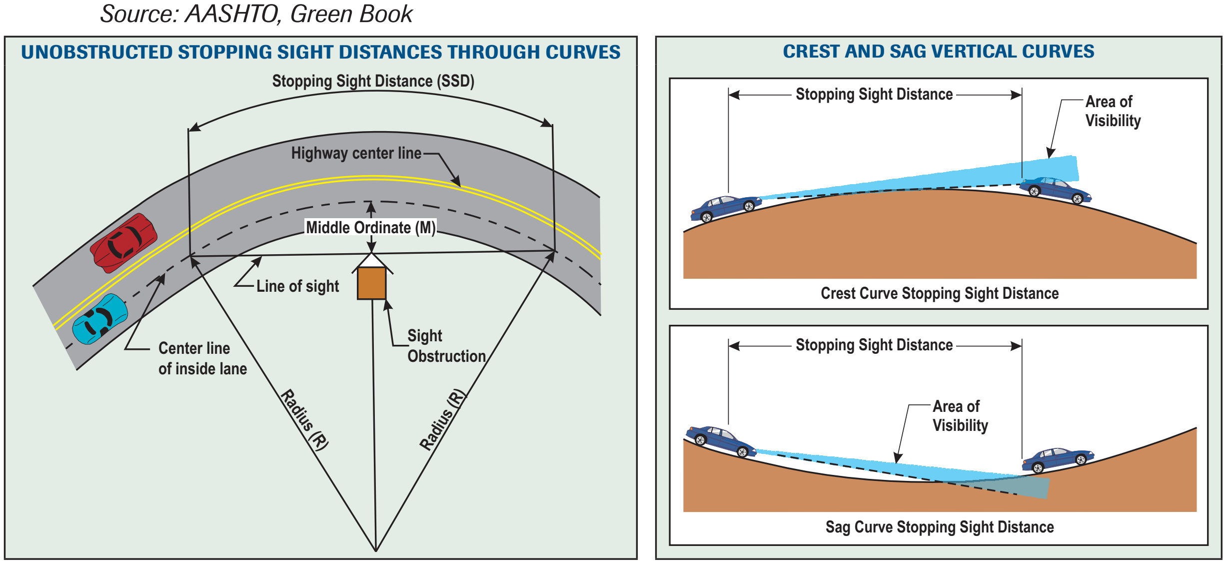
The distance required to identify, react, and stop before hitting an object in the vehicle path is the stopping sight distance (SSD).

Providing appropriate stopping sight distance addresses the need for the driver to be able to identify and react to an obstruction in the roadway ahead. This distance is based on the posted speed and the profile grade of the roadway. Calculations assume a 3.5 feet driver's eye height, a 2 foot object height, 11.2 ft/s^2 vehicle deceleration rate, and a driver reaction time of 2.5 seconds. The following table in Exhibit 4.6 shows the required SSD along a section of roadway for horizontal and vertical curves.

Exhibit 4.6: Minimum Stopping Sight Distance

STOPPING SIGHT DISTANCES (FEET)							
SPEED (MPH)	LEVEL GRADE	DOWNGRADE			UPGRADE		
		3%	6%	9%	3%	6%	9%
25	155	158	165	175	147	143	140
30	200	205	215	227	200	184	179
35	250	257	271	287	237	229	222
40	305	315	333	354	289	278	269
45	360	378	400	427	344	331	320
50	425	446	474	507	405	388	375
55	495	520	553	593	469	450	43
60	570	598	638	686	538	515	495

Source: AASHTO, Green Book



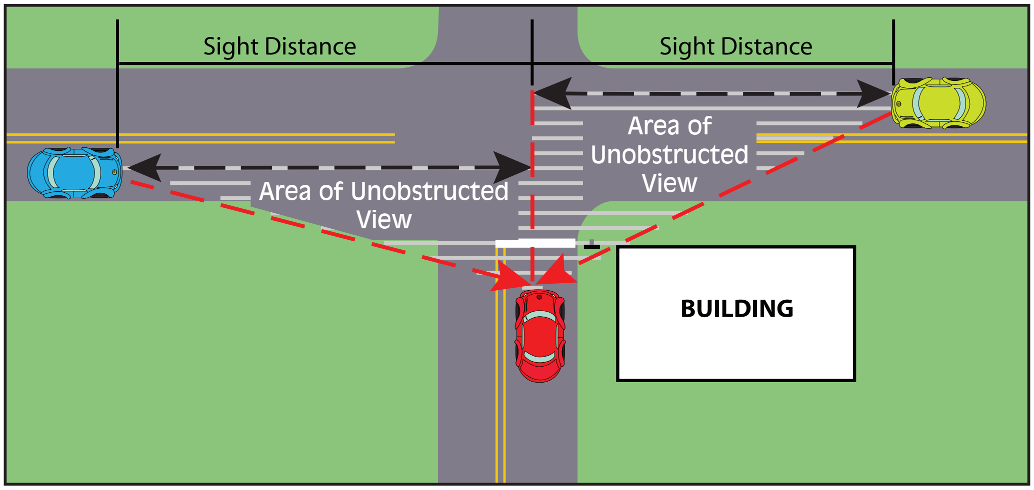
4.5.2. Intersection Sight Distance

Intersection sight distance is the sight distance required by drivers to see one another (i.e., the driver at the entrance on the minor road pulling out onto the major road and the driver traveling along the major road). The sight distance requirements vary based on the type of intersection traffic control. Section 9.5 in the *AASHTO Green Book* provides equations, calculations, additional information and traffic control scenarios for intersection sight distance.

No Control: A clear sight triangle is required for all legs. These distances are typically longer on the minor approaches when compared to stop and yield control on the minor approaches, but shorter than the lengths required on the major approaches for stop and yield control on the major approaches. The speed and grade of each roadway are factors in determining the required sight distance. SDDCTEA's BMTE calculator can be used to compute these sight distances (See Chapter 1, page 1-3).

Stop Control: The clear sight triangle required for two-way stop control is comprised of one leg being the distance from the center of the intersection to a point 14.5 feet from the edge of travelway on the minor roadway, and second leg being a calculated distance along the major roadway. **In reference to the stopped vehicle in Exhibit 4.7, for left turn and crossing maneuvers from the minor roadway, this calculated 'sight' distance applies to both directions (i.e., major roadway traffic approaching from the left and traffic approaching from the right); however, for right turn maneuvers from the minor roadway, the calculated 'sight' distance applies only to the left side (i.e., major roadway traffic approaching from the left).** The calculated distance varies based on vehicle type, speed, grade, skew angle, number of lanes to be crossed, median width, and movement type. Right turns require less sight distance than left-turns. Traffic crossing the intersection requires less distance than left-turns, and rarely govern over left-turns. Therefore, right-turn and left-turn sight distance must be provided for both side street approaches of a typical bidirectional four-leg intersection. Exhibit 4.7 shows sight distance requirements for a passenger car on a flat grade turning onto a two-lane roadway. SDDCTEA's BMTE calculator can be used to determine the required sight distances for other variables (such as grade, vehicle type, etc.) in this type of control.

Exhibit 4.7: Stop Control Intersection Sight Distances For Two-Lane Roadways (Feet)



Note: The vertex (decision point) of the sight triangle on the minor road should be 19.5 ft. from the edge of the major road traveled way.

LENGTH OF LEG ALONG MAJOR ROADWAY		
MAJOR ROAD DESIGN SPEED (MPH)	LEFT TURN FROM MINOR ROAD (LEVEL GRADE) (FT)	RIGHT TURN AND CROSSING MANEUVER FROM MINOR ROAD (LEVEL GRADE) (FT)
25	280	240
30	335	290
35	390	335
40	445	385
45	500	430
50	555	480
55	610	530
60	665	575

Source: AASHTO, Green Book, Tables 9–6 and 9–8

Yield Control: Similar to No Control, yield control requires a longer sight distance leg along the minor roadway. Similar to stop control, the distance along the major roadway varies by vehicle type, design speed, skew angle, number of lanes to cross, median width, and movement type. Unlike stop control, the crossing movement can govern and must be checked. The same sight distance is required for left and right turns. Exhibit 4.8 shows yield control sight distance for passenger vehicles crossing or turning onto a two-lane roadway, with level grades and no skew. SDDCTEA's BMTE calculator can be used to determine the required sight distances for other variables in this type of control.

Exhibit 4.8: Yield Control Intersection Sight Distances (Feet)

LEFT OR RIGHT TURN FROM MINOR ROAD		
MAJOR ROAD DESIGN SPEED (MPH)	LENGTH OF LEG ALONG MAJOR ROAD (FT)	LENGTH OF LEG ALONG MINOR ROAD FOR RIGHT TURNS (FT)*
25	295	82
30	355	82
35	415	82
40	475	82
45	530	82
50	590	82
55	650	82
60	710	82

** The distance is based on the assumption that drivers making left and right turns without stopping will slow to a turning speed of 10 mph; AASHTO page 9-46. The length of leg for left turns is equal to 82 ft. plus the lane width of the major road.*

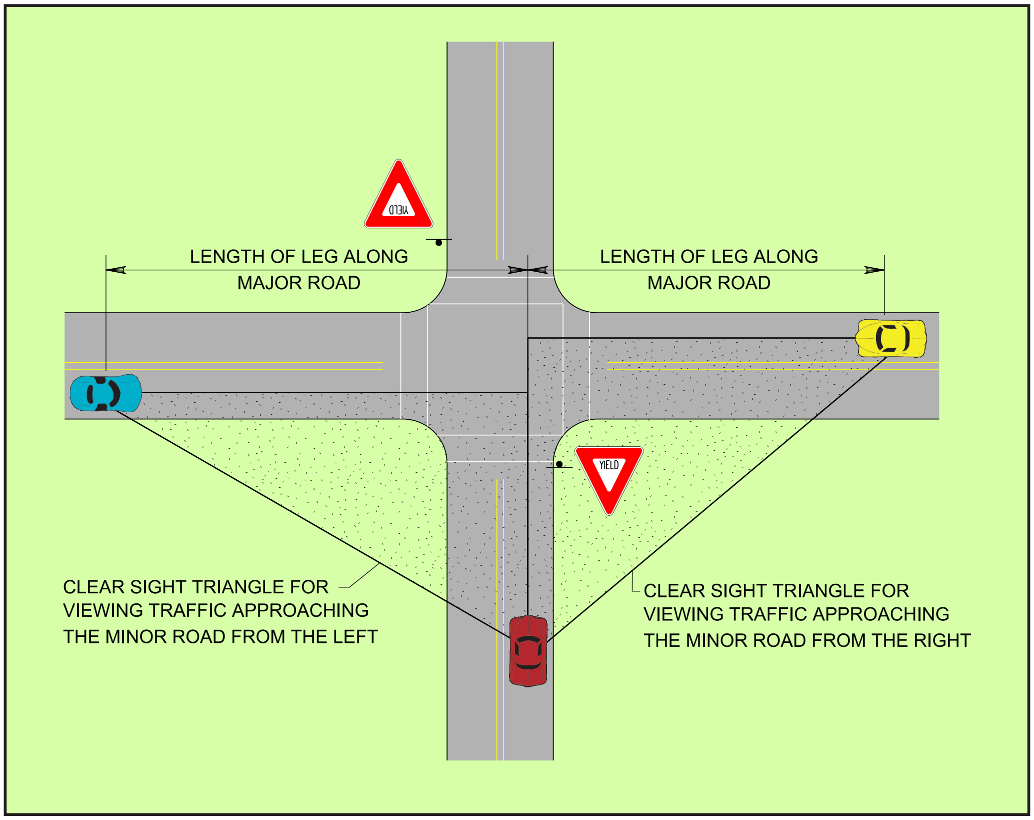
Source: AASHTO, Green Book, Table 9-12 (columns 1 and 2)

CROSSING FROM MINOR ROAD			
MAJOR ROAD DESIGN SPEED (MPH)	LENGTH OF LEG ALONG MAJOR ROADWAY (FT)		
	MINOR-ROAD DESIGN SPEED (MPH)		
	20-50	55	60
25	240	250	255
30	290	300	305
35	335	345	360
40	385	395	410
45	430	445	460
50	480	495	510
55	530	545	560
60	575	595	610

MINOR ROAD DESIGN SPEED (MPH)	LENGTH OF SIGHT TRIANGLE LEG ALONG MINOR ROAD (FT)
25	130
30	160
35	195
40	235
45	275
50	320
55	370
60	420

Source: AASHTO, Green Book, Tables 9-9 and 9-10

Exhibit 4.8: Yield Control Intersection Sight Distances (Feet) (Continued)

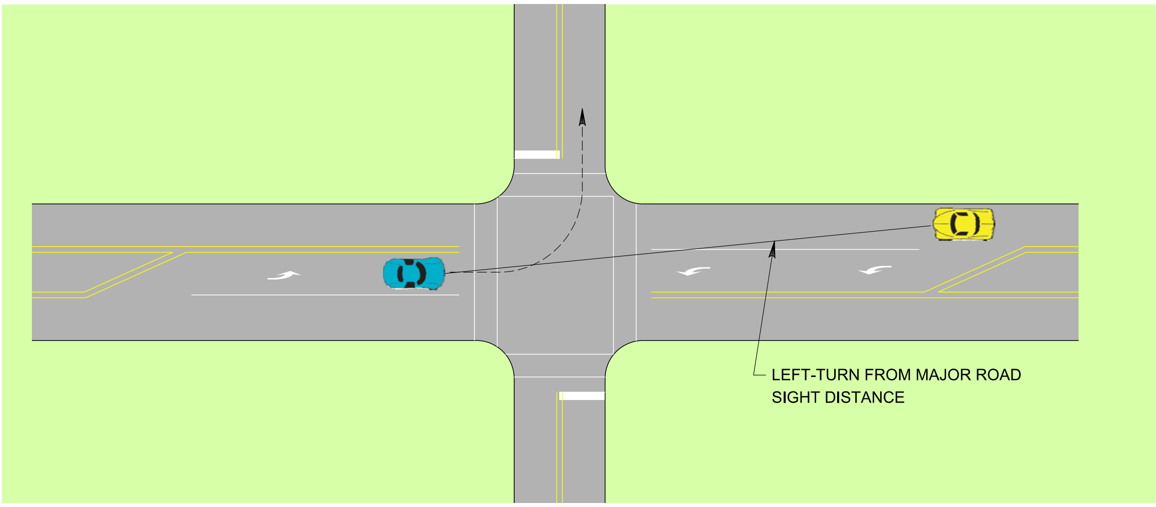


Traffic Signal Control: At signalized intersections, the first vehicles stopped on one approach should be visible to the driver of the first vehicle stopped on each of the other approaches. If right turns are permitted on red, perform a right-turn sight distance calculation as if that approach was stop controlled. If the intersection operates in flash mode regularly, perform a left- and right-turn sight distance calculation as if that approach was stop controlled.

All-Way Stop Control: The first stopped vehicle on one approach should be visible to the drivers of the first stopped vehicles on each of the other approaches. There are no sight distance calculations associated with this form of traffic control.

Le-turns from Major Road: This sight distance is needed for motorists to see oncoming traffic on the major road in order to determine if they have enough time to complete their crossing maneuver. The distance is from the left-turning point to traffic in the opposite direction. Exhibit 4.9 shows the distance requirements for a passenger car crossing one lane of traffic. SDDCTEA's BMTE calculator can be used to determine the required sight distances for other variables in this type of control.

Exhibit 4.9: Left Turn from Major Road on Two-Lane Roadways



LEFT TURN FROM THE MAJOR ROAD	
DESIGN SPEED (MPH)	**SIGHT DISTANCE (FT)**
25	205
30	245
35	285
40	325
45	365
50	405
55	445
60	490

Source: AASHTO, Green Book, Table 9-14

4.5.3. Passing Sight Distance

Passing sight distance refers to the distance required by a typical driver to begin and complete a passing maneuver on a two-lane roadway. A length of roadway cannot be marked as a passing zone (single broken yellow line) unless the minimum passing sight distance is available. Exhibit 4.10 shows passing sight distance requirements for different speeds.

Exhibit 4.10: Passing Sight Distance

MINIMUM PASSING SIGHT DISTANCE	
SPEED (MPH)	MINIMUM SIGHT DISTANCE (FT)
25	450
30	500
35	550
40	600
45	700
50	800
55	900
60	1000

Source: AASHTO, Green Book Tables 6-4 and 7-1; and MUTCD *Table 3B-1*

Refer to Chapter 8—MARKINGS for additional information regarding passing sight distance and the marking of No Passing Zones.

4.6. HORIZONTAL ALIGNMENTS

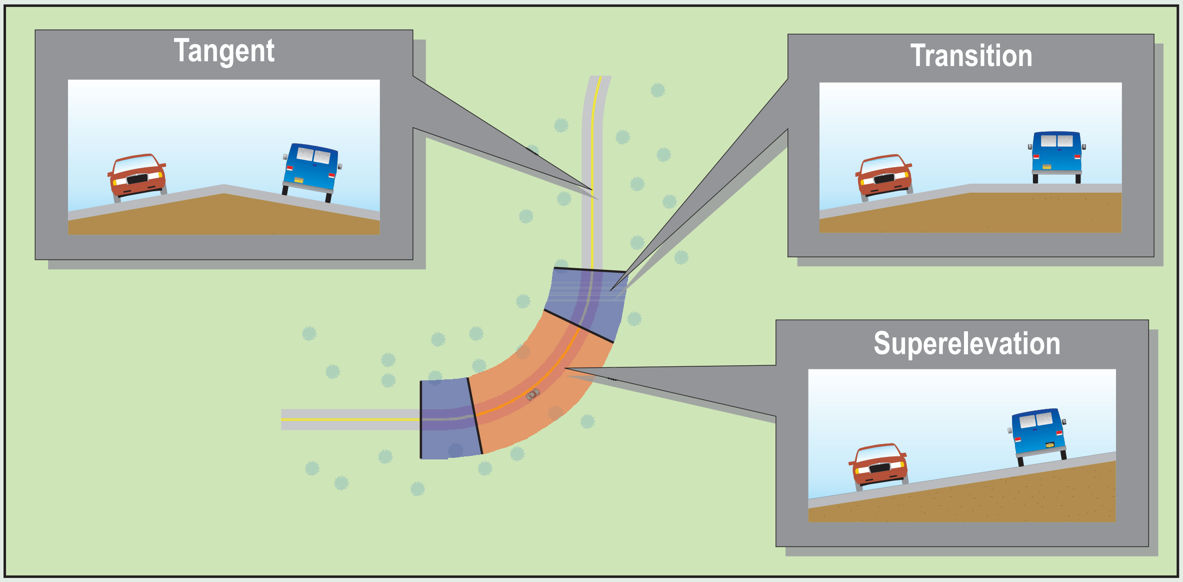
KEY POINT

At a constant speed, as the radius of curves decrease, it is necessary to bank or superelevate the curve to compensate for centripetal forces.

A horizontal alignment is comprised of curves, tangents, and curve transitions. The following illustration shows the locations of tangents, transitions, and superelevation. The goal of a horizontal alignment is to provide a roadway that is suitable in usage to the land that surrounds it, and reinforces the speed that is compatible with that land.

When designing horizontal alignments, criteria from *AASHTO Green Book* should be followed for the allowable curve radii, superelevation rates and transitions. The criteria used should be based on the surrounding terrain, roadway functional classification, and design speed. The *AASHTO Green Book* will provide a variety of options for the maximum superelevation rate that can be utilized. Installations should look at their State DOT standards for horizontal curvature and utilize it for roadway projects. The superelevation rate is often based on climate conditions and surrounding terrain. Refer to chapter 3.3 of the *AASHTO Green Book* for additional information.

TANGENT, TRANSITION, SUPERELEVATION LOCATIONS



4.7. VERTICAL ALIGNMENTS

Topography greatly influences vertical alignment of roadway facilities. Vertical alignment is comprised of tangent grades and vertical curves to traverse the topography of the land. Required grades depend on the topographic characteristics. Typically, higher grades are used in mountainous terrain than would be used in level or rolling terrain. Higher grades impact traffic flow, particularly with trucks and underpowered cars. Relationships between maximum grades and design speed are discussed in the *AASHTO Green Book* Chapter 6.

Vertical curves are used to connect different roadway grades. Like horizontal curves, acceptable vertical curvature depends on the design speed of the roadway and the sight distance needed to identify and react to an object in the roadway. The stopping sight distances presented in Exhibit 4.7 on page 4-19 also apply when designing vertical alignment. Vertical curve rates must provide the correct stopping sight distance, which is based on the height of the vehicle's headlights rather than direct line of sight. The *AASHTO Green Book* sets the design value for headlight height at 2.0 feet. Any object that is within the shadow zone must extend into the headlight beam to be directly illuminated. Therefore, the acceptable rate of vertical curvature varies with speed.

Acceptable vertical curves are defined by the rate of vertical curvature, commonly known as the "K" value. Rate of vertical curvature, K, is the length of vertical curve (L) divided by the algebraic difference between the two tangent grades in percent (A). The length of the vertical curve, L, is calculated by L = K*A. With this formula, stopping sight distance requirements remain the same; the only difference is the K value requirements varying with speed. Exhibit 4.11 shows required K values for varying speeds. Refer to Chapter 3.4 of the *AASHTO Green Book* for additional information.

Exhibit 4.11: Vertical Curve K Values

DESIGN SPEED (MPH)	K
20	57
25	72
30	89
35	108
40	129
45	175
50	229
55	289
60	357

4.8. DRAINAGE

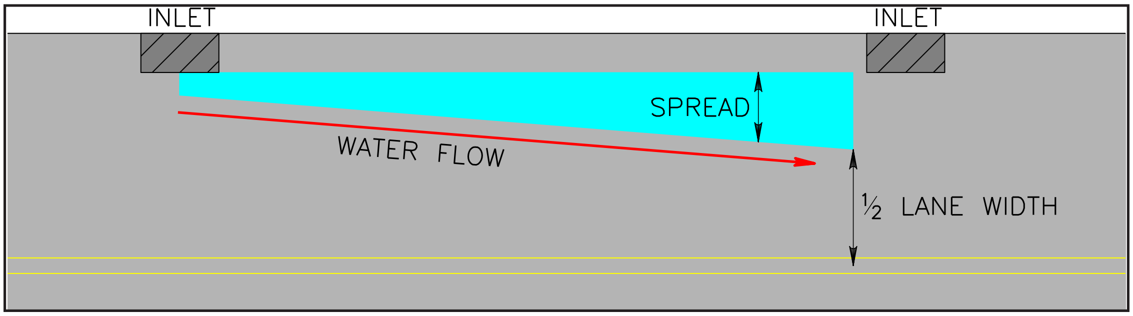
Control of water is very important in roadway design. All roadways should have a sloped cross section to facilitate the quick and efficient removal of water from the roadway. In roadway design, drainage design can influence the final alignment.

Roadways that have curb and gutter adjacent to the travel lanes typically have inlets provided to capture the water from the gutter and redirect it to an acceptable location. Check your state DOT criteria for the minimum slope to be used for drainage. As the amount of water in the gutter increases, the velocity of the water increases, and the water spreads from the gutter into the travel lane. This condition is referred to as spread.

Drainage is important!

The spacing of inlets is determined by the maximum allowable spread of water as it travels through the gutter. Normally, an inlet is required when the calculated spread reaches half the lane width. In other words, for a 12-foot lane, an inlet is required when the calculated spread reaches 6 feet into the lane, as shown in Exhibit 4.12. However, this is just a rule of thumb; the local municipalities or state DOT should be consulted to determine the acceptable spread for the area. For more information on calculating the spread for a facility, consult *AASHTO*'s *Highway Drainage Guidelines*.

Exhibit 4.12: Inlet Spacing



When reviewing roadway design plans, request drainage design calculations to confirm that the spread width will be minimized. Spread is not an issue on roadways that use drainage ditches. Ditches are graded, open channels that are typically located along the bottom of an embankment slope or at the top of a cut slope. They are generally parallel to the highway and carry runoff coming from the pavement, shoulders, and adjacent areas. They also may be used to protect the highway's boundaries from stormwater originating offsite.

The most common types of ditches are triangular, trapezoidal, and rectangular. They are often lined to control velocities and soil erosion. The trapezoidal shape is preferred due to its higher hydraulic efficiency. Triangular shapes often require less width, and can be readily maintained with a grader. Rectangular shapes are generally used in rock areas.

Section 11.4.4 has additional information on use of drainage features with respect to roadside safety.

4.9. OUTSIDE CONTINENTAL UNITED STATES (OCONUS) CONSIDERATIONS

OCONUS installations require special considerations. Generally, host country standards should be utilized for overseas designs. This generally includes traffic control devices and geometric standards. Specifically, per AR 420-1, the OCONUS installation streets and roads are to be considered an extension of the road system of the host country and shall use traffic control device standards and criteria of the host country.

Other nations generally use different signs and pavement markings. There may also be behavioral factors that may differ from continental United States (CONUS) installations. For example, in Japan, drivers use the left side of the road. Also, many Japanese installations have significantly higher pedestrian volumes than most CONUS locations which may influence designs.

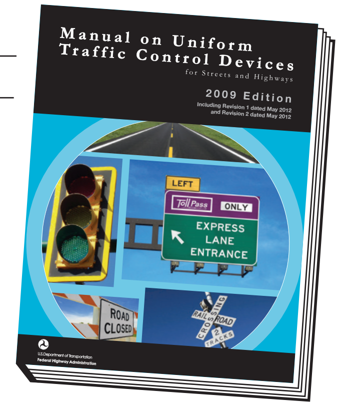
With regards to traffic law enforcement, a similar principle applies for OCONUS installations. Per 32 CFR 634, OCONUS installations must follow the applicable Status of Forces Agreement (SOFA). In this case, the law of the host nation concerning license suspension and revocation is to be followed.

Japanese STOP sign used on a Navy base

CHAPTER 5—MUTCD APPLICABILITY

5.1. CONTROL

Traffic control devices include signs, signals, markings, and a few other devices such as channelizing devices and islands which are used to regulate, warn or guide traffic.



5.1.1. Purpose of Traffic Control Devices

> **KEY POINT**
>
> Motorists should be able to expect that a traffic control device will always have the same meaning and require the same action any time or any place that they see it.

The purpose of traffic control devices on streets and highways is to promote highway safety and efficiency by providing for the orderly movement of all road users. Traffic control devices notify users of regulations, and provide warning and guidance needed for the reasonably safe and efficient operation of all elements of the traffic stream.

Standardization is an important factor in driver compliance. Motorists should be able to expect that a traffic control device will always have the same meaning and will require the same action wherever they see it. Therefore, to maximize safety and efficiency, and to minimize driver frustration, both the design and the application of traffic control devices must be uniform.

5.1.2. Federal Mandates

> **KEY POINT**
>
> The MUTCD is recognized as the national standard for all traffic control devices installed on any street, highway, or bicycle trail open to public travel. The MUTCD is available to download for free at http://mutcd.fhwa.dot.gov.

The *MUTCD* is the national standard for all traffic control traffic devices installed on any street or highway in the United States. The National Committee on Uniform Traffic Control Devices (NCUTCD) and the Federal Highway Administration (FHWA) jointly develop the *MUTCD*, and the U.S. Secretary of Transportation ultimately approves it.

SDDCTEA's DoD Supplement to the *MUTCD* is a companion document to the *MUTCD* applicable to military installations. It discusses military-specific traffic control applications, and contains mandatory requirements for some military-specific traffic control applications. Also, many states either have a state-specific *MUTCD* or a state supplement to the *MUTCD*. (The *MUTCD* website at http://mutcd.fhwa.dot.gov provides information pertaining to the State *MUTCD*s and Traffic Control). In these cases, installations must follow both the DoD supplement and the *MUTCD* that is specific to their host state. The DoD supplement is not a substitute for the state *MUTCD* used in the host state. In the event of a contradiction between the DoD supplement and the state *MUTCD*, the state supplement is to be used.

By military regulations, Commanders are required to conform to the *MUTCD*, per the following two requirements:

1. Per Multi-Service Regulation, DoD Transportation Engineering Program (AR 55-80, OPNAVINST 11210.2, AFMAN 32-1017, MCO 11210.2D and DLAR 4500.19).
2. Per Code of Federal Regulations—Title 23: Highways, Chapter I, Subchapter G, Part 555, subpart f: Traffic Control Devices on Federal—Aid and other streets and highways:

    655.603—Standards

    (a) National *MUTCD*. The *MUTCD* approved by the Federal Highway Administrator is the national standard for all traffic control devices installed on any street, highway, or bicycle trail open to public travel in accordance with 23 U.S.C 109(d) and 402(a). The national *MUTCD* is specifically approved by the FHWA for application on any highway project in which Federal highway funds participate and on projects in federally administered areas where a Federal department or agency controls the highway or supervises the traffic operations.

The primary purpose of the *MUTCD* is to improve safety and reduce driver frustration by promoting uniformity in the design and application of traffic control devices. In addition to sponsoring research to improve safety, FHWA also works internationally to share and borrow ideas so that uniformity is much broader than just in the United States.

Throughout the *MUTCD*, the words standard, guidance, option, and support are used to provide the information required to make appropriate decisions regarding the use of traffic control devices on streets and highways.

In accordance with Section 7-17.e of AR 420-1, OCONUS installation streets and roads are to be considered an extension of the road system of the host country and shall use traffic control device standards and criteria of the host country. Section 1A.13 in the *MUTCD* defines these terms as follows:

- ✓ **Standard** – a statement of required, mandatory, or specifically prohibitive practice regarding a traffic control device. All Standard statements are labeled, and the text appears in bold type. The verb “shall” is typically used. The verbs “should” and “may” are not used in Standard statements. Standard statements are sometimes modified by Options. Standard statements shall not be modified or compromised based on engineering judgment or engineering study.
- ✓ **Guidance** – a statement of recommended, but not mandatory, practice in typical situations, with deviations allowed if engineering judgment or engineering study indicates the deviation to be appropriate. All Guidance statements are labeled, and the text appears in unbold type. The verb “should” is typically used. The verbs “shall” and “may” are not used in Guidance statements. Guidance statements are sometimes modified by Options.
- ✓ **Option** – a statement of practice that is a permissive condition and carries no requirement or recommendation. Option statements sometimes contain allowable modifications to a Standard or Guidance statement. All Option statements are labeled, and the text appears in unbold type. The verb “may” is typically used. The verbs “shall” and “should” are not used in Option statements.
- ✓ **Support** – an informational statement that does not convey any degree of mandate, recommendation, authorization, prohibition, or enforceable condition. Support statements are labeled, and the text appears in unbold type. The verbs “shall,” “should,” and “may” are not used in Support statements.

The *MUTCD* and this pamphlet both reference many other publications. The Reference Section of this pamphlet identifies some of the most relevant publications.

This pamphlet supplements the *MUTCD* for military installations, and is intended for use by military employees and contractors that may be working for the military and who are responsible to place and maintain signs and markings on military installations.

The first *MUTCD* was developed in 1935, and a sampling of some of the signs in the original document are illustrated in Exhibit 5.1. Since 1935 there were nine new editions, and several intermediate updates. Exhibit 5.2 identifies some of the changes in each edition of the *MUTCD*.

Exhibit 5.1: Sample Signs in the 1935 *MUTCD*

Exhibit 5.2: Changes in the MUTCD

***MUTCD* Edition**	**Some of the Changes Through the Years**
1935	✓ Regulatory and guide signs were both white rectangular shapes; and warning signs were yellow diamonds, squares, circles, or octagons (the STOP sign was a yellow octagon) ✓ Markings were only used at “hazardous” locations, and were white, yellow or black
1948	✓ Required retroreflectivity or illumination of regulatory and warning signs ✓ Required pavement markings to be white except yellow could be used for no-passing zones ✓ Discouraged the use of edge line pavement markings
1954	✓ Changed the colors of the STOP sign from black-on-yellow to white-on-red ✓ Introduced the “yield” sign—it was black-on-yellow with the words YIELD RIGHT OF WAY
1961	✓ Shortened the legend on the “yield” sign to YIELD, but kept it as a black-on-yellow sign ✓ Allowed guide signs on Interstate highways to use lowercase letters and be white on green ✓ Recommended white center line markings on paved highways, and required a solid yellow line to indicate a no-passing zone, which was on the right side of the white center line marking
1971	✓ Added many new symbol signs to provide better international uniformity ✓ Added the pennant-shaped no-passing zone sign and the pentagon-shaped school signs ✓ Changed the YIELD signs to the current red and white colors ✓ Required all center line markings to be yellow

Exhibit 5.2: Changes in the MUTCD (Continued)

MUTCD Edition	Some of the Changes Through the Years
1978	✓ Added the Stop Ahead and Narrow Bridge symbol signs (Narrow Bridge sign was eliminated in 2003) ✓ Required guide signs to be white-on-green
1988	✓ Added logo signs (e.g., gas, restaurant, motel, and camping trademark symbols) ✓ Added signs for recreational and cultural interests
2000	✓ This was the first on-line edition ✓ Added Metric units of measurements ✓ Changed the "yield line" from a solid white line to a series of isosceles triangles
2003	✓ Added In-Street Pedestrian Crossing signs ✓ Replaced the advance regulatory speed reduction sign with a warning sign ✓ Allow retroreflective strips on sign posts of regulatory and warning signs to increase visibility ✓ Eliminated the symbol-type Narrow Bridge sign because of confusion
2009	✓ Greatly increased the amount of text and the number of figures and tables ✓ Added paragraph numbering throughout for easier cross-referencing, and eliminated all metric dimensions ✓ Require mixed-case legends for the names of places, streets, and highways on guide signs ✓ Require fluorescent yellow-green color for all school signs

5.1.3. Principles of Traffic Control Devices

As noted in Section 1A.02 of the *MUTCD*, a traffic control device should meet five basic requirements:

- ✓ Fulfill a need;
- ✓ Command attention;
- ✓ Convey a clear, simple meaning;
- ✓ Command respect from road users; and
- ✓ Give adequate time for proper response.

Therefore, it is important to consider the design, placement, operation, maintenance, and uniformity of all traffic control devices in order to maximize their ability to meet these five requirements. Also, carefully consider vehicle speed as an element that governs the design, operation, placement, and location of virtually all traffic control devices.

The proper use of traffic control devices should provide the reasonable and prudent road user with the information necessary to use the streets, highways, pedestrian facilities, and bikeways, both safely and lawfully. Uniformity of the meaning and application of traffic control devices is vital to their effectiveness.

5.1.4. Removing Unauthorized Signs and Markings

It is illegal for anyone to place, maintain, or display upon or in view of any highway any unauthorized sign or marking, which purports to be, is an imitation of, or resembles an official traffic control device. If you are aware of an illegal or non-conforming "traffic-control device," have it removed as soon as possible because an illegal device:

- ✓ Creates disrespect for the official traffic-control devices.
- ✓ Encourages others to install similar illegal devices.
- ✓ May create a safety problem.

There is no need to provide advance notice to road users prior to removing an illegal device.

5.1.5. Engineering Study and Engineering Judgment

Always base the decision to use a particular device at a specific location on either an engineering study or the application of engineering judgment. Refer to SDDCTEA Pamphlet 55-08 for guidance on engineering studies that can be conducted as recommended. Thus, while the *MUTCD* and this pamphlet provide standards, guidance, and options for the design and application of traffic control devices, these documents should not be considered a substitute for engineering judgment.

Exercise engineering judgment in the selection and application of traffic control devices, as well as in the location and design of the roads and streets that the devices complement. A qualified traffic engineer should make the final decision concerning the addition or removal of any traffic control device.

5.1.6. Requests to Experiment with Unique Traffic Control Devices

If a military installation wishes to experiment with a traffic control device that is not included in either the *MUTCD* or this pamphlet, or if they wish to request an official change to or an interpretation of the requirements of the *MUTCD*, an official should submit a request in writing to SDDCTEA. Requests should:

- ✓ Include information in accordance with Section 1A.10 of the *MUTCD* (relating to interpretations, experimentations, changes, and interim approvals);
- ✓ Identify the information that the military installation proposes to compile during any experiment identified in the request, since the collection of any data and the development of any follow-up report generally will be a conditional part of the request.

SDDCTEA may forward an official request to FHWA for review and approval.

5.1.7. Abbreviations for Signs and Markings

Section 1A.15 in the *MUTCD* identifies acceptable abbreviations for use on traffic signs and pavement markings. In some cases a prompt word is required either immediately before or after the abbreviation. Periods should not be used with abbreviations.

In addition to the abbreviations in the *MUTCD*, Exhibit 5.3 and the DoD Supplement identify some additional abbreviations that SDDCTEA approves for use on military installations. If additional abbreviations are desired, the recommended procedure is to forward your suggestions to SDDCTEA for determination of acceptable use. This will also help SDDCTEA expand the list in Exhibit 5.3 and the DoD Supplement.

In the past, FHWA determined that there were a lot of abbreviations that were misinterpreted or were so difficult that they unnecessarily detracted drivers' attention. Table 1A-3 in the *MUTCD* identifies some of the problem words which should not be used.

Exhibit 5.3: Acceptable Abbreviations for Traffic Control

Word Message	Abbreviation*	Word Message	Abbreviation*
Air Force Base	AFB	Physical Training	PT
Air National Guard	ANG	United States Air Force	USAF
Army National Guard	ARNG	United States Air Force Reserve	USAFR
Building	BLDG, Bldg	United States Army	US ARMY, US Army
Department	DEPT, Dept		
Division	DIV, Div	United States Army Garrison	USAG
Fort	FT, Ft	United States Army Reserve	USAR
Headquarters	HQ, Hq	United States Coast Guard	USCG
Joint Base	JB	United States Marine Corps	USMC, US Marine Corps
Marine Corps Air Station	MCAS	United States Marine Corps Reserve	USMCR
Marine Corps Base	MCB	United States Navy	USN, US Navy
Naval Air Station	NAS		
Naval Base	NB	United States Navy Reserve	USNR
Naval Station	NS	Veterans Affairs	VA
Naval Support Activity	NSA		

**Upper/lowercase abbreviations are for use only on guide signs.*

5.1.8. *MUTCD* Target Compliance Dates

The 2009 version of the *MUTCD* has several changes that agencies are required to comply with. Different changes have different compliance dates. These dates are shown in Exhibit 5.4. Note that if the date has passed, every effort should be made to comply as soon as practical.

Exhibit 5.4: Target Compliance Dates Established by the FHWA

2009 MUTCD SECTION NUMBER(S)	2009 MUTCD SECTION TITLE	SPECIFIC PROVISION	COMPLIANCE DATE
2A.08	Maintaining Minimum Retroreflectivity	Implementation and continued use of an assessment or management method that is designed to maintain regulatory and warning sign retroreflectivity at or above the established minimum levels (see Paragraph 2)	June 13, 2014*
2A.19	Lateral Offset	Crashworthiness of sign supports on roads with posted speed limit of 50 mph or higher (see Paragraph 2)	January 17, 2013 (date established in the 2000 MUTCD)
2B.40	ONE WAY Signs (R6-1, R6-2)	New requirements in the 2009 MUTCD for the number and locations of ONE WAY signs (see Paragraphs 4, 9, and 10)	December 31, 2019
2C.06 THROUGH 2C.14	Horizontal Alignment Warning Signs	Revised requirements in the 2009 MUTCD regarding the use of various horizontal alignment signs (see Table 2C-5)	December 31, 2019
2E.31, 2E.33, AND 2E.36	Plaques for Left-Hand Exits	New requirement in the 2009 MUTCD to use E1-5aP and E1-5bP plaques for left-hand exits	December 31, 2014
4D.26	Yellow Change and Red Clearance Intervals	New requirement in the 2009 MUTCD that durations of yellow change and red clearance intervals shall be determined using engineering practices (see Paragraphs 3 and 6)	June 13, 2017 or when timing adjustments are made to the individual intersection and/or corridor, whichever occurs first
4E.06	Pedestrian Intervals and Signal Phases	New requirement in the 2009 *MUTCD* that the pedestrian change interval shall not extend into the red clearance interval and shall be followed by a buffer interval of at least 3 seconds (see Paragraph 4)	June 13, 2017 or when timing adjustments are made to the individual intersection and/or corridor, whichever occurs first

Exhibit 5.4: Target Compliance Dates Established by the FHWA (Continued)

2009 MUTCD SECTION NUMBER(S)	2009 MUTCD SECTION TITLE	SPECIFIC PROVISION	COMPLIANCE DATE
6D.03**	Worker Safety Considerations	New requirement in the 2009 *MUTCD* that all workers within the right-of-way shall wear high-visibility apparel (see Paragraphs 4, 6, and 7)	December 31, 2011
6E.02**	High-Visibility Safety Apparel	New requirement in the 2009 *MUTCD* that all flaggers within the right-of-way shall wear high-visibility apparel	December 31, 2011
7D.04**	Uniform of Adult Crossing Guards	New requirement in the 2009 *MUTCD* for high-visibility apparel for adult crossing guards	December 31, 2011
8B.03, 8B.04	Grade Crossing (Crossbuck) Signs and Supports	Retroreflective strip on Crossbuck sign and support (see Paragraph 7 in Section 8B.03 and Paragraphs 15 and 18 in Section 8B.04)	December 31, 2019
8B.04	Crossbuck Assemblies with YIELD or STOP Signs at Passive Grade Crossings	New requirement in the 2009 *MUTCD* for the use of STOP or YIELD signs with Crossbuck signs at passive grade crossings	December 31, 2019

* Types of signs other than regulatory or warning are to be added to an agency's management or assessment method as resources allow.

** *MUTCD* requirement is a result of a legislative mandate

5.2. TRAFFIC LAW ENFORCEMENT

In accordance with Motor Vehicle Traffic Supervision Regulations [AR 190-5/OPNAV 11200.5D/AFI 31-218(I)/MCO 5110.1D/DLAR 5720.1], traffic violations can be enforced either under:

1. Laws of the state or U.S. territory in which the installation is located, by using a DoD Form 1805 (United States District Court Violation Notice).
2. DoD regulations or administrative procedures established by installation commanders, by using a DD Form 1408 (Armed Forces Traffic Ticket).

In most cases, traffic violators on military installations probably have the greatest fear facing their installation commander as opposed to paying a fine to a local magistrate and possibly receiving points from the state driver licensing bureau. Therefore, Option 2 may be a more effective deterrent to drivers committing a follow-up violation.

Option 2 also provides some opportunities to enforce regulations not addressed in the applicable state motor vehicle code or to reduce the need to install as many traffic control devices. For example:

- ✓ Military regulations may prohibit drivers from using cell phones, or may require all people on motorcycles and mopeds to wear protective helmets, eye protection, hard-soled shoes, long trousers, and brightly colored or reflective outer upper garments; but this may or may not be required at other locations within the state or host nation.
- ✓ Military installations can establish and post (*only at the installation access points*) a base wide speed limit without the need to post speed limit signs at maximum intervals that may otherwise be required by laws of the state or host nation.

Although Option 2 may allow some flexibility, this should not be construed to mean that traffic control devices should not conform to the standards and principles established in the *MUTCD*.

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CHAPTER 6—INTERSECTION TRAFFIC CONTROL

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KEY POINT

The *MUTCD* provides warrants for traffic control devices.

Sign codes used in this pamphlet are consistent with the *MUTCD*. The *MUTCD* uses a unique sign code for each standard sign. See Section 7.1.3 (page 7-10) for more information.

One of the most common questions SDDCTEA receives is, "What is the appropriate type of intersection traffic control for a given set of conditions at an intersection?" In practice, there are six basic types of intersection traffic control:

- ✓ No control
- ✓ YIELD control
- ✓ STOP control
- ✓ Multi-way stop control
- ✓ Traffic control signals
- ✓ Roundabouts

Use the minimum appropriate level of traffic control that promotes safe and efficient traffic operations and minimizes delay while still being cost effective. The *MUTCD* provides guidelines for selecting appropriate traffic control devices. These guidelines are primarily based on traffic volumes on the major street, minor street, pedestrian activity and crash history.

The assessment of needed traffic control must be conducted by a qualified traffic engineer. When appropriate, installations should seek traffic engineering assistance from others, such as the state transportation agency, their county, a local traffic engineering consultant, or SDDCTEA.

Engineering judgment should be used to establish intersection control. The following factors should be considered:

- ✓ Vehicular, bicycle, and pedestrian traffic volumes on all approaches;
- ✓ Number and angle of approaches;
- ✓ Approach speeds;
- ✓ Sight distance available on each approach; and
- ✓ Reported crash experience.

YIELD or STOP signs should be used at an intersection if one or more of the following conditions exist:

- ✓ An intersection of a less important road with a main road where application of the normal right-of-way rule would not be expected to provide reasonable compliance with the law;
- ✓ A street entering a designated through highway or street; and/or
- ✓ An unsignalized intersection in a signalized area.

In addition, the use of YIELD or STOP signs should be considered at the intersection of two minor streets or local roads where the intersection has more than three approaches and where one or more of the following conditions exist:

- ✓ The combined vehicular, bicycle, and pedestrian volume entering the intersection from all approaches averages more than 2,000 units per day;

- ✓ The ability to see conflicting traffic on an approach is not sufficient to allow a road user to stop or yield in compliance with the normal right-of-way rule if such stopping or yielding is necessary; and/or
- ✓ Crash records indicate that five or more crashes that involve the failure to yield the right-of-way at the intersection under the normal right-of-way rule have been reported within a 3-year period, or that three or more such crashes have been reported within a 2-year period.

YIELD or STOP signs should not be used for speed control.

6.1. NO CONTROL

The most basic control type is to have no traffic control. In this case, the motorist has the basic responsibility to navigate through the intersection and to assign right-of-way among other vehicles. State or local laws written in accordance with the 'Uniform Vehicle Code' establish the right-of-way rule at intersections having no regulatory traffic control signs such that the driver of a vehicle approaching an intersection must yield the right-of-way to any vehicle or pedestrian already in the intersection. When two vehicles approach an intersection from different streets or highways at approximately the same time, the right-of-way rule requires the driver of the vehicle on the left to yield the right-of-way to the vehicle on the right.

Some applications for intersections with no control may include very low-volume streets in housing areas, parking areas, or low-volume driveways that intersect local or collector roadways. The absence of traffic control should be used only in very low-volume applications where sufficient sight distance is available.

6.2. YIELD CONTROL

6.2.1. Purpose and Applications

At through streets or highways, the right-of-way can be modified (*or 'assigned'*) by placing YIELD signs or STOP signs on one or more approaches. Vehicles controlled by a YIELD (R1-2) sign must slow down or stop, when necessary, to avoid interfering with conflicting traffic. YIELD signs may be warranted if engineering judgment indicates that one or more of the conditions shown in Exhibit 6.1 exist. Large sight triangles are required with the use of YIELD signs. Adequate intersection sight distance is usually the controlling factor on whether a yield sign can be placed in lieu of a stop sign on low volume roadways.

YIELD sign, R1-2

Exhibit 6.1: When to Use a YIELD Sign

	When the ability to see all potentially conflicting traffic is sufficient to allow a motorist traveling at the posted speed to pass through the intersection or to stop in a reasonably safe manner.
	At a merging area where there is not adequate sight or acceleration distance.
	At a channelized right-turn lane without an adequate acceleration lane.
	At the entrance to a roundabout.
	At the second crossroad of a divided highway, where the median width at the intersection is 30 feet or greater.
	At an intersection where special problems exist and where engineering judgment indicates that the problems are susceptible to correction by the use of a YIELD sign.

6.2.2. Sign Layout and Placement

Sizes of the YIELD sign vary from 30 inches to 60 inches depending on roadway classification. In most cases, the use of a 36-inch by 36-inch by 36-inch sign is appropriate for single-lane conventional roads. The use of a 48-inch by 48-inch by 48-inch sign is appropriate for multi-lane conventional roads and expressways. Expressways are typically divided with full to partial control of access. Conventional roads typically include all roadway classifications less than expressways.

The YIELD sign shall be installed on the right side of the roadway approach to which it applies. The YIELD sign shall be located as close as practical to the intersection it regulates, at the point where a vehicle should yield, while optimizing its visibility to the road user. The maximum distance the YIELD sign should be placed is 50 feet from the edge of pavement of the intersected roadway. When a YIELD sign is installed at an intersection and the sign visibility is restricted, a Yield Ahead (W3-2) sign shall be installed in advance of the YIELD sign.

Yield Ahead sign, W3-2

6.3. STOP CONTROL

6.3.1. Purpose and Applications

KEY POINT

Stop control should never be used for speed control.

STOP sign, R1-1

Stop control should never be used to reduce vehicular speeds. Stop control used in this manner breeds disrespect for STOP signs. When drivers sense that a STOP sign is unwarranted, traffic rarely comes to a full stop, and drivers tend to increase their speed between STOP signs to make up for lost time.

STOP (R1-1) signs should be used if engineering judgment indicates that a stop is always required because one or more of the conditions shown in Exhibit 6.2 exist.

Once the decision has been made to install two-way stop control, the decision regarding the appropriate street to stop should be based on engineering analysis. In most cases, use stop control on the street carrying the lower volume of traffic. Exceptions to using two-way STOP control is when traffic volumes on both streets are balanced and visibility, pedestrian safety, or geometric conditions warrant stopping the other legs. If this is your situation, multi-way STOP control (as discussed in Section 6.4) should be considered.

Exhibit 6.2: When to Use a STOP Sign

	For a street entering a through highway or street.
	At an unsignalized intersection in a signalized area.
	Where there is inadequate intersection sight distance or crash records indicate a need for STOP sign control.

6.3.2. Layout and Placement

At most military installations, STOP signs should be 30 inches or 36 inches. The 30-inch STOP sign is adequate on conventional roads, except when used at intersections with multi-lane approaches, in which case the 36-inch version may be required. At locations where a stop is unexpected, an oversized 48-inch STOP sign can be used.

Proper traffic control is extremely critical. At one installation, an SDDCTEA study noted that a STOP sign was warranted in lieu of a YIELD sign; however, the $250 STOP sign was never installed. A few months later there was a fatality at this location. The Army Safety Center investigated this crash and concluded that the fatality could have been prevented if a STOP sign was in place.

The STOP sign shall be installed on the right side of the roadway approach to which it applies. Locate the STOP sign as close as practical to the intersection it regulates at the point where a vehicle should stop, while optimizing its visibility to the road user. The maximum distance the STOP sign should be placed is 50 feet from the edge of pavement of the intersected roadway. When the STOP sign is installed at the required location and the sign visibility is restricted, install a Stop Ahead (W3-1) sign in advance of the STOP sign.

See page 7-75 for appropriate advance placement distances for warning signs, such as the Stop Ahead sign.

Note that 2-WAY plaques are obsolete, and are no longer allowed to be installed with STOP signs at two-way STOP controlled intersections.

The CROSS TRAFFIC DOES NOT STOP (W4-4p) plaque may be used in combination with a STOP sign when engineering judgment indicates that conditions are present that could cause drivers to misinterpret the intersection, perhaps as a multi-way stop. Alternate messages such as TRAFFIC FROM LEFT (RIGHT) DOES NOT STOP (W4-4aP) plaque or ONCOMING TRAFFIC DOES NOT STOP (W4-4bP) plaque may be used when such messages more accurately describe the traffic controls established at the intersection.

Stop Ahead sign, W3-1

W4-4p

6.4. MULTI-WAY STOP CONTROL

> **KEY POINT**
>
> Per the 2009 *MUTCD*, 2-Way, 3-Way, and 4-Way plaques mounted with stop signs are obsolete.

6.4.1. Purpose and Application

Multi-way stop control is useful as a safety measure at locations where sight distance or crash history cannot be corrected through other means. However, it is a safety concern for pedestrians, bicyclists, and all road users that are expecting other road users to stop. Multi-way stop control can be used where the volume of traffic on the intersecting roads is approximately equal.

Multi-way stop control

R1-3p

The decision to install multi-way stop control should be based on an engineering study. The criteria in Exhibit 6.3 should be considered in the engineering study. Multi-way STOP signs must always be supplemented with an ALL WAY (R1-3p) plaque so that approaching motorists are aware of the traffic control requirements on other approaches. This plaque shall have a white legend and border on a red background. The minimum size for the ALL WAY sign is 18 inches by 6 inches. This plaque should only be used if all approaches to the intersection are required to stop. If all approaches are not required to stop, supplemental plaques should not be installed on the stopped approaches.

Exhibit 6.3: Justification for Multi-way Stop Control

TEMPORARY MEASURE	✓ Where traffic control signals are justified, the multi-way stop is an interim measure that can be installed quickly to control traffic while arrangements are being made for the installation of the traffic control signal.
CRASHES	✓ If a crash problem is present, as indicated by five or more reported crashes in a 12-month period, and susceptible to correction by a multi-way stop installation.
MINIMUM TRAFFIC VOLUMES	✓ The vehicular volume entering the intersection from the major street approaches (total of both approaches) averages at least 300 vehicles per hour for any 8 hours of an average day, and; ✓ The combined vehicular, pedestrian, and bicycle volume entering the intersection from the minor street approaches (total of both approaches) averages at least 200 units per hour for the same 8 hours, with an average delay to minor-street vehicular traffic of at least 30 seconds per vehicle during the highest hour.
HIGH SPEED CONSIDERATIONS	✓ If the 85th-percentile approach speed of the major-street traffic exceeds 40 mph, the minimum vehicular volume warrant is 70 percent of the values shown for the “minimum traffic volume” warrant.
COMBINATION WARRANT	✓ If there are four or more reported crashes in a 12-month period that are susceptible to correction by a multi-way stop installation, and the minimum vehicular volume warrant is 80 percent of the values shown for the “minimum traffic volume” warrant.

Source: FHWA, MUTCD

6.5. TRAFFIC SIGNALS, YES OR NO?

KEY POINT

Traffic signals must meet at least one of the nine traffic signal warrants provided in the *MUTCD*.

Traffic signals assign the right-of-way between conflicting traffic flows at intersections. Traffic signals are needed when STOP sign control cannot do the job effectively. Traffic signals can also better accommodate pedestrian crossings at intersections.

Unwarranted, poorly designed, improperly timed, or poorly maintained traffic signals may cause:

- ✓ Increased crash frequency
- ✓ Excessive delay
- ✓ Disregard of signal indications
- ✓ Circuitous travel by alternate routes

The selection and use of signals should be based on an engineering study of roadway, traffic, and other conditions. At least one of the nine signal warrants (given in the *MUTCD*) must be met before installing traffic signals; however, meeting the warrants do not require the installation of traffic signals. Many state DOTs require at least two warrants be met before installing traffic signals.

The nine *MUTCD* traffic signal warrants are based on vehicular volume, pedestrian activities, and crash experience. The nine warrants are listed and briefly described in Exhibit 6.4. The listing is for informational purposes only and does not provide complete guidance; refer to chapter 4C of the *MUTCD* for additional information on warrants. Warrants must be professionally evaluated by a qualified traffic engineer. If you have an intersection that you feel should be signalized and require assistance with the analysis, consult SDDCTEA or your state department of transportation (for external intersections) for a detailed evaluation.

Exhibit 6.4: Traffic Signal Warrants

WARRANT	PURPOSE
WARRANT 1: EIGHT-HOUR VEHICULAR VOLUME	✓ The eight-hour vehicular volume warrant is intended for application where a large volume of intersecting traffic is the principal reason to consider installing a traffic control signal, or where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or conflict when entering or crossing the major street.
WARRANT 2: FOUR-HOUR VEHICULAR VOLUME	✓ The four-hour vehicular volume signal warrant conditions are intended to be applied where the volume of intersecting traffic is the principal reason to consider installing a traffic control signal.
WARRANT 3: PEAK HOUR	✓ The peak hour signal warrant is intended for use at a location where conditions are such that for a minimum of one hour of an average day, the minor-street traffic suffers undue delay when entering or crossing the major street. The warrant should be applied only in unusual cases where land uses discharge or attract a larger number of vehicles over a short time period.
WARRANT 4: PEDESTRIAN VOLUME	✓ The pedestrian volume signal warrant is intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street. ✓ Intersection MAY be a candidate if the pedestrian volume crossing the major street at an intersection or mid-block location during an average day is 100 or more for each of any four hours or 190 or more during any one hour; and in the same hour, there are fewer than 60 gaps in the traffic stream of adequate length to allow a pedestrian to cross.
WARRANT 5: SCHOOL CROSSING	✓ The school crossing signal warrant is intended for application where the fact that school children cross the major street is the principal reason to consider installing a traffic control signal. ✓ Intersection MAY be a candidate if there are a minimum of 20 students during the highest crossing hour, and there are insufficient gaps in traffic.

Exhibit 6.4: Traffic Signal Warrants (Continued)

WARRANT	PURPOSE
WARRANT 6: COORDINATED SIGNAL SYSTEM	✓ The coordinated signal warrant is intended for application where the progressive movement in a coordinated signal system sometimes necessitates installing traffic control signals in order to maintain proper platooning of vehicles.
WARRANT 7: CRASH EXPERIENCE	✓ The crash experience signal warrant conditions are intended for application where the severity and frequency of crashes are the principal reasons to consider installing a traffic control signal. ✓ Intersection MAY be a candidate if five or more reported crashes, of types susceptible to correction by a traffic control signal, have occurred within a 12-month period.
WARRANT 8: ROADWAY NETWORK	✓ Installing a traffic control signal at some intersections might be justified to encourage concentration and organization of traffic flow on a roadway network.
WARRANT 9: INTERSECTION NEAR A GRADE CROSSING	✓ This warrant is intended for use where the proximity between an intersection and grade crossing is the principal reason to consider installing a traffic control signal.

Source: FHWA, MUTCD

6.6. ROUNDABOUTS

A roundabout is defined as a modified traffic circle that conforms to specific geometric design criteria that promotes driver awareness, reduced traffic speeds, and improved traffic flow. Roundabouts reduce traffic congestion by eliminating left turns. Since each approach to the roundabout is essentially an intersection with a one-way street, the driver is not delayed by traffic flow from two directions. Only right turns are allowed.

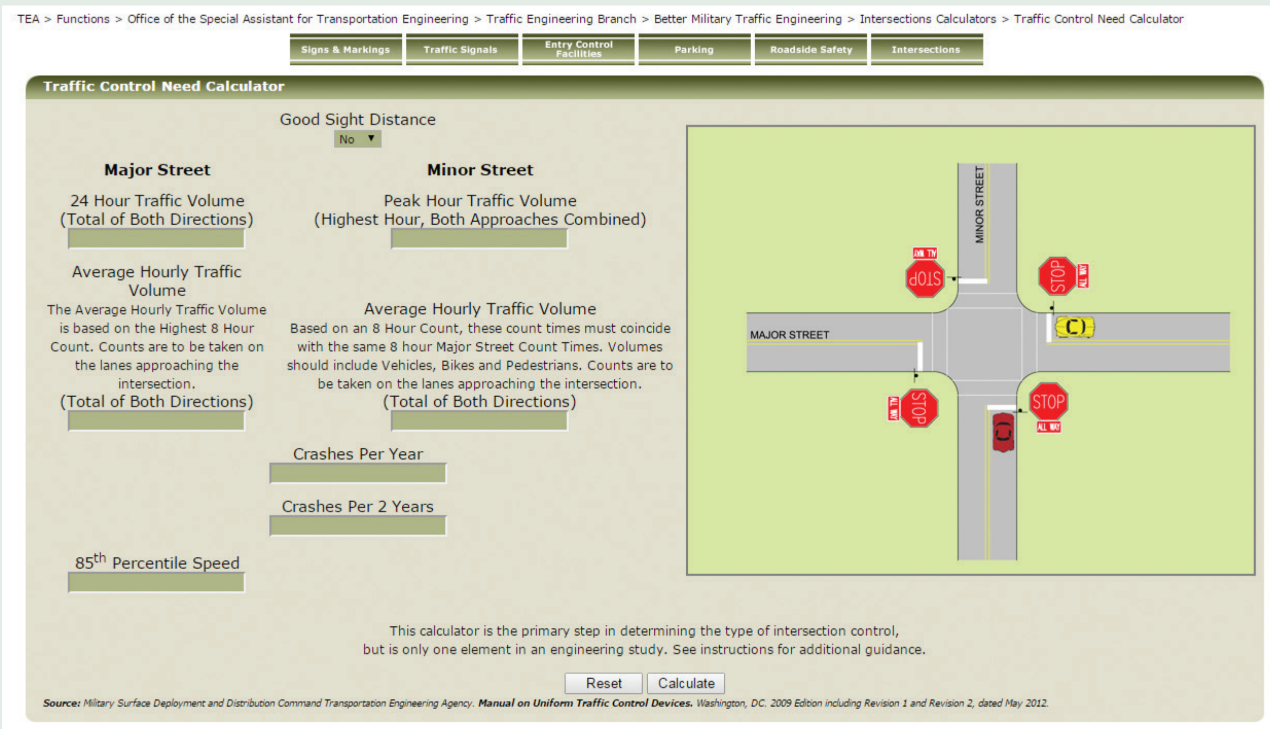
Roundabouts are advantageous because traffic is continuously flowing versus stopping as with traffic signal or multi-way stop control. The disadvantage is that they require a higher initial cost for construction when compared to a traffic signal or stop control. See Chapter 10 for more information on roundabouts.

Roundabout Example

6.7. CONTROL SELECTION

Choosing the proper type of intersection traffic control requires site assessment, warrant analyses and capacity analyses. SDDCTEA is available for professional assistance. SDDCTEA's BMTE has a calculator that can be used to preliminarily analyze an intersection for possible traffic control.

BMTE TRAFFIC CONTROL SELECTION CALCULATOR



6.8. RAILROAD GRADE CROSSINGS

Although not considered to be a traditional intersection configuration, railroad grade crossings are the intersection of a roadway and a railroad track. Trains have the right of way at grade crossings, with different levels of warning used for vehicular traffic. These levels include Active Grade Crossings and Passive Grade Crossings. Active Grade Crossings include flashing lights and may include gates, while Passive Grade Crossings do not use flashing lights or gates, but should be equipped with correct signs and pavement markings.

Traffic control, signs, and pavement markings for railroad grade crossings must conform to standards set forth in the *MUTCD* Part 8. Standards are presented in the *MUTCD* regarding passive and active traffic control systems.

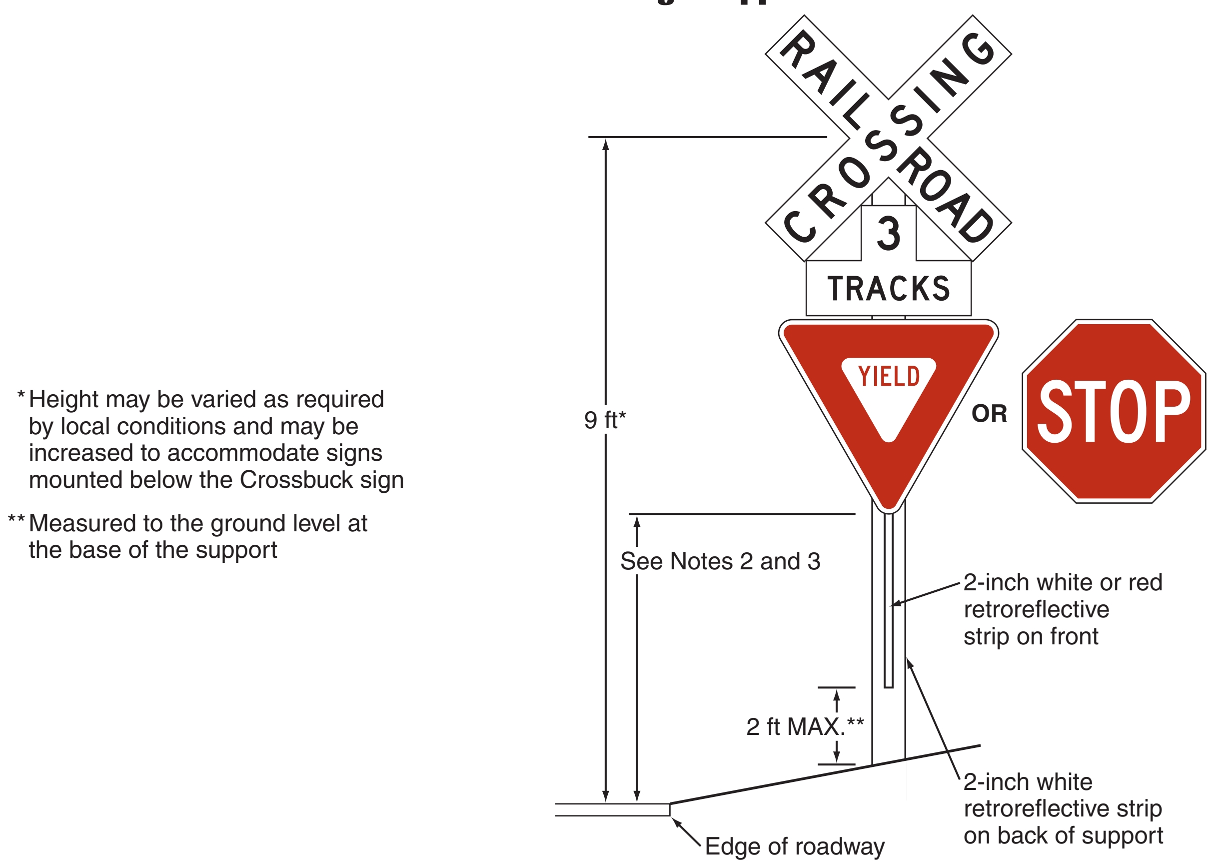
Passive traffic control systems, consisting of signs and pavement markings only, identify and direct attention to the location of the grade crossing advising road users to slow down, yield, or stop at the grade crossing.

Active traffic control systems inform road users of the approach or presence of rail traffic at grade crossings. Examples of some the systems used are four-quadrant gates, automatic gates, flashing light signals, traffic control signals, actuated blank-out and variable message signs, and other active traffic control devices.

6.8.1. Typical Signage for Passive Traffic Control Systems

Per the *MUTCD* Section 8B, a passive grade crossing Crossbuck Assembly shall consist of a Crossbuck (R15-1) sign, and a Number of Tracks (R15-2P) plaque if two or more tracks are present, and provide either a YIELD (R1-2) or STOP (R1-1) sign. Before installing a YIELD sign, an engineering study should be performed to determine if a STOP sign is warranted due to insufficient intersection sight distance. Exhibit 6.5 illustrates a Crossbuck Assembly with a YIELD or STOP sign on the Crossbuck Sign Support. Alternatively, Exhibit 6.6 illustrates a Crossbuck Assembly with a YIELD or STOP sign on a Separate Sign Support.

Exhibit 6.5: Crossbuck Assembly with a YIELD or STOP Sign on the Crossbuck Sign Support

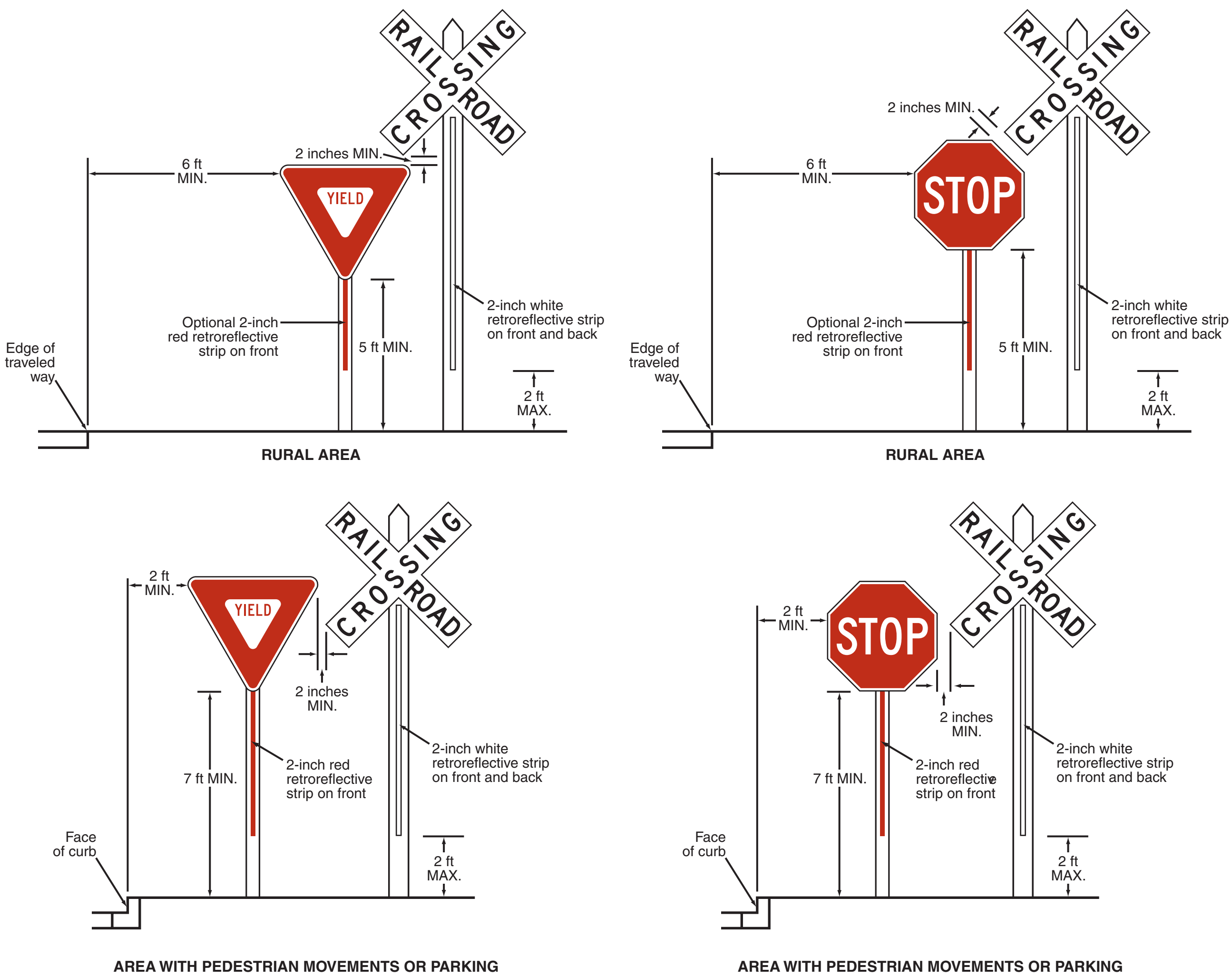


Notes:

1. YIELD or STOP signs are used only at passive crossings. A STOP sign is used only if an engineering study determines that it is appropriate for that particular approach.
2. Mounting height shall be at least 4 feet for installations of YIELD or STOP signs on existing Crossbuck sign supports.
3. Mounting height shall be at least 7 feet for new installations in areas with pedestrian movements or parking.

Source: MUTCD *Figure 8B-2*

Exhibit 6.6: Crossbuck Assembly with a YIELD or STOP Sign on a Separate Sign Support



Notes:

1. YIELD signs are used only at passive crossings.
2. STOP signs are used only at passive crossings and only if an engineering study determines that it is appropriate for that particular approach.
3. Place the face of the signs in the same plane and place the YIELD or STOP sign closest to the traveled way. Provide a 2-inch minimum separation between the edge of the Crossbuck sign and the edge of the YIELD or STOP sign.

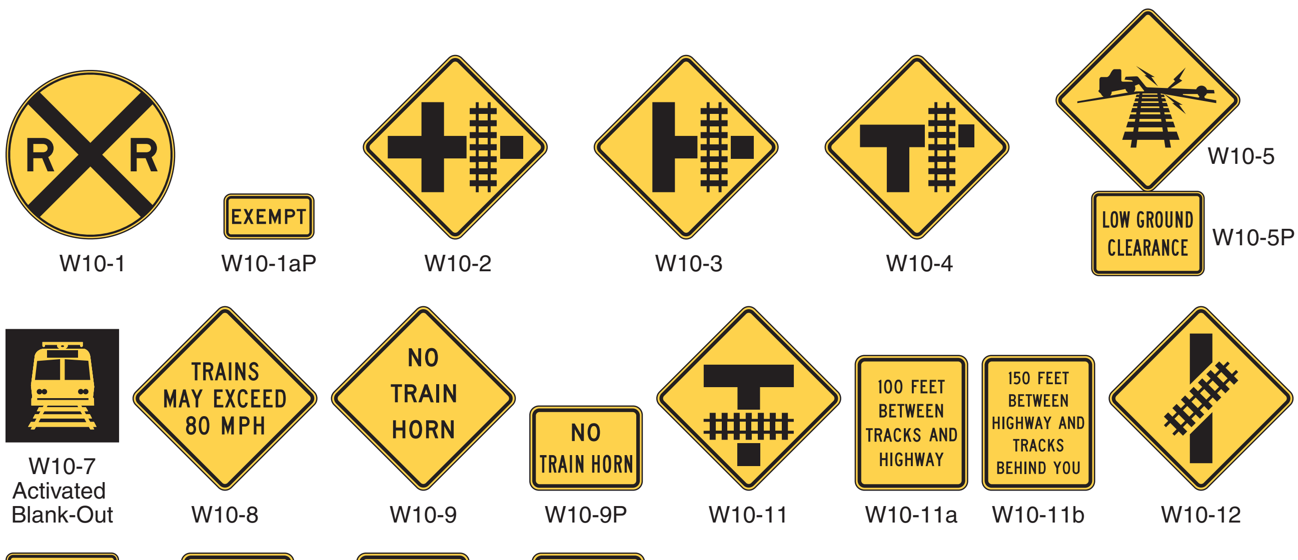
Source: MUTCD, *Figure 8B-3*

6.8.2. Grade Crossing Advance Warning Signs

A Highway-Rail Grade Crossing Advance Warning (W10-1) sign, the first sign shown in Exhibit 6.7, shall be used on each highway in advance of every highway-rail grade crossing in semi-exclusive alignments, except in the following circumstances:

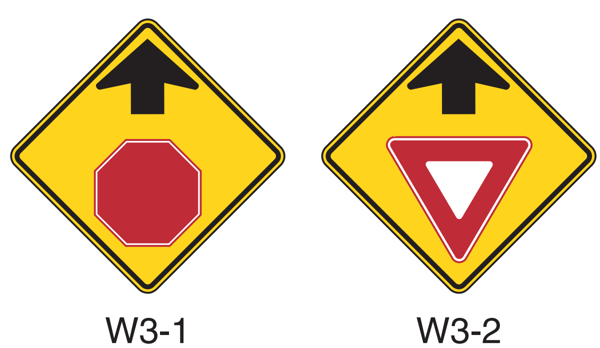
- ✓ On an approach to a grade crossing from a T-intersection with a parallel highway if the distance from the edge of the track to the edge of the parallel roadway is less than 100 feet and W10-3 signs are used on both approaches of the parallel highway.
- ✓ On low-volume, low-speed highways crossing minor spurs or other tracks that are infrequently used and road users are directed by an authorized person on the ground to not enter the crossing at all times that approaching rail traffic is about to occupy the crossing.
- ✓ In business or commercial areas where active grade crossing traffic control devices are in use.
- ✓ Where physical conditions do not permit even a partially effective display of the sign.

Exhibit 6.7: Warning Signs and Plaques for Grade Crossings



Note: The W10-11 sign is a W10-3 sign modified for geometrics. Other signs can be oriented or revised as needed to better portray the geometrics of the roadways and the tracks.

A Yield Ahead (W3-2) or Stop Ahead (W3-1) Advance Warning sign shall also be installed if the visibility of the Crossbuck Assembly is restricted by roadway geometry or obstructions. If a Yield Ahead or Stop Ahead sign is installed on the approach to the crossing, the W10-1 sign shall be installed upstream from the Yield Ahead or Stop Ahead sign.

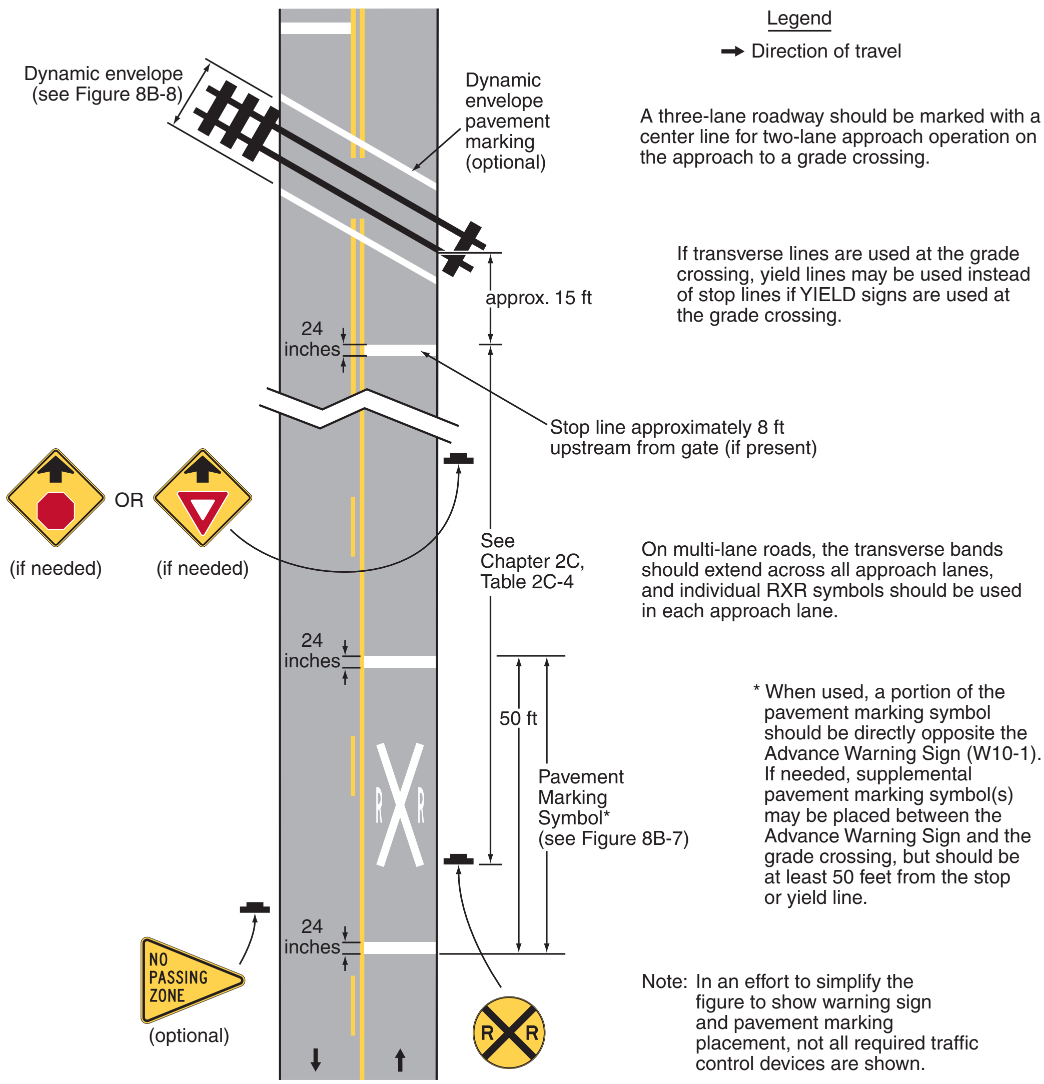


6.8.3. Typical Pavement Markings for Passive Traffic Control Systems

All grade crossing pavement markings shall be retroreflectorized white excluding centerline pavement markings. On paved roadways, pavement markings in advance of a grade crossing shall consist of an X, the letters RR, a no-passing zone marking, and certain transverse lines as shown in Exhibit 6.8. Identical markings shall be placed in each approach lane on all paved approaches to grade crossings where the posted or statutory highway speed is 40 mph or greater.

Pavement markings shall not be required at grade crossings where the posted or statutory highway speed is less than 40 mph if an engineering study indicates that other installed devices provide suitable warning and control. Pavement markings shall not be required at grade crossings in urban areas if an engineering study indicates that other installed devices provide suitable warning and control.

Exhibit 6.8: Example of Placement of Warning Signs and Pavement Markings at Grade Crossings



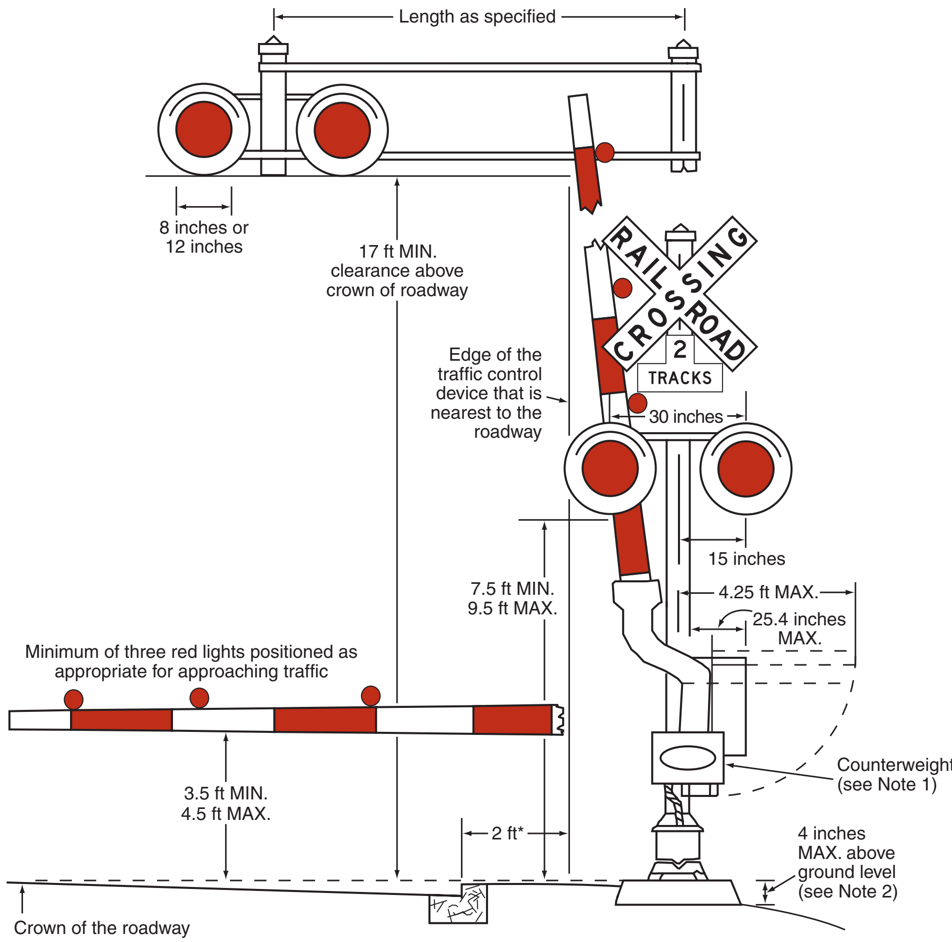
Source: MUTCD, *Figure 8B-6*

6.8.4. Active Traffic Control Systems

Active traffic control systems inform road users of the approach or presence of rail traffic at grade crossings. These systems include four-quadrant gate systems, automatic gates, flashing light signals, traffic control signals, actuated blank-out and variable message signs, and other active traffic control devices.

As illustrated in Exhibit 6.9, post-mounted and overhead flashing-light signals may be used separately or in combination with each other as determined by an engineering study. Flashing lights may be used without automatic gate assemblies as determined by an engineering study.

Exhibit 6.9: Composite Drawing of Active Traffic Control Devices for Grade Crossings Showing Clearances



*For locating this reference line on an approach that does not have a curb, see *MUTCD* Section 8C.01.

Notes:

1. Where gates are located in the median, additional median width may be required to provide the minimum clearance for the counterweight supports.
2. The top of the signal foundation should be no more than 4 inches above the surface of the ground and should be at the same elevation as the crown of the roadway. Where site conditions would not allow this to be achieved, the shoulder side slope should be re-graded or the height of the signal post should be adjusted to meet the 17-foot vertical clearance requirement.

Source: MUTCD*, Figure 8C-1*

When indicating the approach or presence of rail traffic, the flashing-light signal shall display toward approaching highway traffic two red lights mounted in a horizontal line flashing alternately. If used, flashing-light signals shall be placed to the right of approaching highway traffic on all highway approaches to a grade crossing. They shall be located laterally with respect to the highway in compliance with the figure above except where such location would adversely affect signal visibility.

If used at a grade crossing with highway traffic in both directions, back-to-back pairs of lights shall be placed on each side of the tracks. On multi-lane one-way streets and divided highways, flashing-light signals shall be placed on the approach side of the grade crossing on both sides of the roadway or shall be placed above the highway.

Each red signal unit in the flashing-light signal shall flash alternately. The number of flashes per minute for each lamp shall be 35 minimum and 65 maximum. Each lamp shall be illuminated approximately the same length of time. Total time of illumination of each pair of lamps shall be the entire operating time. Flashing-light units shall use either 8-inch or 12-inch nominal diameter lenses, determined similarly as traffic signal indications.

An automatic gate is a traffic control device used in conjunction with flashing-light signals. The automatic gate as shown in the figure above shall consist of a drive mechanism and a fully retroreflectorized red- and white-striped gate arm with lights. When in the down position, the gate arm shall extend across the approaching lanes of highway traffic.

In the normal sequence of operation, unless constant warning time detection or other advanced system requires otherwise, the flashing-light signals and the lights on the gate arm (in its normal upright position) shall be activated immediately upon detection of approaching rail traffic. The gate arm shall start its downward motion not less than 3 seconds after the flashing-light signals start to operate, shall reach its horizontal position at least 5 seconds before the arrival of the rail traffic, and shall remain in the down position as long as the rail traffic occupies the grade crossing.

When the rail traffic clears the grade crossing, and if no other rail traffic is detected, the gate arm shall ascend to its upright position, following which the flashing-light signals and the lights on the gate arm shall cease operation.

Gate arms shall be fully retroreflectorized on both sides and shall have vertical stripes alternately red and white at 16-inch intervals measured horizontally.

Gate arms shall have at least three red lights. When activated, the gate arm light nearest the tip shall be illuminated continuously and the other lights shall flash alternately in unison with the flashing-light signals. The entrance gate arm mechanism shall be designed to fail safe in the down position.

CHAPTER 7—SIGNS

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7.1. GENERAL

A common problem on military installations is too many regulatory and warning signs. There is a misconception that extra signs "can't do any harm." In reality, extra signs create unnecessary clutter and detract from necessary traffic signs.

Other common problems include:

- ✓ Using non-standard, homemade-type signs, frequently with substandard size legends and without retroreflective sheeting material.
- ✓ Installing signs at a substandard height.
- ✓ Installing signs too close to other signs, or too close to a curve, turn, or intersection.
- ✓ Installing totem pole or ladder-type signs.
- ✓ Using improper colors, (e.g., brown and white for regulatory and warning signs).
- ✓ Allowing obsolete (non-retroreflective or non-legible) signs to remain in place.

The "how-to" book for traffic signs is Part 2 of the *MUTCD*. The primary purpose of the *MUTCD* is to improve safety and reduce driver frustration by promoting uniformity in the design and application of traffic control devices.

FHWA also sponsors research to improve the quality and recognition of signs, and works internationally to share ideas with other countries to promote uniformity on a global basis. This sharing of research on sign shapes, colors, symbols, and design details is very important when considering the number of international visitors.

Traffic signs are the most common and recognizable type of traffic control device. In fact, more than half of the *MUTCD* is devoted to the discussion and application of signs.

However, despite the explicit guidance in the *MUTCD*, a continuing problem is the use of unofficial, homemade-type signs, which are sometimes made with the wrong colors and shapes. This problem is common on military installations.

To command proper respect, signs must be legible, visible, and placed correctly. For proper respect, sign messages must be realistic. For example, speed limits must be realistic, be properly maintained, and used properly for the roadway's conditions. Exhibit 7.1 shows additional requirements of signs to command proper respect.

Exhibit 7.1: Sign Requirements

REQUIREMENTS	EXAMPLES
BE LEGIBLE	✓ Use symbol messages when available ✓ Use minimum 6-inch high lettering (except for signs like No Parking signs) ✓ Use the proper type legend from the FHWA's Standard Highway Signs book
BE VISIBLE	✓ Space signs at intervals of at least 200 feet (preferably) from other signs, with an allowance to use 100 feet minimum depending on speed ✓ Orient signs to face approaching traffic ✓ Clear obstructions and roadside features such as vegetation and utility poles ✓ Require Type III or better retroreflective sheeting on new signs ✓ Replace or repair damaged or misaligned signs ✓ Replace signs at least every 10 or 12 years
BE PLACED CORRECTLY	✓ Use proper lateral offset distance from the edge of the road ✓ Install signs at the proper height above the roadway surface ✓ Use an approved breakaway or yielding signpost and install in accordance with the manufacturer's recommendations ✓ Use overhead lane use signs for three or more lanes in one direction, or when a single lane can serve multiple movements

7.1.1. Function and Purpose of Signs

There are only three classifications of signs as illustrated in Exhibit 7.2:

✓ Regulatory—give notice of traffic laws or restrictions.

✓ Warning—give notice of a situation that might not be readily apparent.

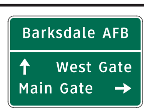
✓ Guide—show route designations, destinations, directions, distances, street names, services, points of interest and other geographical, recreational, or cultural information.

Exhibit 7.2: Sign Type Basics

SIGN CATEGORY	GENERAL SHAPE	BASIC COLOR	COMMON EXCEPTIONS
Regulatory 	Rectangular	Black legend and border on a white background	✓ STOP (R1-1), YIELD (R1-2), and Railroad Crossbuck (R15-1) signs have a unique shape. ✓ STOP (R1-1), YIELD (R1-2), DO NOT ENTER (R5-1), and WRONG WAY (R5-1a) signs are red-and-white in color. ✓ A red circle and slash indicate prohibitions.
Warning 	Diamond	Black symbols, legend, and border on a yellow background	✓ School (S1-1) and Advance Railroad Crossing (W10-1) signs, and the NO PASSING ZONE (W14-3) pennant, have a unique shape. ✓ All plaques and some warning signs have a rectangular shape. ✓ School signs use a fluorescent yellow-green background, and it is also optional for pedestrian and bicycle signs. ✓ Warning signs in construction areas have an orange background.
Guide 	Rectangular	White legend and border on a green background	✓ Route (M-series) markers generally have a unique color and shape. ✓ Motorist service signs (e.g., gas, food, lodging, attractions, etc.) have a blue background. ✓ Recreational signs may have a brown background. ✓ Community Wayfinding signs may have a brown or blue background. Other background colors, conforming to the specific requirements listed in the *MUTCD*, may also be used for the color coding of community wayfinding guide signs.

In addition to the colors depicted in Exhibit 7.3, purple may be used for electronic toll collection (ETC) pictographs.

Exhibit 7.3: Sign Color Examples

SIGN	SIGN CLASSIFICATION
	REGULATORY
	REGULATORY
	WARNING
	WARNING
	WARNING
	GUIDE
	GUIDE
	GUIDE

Although there are only three basic classifications of signs, the *MUTCD* groups signs into a few additional categories as indicated in Exhibit 7.4. Some of these signs are not addressed in this pamphlet because they generally do not apply to military installations.

Exhibit 7.4: Categories of Signs in the 2009 *MUTCD*

TYPE OF SIGN	CHAPTER IN THE MUTCD
Regulatory Signs	2B
Warning Signs	2C
Guide Signs—Conventional Roads	2D
Guide Signs—Freeways and Expressways	2E
Toll Road Signs	2F
Preferential and Managed Lane Signs	2G
General Information Signs	2H
General Service Signs	2I
Specific Service Signs	2J
Tourist-Oriented Directional Signs	2K
Changeable Message Signs	2L
Recreational and Cultural Interest Area Signs	2M
Emergency Management Signs	2N
Temporary Traffic Control Signs	6F
School Signs	7B
Railroad and Light Rail Transit Grade Crossing Signs	8B
Bicycle Signs	9B

7.1.2. Excessive Use of Signs

KEY POINT

There is a common misconception that extra signs "can't do any harm." However, in reality, extra signs create unnecessary clutter and detract from important and necessary traffic signs.

Signs should only be used when warranted by facts and field studies since unnecessary signs create a safety problem by adding extra fixed objects to hit and extra visual clutter to distract drivers. Therefore, avoid excessive use of signs.

For example, signs are generally not necessary to confirm rules of the road or general provisions regarding the operation of vehicles (e.g., slower traffic keep right, pass only on the left, etc.). However, signs are essential where there is failure to conform to the general rules of the road; or, where unusual regulations apply at specific places or specific times, or where hazardous conditions are not self-evident. When signs are required, take a conservative approach since too many regulatory and warning signs will generally cause signs to lose their usefulness.

Guide signs provide information as to highway routes, street names, destinations, distances, available services, and points of interest. Military installations are encouraged to use a frequent display of street name signs and destination signs to keep unfamiliar road users informed of their route and location.

The placement of a sign where it is not appropriate or justified is as objectionable as a substandard or obsolete sign. As soon as possible, remove or cover all signs that were required by uncommon circumstances or temporary restrictions when those conditions cease to exist. Do not allow anyone to use highway signs for advertising or for any purpose other than related to traffic control.

Sometimes it is not that the signs are unnecessary, but that there are too many signs at one location and no one can read them.

Too many signs!

> **Sign Clutter**
>
> Common sign clutter problems on military installations include:
>
> - ✓ Too many signs at a single location; e.g., at an ECF.
> - ✓ Allowing railroad warning and cross buck signs to remain in place even though the railroad tracks were removed or paved over.
> - ✓ Leaving pedestrian crossing signs when the pedestrian walkways were removed.
> - ✓ Using DO NOT ENTER signs at the only entrance to parking lots in an apparent attempt to "reserve" the parking spaces.

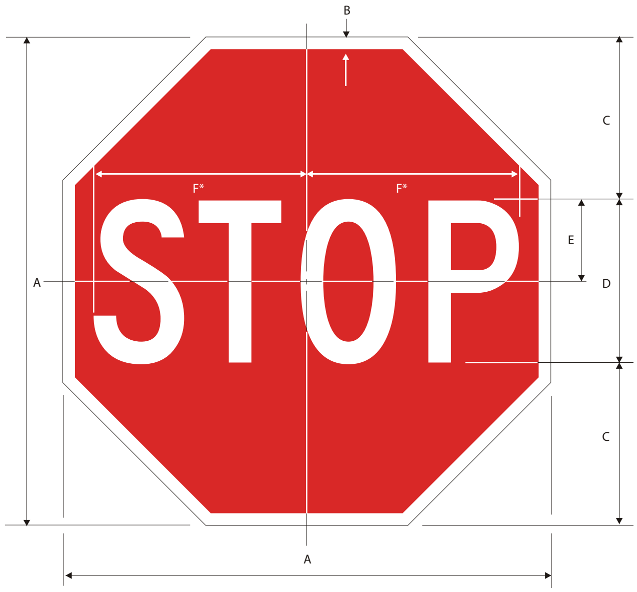
The application of signs should comply with this pamphlet and the *MUTCD*. Engineering judgment and studies are critical to the accurate use of traffic control devices; e.g., a traffic engineering study may indicate that signs are unwarranted at certain locations.

7.1.3. Standard Signs

> **KEY POINT**
>
> Uniformity in the design of sign faces improves sign recognition and legibility; thereby reducing driver frustration and promoting safety.

Homemade-type signs are not only unenforceable, but they are illegal. Therefore, when there is a need for a sign not in the *MUTCD* or the state's list of approved signs, consult SDDCTEA for design assistance. Uniform sign designs help everyone, because as drivers we can see and understand the sign messages in less time. To this end, the *MUTCD* establishes the basic framework for the design and application of signs, and the *Standard Highway Signs and Markings (SHSM) Book* provides detailed drawings of the standard signs and alphabets. The current version of the *SHSM* is the 2004 version. There is an accompanying document, the *2012 Supplement to the 2004 Edition of Standard Highway Signs*. This supplement contains the new and revised signs included in the 2009 version of the *MUTCD*. Both documents are required for all signs included in the *MUTCD*. Exhibit 7.5 shows a typical page from the *SHSM Book*, but with a few extra notes.

Exhibit 7.5: STOP Sign Details from the *SHSM Book*



1 R1-1
STOP

4 *Reduce spacing 40%

A	B	C	D	E	F
18	.375	6	6 C	3	7.75
24	.625	8	8 C	4	10
30	.75	10	10 C	5	12.5
36	.875	12	12 C	6	15
48	1.25	16	16 C	8	20

COLORS: LEGEND — WHITE (RETROREFLECTIVE)
BACKGROUND — RED (RETROREFLECTIVE)

1-1

NOTES:

1. R1-1 is the “sign code” for the STOP sign.
2. The dimensions are for the A, B, C’s in the sign layout. The dimensions are in English units; i.e., in inches.
3. Refer to the Sign and Plaque Size tables throughout the *MUTCD* Chapter 2 for the correct sign size for a given roadway classification.
4. This note applies to dimension F on the STOP sign face, and it means that the spacing between the letters is reduced by this percentage. (See the asterisk beside the dimension “F” on the sign face.)
5. 10-inch Highway Gothic legend, Series C.
6. Both the white and the red colors must be retroreflective.

GOOD

BAD

Some standard signs can be recognized at great distances because of their bold symbols (e.g., Curve, Cross Road) or their unique shape (e.g., STOP, YIELD, Railroad, School, etc.). On the other hand, research indicates that word messages are normally legible from a distance equal to 30 feet for every inch of legend height for drivers with 20/40 corrected vision (as allowed in most states). For example, 6-inch legend should be legible from a distance of about 180 feet.

In addition, some signs may not be completely legible or have a unique shape, but they are readily recognized at greater distances because of their unique mixture of legend sizes (e.g., Speed Limit Sign) or even the mix of word lengths (e.g., DO NOT PASS Sign).

Sign Names

Some sign names in this pamphlet consist of all capital letters while others are in mixed-case lettering. This mix of styles is also used in the *MUTCD* and most other national sign manuals, and is based on the following:

- ✓ All capitals are used when the sign name and the sign legend message is the same (e.g., STOP, YIELD, and DO NOT PASS signs).
- ✓ Mixed-case lettering is used for all symbol signs, and for signs with legend messages when the sign name and the sign message are not the same (e.g., Speed Limit signs, Weight Limit signs, etc.)

Sign Codes

The *MUTCD* and the *SHSM Book* use a unique sign code for each standard traffic sign. The first letter in the sign code should conform to the following *MUTCD* practice:

- ✓ Regulatory signs – R
- ✓ Warning signs – W, except school signs start with the letter S
- ✓ Guide signs – a variety of letters, but most commonly D, G, I, or M

TEA Standard Signs

It is important to use standard sign designs to avoid the "homemade look." In most cases, this means using the sign face designs included in the *SHSM Book*; however, like other highway agencies, military installations also need some unique signs in order to satisfy specific needs. Since these unique signs are not in the *SHSM Book*, SDDCTEA has developed a Standard TEA sign for each of the most common signs special to military installations. **These signs are included in Appendix A of this pamphlet.**

Sign codes assigned by SDDCTEA are similar to those assigned by FHWA except "TEA" is added to the end of the code to distinguish these official signs from those in the *MUTCD* and *SHSM Book*. Therefore, if a sign code such as "R1-7a-TEA" is used, Appendix A of this pamphlet contains the necessary design details. Just like the drawings in the *SHSM Book*, drawings for SDDCTEA-approved signs include the following information:

- ✓ sign code
- ✓ sign size, color, and shape
- ✓ size and series of legend
- ✓ sign face layouts details

Drawings for the standard signs in Appendix A also include a brief description of the sign application. The DoD Supplement to the *MUTCD* also provides details for Standard TEA signs.

7.1.4. Alphabets

KEY POINT

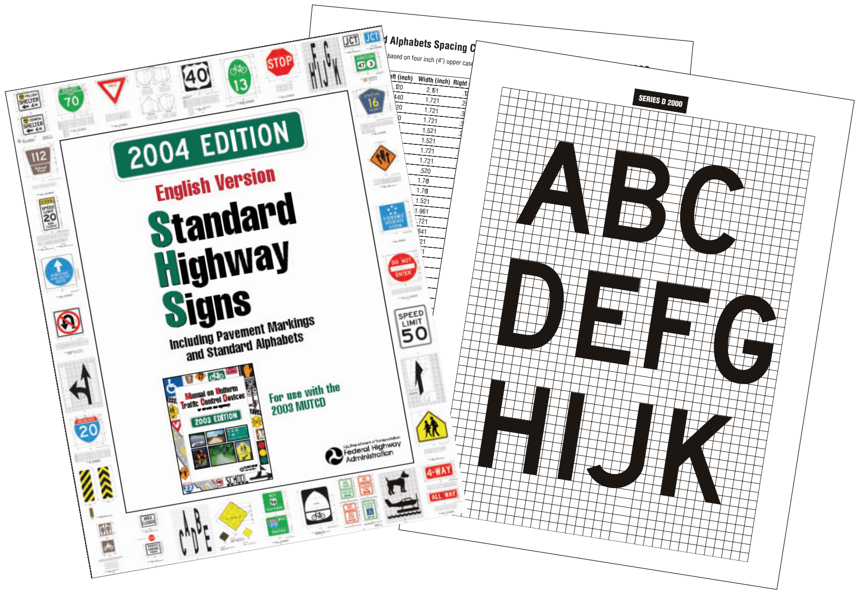
Most letters made with the Series F font are over twice as wide as the same letter made with a Series B font.

KEY POINT

Clearview font was previously used per interim approval, but the interim approval was terminated on January 25, 2016. Therefore, Clearview font can no longer be used on new signing. Existing signs using Clearview font can remain in place until they reach the end of their useful service life.

The *SHSM Book* includes graphics and spacing requirements for the standard alphabets as used on traffic signs; i.e., Highway Gothic. Altogether there are six different font series in order of increasing boldness; i.e., Series B, C, D, E, E-Modified (EM), and F.

Series D is the most common legend for guide signs on conventional roads, and for regulatory and warning signs. Sometimes a lower series (i.e., Series B or C) is used due to limited lateral space on the sign, perhaps most noticeable for No Parking signs. On the other hand, guide signs on expressways and freeways usually use Series E-Modified (EM) legends.



The current *SHSM Book* has spacing charts for each series of Highway Gothic; i.e., Series B, C, D, E, EM, and F. And for each of these six series, the charts include the width of 80 characters and the width of the spacing before and after each of the 80 characters. The characters include the 26 uppercase letters, 26 lowercase letters, 10 digits, and 18 characters that are common to most computer keyboards.

It is important to note that these dimensions are always for 4-inch high characters, which means that users need to multiply these values by a fraction if other legend sizes are used. For example, if using 6-inch legend, it is necessary to multiply the values for the 4-inch legend by the fraction 6/4.

The spacing methodology is illustrated in Exhibit 7.6.

FHWA now has a word spacing calculator on their website for the different series of highway fonts. See the calculator at their website for the Standard Highway Signs manual, http://mutcd.fhwa.dot.gov/ser-shs_millennium.htm.

Exhibit 7.6: Alphabet Spacing Charts

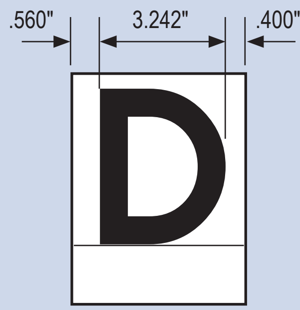
Standard Alphabets Spacing Chart

Series E Modified 2000

Measurements based on four inch (4") upper case letter height

Character	Left (inch)	Width (inch)	Right (inch)
A	.160	4.043	.160
B	.560	3.242	.320
C	.400	3.242	.320
D	.560	3.242	.400
E	.560	2.962	.280
F	.560	[illegible]	.280

Character	Left (inch)	Width (inch)	Right (inch)
o	.440	2.722	.440
p	.800	2.642	.440
q	.440	2.642	.800
r	.800	2.000	.160
s	.360	2.642	.440
t	[illegible]	2.081	.480



Note:
The dimensions came from the yellow highlighted values.

Computer software is available to calculate the length of legends and to design the layout of new signs. Manual spacing charts for all approved fonts are included in Appendix C.

7.1.5. Design Guidelines for Additional Sign Faces

In addition to the standard signs included in the *SHSM Book* or the TEA signs in Appendix A, military installations will frequently need to use some additional signs. Therefore, additional guidance has been developed.

Regulatory and Warning Signs

If your installation requires a unique regulatory or warning sign that is not in either the *SHSM Book* or in Appendix A, adhere to the guidelines listed below when designing the sign.

Guidelines for Designing Regulatory and Warning Signs

1. Follow the basic principles established in the *MUTCD* relating to sign size, shape, color, and legend size and series.
2. Ensure that word messages are clear so that everyone has the same understanding of the sign message. If abbreviations are necessary, only use abbreviations in accordance with Section 5.1.7. Do not use abbreviations listed in Table 1A-3 of the *MUTCD*.
3. Use the appropriate letter width and spacing between individual letters as specified in the Standard Alphabets Spacing Charts (See Part 9 in the *SHSM Book*).
4. Ideally, use spacing between successive lines of legend that is about 75 percent of the average height of the uppercase legend (i.e., capitals) in the adjacent lines of legend.
5. When possible, use a clear spacing between the legend and inside of the borders that is at least 50 percent of the legend height. (It should be noted, that much smaller clear spaces exist on many standard signs, some with clear spaces less than 10 percent of the legend height.)
6. Diamond-shaped warning signs are more difficult to lay out due to their diagonal edges. In the absence of computer software, designers can use scaled strings of cutout legend and either electronically or manually position the legend within the sign border to obtain the best optically-balanced design.
7. Submit the proposed sign design to SDDCTEA for approval. If approved, have the sign fabricated.

By submitting these unique sign designs to SDDCTEA for approval prior to having the sign fabricated, military installations help ensure that the sign message and layout are easy to understand. This practice also enables SDDCTEA to request FHWA concurrence on any new symbols (as required in the *MUTCD*), and it allows SDDCTEA to expand their library of official signs for use on other military installations.

Guide Signs

By their very nature and application, destination and distance signs, and some other guide signs, are unique, one-of-a-kind signs. Therefore, these signs need some final design details to determine the sign layout and dimensions. Specific approval of SDDCTEA is not required, but SDDCTEA is available for consultation.

Legend

All letters on signs are required to be in uppercase letters (i.e., capital letters). The exemption to this is sign lettering for names of places, streets, highways, when used on guide signs are required to be in "mixed-case" (i.e., a combination of lowercase letters with initial uppercase letters) as discussed in Section 2A.13 of the *MUTCD*. Street name signs are also required to be in mixed-case legend per the *MUTCD*. On military installations, names that should be in mixed-case on guide signs include:

- ✓ cities
- ✓ military installations
- ✓ geographic areas within installations
- ✓ gates
- ✓ roads and streets
- ✓ buildings

Using mixed-case legends for these names accomplishes three things:

1. It improves the legibility of the names. The improvement in legibility distance is because some lowercase letters have extenders (b, d, f, h, i, j, k, l and t) and others have descenders (g, j, p, q and y), which creates unique, recognizable word footprints so that drivers frequently do not need to read the names letter-by-letter. Studies show that this increase in legibility distance is about 15 to 20 percent.
2. Mixed-case legends are usually shorter than words with all capitals, thus allowing smaller signs.
3. It helps to set the names apart from other legends.

The *MUTCD* specifies that signs should use the alphabets in the *SHSM Book*, which are generally called "Highway Gothic" fonts. Spacing charts for the Highway Gothic fonts are in Appendix C.

There are several computer software programs available to help design sign faces. Two popular programs are SignCAD and GuidSIGN, both of which also interface with sign manufacturing software.

When designing sign messages, avoid messages shown in Exhibit 7.7.

What are "Mixed-Case" Legends?

This is the common practice for capitalization of titles and headings where a capital letter is used for the first letter of every major word and lowercase letters are used for all other letters. Sometimes this lettering is referred to as "upper-and-lowercase legend," or as "title-case legend."

Some small words (e.g., a, an, and, but, for, nor, of, or, so, the, and to) generally are not capitalized unless they are the first word in the name. However, acronyms such as AFB would always be in all capitals.

Exhibit 7.7: Words and Terms Not Recommended on Signs

DO NOT USE	BECAUSE
"HAZARDOUS" or "DANGEROUS"	Installations should be eliminating these problem locations and there is no need to identify the site for potential lawsuits.
"WARNING"	The shape and color of the sign should provide a warning.
"SLOW"	This relative term means different speeds to different people; i.e., what speed is slow? On the other hand, an Advisory Speed (W13-1P) plaque ("25 MPH") is an acceptable legend.
"NOTICE" or "CAUTION"	These are unnecessary words—a warning sign should provide this information with its shape and color.
"TRAFFIC LAWS STRICTLY ENFORCED"	It is assumed that the traffic laws will be enforced so the legend is unnecessary.
Unfamiliar terms or destinations	These are unnecessary and may create confusion for road users. For example, avoid terms like "TRAFFIC QUEUE," etc.
Cute or trite symbols, phrases, or words	These may reduce road user's respect for signs. For example, do not use, "EVEN IF YOU ARE LATE, DON'T TAILGATE," "ANGER IS ONE LETTER AWAY FROM DANGER," "SPEED LIMIT 44," etc.

7.1.6. Bilingual Messages

KEY POINT

To assist drivers with limited knowledge of the English language, always use symbol-type signs whenever an approved design is available.

One of the benefits of using international style signs is the benefit of universally recognized sign shapes, colors, and symbols. Some areas surrounding military installations have extensive populations that are not fluent in English; however, these drivers can still understand most signs. For example, a STOP sign's shape and color is universal; therefore, there is no need to use bilingual STOP signs with messages such as "STOP / ALTO."

To assist drivers with limited knowledge of the English language, always use symbol-type signs when an approved design is available. If you believe that limited understanding is a significant problem with certain signs, contact SDDCTEA and discuss the possibility of using a bilingual sign.

If you are considering bilingual applications, what would you consider to be the most important? It should not be a STOP, YIELD, Speed Limit or guide sign. Instead, consider ROAD CLOSED; DO NOT STOP ON TRACKS; special parking restrictions; THRU TRAFFIC KEEP RIGHT; and mandatory stops for customs, inspections, etc.

7.1.7. Retroreflectivity and Illumination

KEY POINT

At night, drivers need visible traffic signs and markings to enhance safety and reduce driver stress.

Nighttime driving is inherently more dangerous than travel during the daytime, making it extremely important that signs are visible. Therefore, the *MUTCD* requires traffic signs to be either retroreflective or illuminated to show the same shape and color both day and night. It is more cost effective to make signs retroreflective than it is to illuminate them, and it is also possible that the bulbs will burn out. Therefore, all signs should be made with retroreflective sheeting even if the sign is illuminated.

Nighttime Crash Rate

National studies show that the average fatality rate per mile of travel is about three times higher during the night than during the day. Factors that contribute to a higher nighttime crash rate include:

1. Older drivers have difficulty seeing at night. It has been said, that after age 20, drivers typically need twice as much light every 13 years in order to read. For example, compared to a 20-year old driver, a 33-year old driver needs twice as much light, a 46-year old driver needs four times as much light, a 59-year old driver needs eight times as much light, and a 72-year old driver needs 16 times as much light.
2. There are fewer visual clues to delineate the roadway alignment at night.
3. Dew and frost reduce the retroreflection.
4. Glare from approaching traffic may temporarily blind drivers.
5. There are more intoxicated and sleepy drivers.

What is Retroreflection?

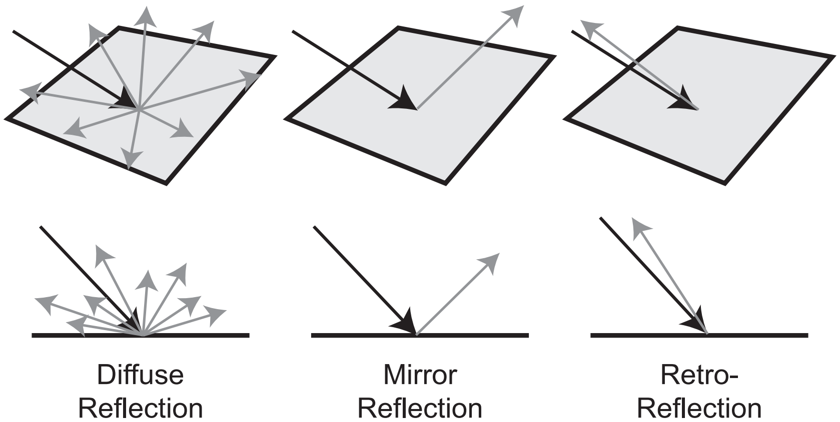
Most objects reflect light. The most common type of reflection is “diffuse reflection” where light scatters after striking rough surfaces such as trees, clothing, and carpet. Only a very small amount of the diffused light reflects back toward the light source.

Another type of reflection is “mirror reflection” that occurs when light strikes smooth or glossy surfaces, and the light reflects off the surface at an equal but opposite angle. Mirror reflection frequently occurs at night on wet roads when the headlights of approaching vehicles create extensive glare.

In contrast, “retroreflection” is the unique ability of a surface to reflect light back toward the light source even when the surface is not perpendicular to the light source; and “retroreflectivity” is the measure of this unique property.

The three types of reflection are illustrated in Exhibit 7.8.

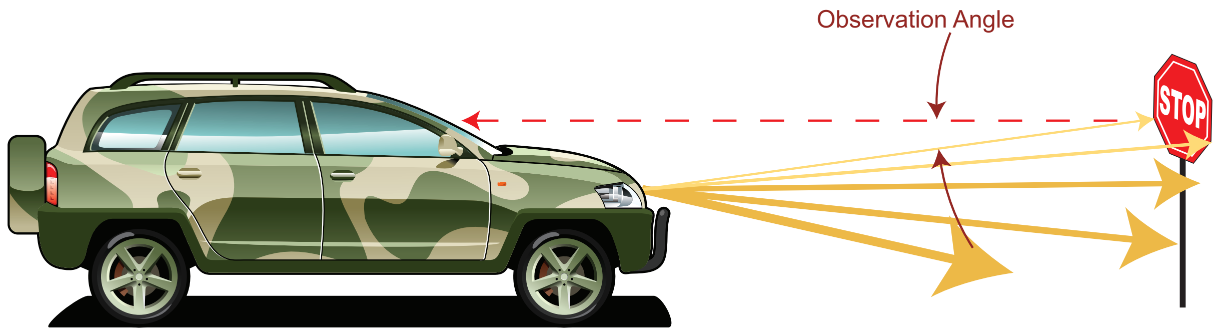
Exhibit 7.8: Types of Reflection



Retroreflective Sheeting Materials

To make signs retroreflective, sign shops apply retroreflective sheeting to the face of each sign, which incorporates either microscopic glass beads or microscopic cube-corner reflectors (frequently called "microprismatic material") behind a smooth translucent pigmented surface layer. If the manufacturers could make perfectly shaped glass beads or cube-corner reflectors, all light from a vehicle's headlights would return directly back to the headlights. Although we do not have perfectly shaped glass beads or reflectors, drivers do see more reflected light when their eyes are closer to the headlights. As illustrated in Exhibit 7.9, the angle formed between the headlights, the sign, and the driver's eyes is the observation angle, and the smaller the angle the higher the retroreflection.

Exhibit 7.9: Graphic Illustration of the Observation Angle



Retroreflective materials are also more efficient when the light source is approximately perpendicular to the sign face; therefore, it is important to have signs oriented toward approaching traffic.

Some traffic signs may look almost new during the day but are completely ineffective at night. This nighttime visibility problem is usually a function of the type and age of the retroreflective material. For example, the STOP sign in Exhibit 7.10 looks almost new during the day, but it is not retroreflective at dusk or nighttime when lights are needed. This is because the sign shop used a non-retroreflective sheeting material (the sign shop also used a non-standard lettering font). Therefore, these problems illustrate the importance of:

Exhibit 7.10: An Unacceptable, Non-retroreflective Sign

- ✓ obtaining all signs from a reputable sign shop;
- ✓ specifying a minimum Type III sheeting type, and;
- ✓ performing nighttime inspections of the signs.

Factors that Affect a Driver's Ability to "Read" Signs at Night

Of the following eight items, military installations can only help drivers by modifying Items 5, 6, 7, and 8:

1. The driver's night vision and acuity.
2. Intensity and light distribution of the headlights.
3. Location of driver's eyes with respect to the headlights.
4. Frost, dew, or snow on the sign face; or rain, snow, fog, smoke, etc., between the vehicle and the sign.
5. Obstructions in the line-of-sight between the driver and the sign.
6. Size and readability of the sign.
7. Locations, mounting height, and orientation of the sign in relation to the vehicle's headlights.
8. Type and age of the retroreflective sheeting material.

Making Retroreflective Signs

Signs are made retroreflective by applying white or colored retroreflective sheeting on the sign blank. Sign messages for mass-produced signs are typically silk-screened directly on the sheeting. All non-black inks need to be a transparent type and applied on white sheeting so that the screened color is both retroreflective and the proper color.

One-of-a-kind signs are typically made with cutout, pressure-sensitive legend (i.e., letters, symbols, numbers, and arrows). Non-black cutout legends and borders need to be made from retroreflective sheeting material.

Measuring Retroreflectivity

Retroreflectivity is measured with a retroreflectometer. Hand-held instruments for use in the field cost about $12,000 and measure the retroreflectivity value at preset angles to simulate what drivers see. Many units also capture GPS coordinates which can be downloaded into an inventory or asset management database.

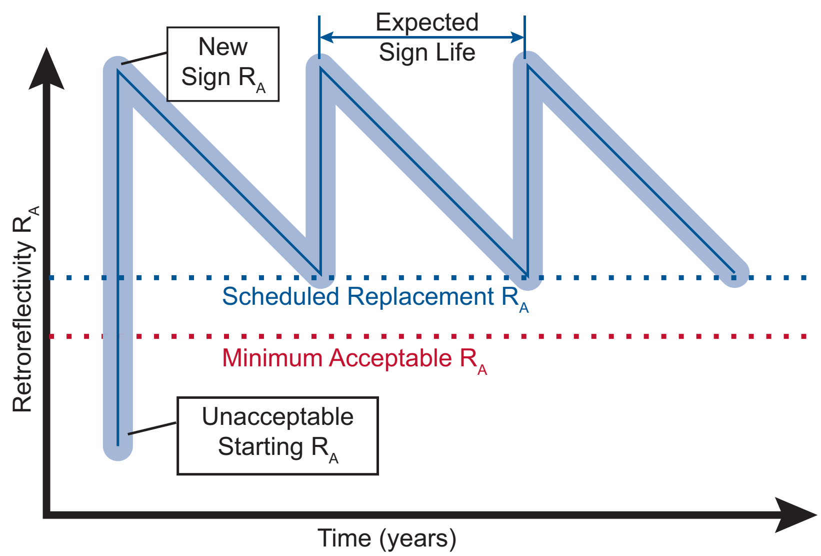
However, using a portable retroreflectometer requires careful attention because signs are normally on posts and either the retroreflectometer needs to be supported by an extension pole and accurately held against the sign face, or the user must climb on a ladder.

In addition, researchers typically suggest taking about three readings on signs, since retroreflectivity sometimes varies at different locations on a sign face. And to make matters worse, the unit must also be precisely centered on white legends on signs such as STOP signs and guide signs. Therefore, up to six readings are sometimes recommended, making the process both challenging and time-consuming. Taking retroreflectivity readings on signs installed over the road on mast arms or sign structures is another problem.

Retroreflectivity readings are normally defined as the value R_A measured in candelas per lux per square meter (cd/lx/m2). The R_A value deteriorates over time, but materials of even the same type and color do not always deteriorate uniformly.

Therefore, it is desirable to provide a safety factor when scheduling replacement signs as illustrated in Exhibit 7.11.

Exhibit 7.11: The Decline of Retroreflectivity over Time



When is Sign Lighting Required?

Since only “brighter” types of retroreflective sheeting materials should be used, only use sign lighting if a traffic engineering study documents a need.

7.1.7.1. Target Compliance Dates

The FHWA’s 2009 *MUTCD* set forth federal requirements that military installations must meet several key traffic control sign compliance requirements between January 2012 and December 2019 for signs on any road used by the traveling public. On May 14, 2012, the FHWA published final rules to revise the *MUTCD* provisions on compliance dates. Most compliance dates have been eliminated; however, it is important to note that the requirements still apply. When a sign has reached the end of its useful service life, it is to be replaced in accordance with these requirements. A brief overview of the *MUTCD* requirements and any applicable dates are as follows:

- ✓ Conform to new requirements relating to sign size, sign type, and placement.
- ✓ Develop an installation-wide sign management system for the purpose of conforming to FHWA’s requirement that agencies implement a program by June 2014 (formerly January 2012) for the maintenance of minimum levels of retroreflectivity.
- ✓ Ensure compliance with minimum retroreflectivity requirements, dependent on sign type.
- ✓ SDDCTEA is available for assistance if your installation does not have a sign management system in place.

The *MUTCD*'s intent is to promote traffic control device uniformity and consistency. This is of particular importance on military installations where roadways are traveled by government personnel from all over the country. Failure to replace non-compliant devices at the end of a sign's service life could result in tort liability in lawsuits, especially in situations where a crash has occurred that can be attributed to inadequate, inappropriate, or non-compliant traffic control devices.

7.1.7.2. Minimum Retroreflectivity Levels

KEY POINT

Because of a congressional mandate, minimum retroreflectivity values now exist for most traffic signs.

Because of safety concerns about nighttime driving, in 1993 Congress directed the U.S. Secretary of Transportation to include minimum retroreflectivity levels in the *MUTCD* for both signs and markings. After extensive research, FHWA adopted minimum retroreflectivity values for traffic signs in 2007, and these values are now included as Table 2A-3 in the *MUTCD*.

However, the values adopted vary by the type and color of sheeting, and the sign size and type of message. Exhibit 7.12 shows minimum retroreflectivity levels for different types and colors of sheeting.

Exhibit 7.12: Minimum Maintained Retroreflectivity Levels[1]

SIGN COLOR	SHEETING TYPE (ASTM D4956-04)				ADDITIONAL CRITERIA
	BEADING SHEETING			PRISMATIC SHEETING	
	I	II	III	III, IV, VI, VII, VIII, IX, X	
WHITE ON GREEN	W*; G ≥ 7	W*; G ≥ 15	W*; G ≥ 25	W ≥ 250; G ≥ 25	Overhead
	W*; G ≥ 7	W ≥ 120; G ≥ 15			Post-Mounted
BLACK ON YELLOW OR BLACK ON ORANGE	Y*; O*	Y ≥ 50; O ≥ 50			2
	Y*; O*	Y ≥ 75; O ≥ 75			3
WHITE ON RED	W ≥ 35; R ≥ 7				4
BLACK ON WHITE	W ≥ 50				-

[1] The minimum maintained retroreflectivity levels shown in this table are in units of cd/lx/m² measured at an observation angle of 0.2° and an entrance angle of -4.0°.

[2] For text and fine symbol signs measuring at least 48 inches and for all sizes of bold symbol signs

[3] For text and fine symbol signs measuring less than 48 inches

[4] Minimum sign contrast ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity)

* This sheeting type shall not be used for this color for this application.

Bold Symbol Signs

- W1-1,2—Turn and Curve
- W1-3,4—Reverse Turn and
- Curve
- W1-5—Winding Road
- W1-6,7—Large Arrow
- W1-8—Chevron
- W1-10—Intersection in Curve
- W1-11—Hairpin Curve
- W1-15—270 Degree Loop
- W2-1—Cross Road
- W2-2,3—Side Road
- W2-4,5—T and Y Intersection
- W2-6—Circular Intersection
- W2-7,8—Double Side Roads
- W3-1—Stop Ahead
- W3-2—Yield Ahead
- W3-3—Signal Ahead
- W4-1—Merge
- W4-2—Lane Ends
- W4-3—Added Lane
- W4-5—Entering Roadway Merge
- W4-6—Entering Roadway
- Added Lane
- W6-1,2—Divided Highway
- Begins and Ends
- W6-3—Two-Way Traffic
- W10-1,2,3,4,11,12—Grade
- Crossing Advance Warning
- W11-2—Pedestrian Crossing
- W11-3,4,16-22—Large Animals
- W11-5—Farm Equipment
- W11-6—Snowmobile Crossing
- W11-7—Equestrian Crossing
- W11-8—Fire Station
- W11-10—Truck Crossing
- W12-1—Double Arrow
- W16-5P,6P,7P—Pointing Arrow
- Plaques
- W20-7—Flagger
- W21-1—Worker

SIGNS

Exhibit 7.12: Minimum Maintained Retroreflectivity Levels[1] (Continued)

Fine Symbol Signs (symbol signs not listed as bold symbol signs)
Special Cases
• W3-1—Stop Ahead: Red retroreflectivity ≥ 7 • W3-2—Yield Ahead: Red retroreflectivity ≥ 7; White retroreflectivity ≥ 35 • W3-3—Signal Ahead: Red retroreflectivity ≥ 7; Green retroreflectivity ≥ 7 • W3-5—Speed Reduction: White retroreflectivity ≥ 50 • For non-diamond shaped signs, such as W14-3 (No Passing Zone), W4-4P (Cross Traffic Does Not Stop), or W13-1P,2,3,6,7 (Speed Advisory Plaques), use the largest sign dimension to determine the proper minimum retroreflectivity level.

Source: MUTCD *Table 2A-3*

Except for white legend and border on overhead signs, Type III or Type IV retroreflective sheeting material should be able to satisfy all of the above minimum retroreflectivity values.

To date, FHWA has not established minimum retroreflectivity values for the following signs:

- ✓ Parking, Standing, and Stopping (R7- and R8-series) signs.
- ✓ Walking/Hitchhiking/Crossing (R9-series, R10-1 through R10-4b) signs.
- ✓ All signs with a blue or a brown background.
- ✓ Bikeway signs that are intended for the exclusive use by bicyclists or pedestrians.

Originally, there was only one type of retroreflective sheeting material, but as technology developed, brighter and more durable materials became available. Moreover, with the mandated minimum retroreflectivity values, Type I and Type II retroreflective sheeting should no longer be used. **SDDCTEA requires that all signs use a minimum of Type III sheeting.**

FHWA has a Retroreflective Sheeting Identification Guide at http://safety.fhwa.dot.gov/roadway_dept/night_visib/sign_visib/sheetguide/. The portion of FHWA's guide that covers rigid signs is included in Exhibit 7.13.

Why Are "Brighter" Signs Necessary Today?

- ✓ Higher travel speeds.
- ✓ Low beam headlights on newer vehicles do not provide as much upward light as older headlights.
- ✓ There are more SUVs and trucks where drivers sit at a greater height above the headlights, and this reduces the amount of retroreflection for the drivers in these vehicles.
- ✓ Signs are set back farther from the roadway to establish a clear zone, but this reduces the amount of illumination and retroreflection.
- ✓ There are more older drivers and they generally have poorer nighttime vision.
- ✓ Better research.

SIGNS

Exhibit 7.13: FHWA's Retroreflective Sheeting Guide*

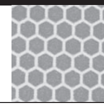
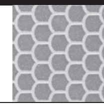
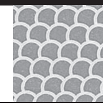
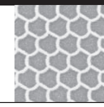
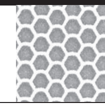
2014 Traffic Sign Retroreflective Sheeting Identification Guide

U.S. Department of Transportation
Federal Highway Administration

This document is intended to help identify sign sheeting materials for rigid signs and their common specification designations. It is not a qualified product list. FHWA does not endorse or approve sign sheeting materials. Many other sheeting materials not listed here are available for delineation and construction/work zone uses.
Many sign sheeting materials have watermarks and/or patterns that are used to identify the material type and manufacturer. The watermarks shown in this guide have been enhanced. The watermarks will be less visible in practice and may not be present on smaller pieces of sheeting due to the spacing.

Retroreflective Sheeting Materials Made with Glass Beads

DO NOT USE

Example of Sheeting (Shown to scale)								
ASTM D4956-04	I	II	II	III	III	III	III	III
ASTM D4956-13	I	[illegible]	II	III	III	III	III	III
AASHTO M268-13	(1)	[illegible])	(1)	A	A	A	A	A
Manufacturer	Several companies	[illegible]ry Dennison®	[illegible]ppon Carbide	3M™	ATSM, Inc.	Avery Dennison®	Nippon Carbide	ORAFOL Americas Inc
Brand Name	Engineer Gra[illegible]	Super Engr G[illegible]de	Super Engr Grade**	High Intensity	High Intensity	High Intensity	High Intensity	ORALITE® High Intensity
Series	Several	T-20[illegible]	15000	2800 3800	ATSM HI	T-5500	N500	5800
NOTES:	(2) (8)	(3) (4) (9)	(4)	(3) (4) (9)	(4)	(4)	(4)	(4)

1) Sheeting material does not meet minimum AASHTO classification criteria.
2) Glass Bead Engineer Grade sheeting is uniform without any patterns or identifying marks.
3) Material no longer sold in the United States as of the date of this publication.
4) Section 2A.08 of the 2009 MUTCD (http://mutcd.fhwa.dot.gov) does not allow this sheeting type to be used for new legends on green signs.

- ASTM D4956-04 is referenced in Table 2A-3 of the 2009 MUTCD.
- ASTM D4956-13 is the most current ASTM sign sheeting specification (the 2013 version is designated by "-13").
- AASHTO M268-13 is the most current AASHTO specification (the 2013 version is designated by "-13").

Manufacturer Contact Information

3M - http://www.3M.com/roadwaysafety
ATSM, Inc. - http://www.atsminc.com
Avery Dennison - http://www.reflectives.averydennison.com
Nippon Carbide - http://www.nikkalite.com
ORAFOL Americas Inc. – http://www.orafolamericas.com

FHWA Publication Number: FHWA-SA-14-022. You may download and print the electronic version of this document, available at www.fhwa.dot.gov/retro

SIGNS

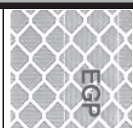
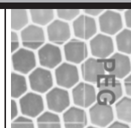
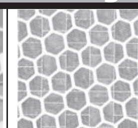
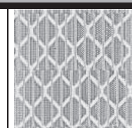
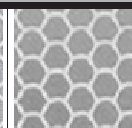
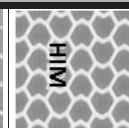
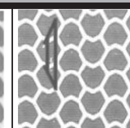
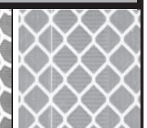
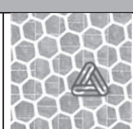
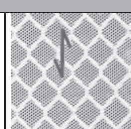
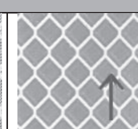
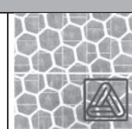
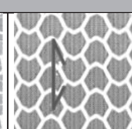
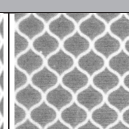
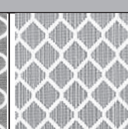
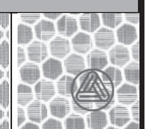
Exhibit 7.13: FHWA's Retroreflective Sheeting Guide* (Continued)

2014 Traffic Sign Retroreflective Sheeting Identification Guide

U.S. Department of Transportation
Federal Highway Administration

This document is intended to help identify sign sheeting materials for rigid signs and their common specification designations. It is not a qualified product list. FHWA does not endorse or approve sign sheeting materials. Many other sheeting materials not listed here are available for delineation and construction/work zone uses.
Many sign sheeting materials have watermarks and/or patterns that are used to identify the material type and manufacturer. The watermarks shown in this guide have been enhanced. The watermarks will be less visible in practice and may not be present on smaller pieces of sheeting due to the spacing.

Retroreflective Sheeting Materials Made with Micro-Prisms

Example of Sheeting (Shown to scale)								
D4956-04	(5)	(5)	III, IV	III, IV, X	(5)	(5)	(5) / X	(5)
D4956-13	I	I	III, IV	III, IV	III, IV	III, IV	VIII	VIII
M268-13	(6)	(6)	B	B	B	B	B	B
Manufacturer	3M™	Avery Dennison®	Avery Dennison®	3M™	ORAFOL Americas Inc	Nippon Carbide	Nippon Carbide	3M™
Brand Name	EGP	PEG	HIP	HIP	ORALITE® HIP	HIM	Crystal Grade	Reflective Sheeting
Series	3430	T-2500	T-6500	3930	5900/5930	CRG 94000	CRG 92000	3940
NOTES:	(8)	(8)						
Example of Sheeting (Shown to scale)								
D4956-04	VIII	VII, VIII, X	IX	IX	(5)	(5)	(5)	(5)
D4956-13	VIII	VIII	IX	IX	IX	IX	XI	XI
M268-13	B	(7)	B	B	B	B	D	D
Manufacturer	Avery Dennison®	3M™	3M™	Avery Dennison®	Nippon Carbide	ORAFOL Americas Inc	3M™	Avery Dennison®
Brand Name	MVP Prismatic	Diamond Grade™ LDP	Diamond Grade™ VIP	OmniView™	Crystal Grade	ORALITE®	Diamond Grade™ DG3	OmniCube™
Series	T-7500	3970	3990	T-9500	95000	7900	4000	T-11500
NOTES:		(9)			(9)			

5) Material was either unavailable in 2005 (previous version of this Guide) or unassigned in the 2004 version of ASTM D4956.
6) Sheeting material does not meet minimum AASHTO classification criteria.
7) Material has been discontinued prior to AASHTO M268-10.
8) Section 2A.08 of the 2009 MUTCD (http://mutcd.fhwa.dot.gov) does not allow this sheeting type to be used for new yellow or orange signs, or new legends on green signs.
9) Material no longer sold in the United States as of the date of this publication.

Resources

Federal Highway Administration – http://www.fhwa.dot.gov/retro
Manual on Uniform Traffic Control Devices (MUTCD) – http://mutcd.fhwa.dot.gov
Texas A&M Transportation Institute – http://tti.tamu.edu/visibility
ASTM – http://www.astm.org AASHTO – http://www.transportation.org

* This exhibit is reduced about 35 percent; therefore, the sheeting examples are shown at a smaller scale.
** As illustrated above, Type I and II materials both have a grainy appearance similar to metallic paint, whereas all other materials have a pattern of hexagons, diamonds, or circular shapes measuring about one-eighth inch across.

Even when brand new, Type I (Engineering Grade) and Type II (Super Engineering Grade) materials frequently cannot meet some of the minimum retroreflectivity values in Exhibit 7.12. Moreover, the higher type materials are more cost effective on an annual cost basis because they last longer. Therefore, Type I and Type II materials are no longer acceptable materials.

Exhibit 7.14 shows a typical life cycle cost analysis. Note that the prices are typical intended for comparative purposes. The higher grade sheeting types have a lower life cycle cost due to their longer lifespan.

Exhibit 7.14: Costs of Common Sheeting Types

SHEETING TYPE	INITIAL SHEETING COST (PER SQ FT)	INITIAL SIGN COST (PER SQ FT)	TYPICAL SIGN LIFE (YEARS)	LIFE CYCLE COST (PER YEAR, PER SQ FT)
I - EG	$0.85	$19.15	7	$2.74
II - SEG	$1.45	$19.75	7	$2.82
III - HI	$1.70	$20.00	12	$1.67
IV - HIP	$4.00	$22.30	12	$1.86
VIII AND HIGHER (OTHER PRISMATICS)	$5.45	$23.75	12	$1.98

Initial sheeting cost per US DOT Maintaining Traffic Sign Retroreflectivity: Impacts on State and Local Agencies, April 2007.

Inferior Type I and Type II Materials

Type I and Type II retroreflective materials should not be used. With reference to Exhibit 7.13, these inferior materials are easy to recognize because they have a uniform appearance similar to metallic automotive paints, whereas the better materials all have a pattern of hexagons, diamonds, or other similar shapes that are about one-eighth inch wide.

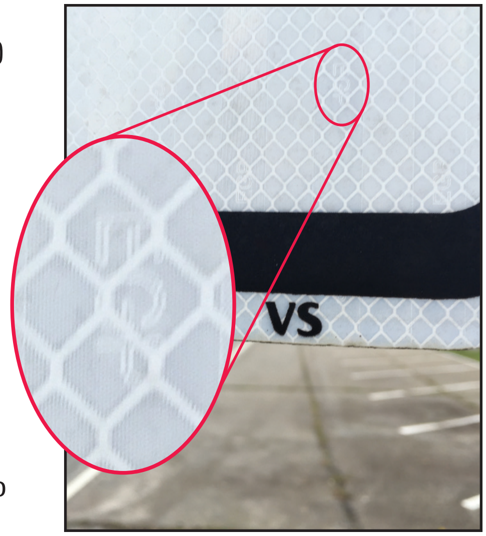
Some prismatic materials, such as Types VII, VIII, IX, and X material have small arrows or “water marks” to indicate what orientation of the material should be at the top of the sign. It is important for sign shops to comply with this recommendation since failure to comply causes some panels to be less retroreflective than other panels.

This is also a problem with legends when in an effort to reduce material usage, a sign shop rotates material in a die-cutting machine or uses nesting software on a computerized sign maker. However, new omni-directional sheeting eliminates the orientation issue. Moreover, additional innovations are on the horizon; e.g., new full cube prismatic sheeting can be engineered to direct a greater amount of light back to the driver and to meet specific retroreflectivity objectives.

The retroreflective sheeting type for all regulatory, warning, and guide signs shall be type III or better. Higher sheeting types (IX, X) should be reserved for urban areas that are generally lighted at night. The brighter sign compliments ambient lighting. These brighter sheeting types can be blinding in rural areas that are otherwise very dark at night.

Some sign sheeting manufacturers have a type of Type I that has an appearance of a higher grade sheeting at first glance by the unsuspecting eye. It has a diamond-shaped honeycomb pattern, but it also has small EGP (i.e., Engineering Grade Prismatic) watermarks visible in the sheeting itself. This type of sheeting is only Type I, and therefore cannot be used.

Section 7.1.16 addresses five methods to manage sign programs to maintain acceptable sign retroreflectivity.



Type I EGP Sheeting Example

Acceptable Retroreflective Sheeting Materials for New Signs

- ✓ Type III or Type IV, or better, for the background material on all signs, and for white legend and border on post-mounted signs.
- ✓ Type VII, VIII, IX, or X material for white legend and border on all overhead signs.

7.8.8. Sign Shapes, Colors, and General Design

Sign shapes and colors should always conform to those in the *MUTCD* and the *SHSM Book*.

The dimensions for signs given in the *MUTCD* are the standard sizes. When listing dimensions for rectangular signs, the width is the first dimension and the height is the second dimension, except dimensions of diamond-shaped and triangular-shaped signs are along each edge. Sign dimensions for width and height should generally be to the nearest 6-inch increment.

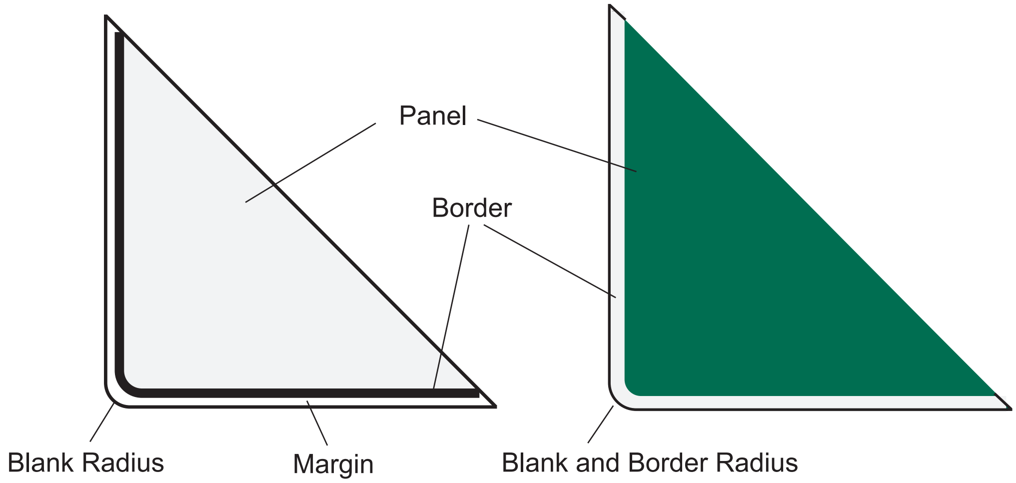
Speed greatly affects the legibility and comprehension of sign legends. Therefore, larger sign sizes are advantageous where increased legibility or emphasis is desirable.

For special circumstances such as limited highway right-of-way, or conditions such as parking facilities, parks, etc., the use of smaller than standard size signs may be justified. When sign sizes are changed, retain the standard shapes, colors, and proportions insofar as practicable.

Unless indicated otherwise, each sign shall have a border of the same color as the legend, at or just inside the panel edge. Except for STOP signs, borders on all signs should have round corners. And with a few exceptions, all sign blanks are required to have rounded corners in order to reduce potential injuries if someone hits the corner of the sign. (Exceptions include the STOP sign, Railroad Crossbuck sign and plaques, temporary signs on plywood blanks, and large signs fabricated from extruded aluminum panels.)

As illustrated in Exhibit 7.15, a dark border on a light background has a "margin" or setback distance from the edge. This setback serves two purposes: (1) it improves aesthetics; and (2) it reduces the possibility that the ink will run over the edge of the blank if manufactured by a silk-screening process. The outside corner radius of a dark-colored border is equal to the radius used on the sign blank, less the width of the margin.

Exhibit 7.15: Location of Borders and Margins



The Appendix in Part 7 of the *SHSM Book* identifies the standard sign blanks. Typical dimensions for margins, borders, and radii are indicated in Exhibit 7.16.

Exhibit 7.16: Typical Dimensions for Margins, Borders, and Blank Radii*

SIGN SIZE* (INCH)	WIDTH OF WHITE BORDERS (INCH)**	WIDTHS FOR SIGNS WITH A BLACK BORDER (INCH)		BLANK RADIUS (INCH)***
		MARGIN	BORDER	
18	0.5	0.375	0.625	1.5
24	0.5	0.375	0.625	1.5
30	0.75	0.5	0.75	1.875
36	0.75	0.625	0.875	2.25
48	1	0.75	1.25	3
60	1	0.75	1.25	3

* Generally the sign width or a side dimension for diamond-shaped signs (use a lower value for signs that have large widths and small heights)

** For example, STOP, YIELD, DO NOT ENTER, and guide signs

*** When applicable

SIGNS

Sometimes it is necessary to use substandard size signs due to limited highway right-of-way, to limit the sign width of overhead signs due to the lane width, or to limit the height of a sign due to vertical clearances. In these situations, there is a natural tendency to crowd letters together; however, legibility may be better with smaller letters and normal spacing between letters than with larger letters and cramped spacing. Spacing between letters should never be reduced more than 50 percent.

7.8.9. Standard Size Sign

For the majority of signs, the *MUTCD* provides multiple sizes for each sign. The sizes are based on the roadway classifications: conventional single lane, conventional multi-lane, expressway and freeway. The SHSM provides sign details for all the sign sizes associated with these roadway classifications (see Exhibit 7.5 that illustrates the differing sizes for a STOP sign.) However, most roads within military installations are classified as conventional single lane or conventional multi-lane roads.

Exhibit 7.17 illustrates sizes of common signs found on military installations, based on a typical conventional roadway system. Minimum sign size may be decreased by 6 inches in alleys that have restrictive physical conditions.

Exhibit 7.17: Sizes of Common Signs on Conventional Roadways

SIGN NAME AND NOMENCLATURE		SIZE, WIDTH X HEIGHT (INCHES)	
		SINGLE LANE	MULTI-LANE
STOP (R1-1)		30x30	36x36
YIELD (R1-2)		36x36x36*	48x48x48*
SPEED LIMIT (R2-1)		24x30	30x36
TURN PROHIBITION (R3-SERIES)		24x24	36x36
DO NOT PASS (R4-1)		24x30	24x30
DO NOT ENTER (R5-1)		30x30	36x36
WRONG WAY (R5-1A)		36x24	42x30
ONE WAY (R6-1)		36x12	54x18
NO PARKING (R7-SERIES)		12x18	12x18
NO TURN ON RED (R10-11, R10-11A)		24x30	36x48

SIGNS

Exhibit 7.17: Sizes of Common Signs on Conventional Roadways (Continued)

SIGN NAME AND NOMENCLATURE		SIZE, WIDTH X HEIGHT (INCHES)	
		SINGLE LANE	MULTI-LANE
TURN (W1-1)/CURVE (W1-2)		30x30	36x36
CHEVRON (W1-8)		18x24	18x24
INTERSECTION (W2-SERIES)		30x30	30x30
STOP/YIELD/SIGNAL AHEAD (W3-SERIES)		30x30	36x36
RAILROAD ADVANCE WARNING (W10-1)		36 DIA	36 DIA
ADVISORY SPEED (W13-1)		18x18	18x18
NO PASSING ZONE (W14-3 PENNANT)		48x48x36*	48x48x36*
DESTINATION (D1-, D2-SERIES)		6-inch legend	6-inch legend

**Length of each side to their would-be intersection as if the edges were not rounded.*

Recommended size is that which is most commonly occurring on military bases. See the MUTCD *for sizes needed on expressway and freeway conditions.*

Source: MUTCD *Tables 2B-1, 2C-2, 8B-1*

SIGNS

7.8.10. Sign Location and Orientation

Longitudinal Placement

If several signs are competing for a driver's attention at the same time, the driver may become confused or make unsafe maneuvers. Therefore, it is important not to overload drivers with unnecessary signs or signs that are too close together.

The longitudinal spacing between signs in a series may vary, but as a general rule the minimum spacing on conventional roadways should be approximately 200 feet, with an allowance to use 100 feet minimum depending on speed. Installations are encouraged, however, to use greater distances on high-speed conventional roads, but it may be necessary to use reduced spacing in some areas if there are a lot of signs.

The actual placement of a sign depends on the type of sign, the nature of the message, and the desired motorist response:

- ✓ Warning signs generally belong in advance of the condition to which they call attention, whereas regulatory signs belong at the location where a traffic law or regulation applies or at intervals throughout a section of roadway where a restriction applies.
- ✓ Regulatory signs can apply at a specific spot location (e.g., a requirement to stop, or a turn prohibition) or along an entire road or portion of road (e.g., a speed limit or weight limit). The first sign should be installed as close as possible to the location where the restriction applies or begins.
- ✓ The minimum advance distance for some warning signs is defined in Exhibit 7.31, but using a greater distance is better than installing signs too close to the hazard that is being warned about.
- ✓ On the other hand, place guide signs at varying locations to inform drivers as to their route of travel, destinations, and points of interest. Exhibit 7.18 defines the priority order when too many signs are competing for the same location.

You can generally shift most signs longitudinally without compromising their intended purpose. Signs may also be shifted longitudinally to improve their visibility, to avoid blocking other signs, to improve safety (by placing sign supports behind an existing barrier), or to improve operations (by providing more distance between signs in a series).

Exhibit 7.18: Sign Location Priority

1. Regulatory Signs—Stop, Yield, Turn Prohibitions, Lane Restrictions, Weight Limit, and Speed Limit, followed by Parking Restrictions and various other regulatory signs.
2. Warning Signs—Turn, Curve, Cross Road, Stop Ahead, Yield Ahead, Signal Ahead, Merging Traffic, Road Narrows, Narrow Bridge, Ramp Narrows, Divided Highway, and various other warning signs.
3. Guide Signs—Route Markers, Trailblazers, Destination, Advance Guide, and Exit Directional.
4. Emergency Service Signs—Hospital, Police, and Telephone.
5. Public Transportation Signs—Park and Ride, Bus Stop, and Light Rail.

While it is preferable to erect signs individually except where one sign supplements another, it is sometimes advantageous to group signs together to eliminate extra posts. This is particularly true in urban areas where the number of signs is greater than the space available. Urban areas, in particular, may require a case-by-case review.

Make signing location decisions on a case-by-case basis considering the signing needs for the entire route. If more than one sign normally belongs at the same location, relocate or eliminate the lower-priority sign. For example:

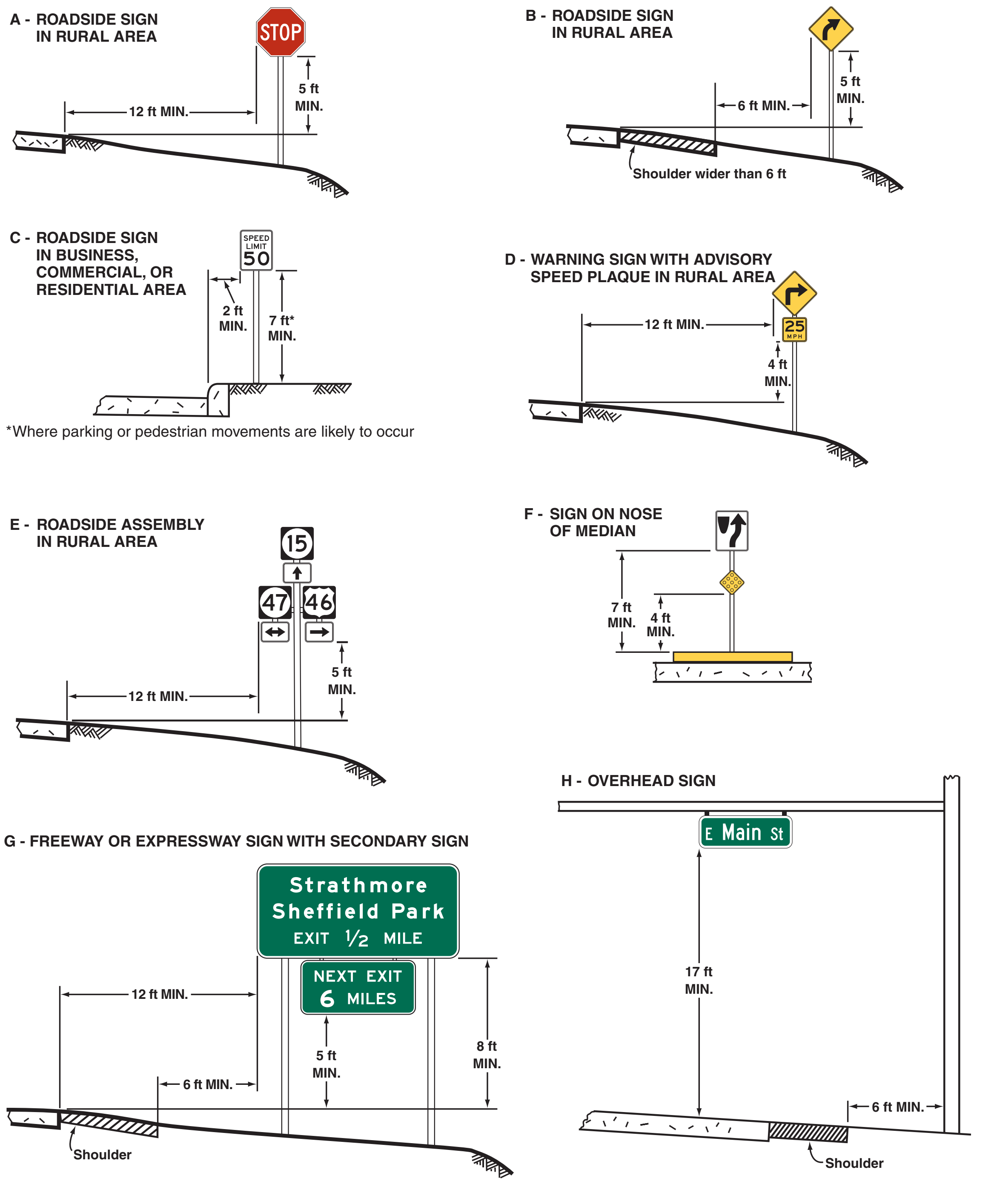
- ✓ If a curve warning sign and a distance sign would normally belong at the same location, the curve sign should have priority because of the need to place it in advance of the curve. On the other hand, you may be able to move a distance sign further ahead of or beyond the curve sign, or even eliminate it if other similar signs are along the roadway.
- ✓ If two restrictions such as a speed limit and a weight limit both begin at the beginning of a side road, the first Weight Limit (R12-1) sign takes precedence to avoid entrapment of over-weight vehicles. In this situation, the R12-1 sign can be installed within about 25 to 50 feet of the beginning of the road to avoid entrapment, and the first Speed Limit (R2-1) sign should be installed 200 feet or more beyond the R12-1 sign.

Also, avoid placing signs at inappropriate locations. For example, do not place Speed Limit (R2-1) signs just before an intersection, or on or immediately in advance of a curve with a lower advisory speed.

Lateral Placement

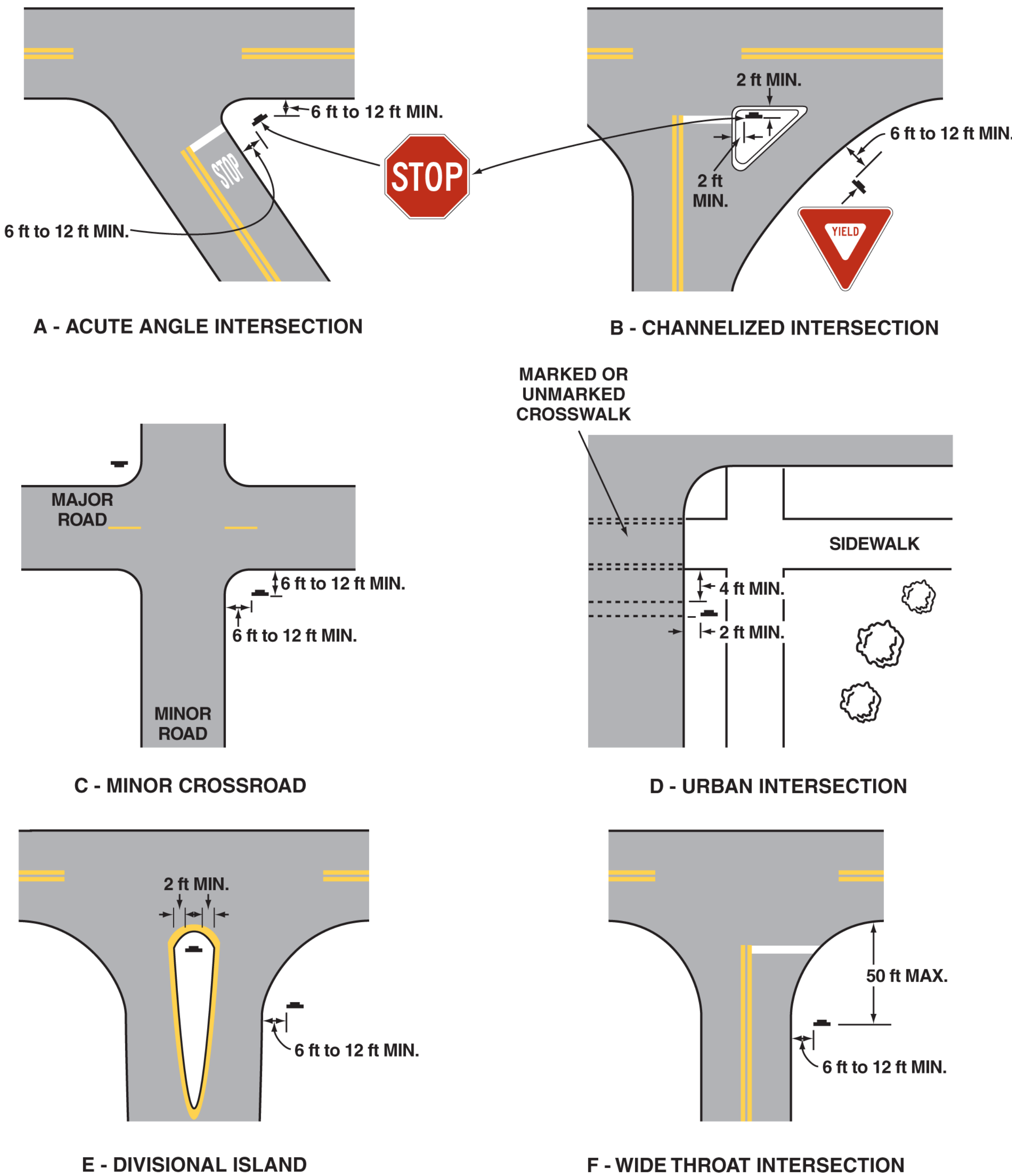
Lateral placement for signing varies by condition and sign type. Sign location requirements are shown in the following figures, as taken from the *MUTCD*. Signs should be located so that they are outside the clear zone unless placed on a breakaway or yielding support, optimize nighttime visibility, minimize the effects of mud splatter and debris, do not obscure each other, do not obscure the sight distance to approaching vehicles on the major street for drivers who are stopped on minor-street approaches, and are not hidden from view.

HEIGHTS AND LATERAL LOCATION OF SIGNS



Note:
See *MUTCD* Section 2A.19 for reduced lateral offset distances that may be used in areas where lateral offsets are limited, and in business, commercial, or residential areas where sidewalk width is limited or where existing poles are close to the curb.

HEIGHTS AND LATERAL LOCATION OF SIGNS



Note: Lateral offset is a minimum of 6 feet measured from the edge of the shoulder, or 12 feet measured from the edge of the traveled way.

Sign Orientation

Signs should be vertically mounted at right angles to the direction of, and facing, the traffic that they are intended to serve. Where mirror reflection from the sign face is encountered to such a degree as to reduce legibility, the sign should be turned slightly away from the road. Signs that are placed 30 feet or more from the pavement edge should be turned toward the road. On curved alignments, the angle of placement should be determined by the direction of approaching traffic rather than by the roadway edge at the point where the sign is located. On grades, sign faces may be tilted forward or back from the vertical position to improve the viewing angle.

An exception to this general rule is noted in Section 7.2.10 for parking signs, because parking signs should be installed between 30 degrees and 45 degrees from the edge of the roadway (i.e., the signs would face drivers if drivers are looking ahead but at an angle toward the parking side of the roadway).

If signs are installed over the roadway, position the overhead signs perpendicular to approaching traffic at the location where the sign is first legible (based on 30 feet per 1 inch of letter height).

7.8.11. Sign Blanks

KEY POINT

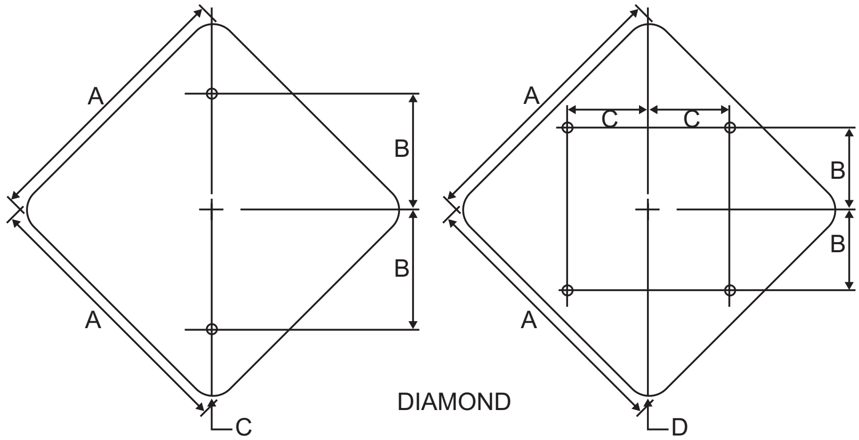
Aluminum is the most cost-effective material for sign blanks, and when the sign needs replaced, the salvage value sometimes is almost 50 percent of the cost of a new sign blank.

Aluminum is the most common material used for sign blanks. Although plywood and steel have been used by some agencies, steel is about three times heavier than aluminum, and neither last as long as aluminum (plywood delaminates and steel rusts). Therefore, all installations are encouraged to specify aluminum for sign blanks.

Part 7 of the *SHSM Book* includes blank standards for over 50 combinations of size, shape, and rotation of the sign blanks. The standards, as illustrated in Exhibit 7.19, include dimensions for corner radii and the locations of the mounting holes. It should be noted that the spatial arrangement of the holes generally defines the number of sign posts and their spacing.

Although not included in the *SHSM Book*, most transportation agencies use 3/8th-inch diameter holes and 5/16th-inch diameter aluminum bolts. In addition, military installations are also encouraged to specify that sign blanks conform to ASTM B 209; Alloy 5052-H36, 5052-H38, 5154-H38, 6061-T6, 3004-H38, or recycled 3004-H38. Sign blanks should have a chemical conversion coating conforming to MIL-C-5541, or revisions thereto. Refer to your state DOT's sign specifications when designing sign requirements.

Exhibit 7.19: Example of a Sign Blank Standard



A	B	C
24	12	15
30	15	1.875
36	18	2.25

A	B	C	D
48	15	15	3
60	18	18	3.75

Suggested minimum sign blank thickness is identified below.

Suggested Minimum Thickness of Aluminum Sign Blanks*

- ✓ 0.080” if stiffeners are used to strengthen the sign, or if both the sign width and the sign height is not greater than 30 inches.
- ✓ 0.100” if the largest dimension (width or height) of a sign without stiffeners is greater than 30 inches, but not greater than 48 inches.
- ✓ 0.125” if the height or width of a sign without stiffeners is greater than 48 inches.

* NOTE: The width and height of a diagonal-shaped sign is the measurements along the edges, typically the value labeled as Dimension “A”

7.8.12. Sign Supports

KEY POINT

Installations are strongly encouraged to specify steel square sign posts because of the inherent advantages and availabilities.

Signs with Areas Less Than 35 Square Feet

Most traffic signs can be manufactured from flat sheet aluminum substrate and mounted on one or two posts depending on the sign area.

To reduce potential injuries and vehicle damage, sign posts located within the clear zone must be a breakaway or yielding design as approved by FHWA. *(However, for consistency and cost effectiveness, it is recommended to utilize breakaway sign posts for signs outside the clear zone as well.)* Breakaway post systems generally rely on a two-piece post, with a weakened connection. In addition to reducing damage to an errant vehicle and its occupants, a two-piece post system also allows the anchor post to be installed from the ground level as opposed to an elevated platform or ladder, thereby reducing the likelihood of someone getting hurt.

Breakaway post requirements are discussed in FHWA's *Maintenance of Signs and Sign Supports: A Guide for Local Roads Maintenance Personnel*, as well as in AASHTO's *Roadside Design Guide*. Your State DOT standards should be used for breakaway post design whenever possible. Common breakaway posts are discussed and illustrated in Exhibits 7.20 and 7.21, respectively.

Exhibit 7.20: Common Breakaway Sign Posts

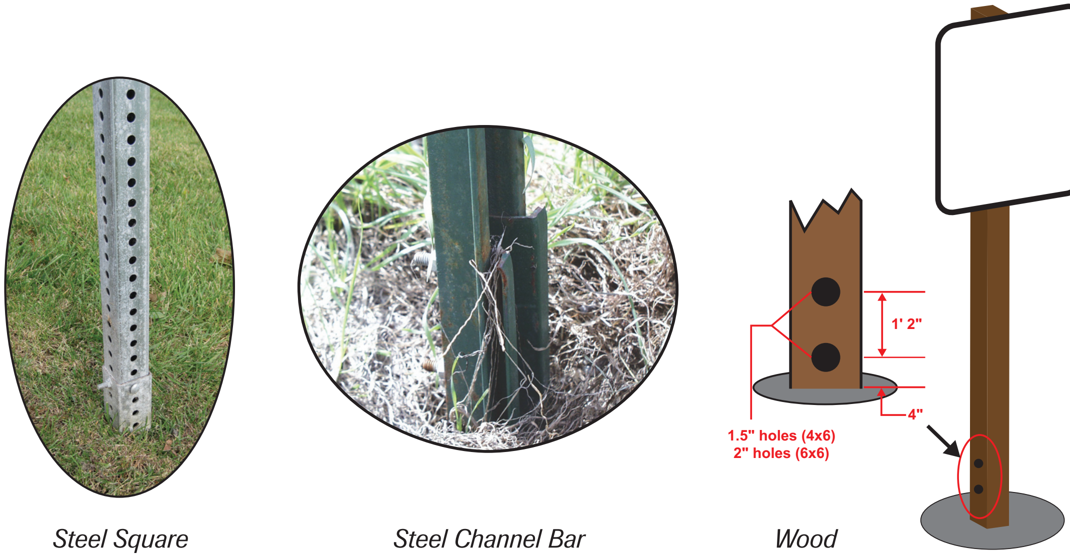
TYPE	COMMENTS*	MANUFACTURERS**
Steel square (common sizes include 1.75”x1.75”, 2”x2”, 2.25”x2.25” & 2.5”x2.5”)	✓ Due to their closed cross section, these posts have great torsional resistance and this eliminates most sign flutter ✓ A sign post is inserted into a 1/4-inch larger size anchor post and is attached with one bolt ✓ Signs can be mounted on all four sides of the post ✓ Posts of this type are also considered breakaway if they are 2 ¼ inches or less in size	✓ Western Highway Products: http://www.westernhighway.com ✓ Nucor Steel Marion: http://www.nucorhighway.com
Steel channel bar (common sizes: 2.5 lb./foot, & 4 lb./foot)	✓ May be less expensive than steel square posts ✓ Unlike square posts, these posts have an open cross section that lacks torsional resistance, which allows signs to flutter in the wind ✓ Because sign posts twist back and forth both above and below the ground, over time the posts work loose in the soil and start to lean, creating an ongoing maintenance problem ✓ A bar weighing 3 pounds-per-foot or less meets breakaway requirements by itself, being a weaker post	✓ Nucor Steel Marion: http://www.nucorhighway.com
Wood posts (common sizes: 4”x4”, 4”x6” & 6”x6”)	✓ Should specify Yellow Pine or Douglas Fir pressure-treated lumber ✓ Generally require a concrete foundation to satisfy national breakaway criteria, thus making replacement problematic ✓ All posts above 4 x 4 inch nominal size must be drilled perpendicular to traffic flow to allow the post to break away if struck by a motor vehicle. ✓ Posts sometimes warp or curl as they weather	✓ Available at larger lumber yards

* Anchor posts should never extend more than 4 inches above the ground to minimize the chance of the anchor post snagging the undercarriage of an impacting vehicle.

** For steel square posts and steel channel bar posts, the post supplier should provide: (1) certification concerning FHWA’s approval, including the maximum number of sign posts that are allowed within a 7-foot path; (2) documentation showing the maximum sign area that the posts will support at various sign heights, based on the locale’s design wind and soil conditions; and (3) proper installation instructions.

SIGNS

Exhibit 7.21: Small Breakaway Sign Posts



Steel Square *Steel Channel Bar* *Wood*

Signs with Areas Greater Than 36 Square Feet

Occasionally, military installations find it necessary to install large signs. When this happens, installations are encouraged to have the signs fabricated from extruded aluminum sign panels. These signs are available from some of the larger sign manufacturers, and typically are 6 inches or 12 inches high. Making a sign from these modular components is reminiscent of building with an erector set in that each piece is bolted together, one on top of the other to form the complete sign.

Large signs also create a need for special posts that require heavy duty breakaway connectors. If the need arises, installations will need to perform or contract out for a structural design.

Overhead Sign Installations

Overhead signs are generally used at the following locations:

- ✓ Traffic signals
- ✓ Three or more lanes in one direction
- ✓ Areas with restricted sight distance
- ✓ Left-hand or multi-lane exits
- ✓ Insufficient space for ground-mounted signs

If your installation believes that overhead signs are warranted, the installation is encouraged to contact SDDCTEA for assistance. In most cases, a mast arm can be installed to support the typical signing needs, but the supporting post may require shielding in the form of guardrail, barriers, or attenuators.

7.8.13. Enhanced Conspicuity of Standard Signs

When engineering judgment indicates that there is a need to draw additional attention to a sign, there are several acceptable methods (per *MUTCD* Section 2A.15) to accomplish this, including:

1. Use a larger sign or an additional sign on the opposite side of the roadway.
2. Attach one or two red or orange flags above a standard regulatory or warning sign, oriented at a 45-degree angle, especially for temporary conditions. (NOTE: Within a short period of time, the flags will lose their color and they will need replaced.)
3. Attach a flashing yellow Warning Beacon to the top of a standard regulatory, warning, or guide sign, except use a red Stop Beacon if attaching to a STOP sign. If attaching to a speed limit sign, use one or more yellow beacons. The beacon (s) are to have a nominal diameter of not less than 8 inches. If more than one beacon is used with a standard speed limit sign, they shall be vertically arranged and flashing alternately. Installations should be aware, however, that the cost of running commercial power to a sign or replacing batteries can be significant.
4. Provide small light emitting diodes (LEDs) along the sign border or to supplement a symbol or word message. If used, the LEDs shall have a maximum diameter of 1/4 inch and shall be white or red if used with STOP or YIELD signs; white if used with regulatory signs other than STOP or YIELD signs; white or yellow if used with warning signs; white if used with guide signs; white, yellow, or orange if used with temporary traffic control signs; and white or yellow if used with school area signs. Note that LEDs around the border are not a substitute for warning beacons, or any other more appropriate treatment.
5. For regulatory and warning signs, attach a minimum 2-inch wide strip of retroreflective sheeting material on the front side of the sign posts from the bottom of the sign to a location not greater than 2 feet above the elevation of the roadway. The color must match the background color of the sign, except that the color of the strip for the YIELD and DO NOT ENTER signs shall be red.

Image provided courtesy of Traffic and Parking Control Co., Inc. TAPCO (www.tapconet.com)

For Option 5, plastic retroreflective sleeves are commercially available from several sources, and sign crews can generally attach them to the posts with self-tapping screws. Depending on the type of sign post, a similar effect can be obtained by applying retroreflective sheeting directly to the front of the sign post.

These retroreflective strips are very effective at night, perhaps because they show the physical location of the sign instead of allowing the retroreflective sign to appear to be floating in the air. During daylight hours, the colored strips are also somewhat effective as an attention-getting device. These strips are recommended since they are relatively inexpensive, require no electricity, and the retroreflectivity generally lasts as long as the sign.

Refer to the *MUTCD* Section 2A.15 for additional details about the five listed options, as well as other methods to enhance sign conspicuity. Strobe lights shall not be used to enhance the conspicuity of highway signs.

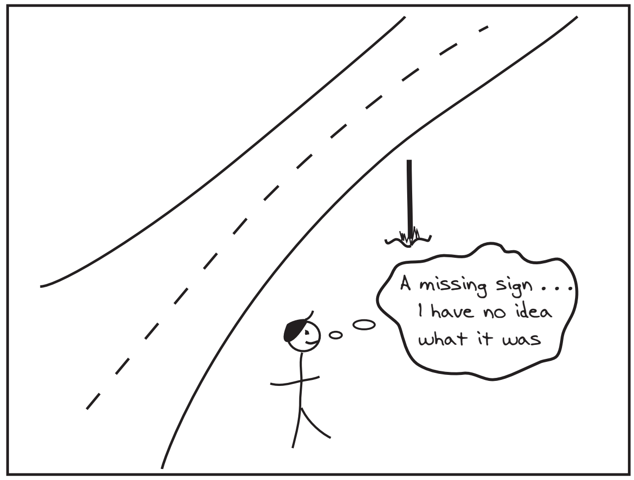
7.8.14. Sign Maintenance

Poorly maintained signs lose the respect of motorists, and consequently lose their effectiveness as traffic control devices. Under most circumstances, it is cheaper to replace damaged or unreadable signs than to attempt to repair them.

It is always a good idea to encourage military personnel to report any missing, damaged or ineffective signs. Ineffective signs include those blocked by vegetation and by other signs.

This sign should have been replaced years ago, before the red color disappeared.

7.8.15. Sign Inventory



One cannot overemphasize the importance of having a good sign inventory. For example, without an inventory, missing signs may go unnoticed for years, perhaps until someone complains or a crash problem evolves and the location is studied. Computerized listings also facilitate drive-by sign inspections.

A good sign inventory system should improve the quality of a signing program and reduce the number of related crashes. A computerized inventory can also assist in determining the anticipated replacement quantity of any given type of sign, based on the age of the signs, for a specified time period.

The process of capturing, analyzing, and presenting sign inventory information has evolved significantly in the last decade. The reduced cost and increased accuracy of using the Global Positioning System (GPS) has made the process of inventorying assets along highways much easier and more viable. In addition, the sophistication of Geographic Information Systems (GIS) has provided better data models for displaying and integrating asset inventories using Linear Referencing Systems (LRS). Today, it is possible to capture road assets using photography and GPS technologies, integrate the GPS locations using the LRS, and generate milepost/offset values for the sign locations.

Items to Capture in a Sign Inventory

- ✓ Roadway name or designation.
- ✓ Direction of travel.
- ✓ Linear location along the road (or GPS coordinates).
- ✓ Side of road (left, median, overhead, or right side).
- ✓ Sign code (i.e., the MUTCD designation) and size.
- ✓ Sign message if unique (e.g., destination and distance signs are generally one of a kind signs).
- ✓ Position of the sign on an assembly with other signs.
- ✓ Type and manufacturer of sheeting.
- ✓ Type and number of sign supports.
- ✓ Date installed.
- ✓ Date last inspected.
- ✓ Inspection comments (physical condition, required maintenance, etc.)
- ✓ Maintenance history (replacement date for sign posts, etc)
- ✓ Lateral offset from the edge of the traveled way
- ✓ Mounting height
- ✓ Sign retroreflectivity (measured using an approved MUTCD method)

SDDCTEA can perform sign management studies for installations. As part of a Sign Management Study, all existing attributes of existing signs are collected, a GIS-based database of sign information is prepared, and professional recommendations on signing improvements are given (addressing proper sign application, elimination of redundant and unnecessary signage, obsolete signage, and signage that is lacking). Additionally, the study will identify signs in need of immediate replacement, and report the remaining sign life (in years) for those not in need of immediate replacement. Costs will be developed for replacement priorities in replacement-year dollars. Upon completion, the database is turned over to the installation for their use. The installation can then maintain the database using ArcGIS. The advantage of SDDCTEA performing this study is that a fresh set of eyes can offer an unbiased outsider's perspective on the appropriateness of signing throughout an installation.

Off-the-shelf databases (such as SignTRACK™) are available to capture virtually any sign element, plus digital pictures, maintenance history, etc. This particular system also provides seamless integration with other SignCAD® products.

One of the most popular software packages used for sign inventories is CartêGraph's suite of modules that facilitates asset management not only for signs, but also for water, sewer, storm water, bridge, lights, pavements, etc. For an initial investment of about $10,000 to $15,000, installations can purchase a personal digital assistant (PDA) with GPS and the necessary licenses and training, and then lease the software suite for about $2,500 per year. This software could be beneficial to an installation that performs its own sign inventory.

Software is also available from GBA Sign Master.

Which is Worse, a Sign with Substandard Retroreflectivity, or a Missing Sign?

If a sign has substandard retroreflectivity, it probably is still effective during the day and perhaps somewhat effective at night. Moreover, there is also an excellent chance that the sign will eventually be replaced.

However, if the sign was knocked down and there is no sign inventory, it is possible that the missing sign may never be replaced. Or even worse, perhaps the missing sign will cause a crash before someone restudies the location and a new sign is installed.

Therefore, the value of a good sign inventory cannot be overemphasized.

The beauty of any electronic sign inventory is that it can help manage a sign maintenance program while keeping costs to a minimum. Military installations can develop their own electronic log of their field reviews using more primitive methods. One method is to manually drive the roads and capture the attributes and location of each sign along the highway. Experienced field and traffic personnel can readily identify the standard signs and select the *MUTCD* sign codes. By keeping an electronic inventory, missing signs and those that need replaced due to their age can be quickly identified.

7.8.16. Sign Management Methods

Historically, the most common method used by highway agencies to evaluate sign retroreflectivity was to have a sign inspector drive the road at night, identify the unacceptable signs, and then schedule them for replacement. However, this method is subjective. With the establishment of minimum retroreflectivity values and depending on existing protocols, this method may or may not meet today's requirements (as discussed in 'Assessment Method A' below).

FHWA has identified five methods to maintain the minimum sign retroreflectivity levels, as identified in Exhibit 7.12. The methods recommended in the *MUTCD* are broken into two categories: assessment methods, and management methods. Each method has advantages and disadvantages. The first two methods, A and B, are assessment methods where signs are evaluated individually, and the last three methods, C, D and E, are management methods where signs are evaluated on a macroscopic basis. These methods are not foolproof, but FHWA requires that every agency implement a program to maintain sign retroreflectivity.

Section 2A.08 of the *MUTCD* States:

"Public agencies or officials having jurisdiction shall use an assessment or management method that is designed to maintain sign retroreflectivity at or above the minimum levels in Table 2A-3."

"Compliance with the Standard in Paragraph 2 is achieved by having a method in place and using the method to maintain the minimum levels established in Table 2A-3. Provided that an assessment or management method is being used, an agency or official having jurisdiction would be in compliance with the Standard in Paragraph 2 even if there are some individual signs that do not meet the minimum retroreflectivity levels at a particular point in time."

Note: MUTCD *Table 2A-3 is shown as Exhibit 7.12 in this pamphlet.*

SIGNS

ASSESSMENT METHODS

Method A: Visual Nighttime Inspection.

As noted before, Method A is the method historically used by most highway agencies, but in order to be acceptable with today's requirements, it must be fine-tuned. Therefore, if Method A is used, inspectors need to be trained, and additional guidelines must be followed.

Although the visual assessment method is subjective, it does help to identify some other issues such as: signs hidden by foliage, signs that are not properly aligned, nighttime visual clutter, visibility issues related to blinding floodlights, and other distractions. If used as the sign assessment method, it should generally be repeated annually, or at least every other year.

Method A could be performed several ways. Three ways are identified by FHWA to support visual nighttime inspections:

✓ Calibration Signs: An inspector views a calibration sign each time before conducting a nighttime field review. The calibration signs have known retroreflectivity levels at or above the specified minimums. The calibration signs are set up in a maintenance yard where the inspector can view the signs in a manner similar to nighttime field inspections. The inspector uses the visual appearance of the calibration sign to establish the evaluation threshold for that night's inspection activities.

✓ Comparison Panels Procedure: This procedure involves assembling a set of comparison panels that represent retroreflectivity levels above the specified minimums. Inspectors then conduct a nighttime field review and when a marginal sign is found a comparison panel is attached and the sign/panel combination is viewed. Signs found to be less bright than the panel would then be scheduled for replacement.

✓ Consistent Parameters Procedure: The nighttime inspections are conducted under conditions similar to those used in the research to develop the minimum retroreflectivity levels. These factors include:

- Using a sport utility vehicle or pick-up truck to conduct the inspection.
- Using a model year 2000 or newer vehicle for the inspection.
- Using an inspector who is at least 60 years old with 20/20 vision (corrected).

In addition, if using this method consider the following:

1. **Consistency of testing**—Conduct inspections during consistent nighttime conditions. For example, always conduct inspections when there is no rain or fog, and when signs do not have snow or dew on their faces. Keep the interior vehicle lights off, and use a pen light for recording the results of the inspection. Use at least three ratings: good, marginal, and defective. Do not start the inspection until it is completely dark.
2. **Speed of vehicle**—Conduct inspections at normal roadway operating speeds. If you have to slow or stop the vehicle to read the sign, this usually means the sign should be replaced.
3. **Vehicle position**—Signs should be inspected from the travel lane, and at the typical viewing distance, that is, at a distance that provides the driver adequate time for an appropriate response.
4. **Headlights**—Use properly aimed low-beam headlights. Take the vehicle to a local mechanic to verify that the head lamps are properly aimed.
5. **Safety issues**—If possible, designate a driver for the vehicle. This serves the dual purpose of allowing the inspector to focus on the sign evaluation, which promotes consistency and accuracy of results, as well as improving safety for everyone on the roadway. If the inspector has to drive, use a tape recorder to record verbal evaluations.
6. **Recordkeeping**—Use a standardized form for tracking inspection results and maintain results in a file cabinet or a computer database for ease of reference and future use. Have the form partially filled out prior to the nighttime review, including the sign location and type listed in the driving order so that the inspector can concentrate on the visual evaluation and only needs to enter the score. The form may be a printout from a computerized inventory or a hand-written form similar to the example.
7. **Replacement**—As soon as possible, replace any sign that is not legible to the inspector at the typical viewing distance and speed. Also, schedule any signs rated as marginal for replacement since it may be at least a year before the signs are reviewed again.

8. **Frequency**—Installations should generally perform inspections on an annual basis, but at least every other year.
9. **Documentation**—Maintain all evaluations for future reference to prove that the inspections were conducted and that defective and marginal signs were replaced.

Nighttime Sign Inspection Form

Road: ____________________ Military Installation: ____________________

Direction: ____________________

Route Start Point: ____________________ Inspector: ____________________

Route End Point: ____________________ Date: ____________________

Trip Odometer	Sign Description	Retroreflectivity			Replacement Date
		Good	Marginal	Defective	
0.1	Speed Limit 35	✔			
0.5	Crossroad			✔	
0.6	STOP		✔		

If using this method, installations are strongly encouraged to retain the list of signs and sign locations in a computerized inventory (e.g., a simple database or spreadsheet) that can be used to generate new inspection forms for the next nighttime inspection. This type of inventory also helps to identify any signs that were lost during the year. However, the ultimate goal should be to eventually transfer the data to a more complex inventory.

Method B: Measured Sign Retroreflectivity.

With this method, retroreflectivity readings are obtained on all signs on an installation. The measured sign retroreflectivity method directly obtains retroreflectivity values by using a retroreflectometer. Sign measurements remove the subjective nature by acquiring a specific retroreflectivity value. Repeatable and adequate measurements require both a calibrated instrument and a knowledgeable operator.

Sign retroreflectivity measurement procedures are relatively straightforward; however, it is important that procedures be followed consistently. ASTM Standard Test Method E1709 outlines the procedures for operating and taking measurements with a retroreflectometer; it specifies that a retroreflectometer operator acquire a minimum of four retroreflectivity measurements per retroreflective sign color. The measurement locations are in different parts of the sign and the readings can be averaged when compared with the *MUTCD* minimum levels, as shown in Exhibit 7.12. When the sign's retroreflective reading is lower than the minimum levels, the sign should be replaced.

Considering the effort involved in this method, along with the cost of obtaining a retroreflectometer, many agencies do not consider this method to be viable. **However, SDDCTEA owns a retroreflectometer and is available to conduct a Sign Management Study for your installation upon request.**

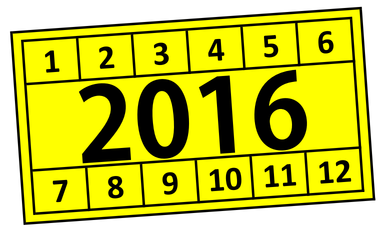
MANAGEMENT METHODS

Method C: Expected Sign Life.

Manufacturers of Type III and higher types of sheeting typically provide a minimum 10-year warranty for their materials during which they guarantee a minimum retroreflectivity. Since the guaranteed retroreflectivity values at the end of the warranty period (typically 80 percent of new minimum values) are significantly greater than FHWA's minimum retroreflectivity values, or the values in Exhibit 7.12, these materials should exceed the manufacturer's warranty even if installed under the harshest conditions; i.e., south-facing signs located at high altitudes with extreme heat and humidity.

Many highway agencies have determined that signs made from Type III or Type IV material have a life expectancy of 12 to 15 years. However, agencies can occasionally monitor some signs and adopt either a longer or a shorter "expected sign life," as appropriate. In addition, military installations can query their state DOT to learn about their experience, with specific manufacturers, types, and colors of sheeting.

Ideally, military installations should be working from a sign inventory database. However, in the absence of an inventory, the sign installation date can be identified by:



- ✓ Applying a durable preprinted label on the back of the sign that displays the year that the sign was installed. The sticker may also include the months, or the months and the days, where the person installing the sign punches out the appropriate numbers to show the installation date prior to affixing it to the sign. Stickers are typically about 3 to 4 inches wide, and are available from companies like 3M, Custom Products Corporation, and others. If using stickers, military installations are encouraged to use different colors for each year to expedite field reviews.
- ✓ Physically writing the installation date on the back of the sign blanks with a durable paint marker.

> **Expected Sign Life?**
>
> The "*Expected Sign Life*" is your best estimate of the maximum number of years that the retroreflectivity of a specific type and color of retroreflective sheeting on a south-facing sign will satisfy the minimum retroreflectivity values. The expected sign life may be based on the manufacturer's warranty or the sign retroreflectivity degradation in the same basic geographic area for each specific manufacturer, type, and color of sheeting.

Military installations must keep in mind, however, that without a sign inventory, the inspector will need to get close enough to each sign to "read" the date on the back of the sign to determine the year that the sign was installed. To put things in perspective, if the expected sign life is 12 years, on average, only every 12th sign will require replacement if the installation date of all signs are inspected annually. Considering the effort with reviewing all signs for the ones requiring replacement that year, this may be a cumbersome task.

Method D: Blanket Replacement.

The blanket replacement method also uses the expected sign life but with this method all signs in a specified area or all signs of a given type are replaced at the same time. This approach simplifies the date of installation by allowing external records to be kept instead of requiring a sign inventory or adding the date to the back of every sign. For example, if all colors of sheeting provide a minimum 13-year life as determined by sampling or via the local DOT, then if your installation replaces all signs in 2016, the next scheduled replacement program would be in 2029.

By replacing all of the signs at the same time, the need to monitor individual sign replacement dates is eliminated. However, it is always a good idea to inspect signs on a regular basis to ensure that signs are present and properly oriented, and that drivers have a clear line-of-sight to the signs. It is also good to perform some of the reviews at night, because night reviews help identify problems caused by lights and other visual distractions.

To provide a more uniform budgetary impact, it may be desirable to:

1. Divide the military installation into several smaller areas, each having a different replacement cycle, or
2. Spread the type of signs over a series of years; e.g., replace STOP and YIELD signs in one year, speed limit signs a second year, other regulatory signs a third year, etc.

It is important to remember, however, that some signs will be replaced mid-cycle due to crashes, construction, etc., and these signs will eventually need to be replaced prematurely in order to maintain the same cycle. However, the blanket method does have many advantages.

Method E: Control Signs.

This method requires the designation of control signs to represent every manufacturer, type, and color combination from ongoing sign purchases. Because it is labor intensive to take retroreflective readings, this method has broader application for DOTs where these costs can be spread over a larger signing program.

Exhibit 7.22 summarizes the five methods to assess and maintain adequate sign retroreflectivity, and the advantages and disadvantages of each.

Exhibit 7.22: FHWA Methods to Assess and Maintain Minimum Retroreflectivity

METHODS	ADVANTAGES	DISADVANTAGES
A. Visual Nighttime Inspection. Inspect all signs at night by a trained sign inspector, driving at normal speeds and using low-beams. The inspector should be 60 or older and should evaluate the signs from the normal viewing distance. The vehicle should be a 2000 model year or newer SUV or pick-up truck. Replace defective and marginally-acceptable signs.	✓ Helps evaluate sign orientation issues and other distractions ✓ Low cost; no retroreflective measuring deceives needed	✓ Requires a trained, nighttime sign inspector ✓ Subjective and inaccurate ✓ Requires a frequent review ✓ Requires some type of inventory to document the signs that are acceptable, marginal, or defective
B. Measured Sign Retroreflectivity. Periodically measure the retroreflectivity of sign backgrounds and retroreflective legends. Replace the individual signs with substandard retroreflectivity values.	✓ Minimizes prematurely replacing signs ✓ Accurate actual measurements	✓ Requires a retroreflectometer ✓ Extremely labor intensive ✓ Potential hazards if climbing ladders ✓ Requires an inventory to document the retroreflectivity readings
C. Expected Sign Life. Replace individual signs based on the age of the sign and the expected sign life. To track the installation date, maintain a sign inventory or identify the year of installation on the back of the signs.	✓ Simple ✓ No need to measure retroreflectivity	✓ Requires an inventory or a sign-dating system ✓ If using a sign-dating system, inspectors need to search for the target year signs

Exhibit 7.22: FHWA Methods to Assess and Maintain Minimum Retroreflectivity (Continued)

METHODS	ADVANTAGES	DISADVANTAGES
D. Blanket Sign Replacement. Replace all signs on the installation or area within the installation at the same time using the previous replacement date and the expected sign life. (A variation could be, replace all STOP signs in Year #1, Speed Limit signs in Year #2, other regulatory signs in Year #3, etc.)	✓ May reduce the mixing of old and new signs ✓ Lowest labor costs	✓ May prematurely replace some signs installed between blanket replacement cycles; e.g., signs that replaced signs damaged in crashes ✓ Special funding may be needed if the effort is base wide
E. Control Signs. Replace individual signs based on measured retroreflectivity of signs that represent the general population of signs purchased and installed in the same basic time frame. The control signs can either be installed in the field or in another location such as in a maintenance yard, but should face south in the northern hemisphere.	✓ Provides for year-to-year differences in materials ✓ Simpler than measuring retroreflectivity of all signs.	✓ Requires a retroreflectometer and a sign inventory ✓ The number of control signs could be extensive since multiple signs should be installed to represent all color combinations from different groups of sign purchases ✓ Evaluating the retroreflectivity of all control signs could be very labor intensive

What Method is Best for Your Installation?

In the long-term, it is safe to say that the simplest and most economical way to ensure that signs satisfy the minimum sign retroreflectivity standards is by using one of two management methods, either Method C or D. Moreover, the choice depends on the availability of a sign inventory.

For example, for installations with a sign inventory, Method C (i.e., the "Expected Sign Life" approach) probably is the best choice because new signs can be ordered based on the sign inventory. However, if a sign inventory does not exist, Method D (i.e., the "Blanket Replacement" approach) is the recommended method.

In either case, the installation needs to temporarily supplement the program with a visual nighttime inspection (Method A) in order to ease into the selected program. For example, if Method C is selected and some sign installation dates are not available, start to track the new installation dates but also replace obvious problem signs based on visual nighttime inspections. Similarly, if Method D is selected, signs that are scheduled for some future blanket replacement period should be routinely inspected at night until all signs are replaced the first time.

However, in the short-term, installations may elect to use Method A as their starting point and then start building a sign inventory database with the goal of ultimately converting to Method C. In this case, the inventory should be complete with replacement dates, sign sizes, type material, etc.

With reference to Exhibit 7.22, purchasing a retroreflectometer should be unnecessary if your installation is using:

- ✓ Method A—Visual nighttime inspection, or
- ✓ Methods C or D and your "expected sign life" is based on the sheeting manufacturer's warranty or information provided by a reliable outside source such as your state DOT. (Installations should retain documentation regarding their information source.)

"First Things, First"

Prior to implementing a major sign replacement program, it is very important to review existing signs to make sure that they are appropriate instead of merely replacing them with the same type of sign. For example:

- ✓ Are the speed limits and advisory speeds appropriate?
- ✓ Did traffic volumes change so much that the STOP signs are now on the major roads instead of on the minor roads?
- ✓ Are there any obsolete signs; e.g., 2-WAY, 3-WAY, or 4-WAY plaques?
- ✓ Are the advance warning signs located at an appropriate distance from the hazard in accordance with Table 2C-4 in the current *MUTCD* (i.e., Exhibit 7.30 in Chapter 7)?
- ✓ Are all of the signs necessary?
- ✓ Do you need a larger sign? For example, the *MUTCD* now requires 36"x36" STOP signs on multi-lane approaches, and on any approach to a multi-lane road with a speed limit of 45 mph or higher. Also, on multi-lane roadways, 36"x36" is now the minimum size for Curve and Turn signs.
- ✓ Can some signs be relocated to spread them out to improve the driver's ability to "read" the signs?
- ✓ Are the signs located in advance of the ECF in accordance with the standards?

7.2. REGULATORY SIGNS

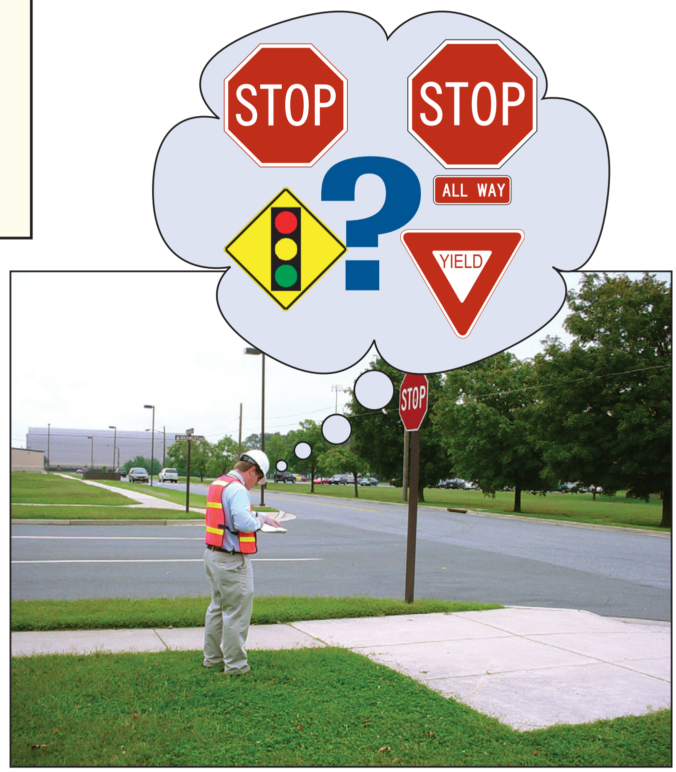
Regulatory signs inform drivers of traffic laws, regulations, or restrictions, for which they can be cited by law enforcement agencies. In light of the enforcement aspect, it is essential that the signs be readily visible and understandable.

Regulatory signs are typically black-and-white rectangular signs, but several exceptions exist. The most common exceptions to the color and shape rules are the STOP and YIELD signs, which are designed to be unique, and thereby quickly recognized without the need to read the signs.

7.2.1. STOP and YIELD Signs

KEY POINT

There are many situations on military installations where unnecessary STOP signs exist, or where the STOP signs are on the major road instead of being on the minor road. These situations waste both time and energy.



One of the most obvious situations where regulatory signs are needed is at intersections. The big question is, "What type of traffic control should be provided?" This answer is addressed in detail in Chapter 6 of this pamphlet.

The normal application of STOP (R1-1) signs is at intersections where the minor legs of the intersection have STOP signs, and the two opposing approach legs with the major movement do not have any traffic control signs.

In most cases, the major and minor roadways are obvious, but in some cases it may be necessary to document the traffic volumes and the turning movements at the intersection during the peak hours.

YIELD (R1-2) signs can be installed in lieu of STOP signs when it is not always necessary for everyone to stop as outlined in Section 2B.09 of the *MUTCD*. However, YIELD signs should only be used when sight distance is such that drivers approaching the YIELD sign have a good view of approaching vehicles on the cross street.

YIELD signs are also used on all approaches to a roundabout.

STOP and YIELD signs are to be located as close as practical to the intersection it regulates, while optimizing its visibility to the approaching drivers. These signs are not required to be placed at the applicable stop or yield line, but the *MUTCD* does recommend that the signs be placed no farther than 50 feet from the edge of the pavement of the intersecting roadway. Examples of this may be at a wide throat intersection or at an intersection with a large corner radius.

> **Where Should You Stop at an Intersection?**
>
> The actual location where drivers are to stop at an intersection with a STOP sign is normally defined in the state's vehicle code. Typically, the law requires that a driver stop at any clearly designated stop line or, if a line is not present, before entering a crosswalk or, if no crosswalk is present, then at a point nearest the intersecting roadway where the driver has a clear view of approaching traffic on the intersecting roadway before entering. Therefore, the location of the STOP sign is generally not a factor.

If it is determined that STOP signs are installed on the wrong approaches, it is generally best to temporarily create a multi-way stop control intersection for about 6 weeks and then to use the suggested "Two-Step Procedure to Change the Multi-way Stop Control to Two-Way Stop Control" as discussed on the next page.

7.2.2. Multi-way Stop Control

> **KEY POINT**
>
> Multi-way stop control should never be used in an attempt to reduce vehicle speeds. However, when used, the ALL WAY plaque should always be used below each STOP sign.

R1-1 &
R1-3P

Some installations have installed STOP signs for speed control purposes. Traffic studies indicate that drivers have a natural tendency to travel even faster than normal between these 'extra' STOP signs and a greater tendency to not stop as they perceive the 'extra' sign as unnecessary. Therefore, warrants are established in Section 2B.07 of the *MUTCD* for multi-way stop applications, and any unwarranted STOP signs should be removed.

When all approaches to an intersection are controlled by STOP signs, an ALL WAY (R1-3P) plaque shall be mounted below each of the STOP signs. Installations should no longer use the obsolete 2-WAY, 3-WAY, and 4-WAY plaques since they do not tell drivers if any of the approaches do not have a STOP sign.

If it is determined that an intersection with multi-way stop control should be changed to two-way stop control, the suggested procedure is highlighted on the next page.

Two-Step Procedure to Change Multi-way Stop Control to Two-Way Stop Control

1. On the "change day," remove the STOP (R1-1) signs, any Stop Ahead (W3-1) signs, any inappropriate plaques, and stop lines on the appropriate approaches, and install a CROSS TRAFFIC DOES NOT STOP (W4-4P) plaque under each of the remaining STOP signs. A battery-operated flashing red light can also be attached to the top of the remaining STOP signs for additional emphasis.
2. Approximately 6 weeks after removing the STOP signs, remove the W4-4P plaques and any flashing red lights.

The combination of a STOP (R1-1) sign and the CROSS TRAFFIC DOES NOT STOP (W4-4P) sign is an unusual color combination. The MUTCD *also includes other similar plaques (see W4-4aP and W4-4bP as shown in the* MUTCD*).*

SIGNS

7.2.3. In-Street and Overhead Pedestrian Crossing Signs

> **KEY POINT**
>
> The Vehicle Code in most states requires drivers to yield to pedestrians in the crosswalks. Therefore, the R1-6a and R1-9a signs should only be used in states that require drivers to stop for pedestrians within the crosswalk.

Many highway agencies are using the In-Street Pedestrian Crossing (R1-6 or R1-6a) sign on the road at marked midblock crosswalks on low-speed roadways. These double-sided signs may be placed on the road within several feet of a marked crosswalk to create an "in-your-face" reminder to drivers that there may be pedestrians in the crosswalk, and that drivers are required to yield to or stop for these pedestrians. The signs also tend to slow the traffic because they reduce the lane width and are in close proximity to vehicles.

Depending upon the state Vehicle Code, states will generally allow either the R1-6 sign or the R1-6a sign. If military installations are not sure of the specific state requirements, someone should review the matter with the state DOT. Installations are also encouraged to ask the DOT if they have a list of approved devices that need to be used.

General recommendations include the following:

- ✓ Use these signs only on roadways with a speed limit of 35 mph or less, and with lanes at least 10 feet wide.
- ✓ Use only at marked midblock crosswalks.
- ✓ Use the appropriate sign to correspond to the requirements of the applicable state vehicle code.
- ✓ Place the sign near the crosswalk, either on the center line, on a lane line, or on a median island.
- ✓ Only place the R1-6 and R1-6a signs on weighted bases. Never install on sign posts.

R1-6

R1-6a

R1-9

R1-9a

**The legend STATE LAW is optional*

The Overhead Pedestrian Crossing (R1-9 and R1-9a) signs may be placed over the roadway at the crosswalk.

The R1-6, R1-6a, R1-9, and R1-9a signs may have either a yellow, fluorescent yellow, or fluorescent yellow-green background. In addition, the words STATE LAW may be eliminated from these signs.

7.2.4. Speed Limit Signs

> **KEY POINT**
> No one wants a citation for exceeding a speed limit, especially if they feel that they did not have adequate advance notice. Therefore, it is important to have signs installed at the appropriate locations to avoid entrapment.

R2-1

Chapter 15 provides the methodology used to determine the appropriate speed limit. The standard Speed Limit (R2-1) sign is 24 by 30 inches for single lane roadways and 30 by 36 inches for multi-lane roadways on military installations. Speed Limit signs generally should be placed at the following locations:

✓ At the beginning of new speed limits
✓ After major intersections
✓ At meaningful intermediate locations within long sections of roadway

The *MUTCD* does not contain any maximum spacing requirements for Speed Limit signs, but some states have unique requirements in order to enforce speed limits under their vehicle code. In the absence of any specific state spacing requirements, installations are encouraged to use maximum 1-mile spacing for speed limits of 35 mph or lower, and maximum 3-mile spacing for higher speed limits. However, avoid placing a Speed Limit sign immediately in advance of a curve or turn, an intersection, a railroad crossing, and other locations that may require a reduction in speed for safety.

> Sometimes, speed limit signs do not produce the desired effects. Typically these speed limits are problematic because the road was either designed to a higher design speed which encourages higher speeds, or because there is an observed lack of enforcement.
>
> Possible solutions include:
>
> ✓ Increase enforcement.
> ✓ Install speed humps which are designed for the specific speed limit (if the criteria in Chapter 16 of this pamphlet are satisfied).
> ✓ Allow on-street parking to effectively narrow the roadway.

Advance Notice of Speed Reductions

When a speed is reduced greater than 10 mph, a Reduced Speed Limit Ahead (W3-5 or W3-5a) sign, as presented in Section 7.3.4., should be placed in advance of the reduced speed as shown on a Speed Limit (R2-1) sign. Side roads connecting to the roadway within the speed zone do not require the W3-5 sign.

W3-5

Boundary Speed Limit Signs

Some military installations have determined that the entire installation or at least a section of the installation (e.g., residential or industrial areas) should have the same basic speed limit. In these situations, it is possible to do a blanket speed posting and install a single sign assembly after entering the "restricted area", instead of the more costly option of placing Speed Limit (R2-1) signs throughout. For a blanket speed posting, install one of the following plaques above the R2-1 sign:

- ✓ RESIDENTIAL (R2-5cP)
- ✓ BASE (R2-5hP-TEA)
- ✓ INSTALLATION (R2-5iP-TEA)

If there are any roadways within the "restricted area" that have a regulatory speed limit different than the blanket speed, then an UNLESS OTHERWISE POSTED (R2-5P) plaque must also be mounted below the R2-1 sign as illustrated.

R2-5hP-TEA, R2-1,
& R2-5P

Since it is essential that every driver see these "*boundary speed limit signs*," installations are encouraged to use the larger, 30"x36" Speed Limit (R2-1) sign. In addition, if there is more than one travel lane on the approach, a second sign assembly is recommended to the left of the left lane; e.g., within a median, or if this is not possible, install a second sign assembly at least 250 feet beyond the first sign assembly.

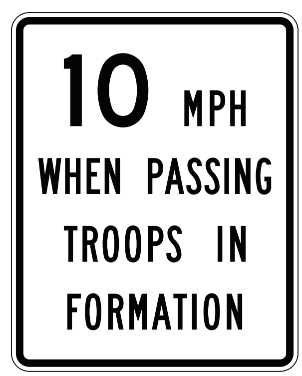
Moreover, when leaving an area with "*boundary speed limit signs*," it is essential that signs be installed for the new speed limit.

If "*boundary speed limit signing*" is not recognized by the state or host nation as discussed as an option in the *MUTCD* (Section 2B.13), then enforcement will have to be under DoD regulations or administrative procedures established by installation commanders as discussed in Section 5.2.

When Passing Troops Speed Limit

Another unique type of speed limit is the 10 MPH WHEN PASSING TROOPS IN FORMATION (R2-1a-TEA) sign, which is for use along roadways where troops periodically walk in formation on the roadway. Enforcement typically will be under DoD regulations or administrative procedures discussed in Section 5.2.

The R2-1a-TEA sign shall only be used as a supplemental sign and mounted below the R2-1 speed limit sign, even in situations where boundary speed limit signs are utilized.



R2-1a-TEA

7.2.5. Turn Prohibition Signs

Some typical sign messages are:

- ✓ No Right Turn (R3-1).
- ✓ No Left Turn (R3-2).
- ✓ NO TURNS (R3-3).
- ✓ No U-Turn (R3-4).
- ✓ No U-Turn/No Left Turn (R3-18).

Place turn prohibition signs where the driver who is most likely to make that turn can easily see the sign. For example, at unsignalized intersections, post-mount the signs on the appropriate side of the roadway. And at signalized intersections, the ideal location is:

- ✓ Near the left overhead traffic signal for No Left Turn, No U-Turn, and the No U-Turn/No Left Turn signs.
- ✓ Near the right overhead traffic signal for No Right Turn signs.
- ✓ Between the signals or near both the left and the right overhead traffic signal for the NO TURNS sign.


R3-1


R3-2

R3-3


R3-4


R3-18

7.2.6. Part-Time Restrictions

If it is not always necessary to have full-time restrictions or prohibitions (such as for turn prohibitions, special speed zones, and reversible-lane operations), a sign that is visible only when the restriction is in effect is the easiest to understand. These signs could be either of the following types:

- ✓ An electronic blank-out sign, where a single sign message is either illuminated or it is "blanked out;" or
- ✓ The whole sign, or a portion of the sign, is capable of being changed, commonly called a changeable message sign (CMS).

However, when funds are not available or conditions do not warrant the above expense, a supplementary plaque may be mounted below the regulatory sign. One of the most effective supplemental plaques is the WHEN FLASHING (S4-4P) plaque if used in conjunction with a yellow flashing light. This message leaves no doubt in the driver's mind as to when the regulation is in effect.

If a flashing light is also impracticable, a supplementary plaque showing the applicable times of the restriction (similar to the S4-1P plaque) may be installed below the regulatory sign. The plaque shows the hours during which the regulation is in effect. The hours should be shown in civilian time, not military time. This combination is not as effective as the other options because motorists sometimes do not have enough time to read and understand the complete message, or may not have an available clock or watch.

R2-1 & S4-4P

R3-2 & S4-1P

R11-4b-TEA

7.2.7. Road and Gate Closure Signs

The ROAD CLOSED (R11-2) sign may be used to mark roads or gates that have been closed either on a permanent or on a part-time basis. The sign should be erected at or near the center of the roadway and on or above a barricade that closes the roadway. Except within work areas (i.e., construction, maintenance, or utility work areas), the barricade should have three alternating red-and-white, striped retroreflective rails that are a minimum of 48 inches in length, and 8 to 12 inches high. The minimum size ROAD CLOSED sign is 48 by 30 inches because it is the last sign the driver will see before he must stop or turn.

R11-2

R11-2g-TEA

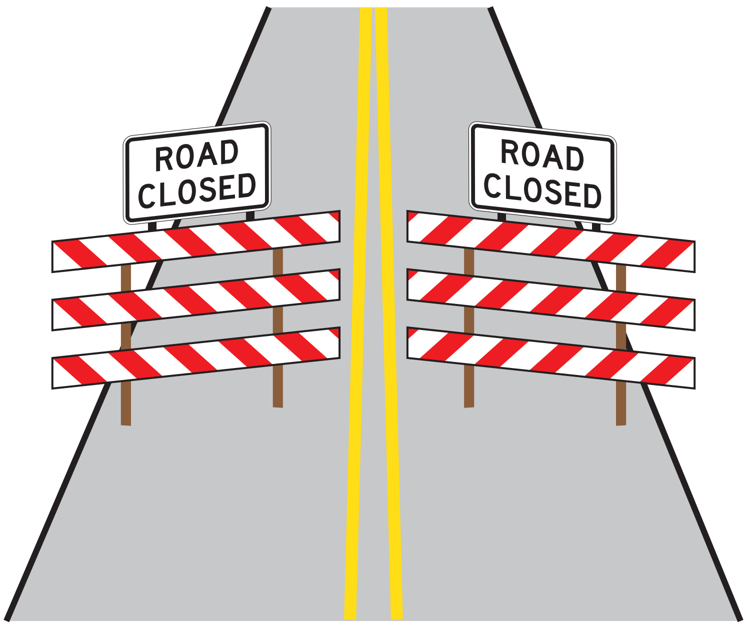
When appropriate, the GATE CLOSED (R11-2g-TEA) sign may be used in place of the R11-2 sign. (See Section 8.6 for information on the use of this sign at gate closures.)

When a road closure occurs on what would otherwise be a continuous roadway, especially if the speed limit is greater than 25 mph, a ROAD CLOSED AHEAD (W20-3) sign or a GATE CLOSED AHEAD (W20-3g-TEA) sign may be appropriate (see Section 7.3.13).

As shown on Exhibit 7.23 and discussed in *MUTCD* Section 2B.67 and pamphlet Section 7.3.15, barricades can be used in lieu of the End-of-Roadway markers. When used, barricades should have retroreflective rails, and except for the red-and-white color, they should comply with the design details in Section 6F.68 of the *MUTCD*. Always use an appropriate warning sign in advance of an "End-of-Roadway Barricade" to warn of the road closure since the barricade is a formidable object. The Road Closed (with distance or AHEAD legend) (W20-3) sign would generally be appropriate.

Do not use the End-of-Roadway Barricade at any location where it could be hit on an end unless it has been crash tested at that angle and determined to be crash worthy at the prevailing traffic speed.

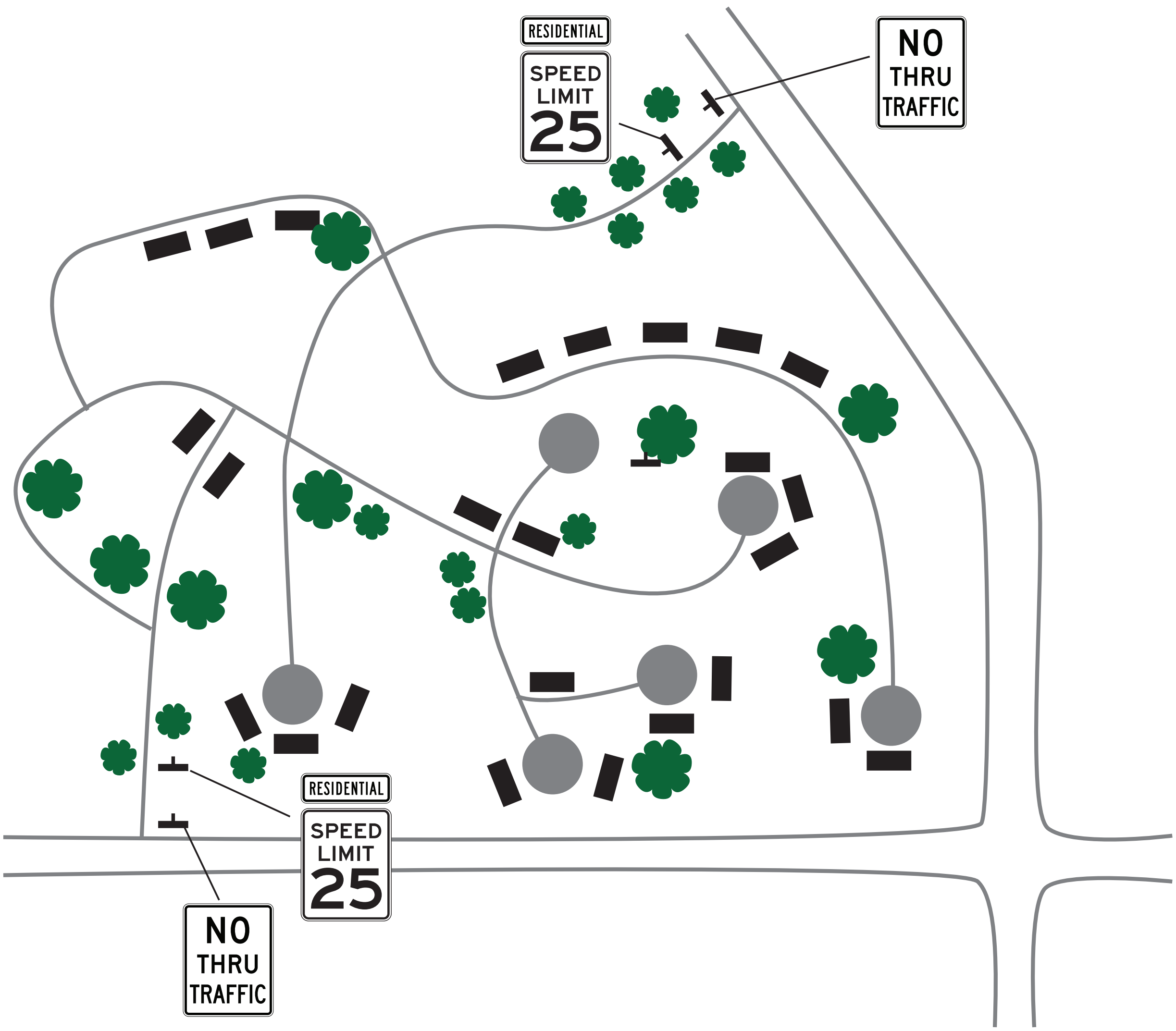
Exhibit 7.23: End-of-Roadway Barricade



7.2.8. NO THRU TRAFFIC Sign

The NO THRU TRAFFIC (R11-4a-TEA) sign may be used to prohibit traffic from using a residential street or other safety-sensitive roadways as through streets. This sign is placed primarily at or near the boundary of these sensitive areas used as shortcuts by commuter traffic.

Exhibit 7.24: Residential Area Signing



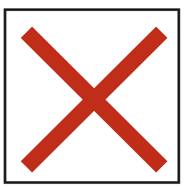
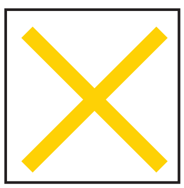
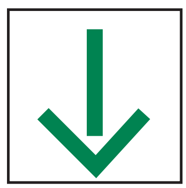
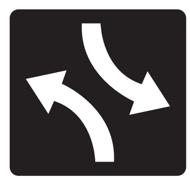
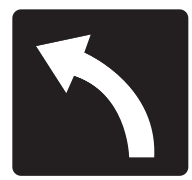
7.2.9. Reversible Lane Signs

When the majority of traffic flows in one direction during part of the day and in the opposite direction during another part of the day, it may be possible to make a reversible-lane providing the roadway has a total of three or more travel lanes. However, when a reversible lane is established, it creates a potential for additional mistakes by drivers, and it is therefore critical that the traffic control be established correctly.

The best traffic control scenario is the use of overhead “lane-use control signals” which display as a minimum the combination of a steady RED X, a steady YELLOW X, and a steady DOWNWARD GREEN ARROW. In addition, it is possible to also have WHITE TWO-WAY LEFT TURN ARROWS and WHITE ONE-WAY LEFT TURN ARROWS.

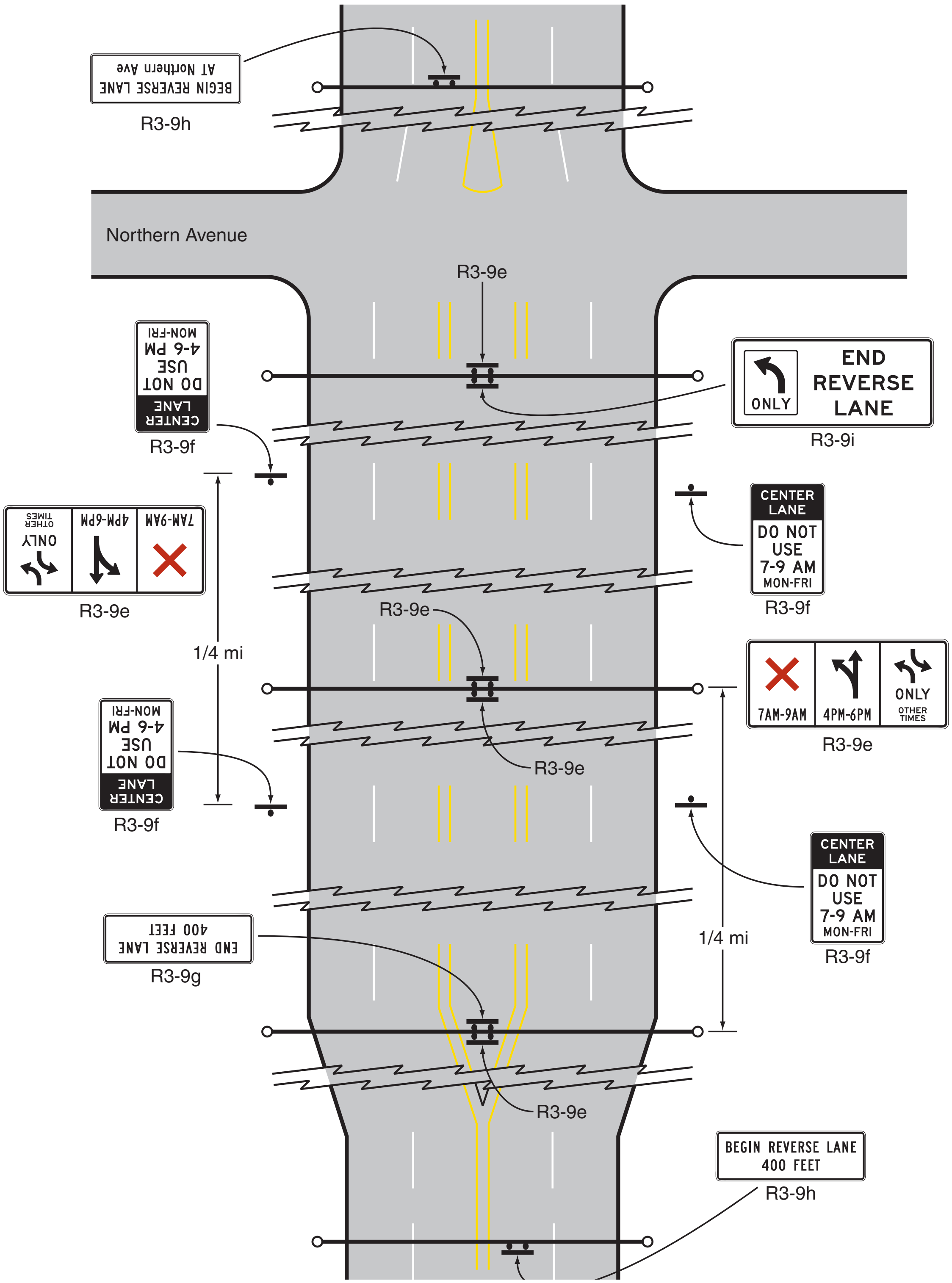
If using fiber optics or LEDs for the signals, it is possible to have a single signal section with more than one indication superimposed on top of each other, but if separate signal sections are used, they need to be arranged in the order indicated in Exhibit 7.25. However, the design and operation of signals requires the expertise of a professional engineer, and is not addressed herein.

Exhibit 7.25: The Relative Order of Overhead Lane-Use Control Signals

RED X	YELLOW X	GREEN DOWNWARD ARROW	WHITE TWO-WAY ARROWS	WHITE ARROW
				

FHWA requires overhead lane control signals anytime that two or more lanes are reversed. However, when only one lane is reversed, it is possible to use a combination of overhead and ground-mounted signs as illustrated on Exhibit 7.26. Refer to chapter 2 of the *MUTCD* for additional guidelines and standards.

Exhibit 7.26: Reversible Lane Control Signs



Source: FHWA, MUTCD *Figure 2B-7*

7.2.10. Parking Signs

The *MUTCD* contains many different types of no parking signs. When applicable, the preferred sign should include the international “no parking symbol” as in the R7-2a sign.

Orientation

Although most traffic signs are installed approximately perpendicular to the edge of the roadway, parking-related signs with arrows used to indicate the extent of a restricted zone, should be installed at an angle of not less than 30 degrees nor more than 45 degrees with the line of traffic flow in order to be visible to approaching traffic. This unusual orientation:

- ✓ makes the signs more visible to the driver that wants to park, but less disruptive to the through driver; and
- ✓ enhances understanding of left and right arrows on signs.

R7-2a

Reserved Parking for Persons with Disabilities

For reserved parking for persons with disabilities, it is necessary to install the Reserved Parking for Persons with Disabilities (R7-8) sign for each parking stall.

When installed in parking lots, the sign should generally be installed at the front of the reserved parking space. If the parking space is a van accessible site, the R7-8P sign shall be installed below the R7-8 sign. To improve visibility of the sign when a driver pulls into the space, the bottom of the sign assembly may be as low as 5 feet above the pavement.

R7-8

R7-8P

Additional information regarding ABA requirements in parking lots is addressed in Section 17.2.9.

Emergency Snow Routes

In an effort to facilitate snow removal, installation officials may designate some roads as snow emergency routes and prohibit parking under emergency declarations. The standard sign for this application is the Emergency Snow Route (R7-203) sign, but the message on the bottom part of the sign may vary as necessary, and include alternate type messages such as NO PARKING DURING DECLARATIONS, NO PARKING DURING EMERGENCIES, etc.

On designated snow emergency routes, the sign is recommended following “major intersections,” and at intervals up to 1,500 feet in built-up areas or 2 miles in rural areas. The definition of “major intersection” is generally defined as an intersection with another road that has an average workday traffic (AWDT) volume of 500 or more vehicles.

R7-203

7.2.11. Signal-Related Signs

When traffic signals are installed, signing is normally designed as part of the signal design, and frequently requires special sign mounting hardware. The important thing is to ensure that the signs are at the proper alignment, and are replaced as necessary. Three of the most common signs are illustrated.

R10-10

R10-11

R10-12

7.2.12. AUTHORIZED VEHICLES ONLY Sign

The AUTHORIZED VEHICLES ONLY (R5-11) sign may be used to identify roadways that are closed to the public. Since the (R5-11) sign is somewhat vague, another option is the GOVERNMENT VEHICLES ONLY (R5-11g-TEA) sign.

When used, erect the sign on the right side of the road or on both sides of the road at the point where the restriction applies, which should always be at an intersection or where unauthorized vehicles can turn to avoid the restricted area.

R5-11

R5-11g-TEA

7.2.13. Truck Route Signs

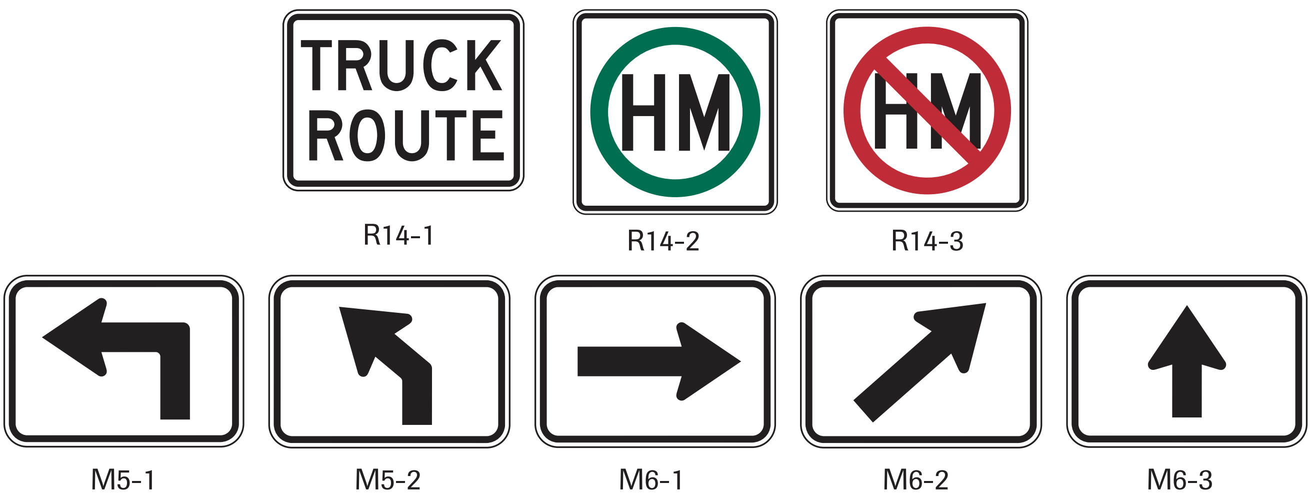
Many military installations establish truck routes, especially routes for trucks transporting explosives or other hazardous materials. By design, these routes typically avoid the more populated areas of installations in an attempt to reduce exposure.

Signs in the *MUTCD* that are designed for this purpose include the TRUCK ROUTE (R14-1) and the Hazardous Material Route (R14-2) signs. If a military installation establishes a route, then the appropriate sign should be installed either in advance of or immediately beyond major intersections or at intermediate locations along the route. If a route turns at an intersection, the sign should always be installed in advance of the intersection and an appropriate arrow plaque should be used beneath the route marker.

It is important to note that the establishment of a truck route or a hazardous materials route does not imply that these vehicles cannot go on other roads. Therefore, if an installation wants to prohibit these vehicles on another roadway, it is necessary to install a Hazardous Material Prohibition (R14-3) sign at the beginning of a road where vehicles have an opportunity to take an alternate route. The R14-3 sign would generally be installed within 25 to 50 feet after the intersection on the route restricting access, and it must be visible to truck drivers that may be about to turn onto the roadway.

Typical signs and arrow plaques used for truck routes are illustrated in Exhibit 7.27.

Exhibit 7.27: Truck Signs



7.2.14. Military Load Classification Bridge Signing

The Military Load Classification (MLC) is a system of standards used by NATO to classify the safe amount of load a surface can withstand. Load-carrying capacity is shown in whole numbers for vehicles, bridges, roads, and routes. Vehicles are classified by weight, type, and effect on routes. Bridges, roads, and routes are classified by physical characteristics, type and flow of traffic, effects of weather, and other special conditions.

Before using a bridge for military traffic, engineers must first determine if the bridge can safely support the loadings. For this purpose, the Army uses the MLC system. TM 3-34.22, *Military Nonstandard Fixed Bridging*, October 2013 provides technical data on the classification (analysis) of bridges, as well as the associated posting. A classification number is assigned to a given bridge to represent how much military vehicular traffic the bridge can carry. Once a bridge has been classified using the "analytical method" discussed in TM 3-34.22, signs must be posted on the bridge to inform users of its classification.

Classified bridges are marked with circular signs, placed at both ends of the bridge that are clearly visible to all oncoming traffic, to indicate the MLC. These circular signs have a yellow background with black text as large as the sign allows and come in two types—normal and dual-classification. See Exhibit 7.28 for sample sign layouts.

Signs for single-lane bridges are at least 16 inches in diameter. Signs for dual-lane bridges are at least 20 inches in diameter and are divided into right and left sections by a vertical line. The classification for dual-lane traffic is on the left half of the sign with two parallel vertical arrows beneath the number. The classification for single-lane traffic is on the right half of the sign with one vertical arrow beneath the number. In cases where a vehicle exceeds the bidirectional loading, it is incumbent on the vehicle operator to ensure that there are no other vehicles that when combined will exceed the structure's weight.

A bridge may have a dual classification—such as for wheeled and tracked vehicles. A special circular sign indicates both classifications. For single-lane bridges, a single sign (20 inches in diameter) is divided into two sections by a horizontal line. The top section shows the wheeled class, and the bottom section shows the tracked class. Symbols representing wheeled and tracked vehicles appear to the left of the corresponding class. For dual-lane bridges, two signs (20 inches in diameter) show the wheeled class on the top and the tracked class on the bottom. As with normal signs, the dual-lane class is on the left and the single-lane class is on the right. Symbols representing wheeled and tracked vehicles appear at the top of the corresponding sign.

Bridges with three or more lanes must have postings for each lane. Minimum widths for the respective MLC determine the number of lanes, as discussed in TM 3-34.22. Heavier loads can often be carried on a restricted lane, such as the center lane of a bridge or the line of rails on a combination road and rail bridge. In such cases, each lane has a bridge-classification sign. Rectangular multilane signs indicate the location and type of traffic allowed to use the restricted lanes.

Refer to TM 3-34.22/MCRP 3-17.1B for additional details; as well as information related to Full NATO bridge signs, and height and width signs.

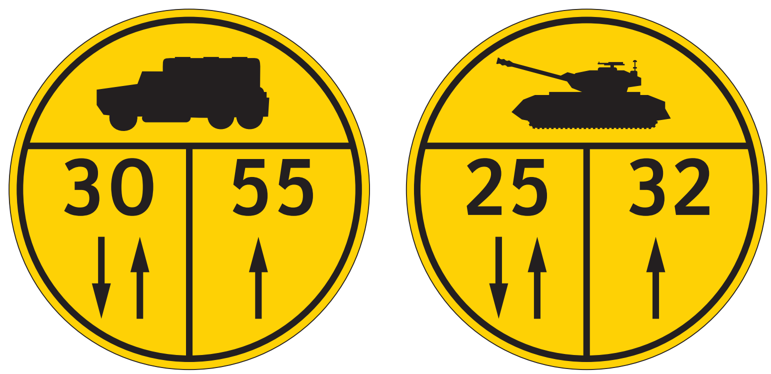
MLC bridge signs, though yellow and back in color, are specified in Army Techniques Publication (ATP) 3-34.81/MCWP 3-17.4 as regulatory. However, per the *MUTCD*, standard practice is white and black regulatory signs for load limit posting in the public sector because these are legal load limits. It is a disconnect to use yellow and back colors for the MLC bridge sign and designate it as regulatory when posting on *MUTCD* applicable roadways. To address this on roadways open to public trucks, AR 420-1, *Army Facilities Management*, Section 7-37 requires (in addition to all bridges with military traffic be posted with the military load class number) that regulatory signing conform to the requirements of the *MUTCD* (*which may result in a dual posting for the weight limit*). In addition, CONUS, AK, HI and U.S. possessions locations shall comply with host state required additional or modified posting standards. At OCONUS (less AK, HI, and U.S. possessions) locations, postings shall comply with host nation standards.

Exhibit 7.28: Sample Bridge Classification Signs

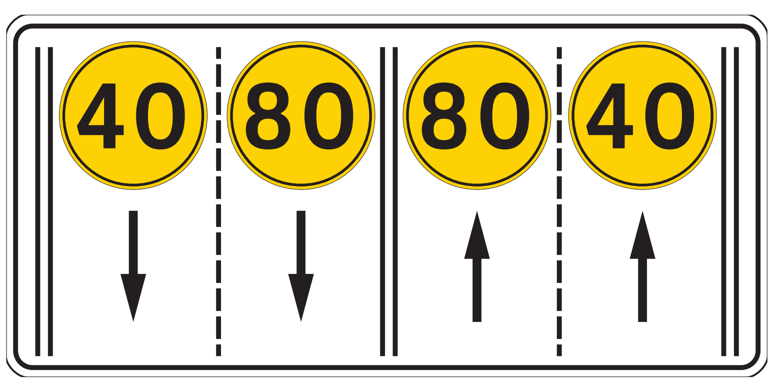
Single Lane MLC sign

Bidirectional MLC sign

Single Lane, Dual Classification MLC sign



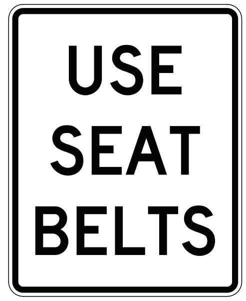
Bidirectional, Dual Classification MLC sign



Bidirectional, Multilane MLC sign

7.2.15. USE SEAT BELTS Sign

Where the regulation exists, the R16-1b-TEA sign shall be placed immediately after the perimeter gate. Note that if state laws require the use of seat belts, this sign is not required. However, in this situation, the R16-1b-TEA sign would serve as a reminder to those drivers who remove their seat belt when producing personal identification when entering the installation.



R16-1b-TEA

R16-5a-TEA

7.2.16. USE PARKING LIGHTS AT GATES Sign

In an effort to reduce glare for security personnel at ECFs, the USE PARKING LIGHTS AT GATE (R16-5a-TEA) sign may be used in advance of ECFs to request motorists to use their parking lights.

7.2.17. Radio and Cell Phone Prohibition Signs

Some military installations have restrictions on the use of cell phones while driving. In that situation, the NO CELL PHONE WHEN DRIVING (R22-1-TEA) sign may be installed for inbound traffic in the vicinity of the gate, and at select locations within the installation.

On the other hand, military installations sometimes have localized restrictions on the use of two-way radios and cell phones in the proximity of explosives or other sensitive areas. When this condition exists, the TURN OFF 2-WAY RADIO AND CELL PHONE (R22-2-TEA) sign or the NO RADIO TRANSMISSIONS (R22-3-TEA) sign may be installed in advance of applicable locations. The RADIO TRANSMISSIONS PERMITTED (R22-4-TEA) sign should be used to inform drivers when the prohibition no longer applies.

R22-1-TEA

R22-2-TEA

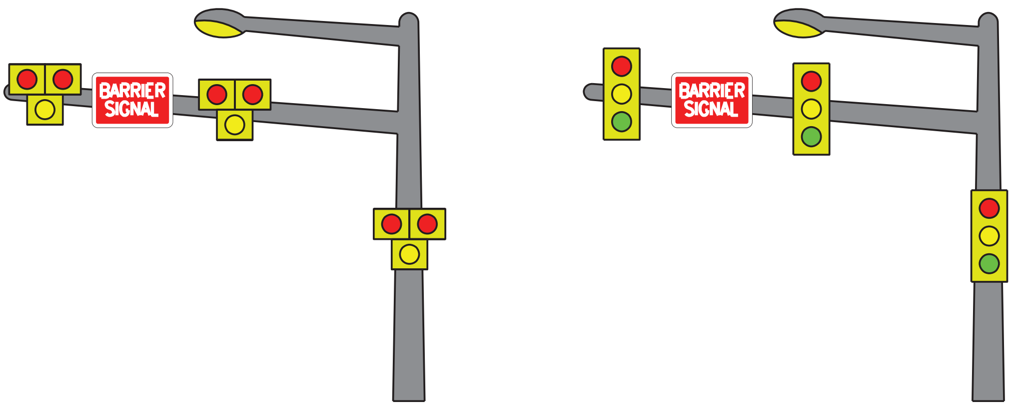
R22-3-TEA

R22-4-TEA

7.2.18. Barrier Signal Sign

The Barrier Signal sign (R10-13a-TEA) should be mounted on the mast arm of an overhead active vehicle barrier signal to supplement the signals or hybrid beacons (whichever is used). Exhibit 7.29 shows this sign in use. Refer to SDDCTEA Pamphlet 55-15 for more information on the AVB Safety Schemes that utilize this sign.

Exhibit 7.29: Barrier Signal Sign Use



7.3. WARNING SIGNS

Warning signs alert drivers to traffic or road conditions ahead. In this context, very few warning signs can be justified in low-speed, built-up areas on military installations. Principal uses of warning signs on military installations include warning of an approaching checkpoint, active vehicle barrier, or pedestrian crossing.

In more rural settings, additional warning signs may be warranted for a variety of things, including unexpected turns and curves, STOP signs with poor visibility, pedestrian crossings, animal crossings, low aircraft, tank crossings, etc. Warning signs should be installed only where they will aid a large number of drivers. They should not be used where an alert driver would be aware of the situation.

7.3.1. Placement

The placement of warning signs must allow drivers sufficient time to see the sign, understand the intent, identify the potential hazard, decide what action must be taken, and then perform any necessary maneuver. Exhibit 7.30, which is derived from Table 2C-4 of the *MUTCD*, provides the minimum recommended sign placement distances for warning signs which may be increased if there are no roadside constraints.

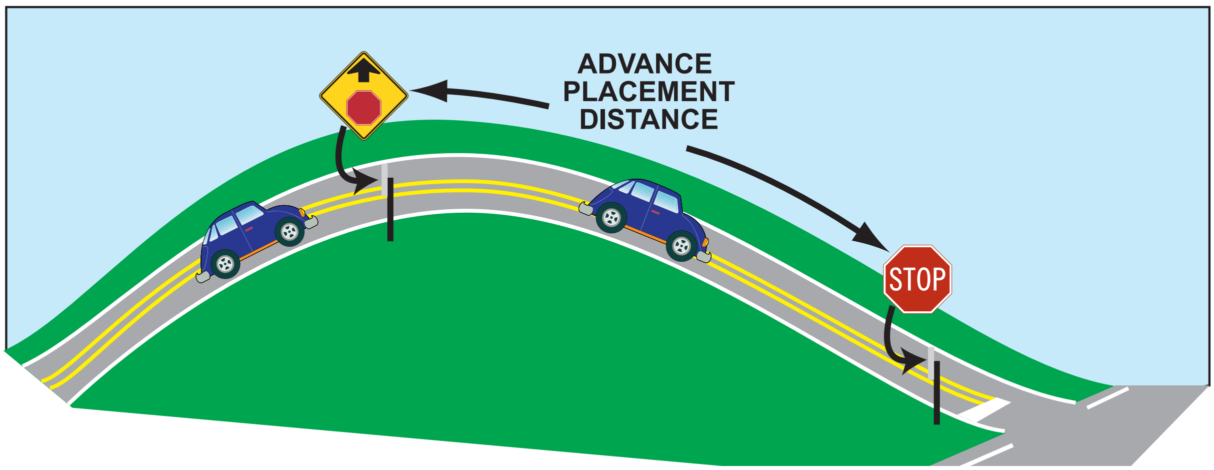
When using Exhibit 7.30, note that Condition A is only for those situations where motorists may have to change lanes in heavy traffic. Applicable signs using Condition A include:

- ✓ Merge (W4-1).
- ✓ Lane Reduction Transition (W4-2L, W4-2R).
- ✓ Entering Roadway Merge (W4-5).
- ✓ RIGHT LANE ENDS (W9-1).

SIGNS

Condition B is for situations where motorists are required to decelerate to an advisory speed for the impending condition—specifically, a potential stop situation (i.e., 0 mph) or a location where the road user must decrease speed to maneuver through the warned condition (i.e., 10, 20, 30, 40, 50, 60, 70 mph). Refer to Chapter 15 for information concerning advisory speeds.

For advance placement of Stop Ahead, Yield Ahead, Signal Ahead and Intersection Warning signs, since these are potential stop situations, assume a "0 mph" advisory speed because some drivers may wish to turn at the intersection or may need to stop due to other stopped, turning, or conflicting traffic. For example, the minimum advance placement distance for a warning sign for a potential stop condition is 175 feet on a 45-mph roadway.



Situations where the driver must decrease speed to maneuver through the warned condition (such as turns/curves and reverse turns/curves), use the applicable advisory speed for the turn/curve to determine the advance placement distance for warning signs.

Exhibit 7.30: Guidelines For Advance Placement of Warning Signs

Posted or 85th-Percentile Speed	Advance Placement Distance[1]								
	Condition A: Speed reduction and lane changing in heavy traffic[2]	Condition B: Deceleration to the listed advisory speed (mph) for the condition							
		0[3]	10[4]	20[4]	30[4]	40[4]	50[4]	60[4]	70[4]
20 mph	225 ft	100 ft[6]	N/A[5]						
25 mph	325 ft	100 ft[6]	N/A[5]	N/A[5]					
30 mph	460 ft	100 ft[6]	N/A[5]	N/A[5]					
35 mph	565 ft	100 ft[6]	N/A[5]	N/A[5]	N/A[5]				
40 mph	670 ft	125 ft	100 ft[6]	100 ft[6]	N/A[5]				
45 mph	775 ft	175 ft	125 ft	100 ft[6]	100 ft[6]	N/A[5]			
50 mph	885 ft	250 ft	200 ft	175 ft	125 ft	100 ft[6]			
55 mph	990 ft	325 ft	275 ft	225 ft	200 ft	125 ft	N/A[5]		
60 mph	1,100 ft	400 ft	350 ft	325 ft	275 ft	200 ft	100 ft[6]		
65 mph	1,200 ft	475 ft	450 ft	400 ft	350 ft	275 ft	200 ft	100 ft[6]	
70 mph	1,250 ft	550 ft	525 ft	500 ft	450 ft	375 ft	275 ft	150 ft	
75 mph	1,350 ft	650 ft	625 ft	600 ft	550 ft	475 ft	375 ft	250 ft	100 ft[6]

Notes:

1. The distances are adjusted for a sign legibility distance of 180 feet for Condition A. The distances for Condition B have been adjusted for a sign legibility distance of 250 feet, which is appropriate for an alignment warning symbol sign. For Conditions A and B, warning signs with less than 6-inch legend or more than four words, a minimum of 100 feet should be added to the advance placement distance to provide adequate legibility of the warning sign.
2. Typical conditions are locations where the road user must use extra time to adjust speed and change lanes in heavy traffic because of a complex driving situation. Typical signs are Merge and Right Lane Ends. The distances are determined by providing the driver a PRT of 14.0 to 14.5 seconds for vehicle maneuvers (2004 AASHTO Policy, Exhibit 3-3, Decision Sight Distance, Avoidance Maneuver E) minus the legibility distance of 180 feet for the appropriate sign.
3. Typical condition is the warning of a potential stop situation. Typical signs are Stop Ahead, Yield Ahead, Signal Ahead, and Intersection Warning signs. The distances are based on the 2004 AASHTO Policy, Exhibit 3-1, Stopping Sight Distance, providing a PRT of 2.5 seconds, a deceleration rate of 11.2 feet/second^2, minus the sign legibility distance of 180 feet.
4. Typical conditions are locations where the road user must decrease speed to maneuver through the warned condition. Typical signs are Turn, Curve, Reverse Turn, or Reverse Curve. The distance is determined by providing a 2.5 second PRT, a vehicle deceleration rate of 10 feet/second^2, minus the sign legibility distance of 250 feet.
5. No suggested distances are provided for these speeds, as the placement location is dependent on site conditions and other signing. However, the alignment warning sign should be installed in advance of the curve and at least 100 feet from any other signs.
6. The minimum advance placement distance is listed as 100 feet to provide adequate spacing between signs.

Source: FHWA, MUTCD *Table 2C-4*

7.3.2. Horizontal Alignment Signs (W1-Series)

There are a variety of horizontal alignment signs that can be used in conjunction with pavement markings and delineation to inform drivers of a change in the roadway alignment. As with all signs, uniformity of application is necessary to provide a consistent message to drivers.

Horizontal alignment signs are not recommended if drivers can safely drive the road at the speed limit, or if the road is a low-volume, local road type facility. However, as a minimum, military installations are encouraged to install horizontal alignment signs on all roads with an average workday traffic volume (AWDT) of at least 1,000 vehicles in accordance with Exhibit 7.31. Refer to Section 15.6 for information concerning advisory speeds.

Exhibit 7.31: Suggested Application of Horizontal Alignment Signs

TYPE OF HORIZONTAL ALIGNMENT SIGN	DIFFERENCE BETWEEN SPEED LIMIT AND ADVISORY SPEED*		
	5 MPH	10 MPH	15 MPH OR GREATER
Turn (W1-1), Curve (W1-2), Reverse Turn (W1-3), Reverse Curve (W1-4), Winding Road (W1-5), and W1-10 series	Recommended	Required	Required
Advisory Speed Plaque (W13-1P)	Recommended	Required	Required
Chevron Alignment (W1-8) or One-Direction Large Arrow (W1-6)	Optional	Recommended	Required
* These recommendations apply to all roads with an AWDT volume in excess of 1,000 vehicles			

An advisory speed is a recommended safe speed to warn for a condition. An advisory speed sign is commonly used with a horizontal geometry sign.

W1-2 & W13-1P

Some of the most common signs used for changes in horizontal alignment are illustrated below.


W1-1L


W1-2L


W1-3L


W1-8


W1-4L


W1-5R


W1-6

Note that the first five signs have either an “L” (for left) or an “R” (for right) as the suffix at the end of the sign code. Frequently, these signs are referenced without the suffix so that a single designation such as the Turn (W1-1) sign includes both the W1-1L and the W1-1R signs. Signs with an “L” indicate that the first turn is to the left, and those with an “R” indicate that the first turn is to the right. The “L” signs and the “R” signs are mirror images of each other.

The W1-6 and W1-8 signs can be rotated clockwise or counterclockwise 180 degrees to accommodate either direction; therefore, there is no need for a suffix.

The Chevron Alignment (W1-8) sign may be used for additional emphasis and guidance within a change in horizontal alignment, and may be used as an alternate to standard delineation. When used, place the W1-8 signs on the outside of the turn or curve at approximately a right angle to approaching traffic. The bottom of W1-8 signs may be mounted at the substandard height of 4 feet above the nearest edge of pavement to provide additional visual impact.

> It is important to note that the difference between the W1-1 and W1-2 signs, and the W1-3 and the W1-4 signs is the severity of the change in horizontal alignment. If the “advisory speed” is 30 mph or less, the Turn (W1-1) sign or the Reverse Turn (W1-3) sign should be use; but if the “advisory speed” is greater than 30 mph, the Curve (W1-2) sign or the Reverse Curve (W1-4) sign should be used.

For sharper curves and turns, two separate sign posts are generally used to install W1-8 signs on two-lane, two-way roadways; but for flatter curves, it generally is acceptable to mount back-to-back signs on the same post, with the signs oriented perpendicular to the highway centerline.

Exhibit 7.32 shows the recommended spacing of the W1-8 signs based on two different methods: (1) the advisory speed on the curve; or (2) the radius of the curve.

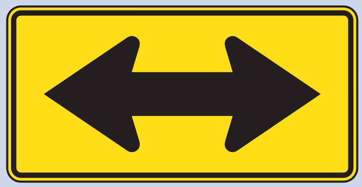
Exhibit 7.32: Methods to Determine Spacing of Chevron Alignment Sign

Method 1: Based on the Advisory Speed (mph)	Method 2: Based on the Curve Radius (feet)	Sign Spacing (feet)
15 or less	Less than 200	40
20 to 30	200 to 400	80
35 to 45	401 to 700	120
50 to 60	701 to 1,250	160
More than 60	More than 1,250	200

Source: FHWA, MUTCD *Table 2C-6*

T-Intersections

By definition, T-intersections are not end-of-roadway situations since there are alternate vehicular paths. Therefore, at T-intersections, consider using a 48"x24" Two-Direction Large Arrow (W1-7) sign on the far side of the through roadway facing traffic on the stem of the T-intersection. Only use the larger 60"x30" sign if it is very unlikely that a vehicle on the through roadway could hit the edge of the W1-7 sign.



7.3.3. Intersection Warning Signs (W2-Series)

Warning signs may be used to warn drivers of the presence of an intersection and the possibility of turning or entering traffic. Some of the most common W2-series signs are illustrated on the following page.

These signs should be used where engineering judgment indicates a need to inform the road user in advance of an intersection, such as for hidden intersections or major intersections with the possibility of turning or entering traffic.

The Circular Intersection (W2-6) sign is designed for application at both traffic circles and at modern roundabouts. Although optional, the ROUNDABOUT (W16-17P) plaque or the TRAFFIC CIRCLE (W16-12P) plaque may be added below the W2-6 sign as appropriate.

Although roundabouts are similar to the older traffic circles, there are differences both in the physical design and in the traffic control which improves both capacity and safety. In order to qualify as a roundabout, each approach to the circular intersection must have:

1. a YIELD sign, and
2. a splitter island designed to slow traffic and to deflect all vehicles to the right to ensure that they travel counterclockwise around the central island.

In lieu of using a ROUNDABOUT (W16-17P) or TRAFFIC CIRCLE (W16-12P) plaque, consider using an Advisory Speed (W13-1P) plaque or a black-on-yellow Advance Street Name (W16-8P) plaque below the Circular Intersection (W2-6) sign.

W2-1

W2-2

W2-3

W2-4

W2-5

W2-6

W16-12P

W16-17P

7.3.4. Advance Traffic Control Signs (W3-Series)

The Stop Ahead (W3-1), Yield Ahead (W3-2), and Signal Ahead (W3-3) signs are to be used if the STOP (R1-1) sign, YIELD (R1-2) sign, or traffic control signal (a minimum of two signal faces) are not visible for a sufficient distance to permit the road user to respond to the traffic control device. Exhibit 7.33 provides minimum sight distance values that trigger the need for these signs. However, when an advance traffic control sign is warranted because of insufficient sight distance, the physical location of the sign should conform to the guidelines in Exhibit 7.30, where the advance placement distance is the appropriate "0-mph value" under Condition B, when measured from the intended stopping location.

W3-1

W3-2

W3-3

Exhibit 7.33: Warrants for Advance Warning Signs

85TH-PERCENTILE SPEED (MPH)	MINIMUM CONTINUOUS SIGHT DISTANCE (FEET) FOR TRAFFIC CONTROL DEVICE VISIBILITY	
	STOP OR YIELD SIGN*	SIGNAL FACES (2 MINIMUM)**
25	155	215
30	200	270
35	250	325
40	305	390
45	360	460
50	425	540
55	495	625
60	570	715

* From Table 6C-2 of the *MUTCD*.

** From Table 4D-2 of the *MUTCD*. These values are slightly greater than the minimum SSD values, presumably because signals are located beyond the stop lines.

The Reduced Speed Limit Ahead (W3-5) sign should be used to warn of a reduced speed zone where the speed limit is being reduced by more than 10 mph, or where engineering judgement indicates the need for the advance notice.

W3-5

7.3.5. Entry Control Facility Signs

There are several unique warning signs that are frequently used at ECFs in accordance with SDDCTEA Pamphlet 55-15 and the DoD Supplement to the MUTCD. The first and only unique warning sign approaching the ECF is generally either the CHECKPOINT (W3-10a-TEA) sign, or in the event of a multi-lane or high-speed approach, the larger CHECKPOINT (__) FEET—BE PREPARED TO STOP (W3-10b-TEA) sign.

W3-10a-TEA

W3-10b-TEA

After the checkpoint, additional warning signs are frequently used for motorists as they approach an active vehicle barrier (AVB). These signs include the ACTIVE BARRIER AHEAD (W3-3a-TEA) sign and the BARRIER ACTIVATED WHEN FLASHING (W3-3b-TEA) sign. As the sign suggests, the second sign is always used with flashing lights that would be activated prior to the physical activation of the AVB.

Chicanes are sometimes used as a security measure approaching and leaving ECFs in order to physically slow traffic and help contain potential threats. This can be accomplished by the use of serpentine roadways, or in some cases the creation of an obstacle course. Therefore, special signs such as the Winding Road (W1-5) sign with a CHICANE placard (W1-5P-TEA) may be used. Depending on the path, the mirror image of the W1-5R sign may be more appropriate (i.e., the W1-5L sign, where motorists first turn to the left as they begin the serpentine roadway).

W3-3a-TEA

W3-3b-TEA

W1-5R and
W1-5P-TEA plaque

Refer to SDDCTEA Pamphlet 55-15 for proper placement of signs and corresponding sign enhancements.

7.3.6. Pedestrian Crossing (W11-2) Sign

This section provides a general discussion on pedestrian signing for crosswalks. Refer to Chapter 13 for detailed guidelines on installation warrants, signing and striping of crosswalks. Assuming the warrants are met for installation of a crosswalk, and the Guidelines for Enhancements (Exhibit 13.4 in Chapter 13) recommend pedestrian actuated signals or pedestrian hybrid beacons, refer to Chapter 13.

Pedestrian crossing signs should be used to sign uncontrolled crosswalks. Uncontrolled crosswalks include those that are not controlled by stop or yield signs, or traffic signals. These are mostly encountered at midblock locations, and when crossing the (uncontrolled) major roadway at unsignalized two-way stop controlled (on the minor roadway) intersections. An exception to this is at roundabouts where the entrance to the roundabout is yield controlled and where crosswalks exist, the W11-2 sign with the downward pointing arrow (W16-7P) supplemental plaque is appropriate. Note that installation of midblock crossings must meet the warrants as presented in Section 13.4.

At marked midblock crosswalks, the Pedestrian Crossing (W11-2) sign with a downward pointing arrow (W16-7P) plaque shall be installed at the crosswalk. Per SDDCTEA Crosswalk Guidelines, there must be adequate sight distance prior to installation.

> As noted in Section 13.4, marking midblock crosswalks should be done very carefully since studies suggest that by themselves, marked crosswalks frequently do more harm than good from a safety perspective, perhaps because they give pedestrians a false sense of security. Because of this, SDDCTEA developed warrants that must be met for the installation of a mid-block crossing or a crossing on an uncontrolled approach. Additionally, layouts for the signing and marking of them have also been developed. Refer to Chapter 13.

At unmarked midblock crossing areas, the W11-2 sign may be installed in advance of the known crossing areas with an appropriate distance plaque (W16-2P or W16-4P) beneath the W11-2 sign.

As a final note, pedestrian signs and their plaques can use the fluorescent yellow-green background. Therefore, instead of yellow or fluorescent yellow retroreflective sheeting material, these signs can be made from the yellow-green material, but installations should avoid mixing the two colors within the same vicinity.

> Studies show that unusual signs such as larger sizes, substandard mounting heights, and unusual sign colors, all produce higher conspicuity. However, as the unusual becomes commonplace, the devices lose their attention-getting abilities. Therefore, FHWA has limited the use of the fluorescent yellow-green color to the following warning-type signs—required for school signs, and optional for pedestrian and bicycle signs.


W11-2


W16-7P

W16-2P

W16-4P

7.3.7. LOW AIRCRAFT (W11-26-TEA) Sign

The LOW AIRCRAFT (W11-26-TEA) sign should be used in advance of a runway when the sudden appearance or noise from a low-flying aircraft might startle an otherwise unsuspecting driver. Since the area of influence is variable, the W11-26-TEA sign should generally be installed about 500 feet in advance of the point of maximum impact, which typically would be from the center of the crossing. See Section 9.2 for use of the LOW AIRCRAFT sign when a roadway must be closed for planes taking off and landing.

W11-26-TEA

W11-27-TEA

W11-28-TEA

W11-29-TEA

7.3.8. TAXIWAY (W11-27-TEA) Sign

The TAXIWAY (W11-27-TEA) sign is designed to alert drivers when an aircraft taxiway either crosses or runs adjacent to the roadway.

7.3.9. TANK CROSSING (W11-28-TEA) Sign

The TANK CROSSING (W11-28-TEA) sign may be used to alert drivers to the possible presence of heavy armament vehicles that may cross the roadway. This is especially important because tank operators have restricted visibility and may not see other oncoming vehicles.

7.3.10. HAZARDOUS CARGO CROSSING (W11-29-TEA) Sign

The HAZARDOUS CARGO CROSSING (W11-28-TEA) sign may be used to warn drivers that there may be trucks hauling hazardous materials crossing the roadway.

7.3.11. Playground (W15-1) Sign

If a playground exists near the roadway and children are apt to run onto the roadway, a Playground (W15-1) sign may be installed in advance of the access area. When used, the sign may have a yellow or fluorescent yellow-green color, but the goal should be to use the same color for the same type of sign whenever the sign is used.

W15-1

7.3.12. Advance Street Name (W16-8P, W16-8aP) Plaques

Advance Street Name (W16-8P, W16-8aP) plaques may be used below an intersection warning sign (e.g., W2-1, W2-2, W2-3, W2-4, and W2-5) or an advance traffic control sign (e.g., W3-1, W3-2, and W3-3). To improve legibility of the street name, use Highway Gothic, mixed-case legend.

W16-8P

W16-8aP

7.3.13. Gate and Road Closures

External guide signs should always identify hours of operation for gates that are closed on a routine basis during the work week. However, it is also desirable to install advance warning signs on approaches to these gates. The GATE CLOSED AHEAD (W20-3g-TEA) sign would normally be appropriate.

There are also situations where roads are closed on a somewhat random basis, perhaps because of explosives testing, missile launching, rifle range, etc. In these situations, the ROAD CLOSED AHEAD (W20-3) sign as used in the *MUTCD* may be appropriate, except that the color should be black-on-yellow instead of black-on-orange.

In both situations, it is desirable to install an Applicable Hours (W16-20P-TEA) plaque below the warning sign. Other options include folding or removing the advance sign or using a WHEN FLASHING (W16-13P) plaque.

W20-3 &
W16-20P-TEA

W20-3g-TEA &
W16-20P-TEA

7.3.14. SPEED HUMP (W17-1) Sign

> **KEY POINT**
>
> A speed hump is an acceptable traffic-calming measure. However, the short, 2- to 4-foot long speed bumps are not acceptable because they can cause extensive vehicle damage, loss of control for cyclists, and ejection of fire truck personnel. Moreover, some people have determined that the faster a vehicle travels, the lower the pain level.

W17-1

In an effort to slow traffic in congested areas, some installations have installed speed humps as a traffic-calming measure. These humps provide gradual vertical deflections of 3 to 4 inches within a 12- to 20-foot section of highway. In some cases, upward and downward slopes are each about 6 feet long, but an 8- or 10-foot flat section is created on the top for a pedestrian crosswalk.

In either situation, the SPEED HUMP (W17-1) sign is appropriate, but an Advisory Speed (W13-1P) plaque should always be added below the sign with the suggested safe speed.

7.3.15. Object Markers

> **KEY POINT**
>
> Object markers are small signs without a word message or a pictorial representation of a traffic control message.

Most object markers look like signs. In reality, they are not that much different than the Chevron Alignment (W1-8) sign, because they serve a similar purpose. Where Chevron Alignment signs warn drivers of curves, object markers warn drivers of nearby objects.

Figure 2C-13 in the *MUTCD* shows several types of object markers, including markers with either three or nine yellow or red circular retroreflectors that are a minimum of 3 inches in diameter. These circular devices are typically acrylic retroreflectors that are very bright when viewed at an angle perpendicular to the marker, but they have almost no retroreflectivity when viewed at an angle of 30 degrees or more from normal.

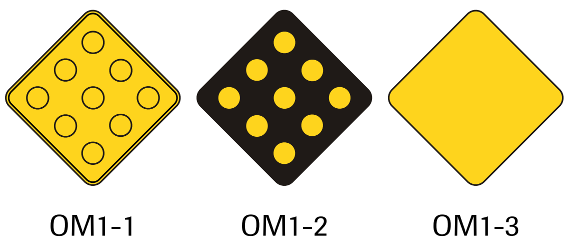
Therefore, military installations are encouraged not to use object markers with circular acrylic retroreflectors because the object markers frequently are not visible to drivers—for example, when turning at intersections, traveling around sharp turns and curves, and at any location where the markers become misaligned. For that reason, Exhibit 7.34 only shows the recommended object markers, all of which use retroreflective sheeting material.

These object markers are frequently grouped into the following four basic types:

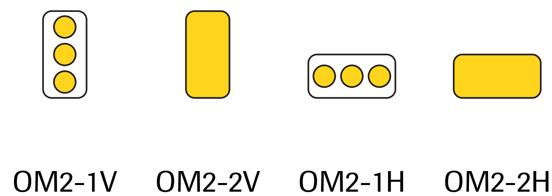
- ✓ Type 1 – OM1-1, OM1-2, OM1-3
- ✓ Type 2 – OM2-1V, OM2-2V, OM2-1H, and OM2-2H
- ✓ Type 3 – OM3-L, OM3-C, OM3-R
- ✓ Type 4 – OM4-1, OM4-2, OM4-3

Exhibit 7.34: Object Markers

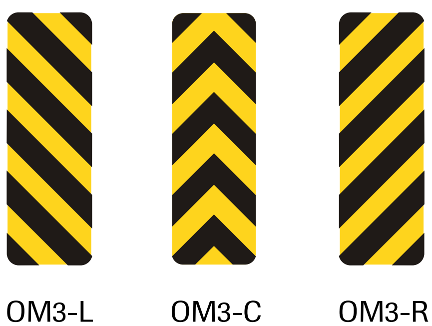
Type 1 Object Markers
(obstructions within the roadway)



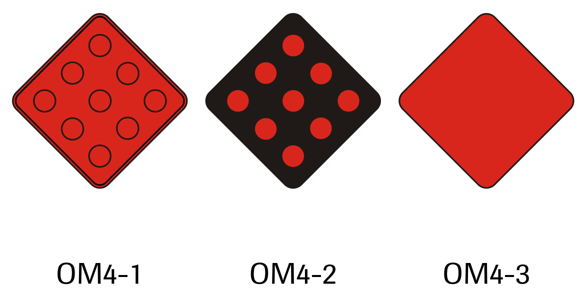
Type 2 Object Markers
(obstructions adjacent to the roadway)



Type 3 Object Markers
(obstructions adjacent to or within the roadway)



Type 4 Object Markers
(end of roadway)



Markings for Objects in the Roadway

Objects within the roadway include bridge piers and channelizing islands, and these can be marked with either a Type 1 or Type 3 object marker. If using the Type 3 marker, use the OM3-L marker on the left side of the intended travel path and the OM3-R marker on the right side of the intended travel path. If traffic can pass on either side of the object, use the OM-3C object marker. Wherever possible, align the inside edge of a marker with the inside edge of the object, and install the bottom of the marker at an elevation 4 feet above the near edge of the traveled way.

If object markers or other signs need to be installed within a concrete median or channelizing island, military installations are encouraged to use a steel square post within a 4-inch diameter, dirt-filled, hole in the concrete. The holes can be formed during construction of new medians or islands during construction by using a vertical hollow plastic pipe to create the hole, or a hole can be drilled after construction. In either case, the anchor should extend no more than about 1 inch above the top of the median or channelizing island.

Markings for Objects Adjacent to the Roadway

Objects adjacent to the roadway should be marked with either a Type 2 or Type 3 object marker. Exhibit 7.35 shows a typical installation involving both Type 2 and Type 3 object markers. Note that a Type 3 object marker is used on each end of the bridge abutments with the diagonal lines sloping down toward the side of the marker that vehicles should pass on.

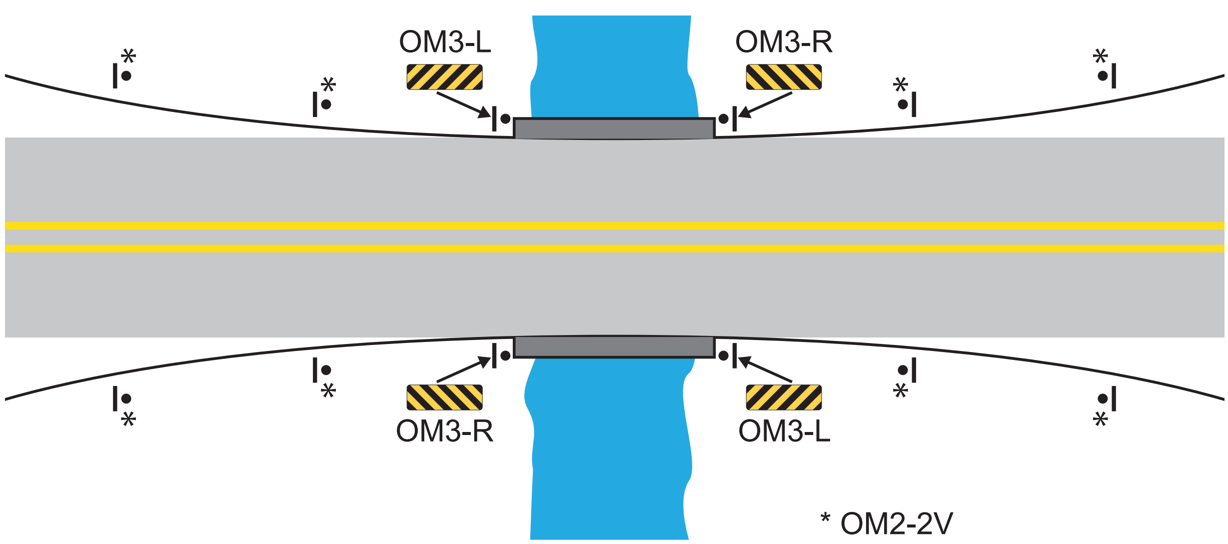
Type 2 object markers are excellent for warning of the presence of linear objects such as guard rail on the approach to bridges or the parapet on long bridges, especially when these obstructions are within 8 feet of the travel way. Wherever possible, also align these markers with the inside edge of the object and install the bottom of the marker at an elevation 4 feet above the near edge of the traveled way.

Typical spacing of Type 2 object markers would be 35 to 50 feet on short sections and greater spacings for long sections of linear objects.

Type 2 object markers and post-mounted delineation are essentially the same. Flexible delineators are preferred for roadside safety reasons; if struck by a vehicle, the delineator easily flexes and regains its position after a vehicle travels over it. The difference is essentially one of application—if used in conjunction with an object we would call it an object marker, but if used merely to keep nighttime drivers on the road we would consider it delineation.

Therefore, if OM2-2V markers are used to warn motorists of a raised concrete right-turn island, most highway engineers would consider them to be object markers, whereas if used within dirt or grass to warn of the edge of the pavement most highway engineers would consider it as delineation.

Exhibit 7.35: Common Use of Object Marker



SIGNS

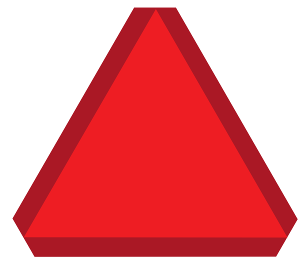
End-of-Roadway Markers

End-of-Roadway (OM4-3) object markers warn road users of the end of a dead-end roadway where there are no other alternative vehicular paths.

To increase the target value, use a series of three or more of the End-of-Roadway (OM4-3) markers across the end of the roadway. Another option is to place a red-and-white Type III barricade across the end of the roadway as discussed in Section 7.2.7.

7.3.16. Slow-Moving Vehicle Emblem

Although technically not a traffic sign, the Slow-Moving Vehicle Emblem is intended as a unique identifier for attachment to vehicles which, by design, always move slowly (25 mph or less) on the public roads. The emblem measures 16"x14," and should be mounted on the center of the back of all slow-moving equipment at a height of 2 to 6 feet above the ground.



The center triangle is fluorescent yellow-orange, but it is not retroreflective, while the dark red is highly retroreflective. As a result, under headlight illumination at night, the emblem appears as a hollow red triangle.

The emblem can be purchased from a number of safety equipment suppliers.

7.4. GUIDE SIGNS

KEY POINT

Guide signs provide information for highway routes, street names, destinations, distances, available services, and points of interest. Military installations are encouraged to use a frequent display of street name signs and destination signs to keep unfamiliar road users informed of their route and location.

At most military installations, guide signing is inadequate and should be upgraded as soon as possible. Too often, tall ladder-type destination signs are used to guide motorists, and these signs have too many messages for drivers to safely read. Of utmost importance is the replacement of these ladder-type signs with a visitor guidance system that includes street name and destination signs having a letter height of 4 or 6 inches and a maximum of three destinations per guide sign.

Even with the best directional signs, it is impossible to assist every unfamiliar driver with finding their facility. Therefore, visitor centers and gate houses should have printed maps available for distribution upon request.

7.4.1. General Design Criteria

Guide signs are normally rectangular, with the sign width as the longer dimension. All guide signs should have white lettering, arrows, and borders. The background color should typically be green, except:

✓ motorist service signs should have a blue background color, and

✓ cultural or recreational interest signs may have a brown background color.

Guide signs must be legible to approaching drivers. Where speeds or volumes are high, larger signs are required. At locations where traffic is moving slowly or must stop, smaller signs may be used.

> The *SHSM* Book currently does not contain as many design details for guide signs as it does for regulatory and warning signs, probably because guide signs are typically one-of-a-kind designs. Therefore, it is no surprise that there is a great diversity in the design of guide signs on a state-to-state basis. Fortunately, there is a consortium of transportation agencies and software manufacturers working with FHWA to help standardize the designs.

On military installations, guide signs primarily consist of the following:

✓ Destination signs to the installation and the specific gates.

✓ Destination signs to internal facilities (e.g., visitors' center, credit union, and major buildings).

✓ Street name signs.

Many guide signs have arrows to show direction, and the arrows can be rotated at various angles as appropriate. When used on guide signs on conventional highways, the preferred arrow design is FHWA's Type B arrow. Exhibits 7.36 and 7.37 provide additional details.

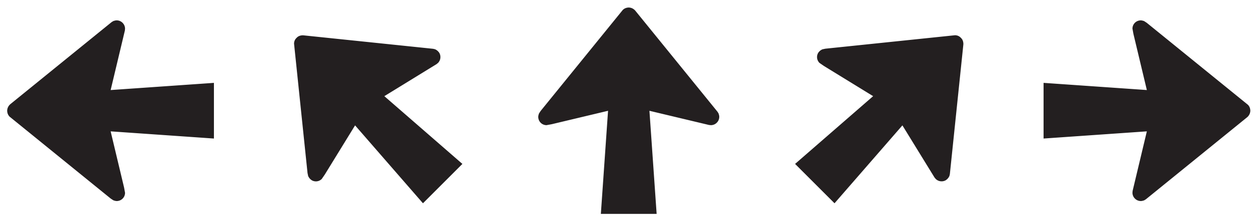
A maximum of three destinations should generally be included on a given sign, although a header line may also be included. The minimum recommended legend size for the names of destinations is as follows:

Exhibit 7.36: Recommended Legend Sizes

SPEED LIMIT	WORDS & NUMBERS (INCHES)	NOMINAL ARROW (INCHES)
25 mph or less	4	6x6
30 mph or higher*	6	9x9
* Except not applicable on multi-lane roadways with a speed limit greater than 40 mph.		

SIGNS

Exhibit 7.37: Typical Orientations of the Type B Arrow



7.4.2. Lettering Style

Historically, the names of cities and other destinations, streets, and buildings used on guide signs on conventional highways have been in all capital letters ("uppercase legends"), whereas the names used on freeways have been in "mixed-case" (the combination of capital letters and "lowercase lettering letters"). However, names in mixed-case lettering is legible from a greater distance than names in all capital letters because mixed-case lettering has ascending and descending letterforms that aids word recognition. Therefore, beginning with the 2009 *MUTCD*, FHWA now requires the use of mixed-case lettering for all names used on guide signs.

The *MUTCD* currently defers to the *SHSM Book* for the design of uppercase letters (capitals), lowercase letters, numerals, route shields, and spacing. The standard alphabet currently is a Gothic-style alphabet which was developed in the 1940's and 1950's, and it is frequently referred to as "Highway Gothic."

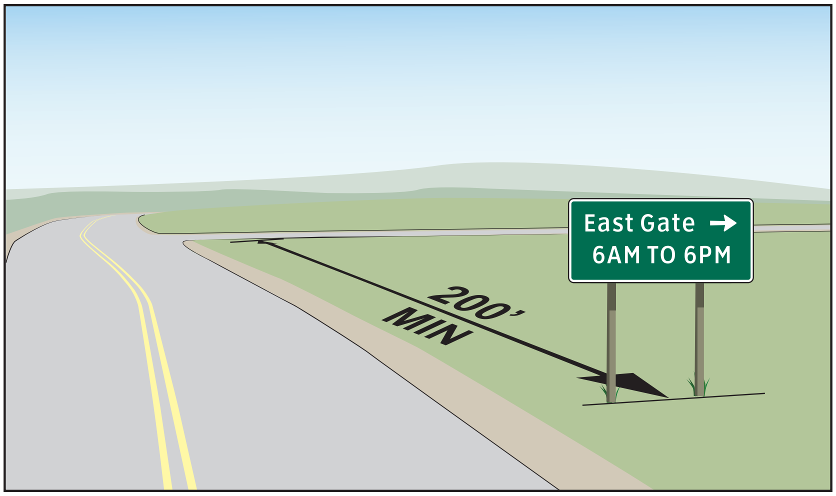
There are six different font series in Highway Gothic, Series B, C, D, E, E-Modified, and F. Within military installations, the suggested font is Highway Gothic Series C for Street Name signs and Highway Gothic Series D for destination signs. However, if signs made with these fonts would be too big, the next smaller size can be used. The larger sizes (Series E, E-Modified, and F) are generally used on freeways.

7.4.3. Destination Signs when Approaching the Base

When approaching a military installation, the advance signs need to identify the name of the installation, and direct motorists toward the proper gate. If there is more than one gate, the destination signs would be similar to the following, where destinations straight ahead would be identified first, and then those destinations to the left, and then the ones to the right. If more than one destination is in the same direction, the closest one should be above the other.

If a gate is not open at all times and the gate is some distance from the roadway, the hours of operation should be included on the signs as illustrated in the following figure.

If trucks are required to use a special gate, the destination sign could include the words "NO TRUCKS" after the gate name, or a special black-on-white sign could be installed in advance of the destination sign with a message such as "ALL TRUCKS USE WEST GATE."



Since these signs will frequently be on public highways, it probably will be necessary to work with the local transportation department to either have them install the signs or to authorize the military installation to install the signs on their roadways.

7.4.4. Wayfinding Signs

Community wayfinding guide signs are part of a coordinated and continuous system of signs that direct tourists and other road users to key civic, cultural, visitor, and recreational attractions and other destinations within a city or a local urbanized or downtown area. Community wayfinding guide signs, as discussed in *MUTCD* Section 2D.50, are a type of destination guide sign for conventional roads with a common color and/or identification enhancement marker for destinations within an overall wayfinding guide sign plan for an area. Wayfinding signs are limited to conventional roads only. The destination signing used on military installations is considered to be Community Wayfinding signing. This allows the use of colors other than green background with white lettering that is typical for guide signs.

One such use could be at an installation that has frequent graduation ceremonies, to identify the route to the graduation ceremony location for visitors. Though the use of pavement marking symbols is allowed for route identification, as later discussed in Section 8.2.18, guide signs for wayfinding are recommended for several reasons:

- ✓ Signs last much longer than pavement markings. Standard paint pavement markings can be expected to only last 6-12 months before they will need to be re-painted. Some costlier materials like thermoplastic will last a few years. Signs can last up to 10 years or more.
- ✓ Signs are still visible in inclement weather. Snow will cover markings making them difficult to see, and rain will also obscure marking color and visibility. Signs normally are retroreflective, and are much more visible in inclement weather.
- ✓ If the venue changes locations, signs can be more easily moved to redirect visitors, whereas pavement markings will have to be obliterated from the pavement.
- ✓ Non-standard line pavement markings with non-standard paint colors could be confusing for drivers with color blindness or other visual acuity issues.

7.4.5. Destination Signs on the Base

Destinations signs should be limited to three lines of legend and should be used to direct visitors to facilities that generate significant visitor traffic. When used, the signs should be located at least 200 feet in advance of an intersection where a turn is required.

7.4.6. Street Name Signs

> **KEY POINT**
>
> Unacceptable Street Name signs are common on military installations. Typical issues include very small legend, and non-retroreflective legend and background. In addition, better legibility can be obtained by using mixed-case legends.

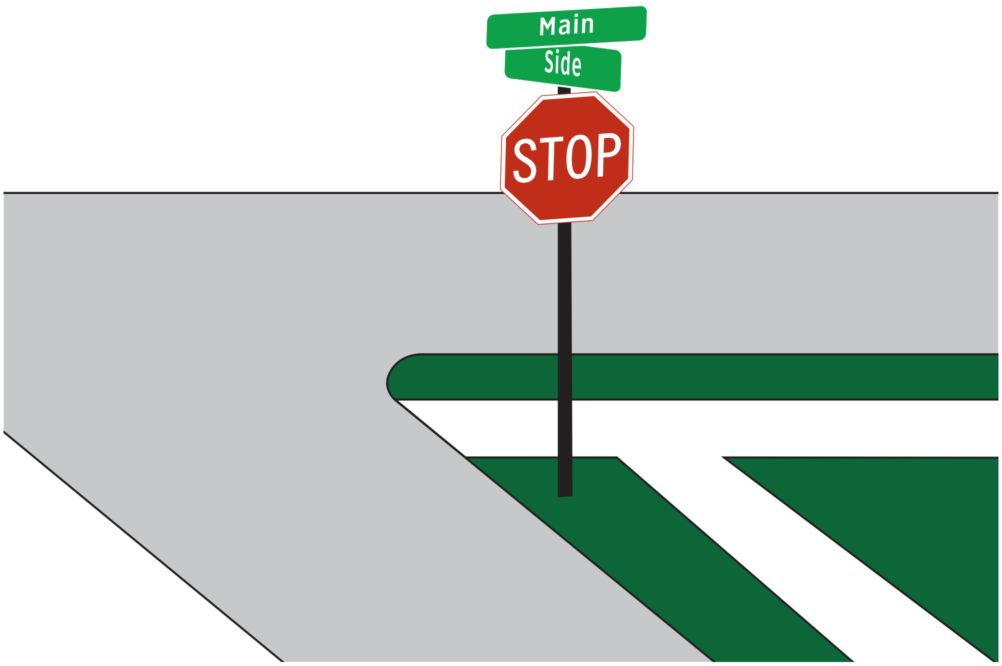
At minor intersections, one Street Name sign facing each approach is permissible; but at major intersections, military installations are encouraged to install Street Name signs on diagonally opposite corners so that they will be on the far right-hand and near left-hand corners of the intersection for traffic on the major street. The signs are normally double-sided so that they can be read in both directions of travel.

All Street Name signs should have white, mixed-case legend. The recommended background color is green; however, blue, brown, or black background colors are permissible; but it is desirable to have the colors consistent throughout the military installation, or at least throughout a unique area within the installation. The standard legend is 6 inches high, except 8-inch legend should be used on multi-lane roads with a speed limit over 40 mph and 4-inch legend may be used for roads with a speed limit of 25 mph or less. Sign borders may be eliminated to reduce the size of the signs.

Street Name signs are usually installed on their own sign post, but they may be placed above a STOP or YIELD sign.

Special hardware is available to mount the sign blades from their bottom edge so that both sides of the sign are clearly visible to approaching drivers.

If signs are mounted above a STOP or YIELD sign, everyone is encouraged to mount the one with the name of the cross street on the top so that the unique shape of the STOP or YIELD sign is not compromised.



The signs may also be mounted overhead or cantilevered from an existing support. If cantilevered, the signs should always be cantilevered toward the intersection so that the Street Name sign for the crossing street is clearly visible and not hidden by the other Street Name sign.

If street name signs are mounted overhead, the *MUTCD* recommends using minimum 12-inch mixed-case legends.

7.4.7. Guide Signs at Entry Control Facilities (ECFs)

At ECFs, overhead signs or signals are frequently used for lane control. If signals are used, the signal heads should be similar to the RED X or the GREEN DOWNWARD ARROW signals.

Signs that are commonly used in advance of an ECF include:

- ✓ USE PARKING LIGHTS AT GATE (R16-5a-TEA)
- ✓ ACTIVE BARRIER (W3-3A-TEA)
- ✓ BARRIER ACTIVATED WHEN FLASHING (W3-3b-TEA)
- ✓ CHECKPOINT (W3-10-TEA)
- ✓ CHECKPOINT ___ FT—BE PREPARED TO STOP (W3-10b-TEA)

7.4.8. Directional Signs at Base Exit

When exiting a military installation, it is desirable to have signs to show directions to nearby numbered traffic routes and cities to help orient unfamiliar drivers. If these signs are along a public highway, the military installation should discuss the issue with the local or state transportation agency to determine responsibility.

CHAPTER 8—MARKINGS

8.1. GENERAL

Most people understand the term "pavement markings," but most transportation agencies use the shorter but more encompassing term, "markings." "Markings" include not only pavement markings such as centerlines, edge lines, stop lines, pavement legends and arrows; but also delineators, channelizing devices, islands, and rumble strips.

Like traffic signs and other traffic control devices, markings should always conform to the FHWA's *MUTCD*. Specifically, Part 3 of the *MUTCD* addresses markings, and is available at http://*MUTCD*.fhwa.dot.gov/pdfs/2009/part3.pdf.

Markings frequently supplement signs or traffic signals to provide guidance on roadway alignment, no-passing zones, turn restrictions, and stopping or yielding locations.

8.2. PAVEMENT MARKINGS

KEY POINT

Pavement markings are the only traffic control device that is visible to drivers without taking their eyes off the road.

"Pavement markings" are the most common type of "marking" and, as the name suggests, they are on the pavement; i.e., the physical surface of a roadway or shoulder.

Pavement markings may be categorized into two primary groups:

1. Longitudinal markings help facilitate vehicle guidance and location.
2. Transverse markings provide regulatory, warning, and guidance information to the motorist. Transverse markings include word and symbol markings, arrows, stop lines, yield lines, crosswalk lines, speed measurement markings, speed hump markings, parking space markings, etc.

Both types of pavement markings provide vital information to the vehicle operator. Therefore, they must be uniform in design, position, and application.

8.2.1. Materials

Many different types and classes of pavement marking materials are available today. Common types of materials used in the United States for pavement markings, as well as considerations relating to their use include:

Waterborne paint

- ✓ Sprayable latex paint with embedded glass beads
- ✓ Typically heated prior to application
- ✓ Most common and lowest cost material for longitudinal lines

- ✓ Generally less durable than other materials
- ✓ Less sensitive to changes in temperature and moisture than thermoplastics

Preformed (cold) thermoplastic

- ✓ Preformed, ready to position thermoplastic markings with partially embedded glass beads
- ✓ Applied with a propane heat torch
- ✓ Most common material for transverse markings and other labor-intensive markings

Hot thermoplastic

- ✓ Four-component material consisting of thermoplastic binder, pigment, glass beads, and filler
- ✓ Most commonly sprayed but also can be extruded
- ✓ Provides high durability and good retroreflectivity when applied properly
- ✓ Well suited for use on asphalt surfaces
- ✓ Relatively low cost
- ✓ Frequently used for longitudinal markings in high-traffic areas

Preformed plastic tape

- ✓ Cold applied (preformed) polymer tape with no drying or curing time
- ✓ Applied by removing adhesive backing and pressing onto the pavement with a roller or truck tire
- ✓ Significantly higher initial cost
- ✓ Highly durable and abrasion-resistant with excellent retroreflectivity
- ✓ Frequently used for transverse markings or longitudinal markings in high-traffic areas

Epoxy

- ✓ Sprayable epoxy resin paint
- ✓ Exceptional adhesion to both bituminous and concrete surfaces with good abrasion resistance and retroreflectivity
- ✓ More expensive than waterborne paints and about the same or slightly more expensive than thermoplastics

Methyl methacrylate (MMA)

- ✓ Non-hazardous, two-component material that can be sprayed or extruded
- ✓ Has been shown to provide much longer service life than waterborne paint and perform well in cold weather climates
- ✓ Bonds well to concrete pavements and is resistant to common surface chemicals such as oil and antifreeze
- ✓ Cost comparable to epoxy materials
- ✓ Requires special equipment for application

Polyurea

- ✓ Sprayable, two-component material
- ✓ Marketed as durable material that provides exceptional color stability, resistance to abrasion, and adhesion to all pavement surfaces with less sensitivity to pavement surface moisture and temperature
- ✓ Some materials must be applied by special striping apparatus while others can be applied with standard epoxy truck

For longitudinal lines, waterborne paint with embedded glass beads is the most popular and cost-effective pavement-marking material. Waterborne paint is essentially a latex paint, and while it is generally the least durable of the above materials, in most cases the better waterborne paints will last at least 2 years.

On the other hand, preformed thermoplastic is the most common material for application of transverse markings and other labor-intensive markings.

Not all pavement-marking materials are compatible with each other or with some road surfaces. However, both paint and thermoplastic can be applied over any of the other common materials with the exception of tape.

Installations should use ONLY those materials that are approved for use in the State in which the installation is located. Inlaid blocks, bricks, and metal strips should never be used for pavement markings.

The Most Durable Materials

Waterborne paint is the most cost-effective pavement marking material, but the Texas Transportation Institute determined that the most durable pavement marking materials are:

- ✓ thermoplastic on bituminous pavements; and
- ✓ either thermoplastic or epoxy on Portland cement pavements (epoxy is not used for legends).

8.2.2. Application of Waterborne Paint

KEY POINT

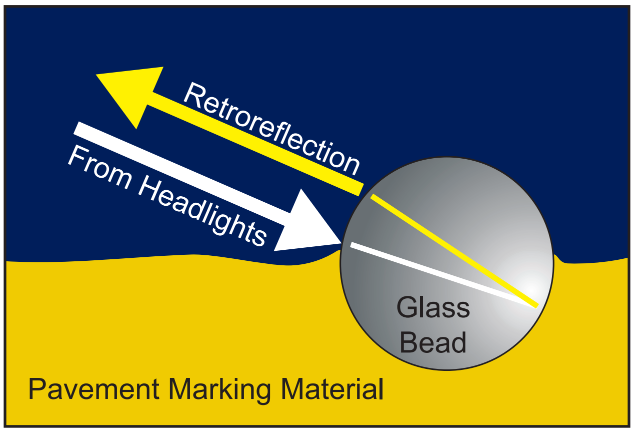
Waterborne paint with embedded glass beads is the most popular and cost-effective pavement-marking material for longitudinal lines.

Waterborne paints are generally applied at a wet thickness of at least 15 mils (i.e., 0.015 inch). Therefore, if you do the math, one gallon of paint is needed for every 321 feet of 4-inch wide line. In reality, there would be a small amount of overspray so a gallon of paint may not go quite that far.

Waterborne paints are typically heated to approximately 130°F prior to application to improve the bond with the pavement and to reduce the drying time.

All pavement markings need to be retroreflective to make them visible at night. To make them retroreflective, paint and most other pavement-marking materials rely on round glass beads embedded into the surface of the pavement marking material. When a vehicle's headlights illuminate a glass bead, the light:

1. Refracts or bends as it enters the bead;
2. Reflects off the backside of the bead if this part of the bead is embedded in the pavement marking material;
3. The reflected light becomes the color of the pavement marking material and again refracts as it leaves the glass bead; and
4. Returns to the general vicinity of the headlights and the driver.



It is essential that the proper type and quantity of glass beads are immediately added to the freshly-applied paint before it solidifies. Specify at least 7 pounds of glass beads for every gallon of paint. If the beads have insufficient embedment, traffic will dislodge the beads, and if they are embedded too much they will not reflect. Research shows that 60 percent embedment should be the goal. Therefore, the application is critical.

After application of paint, traffic should be kept off the paint until tires driven on the line do not track paint onto the road. Typical track-free dry time is about 2 minutes. If the lines are driven on too soon, in addition to tracking the paint on the road, glass beads can be pressed so deeply into the wet paint that they are no longer retroreflective.

Important Application Conditions

- ✓ The pavement must be dry and free of dirt, dust and other contaminants, including poorly adhered old markings.
- ✓ The air temperature must be above the dew point and at least 40°F.
- ✓ No serious threat of rain within the next 4 hours.

The performance of pavement marking materials is dependent on the type of road surface, the quality of the application, and winter maintenance. Some materials work better in the colder adverse weather conditions than other products, but there is no guarantee that these materials will be the best in the warmer climates. Therefore, military installations are encouraged to review their material specifications with the local state department of transportation.

Pavement markings should be inspected annually to ensure that they are in acceptable condition.

8.2.3. Application of Thermoplastics

As with waterborne paint, the ideal pavement conditions are clean, dry, and not too cold. The pavement surface must be dry and free of dirt, dust, and other contaminants, including poorly adhered old markings and glass beads. Pavement and air temperatures must be at least 50°F and 55°F, respectively. Do not apply on top of any existing marking materials other than thermoplastic. Loose thermoplastic should be removed, and any oxidized old thermoplastic should be scraped to expose fresh surface material.

8.2.4. Additional Application Considerations

Pavement type and age should be considered during material selection. Many State DOTs have recommended material types and application specifications for certain pavement types. These specifications will vary by agency, but the following are some common considerations:

New asphalt pavements

- ✓ Waterborne paint may dissolve road oils and cause a discoloration of the pavement marking. A double application may be necessary to achieve proper color and is sometimes specified.
- ✓ Nearly all thermoplastic materials are well-suited for new asphalt surfaces given the thermal bond that is formed via heat fusion.
- ✓ Permanent tape can be inlaid into freshly placed bituminous surfaces.

Old asphalt pavements

- ✓ Asphalt surfaces wear and become more brittle through traffic exposure and oxidization over time. In order to aid in forming a thermal bond, primers are recommended prior to application of thermoplastics on asphalt surfaces that are older than a specified threshold (typically 2-3 years), heavily oxidized, or have exposed aggregates.
- ✓ Permanent tape can be grooved into older bituminous surfaces while temporary tape can be glued into place. However, permanent tape is not typically a cost-effective choice for older asphalt pavements given the higher cost of the tape and the potential for roadway resurfacing.
- ✓ Waterborne paint may be used on older asphalt pavements without primer.

Concrete Pavements

- ✓ Thermoplastics are generally undesirable on concrete surfaces due to the potential for premature de-bonding of the material since a thermal bond is not possible. Therefore, primers are recommended prior to application of hot thermoplastics on all concrete surfaces (particularly those that are new) to enable a mechanical bond between the liquid thermoplastic and the pores of the concrete.
- ✓ Permanent tape can be grooved into concrete surfaces while temporary tape can be glued into place.
- ✓ Waterborne paint may be used on concrete pavements without primer.
- ✓ Epoxies are commonly used by State DOTs and do not require a primer application on any road surfaces.

8.2.5. Minimum Retroreflectivity

In 1993 Congress directed the U.S. Secretary of Transportation to revise the *MUTCD* to include minimum levels of retroreflectivity for both traffic signs and pavement markings. After the congressional mandate, FHWA sponsored extensive research on the retroreflectivity needs of drivers for both signs and pavement markings. After extensive research, FHWA adopted minimum retroreflectivity values for most types of traffic signs in 2007.

Although FHWA has not adopted minimum retroreflectivity for pavement markings, on April 22, 2010, FHWA did publish a proposed change to Section 3A.03 of the *MUTCD* which includes minimum retroreflectivity values for pavement markings as included in Exhibit 8.1. As proposed, these minimum values would only apply to centerlines, lane lines, and edge lines, and only when these longitudinal lines are either required or recommended in the *MUTCD* (see Exhibit 8.2).

FHWA is also proposing several ways to manage minimum retroreflectivity similar to the methods for traffic signs. However, maintaining acceptable retroreflectivity for pavement markings will be a challenge because of the concerns noted on the next page.

To help meet minimum retroreflectivity values in Exhibit 8.1, consider the following:

1. Because the minimum retroreflectivity value of 250 mcd/m2/lux for two-way roads with only centerline markings will be difficult to maintain, when centerlines are required on roads with a speed limit of 55 mph or higher, always also install edge lines.
2. Consider using raised retroreflective pavement markers (RRPMs) to supplement the longitudinal lines, thereby eliminating the minimum retroreflectivity requirements as noted in the first exception in Exhibit 8.1.

Exhibit 8.1: Proposed Minimum Maintained Retroreflectivity Values for Centerlines, Lane Lines and Edge Lines*

ROAD CATEGORY	POSTED SPEED (MPH)		
	≤ 30	35-50	≥ 55
Two-lane roads with centerline markings only**	n/a	100	250
All other roads**	n/a	50	100

* Measured at standard 30-meter geometry in units of mcd/m^2/lux.

** Exceptions:

- ✓ When RRPMs supplement or substitute for a longitudinal line (see Section 3B.13 and 3B.14 in the *MUTCD*), minimum pavement marking retroreflectivity levels are not applicable as long as the RRPMs are maintained so that at least three are visible from any position along that line during nighttime conditions.
- ✓ When continuous roadway lighting assures that the markings are visible, minimum pavement marking retroreflectivity levels are not applicable.

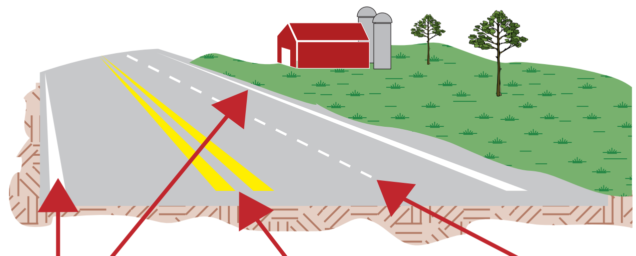
Concerns with any Future Minimum Retroreflectivity Values

1. Most markings are "manufactured" on location under varying temperature and humidity conditions, applied over existing surfaces that may be less than ideal (e.g., rough texture due to surface treatment, oil contaminants, etc.), and sometimes vehicles drive on the markings before they are cured, all of which have a negative effect on the retroreflectivity.
2. Some properly-applied markings deteriorate much faster than other markings because vehicles frequently ride on or cross over the markings (e.g., longitudinal lines in heavy weaving areas, around curves, and at intersections). In addition, the asphalt in bituminous roadways sometimes bleeds and the material may track onto the markings, causing discoloration and loss of retroreflectivity.
3. Snowplows, sanding, chemicals, and tire studs and chains cause markings to deteriorate very quickly during the winter months within many areas, and blowing sand may also cause similar problems in other areas.
4. If markings wear out during the winter, it may not be possible to replace them for several months.

8.2.6. Longitudinal Pavement Markings

KEY POINT

The primary role of longitudinal pavement markings is to provide continuous alignment guidance.



Longitudinal markings are the primary source of information for positioning vehicles on the roadway. As illustrated in Exhibit 8.2, these longitudinal markings include:

- ✓ Centerlines, which separate opposing flows.
- ✓ Edge lines that delineate the edge of the roadway.
- ✓ Lane lines, which are between lanes of traffic traveling in the same direction.

Exhibit 8.2: Required and Recommended Longitudinal Lines

TYPE	REQUIRED	RECOMMENDED
CENTERLINES	✓ On all paved urban arterials and collectors that have a travel width of 20 feet or more and an AWDT of 6,000 vehicles or greater ✓ On all paved two-way roads with three or more traffic lanes	✓ On paved urban arterials and collectors that have a travel width of 20 feet or more and an AWDT of 4,000 vehicles or greater ✓ On all paved rural arterials or collectors with a travel width of 18 feet or more and an AWDT volume of 3,000 or greater ✓ On other roads where an engineering study indicates a need
LANE LINE	✓ On all freeways and Interstate highways	✓ On all roads with two or more travel lanes in the same direction
EDGE LINES	✓ On all freeways and expressways ✓ On all paved rural arterials with a travel width of 20 feet or more and an AWDT of 6,000 vehicles or greater	✓ On all paved rural arterials and collectors with a travel width of 20 feet or more and an AWDT of 3,000 vehicles or greater ✓ On other paved streets and highways where an engineering study indicates a need for edge lines

Source: FHWA, MUTCD

Exhibit 8.2 also contains guidelines on when to install these lines. Most military installations already install more longitudinal lines than are required in accordance with the *MUTCD*; but once installed, it is very important to maintain these longitudinal markings to ensure that the markings are continuously visible along the roadway. Maintaining quality longitudinal pavement markings is especially important in areas where longitudinal construction joints do not coincide with the longitudinal pavement markings, because when markings become worn and are no longer highly retroreflective, drivers tend to follow the construction joints, especially at night when the roads are wet.

Longitudinal markings should have a minimum width of 4 inches, although wider lines are helpful both day and night. The basic types of longitudinal markings are illustrated in Exhibit 8.3. Centerline pavement markings for two-way no-passing zones should always be solid, double-yellow longitudinal lines. Therefore, a single solid yellow line, as illustrated to right, should not be used in the center of a two-lane roadway.

Proper installation and maintenance of pavement markings is important since longitudinal construction joints can sometimes be falsely interpreted as pavement markings. When markings become worn, drivers tend to follow these joints, particularly in adverse weather or at night.

Dimensions of longitudinal pavement markings generally vary by state. Exhibit 8.4 shows typical dimensions and spacing for longitudinal pavement markings. In general, longitudinal markings should have a minimum width of 4 inches, although wider lines are helpful both day and night. Double lines should typically have a 4- or 6-inch space between them. Broken lines should have a 10-foot line and a 30-foot skip. Dotted lines should have 2-foot line and a 4-foot skip.

White Lane Line Pavement Markings

Use lane line markings on all multi-lane roadways, to delineate the separation of adjacent travel lanes going in the same direction of travel.

The normal broken white lane line should become a solid white line in advance of any intersection controlled by a traffic signal, STOP sign, or YIELD sign. The length of the solid line should generally be at least 150 feet.

Also use solid lane lines to separate through lanes from left or right turn lanes, in which case the length of the solid line should be approximately two-thirds the length of the full width turn lane.

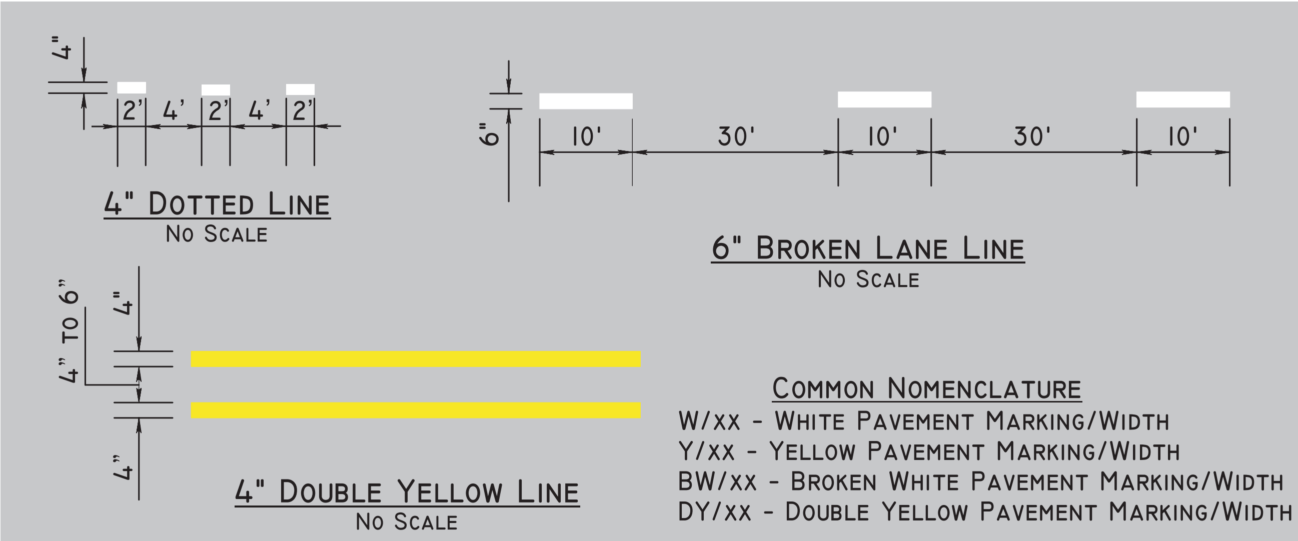
Solid white lane line markings should also be used to separate through lanes from auxiliary lanes such as uphill truck lanes and any preferential lanes. Military installations are encouraged to use wider lane lines, such as 8-inch wide lines, to emphasize the fact that something is unusual in these areas.

Exhibit 8.3: Primary Longitudinal Pavement Markings

Solid Yellow Line	The solid yellow line indicates a no-passing zone applying to traffic with the solid line to its immediate left. Used alone, a single solid yellow line is only used to define the median of a freeway or divided roadway, or left edge of a one-way roadway.
Double Solid Yellow Line	A double solid yellow line divides lanes of traffic flow in opposing directions where passing is prohibited in both directions.
Broken Yellow Lines	A broken yellow line defines the center of a two-lane, two-way roadway where passing is permitted in both directions.
Combination Single Solid/Broken Yellow Line	This combination is used when passing is permitted in one direction (adjacent the broken yellow line), and prohibited in the other (adjacent the solid yellow line).
Broken White Lines	A broken white line is used to delineate lanes for travel in the same directions. Lane changing is permitted.
Solid White Line	A solid white line is used to mark the right edge of the roadway, and to mark lanes for travel in the same direction where lane changing is discouraged. Its normal application is as a lane line on multi-lane approaches to intersections and, particularly, to delineate left- and right-turn lanes.
Double Solid White Line	The double solid white line may be used between travel lanes in the same direction where crossing the double line is prohibited. For example, the double solid white line may be used on a bridge to prevent lane changing.
Dotted Lines	The dotted line delineates the extension of pavement markings through an intersection or interchange area. It should be the same width and color as the line it extends.

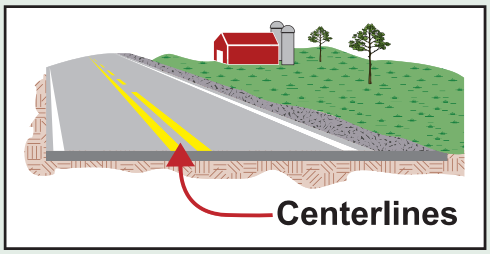
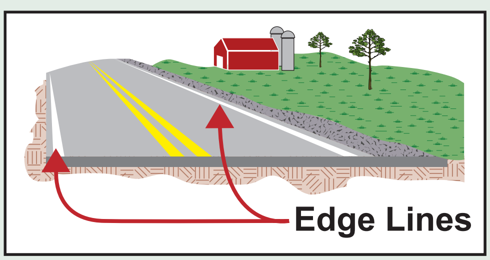
Source: FHWA, MUTCD

Exhibit 8.4: Typical Dimensions of Longitudinal Pavement Markings



Warrants for the use of pavement markings are contained in the *MUTCD*. Exhibit 8.5 below outlines the *MUTCD* warrants for centerlines and edge lines.

Exhibit 8.5: Warrants for Centerline and Edge Line Pavement Markings

TYPE, PURPOSE, AND APPLICATION	*MUTCD* CRITERIA	BENEFITS
CENTERLINES  ✓ Provides separation of traffic traveling in opposite directions ✓ Provides delineation of separation	Standards: ✓ Mandatory for all paved urban arterials and collectors with a travel way width of 20 feet or more and an ADT of 6,000 or more ✓ Mandatory for all paved two-way streets or highways that have three or more traffic lanes Guidance: ✓ Should be placed on all urban arterials and collectors with a travel way of 20 feet or more and ADT of 4,000 or more ✓ Should be placed on all paved rural arterials with a travel way width of 18 feet or more and an ADT of 3,000 or more ✓ Should be placed on other paved areas and travel ways less than 16 feet wide as a traffic engineering assessment indicates	✓ 30% reduction in head-on crashes
EDGE LINES  ✓ Provides an edge of pavement guide for drivers ✓ May result in lower speeds since travel lanes appear narrower	Standard: ✓ Mandatory for freeways, expressways and paved rural arterials with travel way widths of 20 feet or more and an ADT of 6,000 or more Guidance: ✓ Should be placed on all rural arterials and collectors with a travel way of 20 feet or more and an ADT of 3,000 or more Options: ✓ May be placed where centerlines are not present ✓ May be used to minimize driving on shoulders	✓ 11 to 25% reduction in run-off-the-road crashes

Source: FHWA, MUTCD

8.2.7. No-Passing Zone Pavement Markings

When centerline markings are used, establish no-passing zones at all vertical or horizontal curves where the passing sight distance is less than the values specified in Exhibit 8.6. When measuring sight distance, the height of the driver's eye and the oncoming vehicle are both assumed to be 3.5 feet above the road surface as indicated in Exhibit 8.7.

The Following are Additional Locations for No-Passing Zones:

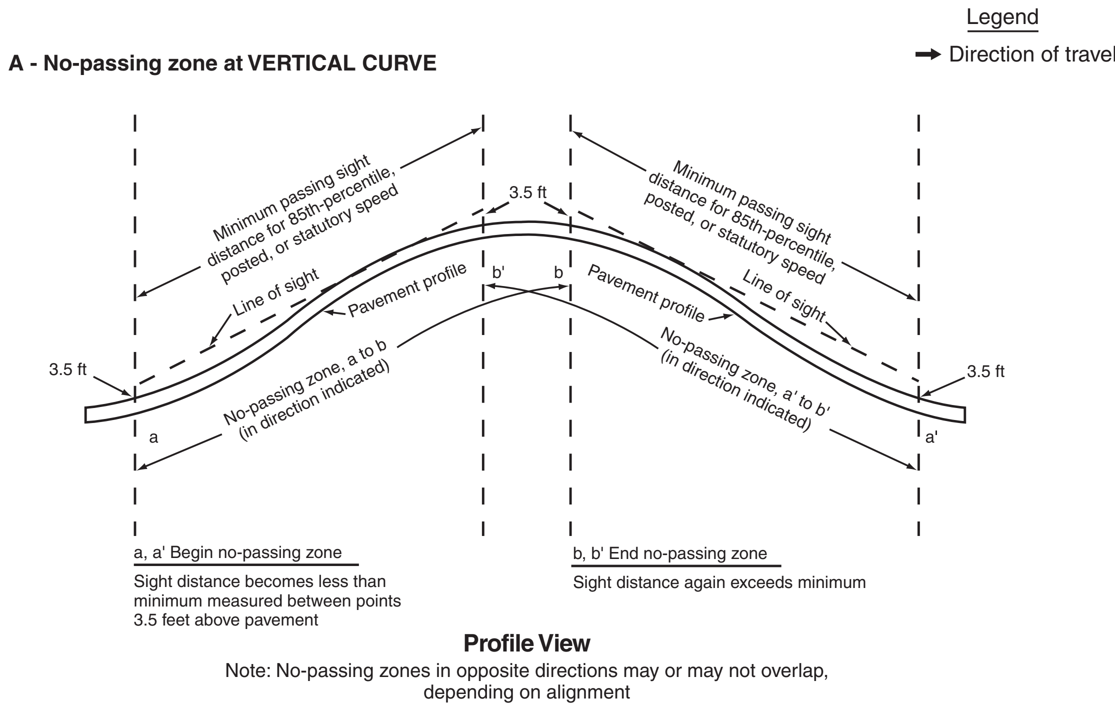
1. In advance of an obstruction such as a bridge support pillar, a channelizing island, or a pedestrian safety zone, that separates the two lanes of traffic.
2. In advance of and on or within, any narrow bridge, tunnel or underpass; and in advance of any one-lane bridge or section of highway.
3. In advance of a STOP (R1-1), YIELD (R1-2) sign, or traffic signal.
4. In advance of an intersection with a major roadway where passing is undesirable due to the high number of crossing or turning movements.
5. In advance on an intersection, along the length of a left-turn lane and the taper for the left-turn lane.
6. In advance of a highway-rail grade crossing.
7. In advance of and within a school zone.
8. In areas where an analysis of vehicle crashes shows an unusually high number of passing-related crashes.
9. In areas where the roadside development includes many driveways and intersections where passing would create frequent potential conflicts.
10. At locations where the roadway width is very restrictive, shoulders are nonexistent or in poor condition, or obstacles are close to the roadway.
11. Approaching and on bridges.
12. In areas where traffic volumes are very heavy and there would be limited opportunities for motorists to pass other vehicles.
13. Where a passing zone would otherwise be less than 400 feet in length.
14. Where engineering judgment indicates that allowing passing is undesirable because a better passing area exists farther ahead.

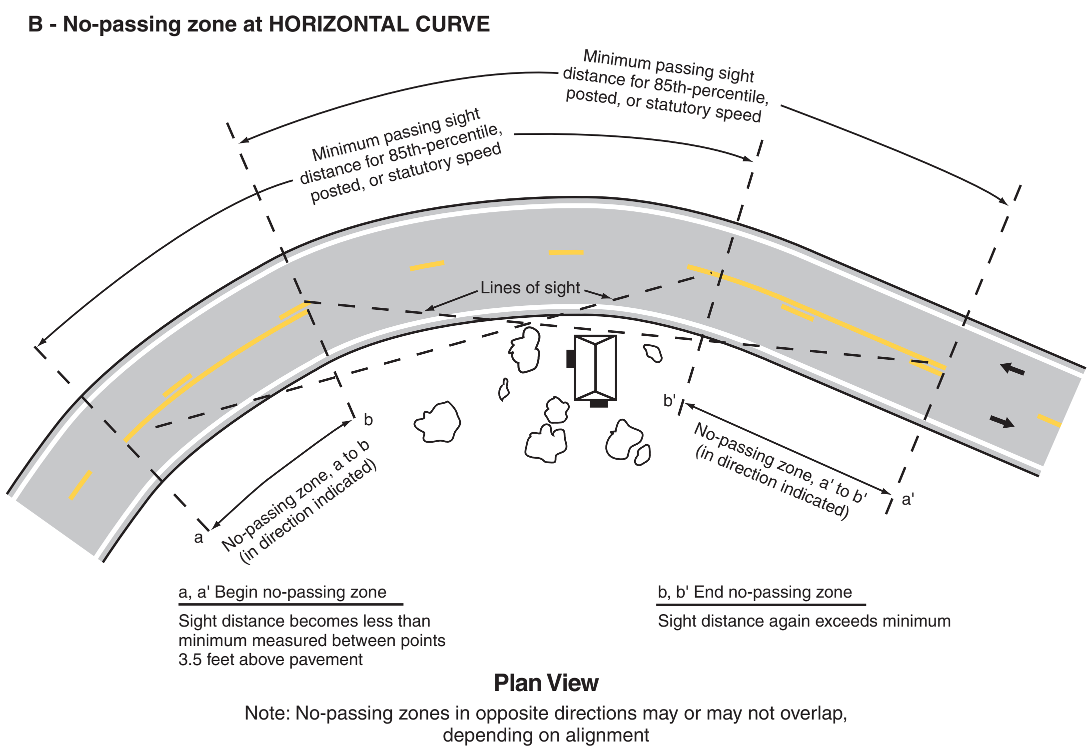
If establishing a no-passing zone because of Items 1 through 7, suggest using a minimum length of no-passing zone in advance of the physical feature that is 50 percent of the distances in Exhibit 8.6.

Exhibit 8.6: Minimum Passing Sight Distance

Speed (mph) *	Min. Sight Distance (ft.)
25	450
30	500
35	550
40	600
45	700
50	800
55	900
60	1,000
65	1,100
70	1,200
* 85th-percentile, posted, or statutory speed	

Exhibit 8.7: Determining Limits of No-Passing Zones at Curves





Source: FHWA, MUTCD

8.2.8. Longitudinal Pavement Markings at Opposing Left-Turn Lanes

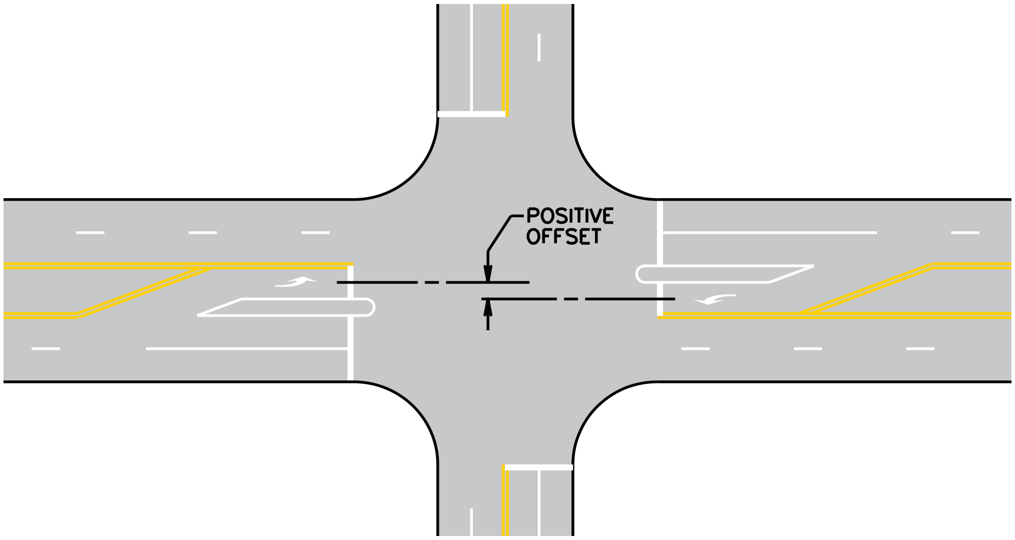
> **KEY POINT** Opposing left-turn lanes can create sight distance problems for drivers if vehicles are in both turn lanes at the same time. A positive offset between the opposing turn lanes can reduce the number of crashes, and this offset can frequently be accomplished by narrowing the travel lanes.

When opposing left-turn lanes exist at an unsignalized intersection or at a signalized intersection where vehicles are allowed to turn left on a "green ball," a sight distance problem frequently exists for drivers in a left-turn lane if another vehicle is in the opposing left-turn lane. This sight distance problem can be reduced if a positive offset exists between the opposing left-turn lanes as indicated in Exhibit 8.8.

A study at intersections in Wisconsin suggests that a positive offset reduces the total number of crashes at an intersection by 34 percent[1]. Therefore, military installations are encouraged to incorporate positive offset whenever possible. Research also suggests that the minimum desirable positive offset is 2 feet for passenger cars and 3.5 feet if truck traffic is involved.

Reconstructing intersections to improve sight distance can be costly; however, where pavement width allows, use solid lines to form a buffer island between the left-turn lane and the adjacent through lane similar to the depiction in Exhibit 8.8. Sometimes it is feasible to use reduced lane widths through the intersection to accommodate the creation of a painted island. For example, if there is one 12-foot wide through lane and a 12-foot wide left-turn lane in each direction, a 3.5-foot positive offset can be achieved by reducing each lane to a width of 10.83 feet.

Exhibit 8.8: Positive Offset at Opposing Left-Turn Lanes



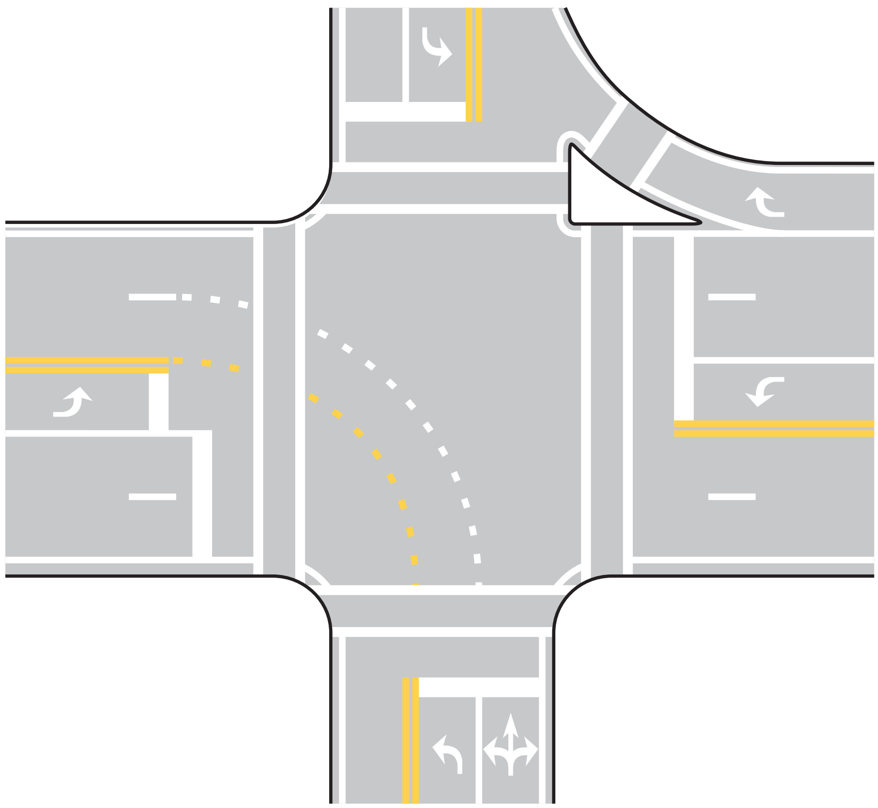
[1] Safety Evaluation of Offset Improvements for Left-Turn Lanes (FHWA-HRT-09-035), http://www.fhwa.dot.gov/publications/research/safety/09035/index.cfm

8.2.9. Extensions Through Intersections

Sometimes a dotted extension line is required or may be optional through an intersection. These dotted lines are sometimes affectionately called "puppy tracks," and as shown in Exhibits 8.3 and 8.4, these dotted lines typically should be 2 feet long with 4 feet between the line segments. These dotted lines should be at least as wide as the lines that they extend.

In accordance with the *MUTCD*, dotted extension lines are mandatory for double turn lanes in order to emphasize the need for vehicles in adjacent lanes to turn into the proper lane and to help vehicles from sideswiping other turning vehicles (see Exhibit 8.9). Dotted extension lines may also be used at offset intersections where a through lane does not line up with the receiver lane on the far side of the intersection.

Exhibit 8.9: Extensions for Double-Turn Lanes

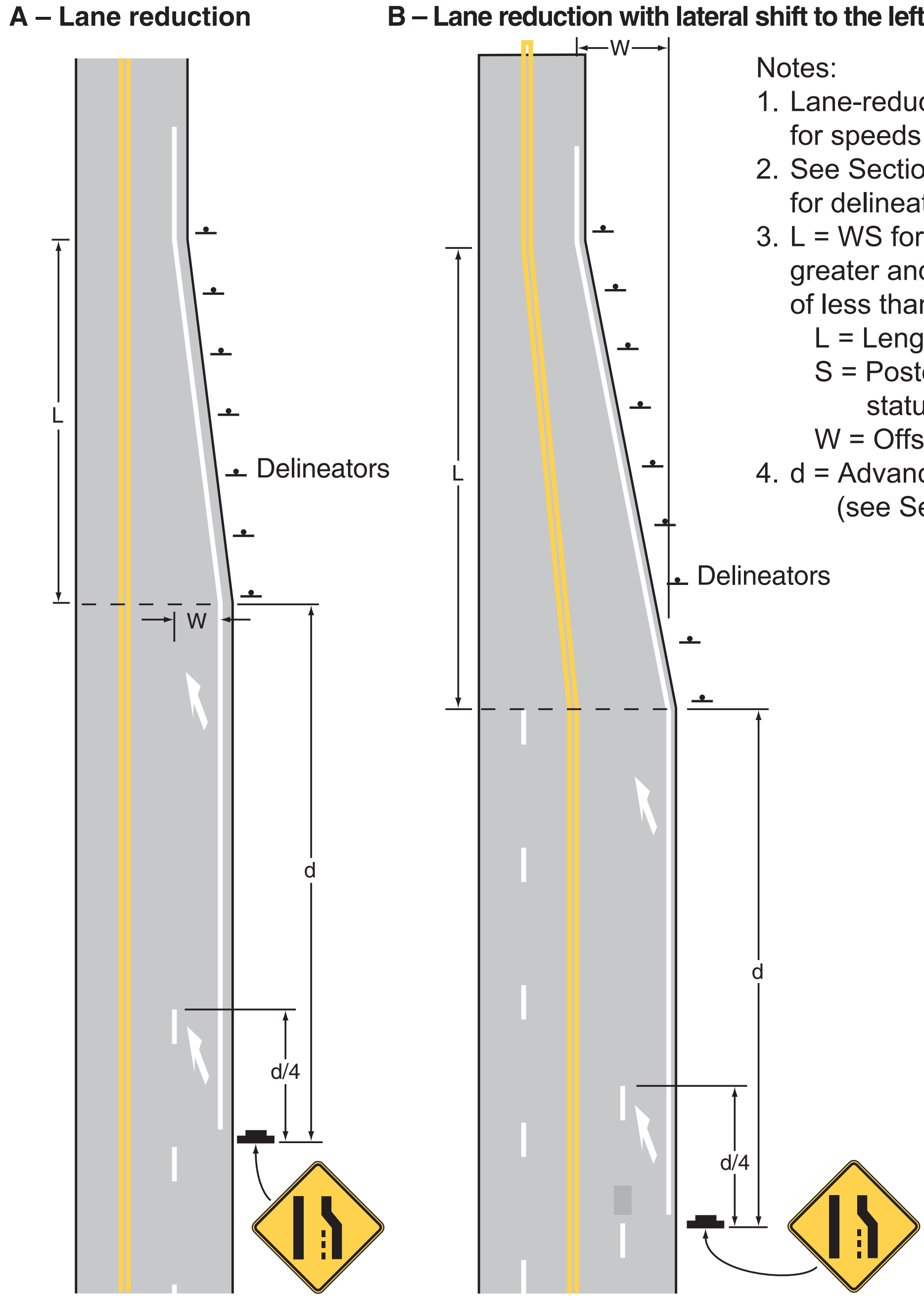


8.2.10. Lane Reduction Transition Markings

Section 3B.09 of the *MUTCD* discusses lane reductions from two directional lanes to one directional lane, with several different scenarios identified in Figure 3B-14 of the *MUTCD*.

Exhibit 8.10 illustrates a typical situation. Essentially, the added marking is an edge line even when edge lines are not provided on the balance of the road. It is important to keep in mind that the value "d" is the advance warning sign distance for "Condition A" in Exhibit 7.30.

Exhibit 8.10: Typical Lane Reduction Marking



Notes:
1. Lane-reduction arrows are optional for speeds of less than 45 mph
2. See Section 3F.04 in the *MUTCD* for delineator spacing
3. L = WS for speeds of 45 mph or greater and L = $WS^2/60$ for speeds of less than 45 mph, where:
   L = Length of taper in feet
   S = Posted, 85th-percentile, or statutory speed in mph
   W = Offset in feet
4. d = Advance warning distance (see Section 2C.05 in the *MUTCD*)

Source: FHWA, MUTCD, *Figure 3B-14*

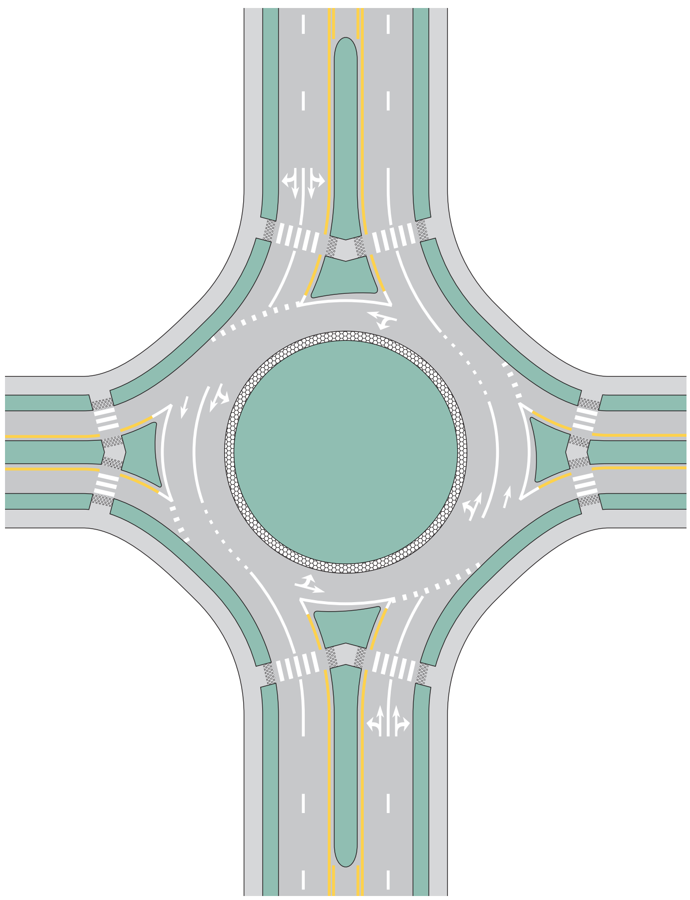
8.2.11. Markings for Roundabouts

Because roundabouts provide additional capacity, safety, and many other environmental benefits, they are becoming more popular in the United States. However, roundabouts should always be designed by an experienced professional, and the designer should provide a recommended pavement marking plan for the more complex designs. FHWA has also added a Chapter 3C in the *MUTCD*, which includes 15 different examples of roundabouts and the proper application of pavement markings.

If an approach to a roundabout has more than one lane, advance lane-assignment pavement marking arrows should be used on that approach to clearly inform drivers which lane to be in as they enter the roundabout. In these cases, the roundabout is classified as a multi-lane roundabout, and both pavement marking arrows and lane lines will normally be required within at least part of the circulatory roadway. If drivers are in the proper lane on the approach to the roundabout, they should not have to cross over any longitudinal lane lines as they maneuver around the roundabout (see Exhibit 8.11).

SDDCTEA can provide assistance with the design and pavement marking plan for roundabouts.

Exhibit 8.11: Spiral Curves on a Multi-Lane Roundabout



Source: FHWA, MUTCD

8.2.12. Transverse Markings

Transverse markings may indicate a command to stop at an intersection, to advise caution for pedestrians that may be in a crosswalk, or to advise against travel within boundaries defined by crosshatching or painted islands. Transverse markings include:

- ✓ Stop lines and yield lines
- ✓ Words and symbol markings
- ✓ Crosshatch markings
- ✓ Crosswalk markings
- ✓ Parking space markings

These markings are discussed in detail in the sections that follow. In addition to Section 8.2.14, crosswalk markings are also discussed in Chapter 13. Refer to Chapter 17 for parking space markings.

8.2.13. Stop and Yield Lines

KEY POINT

Improper placement of stop and yield lines is problematic.

Stop and yield lines should be between 4 and 30 feet from the near edge of the intersecting roadway, and at the location where motorists should stop or yield.

Stop Lines

The stop line is retroreflective white, and is no less than 12 inches nor more than 24 inches wide. The width depends on the speed of the roadway and/or the presence of hazardous conditions.

Stop lines should be used at signalized intersections, and they may also be used to show the preferred stopping location at STOP (R1-1) signs and at Stop Here For Pedestrians (R1-5b or R1-5c) signs.

At intersections with STOP signs, there is a tendency to place these lines too far back from the edge of the intersecting roadway, frequently at a location where drivers do not have a clear line of sight to proceed safely. For example, if the van in the following picture was stopped at the stop line, the driver's line of vision would be blocked by the trees on the left side of the road. Other common sight obstructions include on-premise signs, utility poles, mailboxes, signal controller cabinets, road embankments, etc.

Because even the proper placement of the stop line does not mean that drivers will stop at that location, it is always best to remove the sight obstruction whenever possible.

The stop line is about 30 feet from the near edge of the cross street. If drivers stop at the stop line, their line of sight would be blocked by the line of trees.

Therefore, it is important to review sight distance when selecting the location of the stop lines.

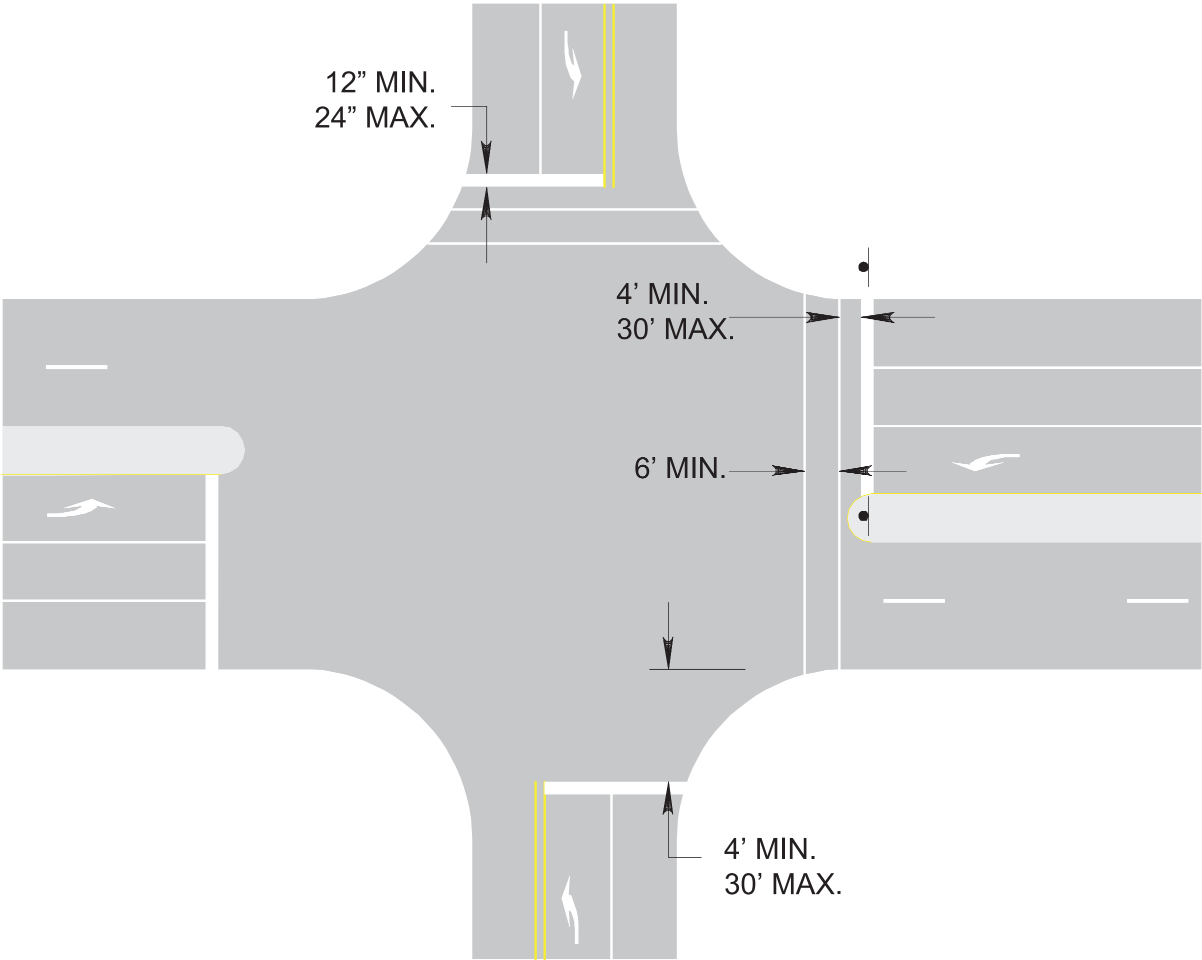
Ideally, stop lines should be set back a sufficient distance from the intersection to accommodate trucks turning into the approach roadway. At signalized intersections, the location of the lines should be adjusted to accommodate the trucks so they can clear a queue of vehicles stopped at the stop line.

Moreover, if the stop line for the left lane(s) is pulled back farther than the stop line for the right lane, the staggered stop line also improves sight distance for any driver that may be trying to make a right-turn-on-red.

From a safety standpoint, sight distance is probably more important than accommodating the trucks. Therefore, before placing stop lines at non-signalized intersections, it is important to review sight distance between the driver and an approaching vehicle. When measuring intersection sight distance, make the assumptions that the driver's eyes will be at a location about 8 to 10 feet behind the proposed stop line and at an elevation of 3.5 feet above the road surface, and that the approaching vehicle will be 3.5 feet high.

Other design details are illustrated in Exhibit 8.12.

Exhibit 8.12: Stop Line Placement

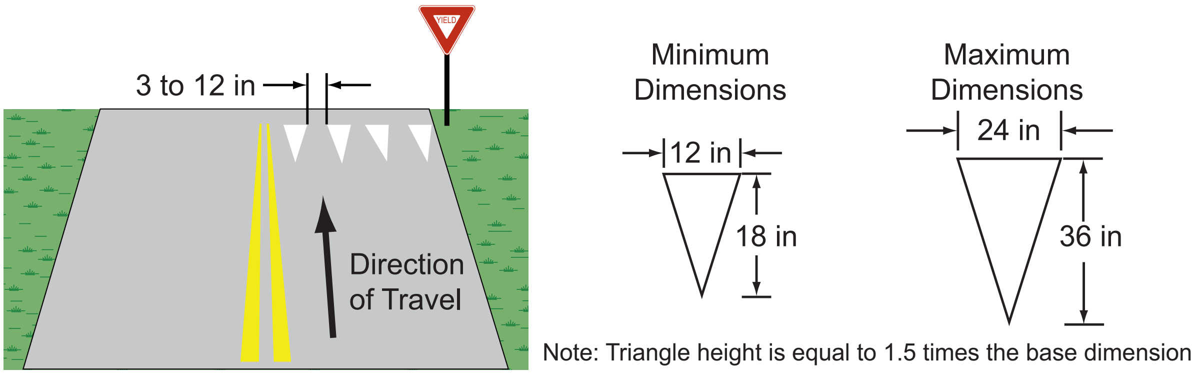


Yield Lines

Prior to the year 2000, the solid stop lines were used at both STOP and YIELD signs. However, the *MUTCD* now requires yield lines to be similar to the type used in Europe, consisting of a series of white isosceles triangles sometimes referred to as "shark's teeth." The row of white triangles should extend across the lane to indicate the location at which drivers are to stop if necessary. The orientation of the triangles resembles a YIELD sign, where each triangle should have a base of 12 to 24 inches, and a height equal to 1.5 times the base. The space between the triangles should be 3 to 12 inches.

Yield lines may supplement YIELD signs (as illustrated in Exhibit 8.13) or Yield Here to Pedestrians (R1-5 or R1-5a) signs (as illustrated on the crosswalk layout drawings in Chapter 13). Determining their location at intersections is similar to determining the location of stop lines.

Exhibit 8.13: Typical Yield Line Details



Note: Triangle height is equal to 1.5 times the base dimension.

8.2.14. Crosswalk Markings

Crosswalk markings are problematic because despite the fact that most people believe they are helpful, in reality their presence frequently increases the number of vehicle-pedestrian crashes.

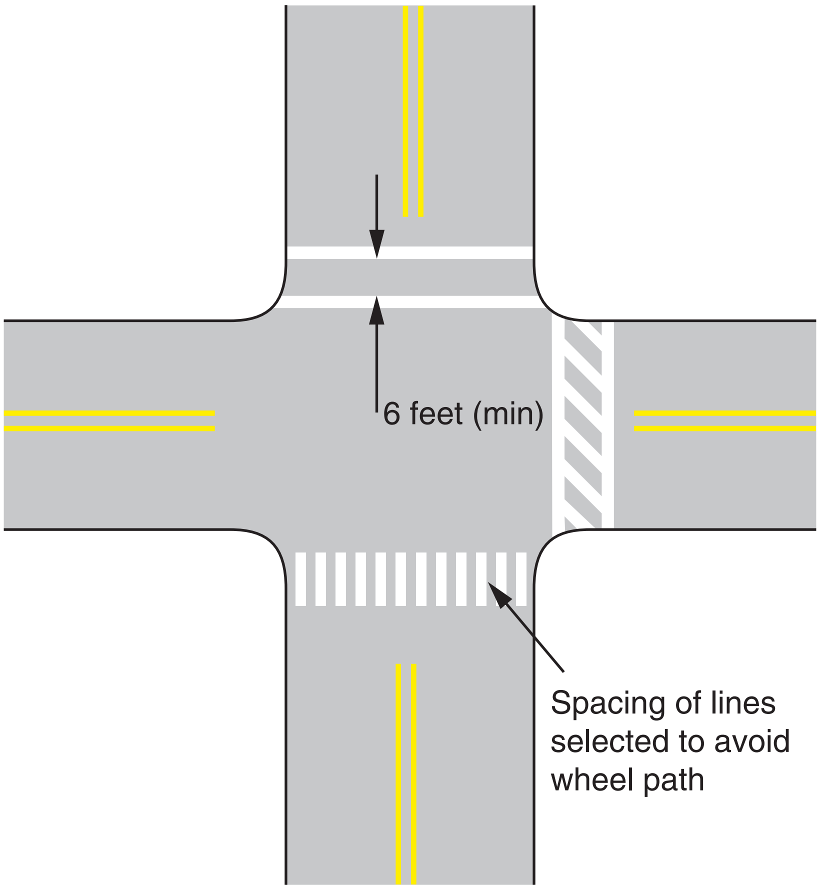
Crosswalk markings are common at intersections. Exhibit 8.14 illustrates the three types of crosswalk markings commonly used in the United States. Although any of these three types are acceptable, it is desirable not to mix the types.

The minimum effective width of a marked crosswalk is 6 feet, as measured between the inside edge of any transverse markings. The table included in Exhibit 8.14 shows some key design elements.

Some highway agencies use bricks or pavers between the two white crosswalk lines. Although these roadway materials are acceptable, it is extremely important that the bricks or pavers do not become misaligned and create safety problems for pedestrians.

There are also decorative pavement marking materials that are commercially available to simulate brick, pavers, flagstone, etc. However, in accordance with Section 3G.01 of the *MUTCD*, these materials would not be acceptable if they use white or yellow colors designed to warn or regulate traffic, or if any of the colors are retroreflective. In addition to these prohibitions, some of the patterns and colors are so "busy" that if a pothole were to develop in the crosswalk, a pedestrian may not even see it. Therefore, military installations are discouraged from using any decorative pavement marking materials.

Exhibit 8.14: Types of Crosswalk Markings



TYPE OF CROSSWALK MARKINGS	WIDTH OF TRANSVERSE MARKINGS	WIDTH OF STRIPES
STANDARD – SOLID WHITE CROSSWALK LINES	6-24 inches	n/a
DIAGONAL STRIPES	optional, but 6-24 inches if used	12-24 inches*
PIANO KEYS – LONGITUDINAL STRIPES	optional, but 6-24 inches if used	12-24 inches*
** with gaps of 12-60 inches between stripes*		

Midblock crosswalks (i.e., not at an intersection) are especially problematic, perhaps because marking a crossing sometimes provides a false sense of security to the pedestrians. In fact, research at 1,000 locations in 16 states indicates that just adding crosswalk markings at known midblock crossing areas generally decreased pedestrian safety. Therefore, before installing a new crosswalk, an engineering study is needed to determine whether the location is suitable for a marked crosswalk. Midblock crossings, and crossings on uncontrolled approaches at intersections, must meet installation warrants as developed by SDDCTEA; see Section 13.4.

The study should consider traffic and pedestrian volumes, vehicle mix, vehicle speeds, sight distance, and other factors. The engineer should also consider providing raised medians or islands, reducing the street width, adding other traffic calming measures, and installing pedestrian-type signs, street lighting, etc. For more information, see Section 13.4.

> At new crosswalks, it is necessary to install curb cuts, curb ramps, and detectable warning surfaces in accordance with the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)," as well as PROWAG guidelines.

Crosswalks which are not perpendicular to the roadway they cross should be avoided. With a perpendicular crosswalk, the crossing distance and time that a pedestrian is in the roadway exposed to traffic is minimized. If the crosswalk is not perpendicular to the roadway, it should not be greater than 20 degrees off of perpendicular to the roadway. These configurations are shown in Exhibit 8.15.

Exhibit 8.15: Skewed Crosswalk Configurations

8.2.15. Pavement Word and Symbol Markings

Details for pavement word and symbol markings are included in the “Pavement Marking Chapter” of the *SHSM Book*. Because these words and symbols are viewed from a very low angle, words and symbols are stretched or elongated so that they look normal from a low viewing angle.

The use of word-type pavement messages is frequently called “horizontal signing,” and it is an effective way to communicate with drivers providing the markings are visible. Therefore, installations are encouraged to use pavement word and symbol markings to supplement traditional regulatory, warning, and directional signs.

Thermoplastic is the recommended material for pavement words and symbol messages.

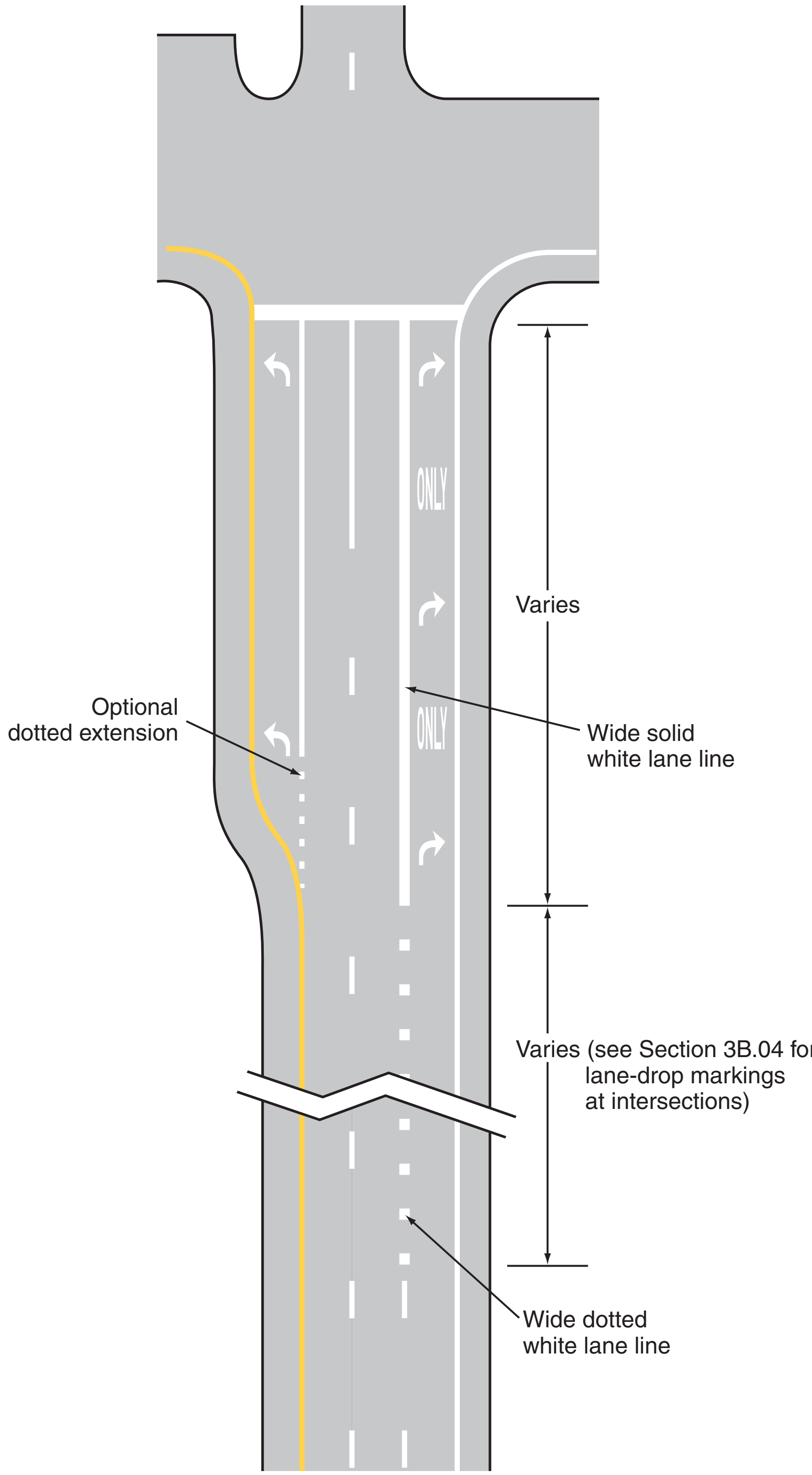
Words and symbols shall conform to Figures 3B-16 through 3B-31 in the *MUTCD*. The standard height of word messages is 8 feet on all types of roads, except “SCHOOL” is 10 feet high. A maximum of three lines of message may be used. When two or three lines of message are used, they are to be read in the direction of travel; i.e., motorists read the messages as they encounter them.

Except for the opposing arrows of a two-way left-turn lane marking (see Figure 3B-7 in the *MUTCD*), successive lines of a message should be spaced at four to ten times the legend height (i.e., a typical spacing of 32 to 80 feet).

Perhaps the most common of these markings is the turn arrow. In most cases, the turn arrow is used by itself, but whenever the required turn is not obvious, the word “ONLY” should be used as illustrated in Exhibit 8.16.

Other common word and symbol markings include the railroad crossing symbol, and the word messages “STOP AHEAD” and “PED XING.”

Exhibit 8.16: Example of Turn Arrows



Source: FHWA, MUTCD

8.2.16. Route Identification Markings

The *MUTCD* allows for only 5 different colors of marking in *MUTCD* Section 3A.05—red, white, yellow, blue, and purple. Each of these colors have a specific purpose as outlined in this section. There are no other colors allowed, and no other purposes allowed in the *MUTCD* for line markings. Although some installations may have had some success with painting lines in the lane to designate guidance to certain functions (such as graduation ceremonies), areas, etc., they are technically in violation of the *MUTCD*; especially if one of the above mentioned colors are used for that purpose.

Wayfinding guide signage as per *MUTCD* Section 2D.50, and discussed in pamphlet Section 7.4.4, is recommended for several reasons:

1. Signs last much longer than pavement markings. Standard paint pavement markings can be expected to only last 6-12 months before they will need to be re-painted. Some costlier materials like thermoplastic will last a few years. Signs can last up to 10 years or more.
2. Signs are still visible in inclement weather. Snow will cover markings making them difficult to see, and rain will also obscure marking color and visibility. Signs normally are retroreflective, and are much more visible in inclement weather.
3. If the venue changes location, signs can be more easily moved to redirect visitors, whereas pavement marking will have to be obliterated from the pavement.
4. Non-standard line pavement markings with non-standard paint colors could be confusing for drivers with color blindness or other visual acuity issues.

An additional option to consider is the use of pavement marking symbols, as the *MUTCD* does provide some flexibility in this area. Per *MUTCD* Section 3B.20, painted symbols may be used for identifying routes. Text may be used along with arrows that are white in color. For example, if an installation has frequent graduation ceremonies and wishes to identify the route to the graduation ceremony for visitors, the installation may use a white arrow above and abbreviated text (maybe the word “GRAD” or full “GRADUATION” if it fits). Another option to consider that complies with the intent of the *MUTCD* is to develop a special symbol for the graduation location (maybe the ‘unit patch’), and paint that in the center of the lane to supplement signing. Include arrows as necessary to denote a change of direction. White is recommended for these symbols, but the installation could use other colors as per Figure 3B-25 in the *MUTCD*. This will allow the installation to designate a lane and only have the logos to maintain, which the installation maintenance crew can paint in-house using a template and standard pavement marking paint.

For authoritative regulation, refer to Section 7-14 (d) of AR 420-1 which requires Army installations to meet *MUTCD* or host nation standards and criteria. At CONUS, AK, HI, and U.S. possessions installations, approval to use nonstandard devices must be obtained from SDDCTEA prior to use. Requests must contain full justification and rationale for waiver from criteria in the *MUTCD*. However, since there are options for installations that are in conformance with the *MUTCD* (as stated above), SDDCTEA would not provide a waiver to allow installations to paint lines in the lane to designate guidance to certain functions.

8.2.17. Crosshatch Markings

KEY POINT

Crosshatch markings are both time-consuming and expensive to install. Therefore, military installations are encouraged to take a very conservative approach in their use.

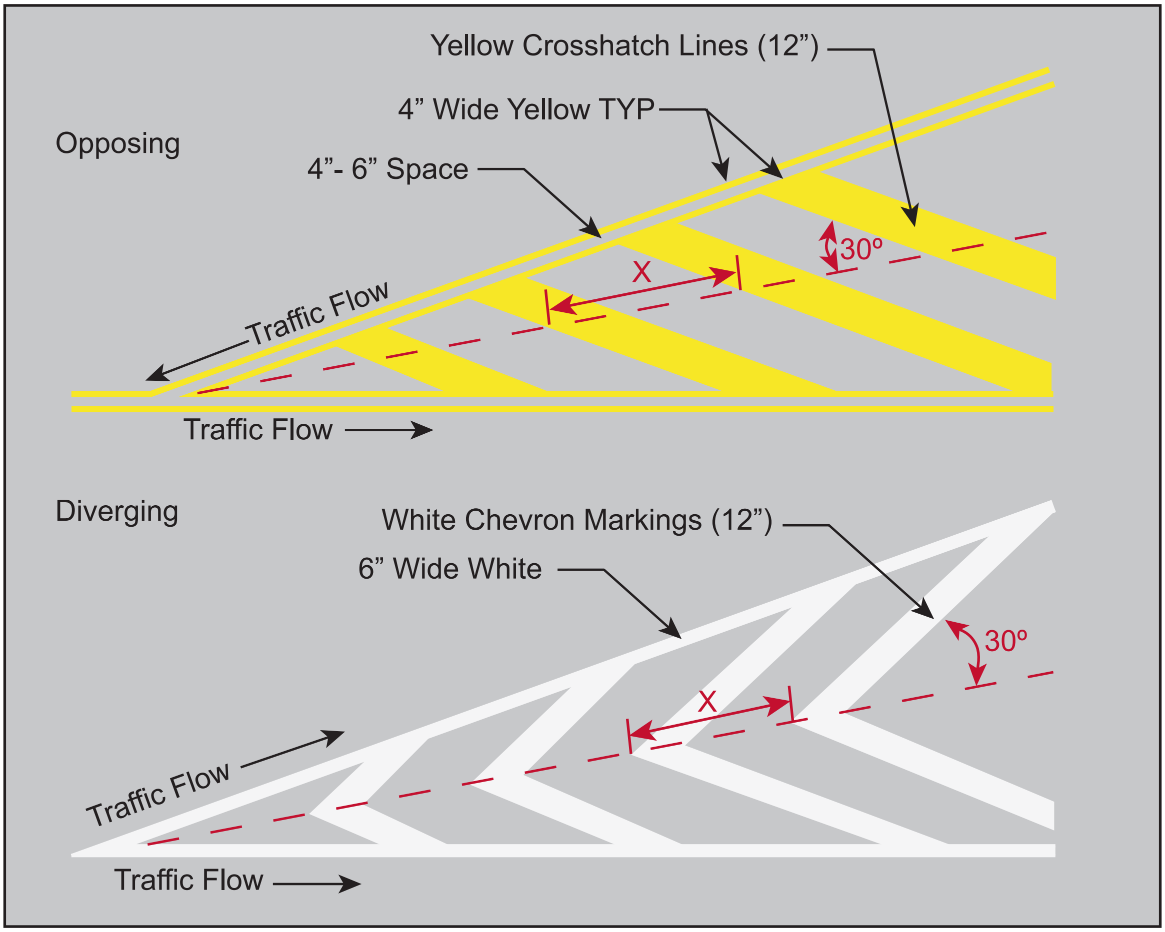
Crosshatch markings may be used to discourage travel on certain paved areas, such as shoulders, gore areas, buffer areas approaching and around obstructions in the roadway, within painted channelizing islands, and in buffer areas separating preferential travel lanes and other travel lanes.

When crosshatch markings are used in paved areas on the left side of the roadway or in areas that separate opposing directions of traffic, they shall be yellow diagonal markings; and when crosshatch markings are used on the right side of the roadway or in areas that separate traffic going in the same direction they shall be white. However, in areas that separate traffic flows in the same general direction, the white markings shall be chevron markings, with the point of each chevron facing toward approaching traffic. These two types of crosshatch markings and their proper orientation are illustrated in Exhibit 8.17.

Crosshatch markings are always optional in the *MUTCD* with the exception that white chevron markings should be used within buffer areas to separate preferential lanes from other travel lanes (see Paragraph 04 of Section 3D.02, and Drawing A in Figure 3D-2 of the *MUTCD*).

Although these markings may be helpful to drivers, the installation is both time-consuming and expensive. Therefore, military installations are encouraged to take a very conservative approach in their use. Moreover, when used, military installations are encouraged to use 12-inch wide lines at a 30-degree angle as illustrated in Exhibit 8.17.

Exhibit 8.17: Typical Crosshatch Markings



* Where “X” is a function of the speed: 24 feet for speeds below 30 mph, 36 feet for speeds of 30 to 45 mph, and 48 for speeds over 45 mph. In addition, if these markings are used over an extensive length, “X” should be increased to 100 feet or more.

Two common problems on military installations are the improper color and the improper orientation of the lines. Therefore, if using crosshatch markings, consider the following:

- ✓ Use yellow markings on the left side of one-way roads and between opposing travel lanes.
- ✓ Use white markings on the right side of a travel lane or when traffic is going the same direction on both sides of the markings.
- ✓ Angle the markings in the proper direction. Think of diagonal lines as physical barriers, which if hit would deflect an errant vehicle back into the proper travel path.

The following photo shows an incorrect application of crosshatching markings, also with corrected markings.

Wrong color and wrong angle

8.2.18. Do Not Block Intersection Markings

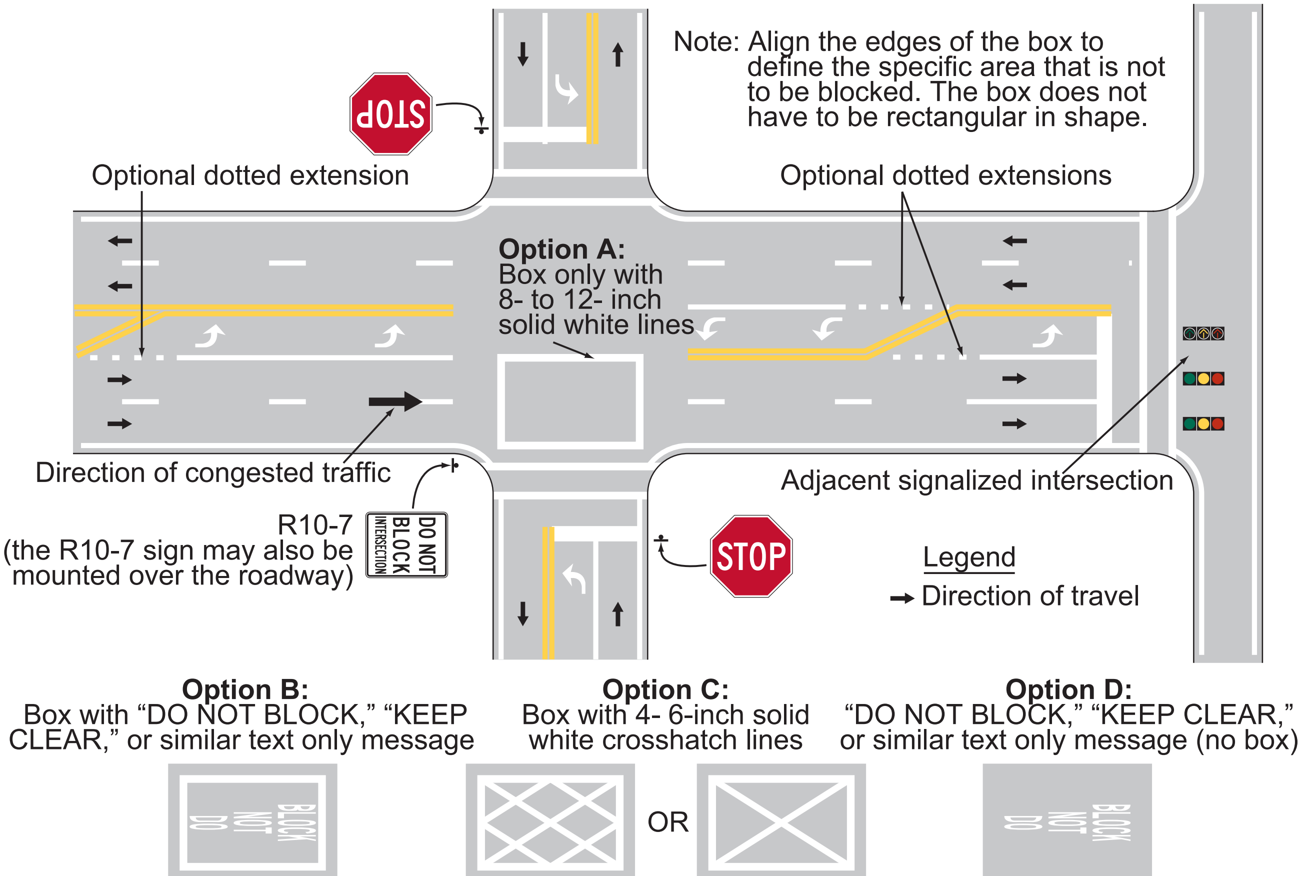
Do Not Block Intersection Markings may be used to mark the edges of an intersection area that is in close proximity to a signalized intersection, railroad crossing, or other nearby traffic control that may cause vehicles to stop within the intersection and impede other traffic entering the intersection.

If used, the Do Not Block Intersection Markings should consist of 8-inch or 12-inch solid white lines that outline the area of the intersection as illustrated in Exhibit 8.18.

The box should envelop the area normally enclosed within the extension of the edge lines or centerlines. A minimum of 4 feet should exist between any crosswalks and the box.

Do not use “Do Not Block Intersection Markings” unless accompanied by one or more DO NOT BLOCK INTERSECTION (R10-7), DO NOT STOP ON TRACKS (R8-8), or similar signs.

Exhibit 8.18: Do Not Block Intersection Markings



Source: FHWA, MUTCD

8.2.19. Speed Hump Markings

A speed hump is a raised surface on the roadway that is typically 3 to 4 inches in height, and typically either 12 or 22 feet in length. Speed humps are the most popular traffic calming measure used in the United States, likely because they are effective in reducing speeds at minimal cost. However, military installations are discouraged from using speed humps on any roadway with a speed limit of 35 mph or higher.

The most common speed hump is 12 feet in length and generally consists of a 6-foot incline followed by a 6-foot decline. The longer and more effective design is the same except it has a 10-foot long elevated section between the incline and the decline. The latter type is also called a "speed table," and is sometimes used for an elevated crosswalk.

To effectively warn approaching traffic, all speed humps should have pavement markings that comply with the *MUTCD*, specifically *MUTCD* Sections 3B.25 and 3B.26, and *MUTCD* Figures 3B-29, 3B-30, and 3B-31.

8.2.20. Obliteration of Pavement Markings

When traffic patterns change, it is important to remove the old pavement markings and apply new ones in the proper location. Although grinding has been used to remove old markings, the disadvantage of using grinding to remove markings is that this process creates permanent scars that will frequently exist for the life of the pavement.

Similarly, painting over the old markings with black paint is not acceptable because eventually the original line will again be visible. In addition, black painted lines can be compelling during the day and on a wet night they are often more visible than the real pavement markings.

High-pressure water blasting is another option for marking obliteration that overcomes the concerns associated with other techniques.

8.3. DELINEATION

Pavement markings are useful during both the day and night, but delineation as used along roadways essentially provides only guidance at night.

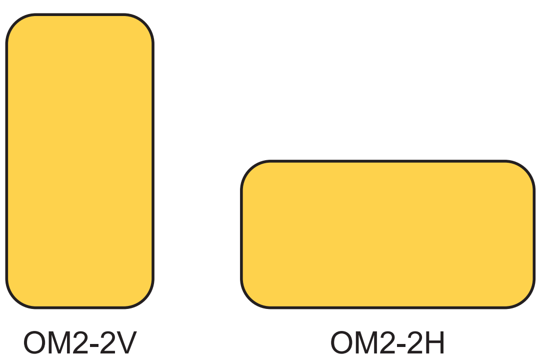
8.3.1. Post-Mounted Delineators

Delineators installed on posts consist of a retroreflective device with a minimum dimension of 3 inches, and installed with the top of the “retroreflector” about 4 feet above the elevation of the near edge of the roadway. The two most common methods are:

The OM2-2V or OM2-2H markers in Exhibit 8.19 illustrate one type of delineator consisting of yellow sheeting affixed to a metal or plastic substrate and then attached to a steel or wood post.

A flexible delineator post, which includes a 3-inch wide by 12-inch high strip of retroreflective sheeting affixed near the top of a plastic or fiberglass post that is about 5.5 feet in length.

Exhibit 8.19: Delineators



The preferred method is the flexible delineator post. The main advantage is that the flexible delineator post is much less likely to damage an errant vehicle. Moreover, the flexible delineator post can typically receive five to ten hits before it needs replaced, making it the more economical option.

Normal lateral placement is 2 to 8 feet from the outer edge of the shoulder, or from the edge of the roadway if shoulders are not present. Delineators should generally be white in color, except they should be yellow if on the left side of a one-way road or in the center of a divided highway.

If used on tangent sections of roadway, delineators should be spaced at uniform distances of 200 to about 528 feet apart. However, on curves, the spacing should be less, with the suggested spacing as indicated in Exhibit 8.20.

Exhibit 8.20: Delineator Spacing on Horizontal Curves

RADIUS OF CURVE (FEET)	APPROXIMATE "S" SPACING (FEET)*
50	20
115	25
180	35
250	40
300	50
400	55
500	65
600	70
800	80
1,000	90

* The "S" spacing is the recommended spacing on the curve. Immediately in advance of or beyond a curve, and proceeding away from the end of the curve, the spacing of the first delineator is 2S, the second 3S, and the third 6S but not to exceed 300 feet.

Chevron Alignment (W1-8) signs can also serve as delineation, since they provide both daytime and nighttime guidance. When the W1-8 signs are used, there is no reason to use post-mounted delineators at the same location.

8.3.2. Raised Pavement Markers

Retroreflective Raised Pavement Markers (RRPMs)

Retroreflective raised pavement markers (RRPMs) can be used to supplement pavement markings such as painted longitudinal lines. As such, the RRPMs assist drivers by providing improved nighttime visibility, especially when the roads are wet and the standard pavement marking lines may be covered with a film of water. If using RRPMs, the color of the retroreflectors should always be the same color as the pavement markings, except they shall be red when facing wrong-way traffic. Check your state DOT practices when considering the use of RRPMs. Some states commonly use yellow centerline RRPMs along the entire length of a roadway in tangent and curve sections, and only use white edge line RRPMs in curve sections. Otherwise, they are also commonly used on in the roadway immediately adjacent to curbed approach ends of raised medians and curbs of islands, or on top of such curbs. Some states that use RRPMs have specified distances used in tangent sections, and decrease the spacing in curves. The decreased spacing depends on the curve radius, where shorter radii using shorter spacing.

Retroreflective raised pavement markers

RRPMs can be used in snow zones, but they are more costly. Snowplowable models typically are partially embedded into the roadway and have metal rails that lift the snowplow blade up and over the retroreflectors. The life expectancy of RRPMs is about 2 or 3 years.

Non-Retroreflective Raised Pavement Markers (RPMs)

Some southern states use a combination of RRPMs and non-retroreflective raised pavement markers (RPMs) in lieu of “painted” longitudinal lines. Most non-retroreflective RPMs are ceramic markers, where the color should always be the same as the color of the line that they are substituting.

Except for the ease of eradication, there probably are few advantages in using non-retroreflective RPMs. However, if they are used, it is important that they be placed at short intervals, and that the number and spacing of the retroreflective units be installed in accordance with state standards so that drivers clearly know if it is a solid line or a broken line.

Non-Retroreflective RPMs

Lighted Raised Pavement Markers

Lighted RPMs are allowable per the *MUTCD*. These are typically lighted by LEDs, and wired to an electrical service or battery pack on the roadside. When used, they are to be constantly lighted versus flashing. While they can have advantages, such as not requiring headlight illumination, this case is rare since roadway pavement markings are in line with a vehicle's headlights, especially when markings are retroreflective. Lighted RPMs can be beneficial on bridge or tunnel lanes, especially those that use reversible lanes, by providing additional information to motorists. They can also have benefit in sharp curves where headlights are not in line with markings in time to provide sufficient warning to motorists.

Lighted RPM Example

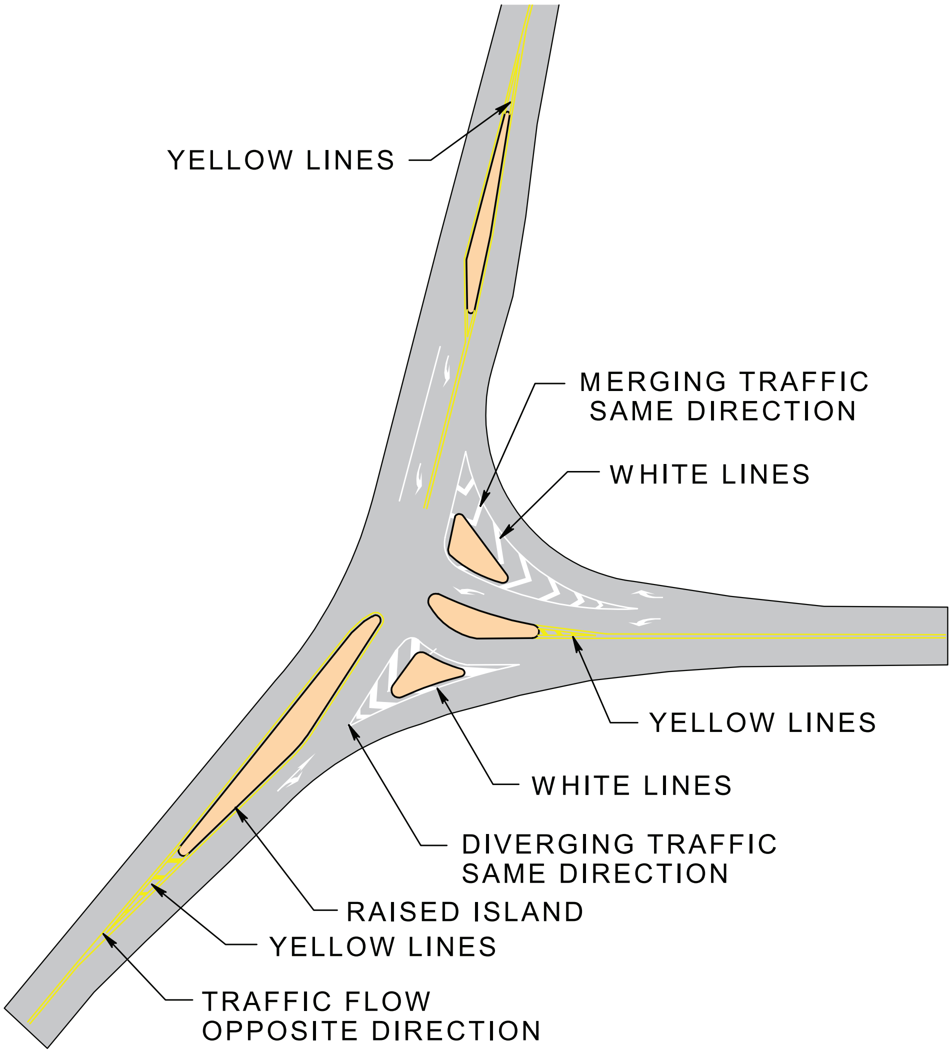
8.4. ISLANDS

KEY POINT

As used herein, an island is the defined area between traffic lanes for control of vehicular movements or for pedestrian refuge. Within an intersection area, a median or an outer separation of a turning movement is also an island.

Exhibit 8.21 depicts an intersection with five islands. Note that the crosshatching and chevron markings are optional, but if used, the three crosshatched areas in the middle of the road would be yellow and the two areas with chevrons would be white.

Exhibit 8.21: An Intersection with Several Islands



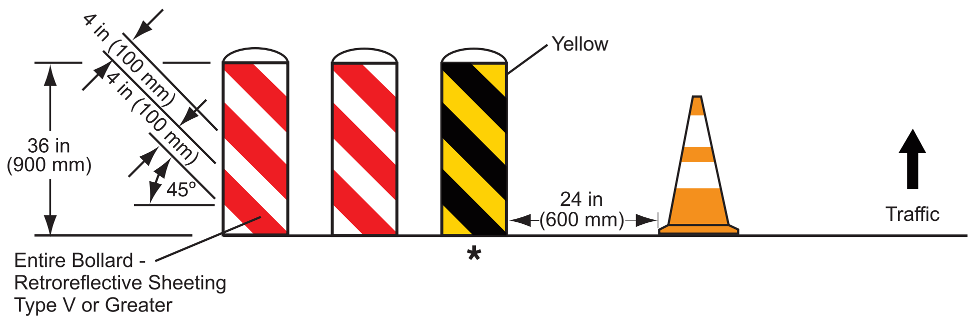
8.5. BOLLARD MARKINGS

The most common in-roadway bollard system is at an entry control facility in order to provide security benefits by limiting vehicular speeds and movements. However, SDDCTEA does not endorse the use of these systems and encourages other design options to address security concerns.

Since a bollard is a fixed object like a tree or utility pole, existing standards such as the *MUTCD* and AASHTO Roadside Design Guide discourage their use. Also, bollards are not continuous like other barrier systems. Vehicular impacts may result in significant penetration increasing the potential severity of the crash. In some vehicles, bollards may penetrate the passenger compartment depending on the vehicular speed upon impact.

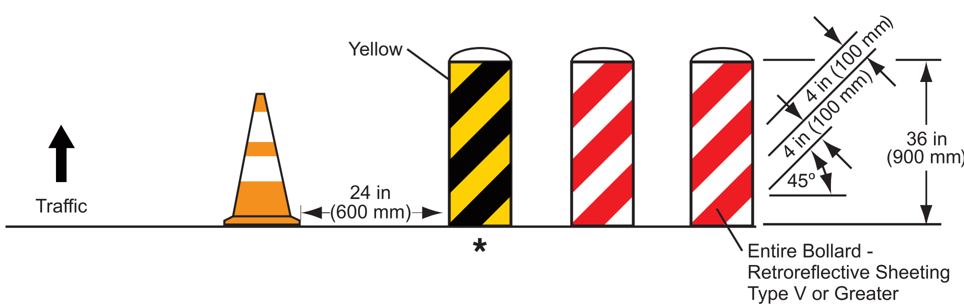
If existing systems are in use and must remain in use, they shall be delineated. The bollards themselves shall be delineated with retroreflective markings as shown in Exhibit 8.22 and the roadway alignment shall be delineated using signs and traffic cones/panels. Proper spacing is critical to allow vehicles to navigate the system safely. (Refer to SDDCTEA Pamphlet 55-15 for a detailed Traffic Control Plan for an Existing Bollard Serpentine.) When systems are not used for all time periods, flashers can be used to advise motorists of when serpentine bollards are in place.

Exhibit 8.22: Bollard Delineation Detail



BOLLARDS TO LEFT OF TRAFFIC

*May Install Object Marker Sign to Bollard



BOLLARDS TO RIGHT OF TRAFFIC

*May Install Object Marker Sign to Bollard

In addition to being utilized at ECFs, bollards are also present at various locations throughout military installations. A bollard that is within the roadway or adjacent to the roadway (i.e., within a specified distance) is considered a hazard. (Refer to Chapter 11 to determine the applicable 'clear zone' distance and if an existing bollard is considered a hazard.) Bollards that fall within the roadway clear zone and are considered a hazard, must be delineated at a minimum. A bollard adjacent to or within the roadway shall utilize the alternating black and retroreflective yellow stripes. As illustrated in Exhibit 8.22, the stripes shall be sloped down at an angle of 45 degrees toward the side on which traffic is to pass the bollard. If traffic can pass to either side of the bollard, the stripes shall form chevrons that point upwards. Refer to Section 7.3.15—Object Markers for an illustration of the chevron marking.

8.6. GATE MARKINGS

KEY POINT

Gates on military installations need to be formidable devices; therefore, it is essential that the gates are highly visible and that drivers have adequate advance warning when they are closed.

Gates are common at military installations to physically prevent road users from proceeding past a particular point without authorization. Gates on military installations may include the following:

- ✓ Railroad Grade Crossing Style. An arm or a physical fence that is moved from a vertical to a horizontal position similar to railroad grade crossing gate to effectively block motor vehicles. The gate may be stiffened and the outer end may lock into place. See section 5.8 for additional information on railroad grade crossing gates.
- ✓ Swinging Gate. A fence that is rotated on a vertical support from a position that is parallel to traffic to a position that is perpendicular to traffic.
- ✓ Gate on Rollers. A fence on rollers that is perpendicular to traffic and that retracts to open and extends to close.

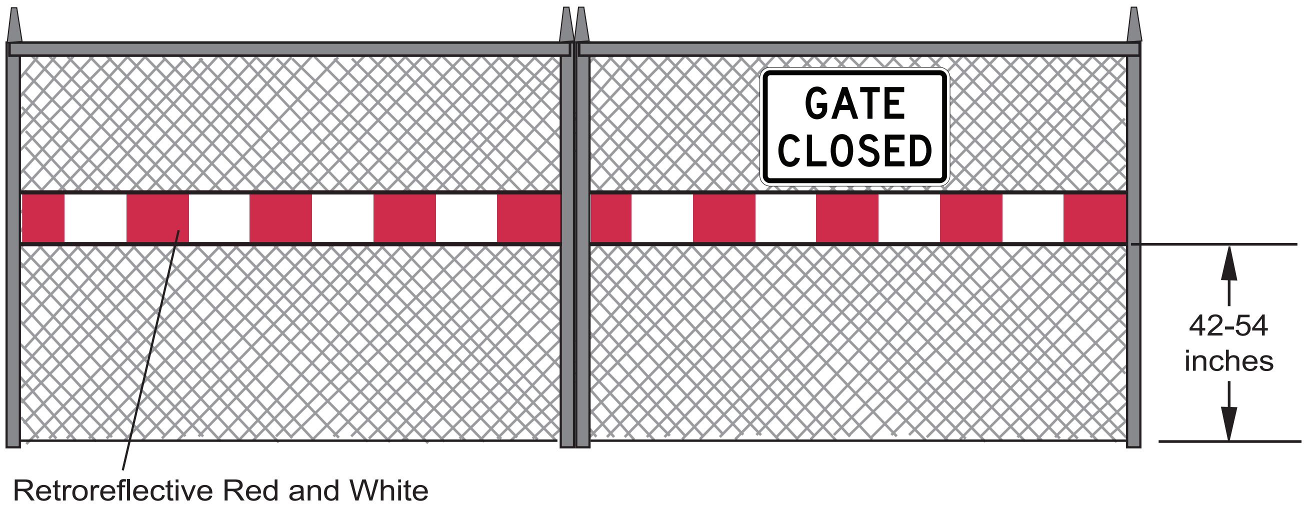
Since gates are formidable devices, it is essential that they be clearly visible day and night. When closed, gates shall be retroreflective from both directions. The grade of sheeting shall be a minimum of a Type III material.

Safety Issues for Swinging Gates

- ✓ When open, the gate supports should be a minimum of 2 feet from the face of the curb or the edge of the pavement.
- ✓ When swinging gates are in the open position; i.e., parallel to the flow of traffic, they should be rotated to the downstream direction from the perspective of traffic in the lane adjacent to the gate support in order to minimize the possibility of the gate spearing an errant vehicle. Therefore, on a two-way roadway, both gates would be rotated clockwise to open them, and when open they would be pointing in opposite directions.

When gates are used to close off a roadway either on a permanent or on a part-time basis, a GATE CLOSED (R11-2g-TEA) sign shall be used in combination with retroreflective, alternating, vertical red and white stripes (16 inches in width) on a sign panel (see Section 8C.04 of the *MUTCD*) as illustrated in Exhibit 8.23. This sign panel must be a minimum of 4 inches in width and span the entire length of the gate on both sides. The total surface area of the retroreflective strip shall not be less than 1152 square inches per approach lane.

Exhibit 8.23: Gate Closed Signing



Section 2B.68 of the *MUTCD* requires gates to have a horizontal strip of retroreflective sheeting on both sides of the gate, except if used on a one-way roadway. In this situation, the retroreflectorization may be omitted on the side of the gate facing away from approaching traffic. However, on military installations, a back-to-back installation is recommended to avoid problems with a wrong-way driver.

A minimum of two GATE CLOSED signs are require, one for the in-bound approach and one for the out-bound approach. STOP signs provide the message that vehicles can proceed after having stopped, therefore a STOP sign is not appropriate and shall not be used in lieu of the GATE CLOSED sign.

Refer to Sections 7.2.7 and 7.3.13 for details regarding the use of the GATE CLOSED AHEAD (W20-3g-TEA) advance warning sign.

On some access roads to gates that are open only during certain periods, especially if it is several miles to the gate, a destination sign should be used to advise motorists of gate hours. The sign should be placed at a point where it will prevent needless travel when the gate is closed. Hours should be shown in civilian time, not military hours. The sign should have white lettering on a green background (see Section 7.4.3).

There are two safety issues with the above gate. First, in accordance with the *MUTCD*, a fully retroreflective horizontal rail with alternating red and white vertical stripes (see Exhibit 8.23) is required on both sides of each gate. Second, as required in *MUTCD* Section 2B.68, the vertical gate supports should be set back at least 2 feet from the edge of the traveled way (or from the face of curb in a curbed roadway section).

The rolling fence at the above ECF should have at least one fully retroreflective horizontal rail with alternating red and white vertical stripes. The rail will help drivers visually determine if the gate is closed, or if one or two in-bound lanes are open.

CHAPTER 9—TRAFFIC SIGNALS AND ITS

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CHAPTER 9—TRAFFIC SIGNALS AND ITS

9.1. TRAFFIC SIGNALS: THE BASICS

Traffic signals are a valuable tool in assigning right-of-way at intersections where, without such control, there would be excessive delay or safety concerns.

As a result, there are more than 300,000 traffic signals nationwide. However, traffic signals themselves can significantly worsen traffic congestion and create safety concerns if they are not designed, maintained, and operated properly.

- ✓ Five percent of traffic congestion can be attributed to traffic signals.
- ✓ Traffic signal congestion costs approximately $10,000 in delay and fuel costs per intersection per year.
- ✓ Six percent of all fatal crashes occur at signalized intersections.

Traffic signals are needed when STOP sign control cannot do the job effectively. STOP signs do not work well when there is a high volume of traffic or it is difficult for vehicles on the side roads to safely pull out. Signals can also be used to make it safer for pedestrians to cross the street, and for emergency vehicles to enter the roadway.

Typical traffic signal head

Prior to being installed, traffic signals must meet at least one of the nine traffic signal warrants presented in Exhibit 6.4 and the *MUTCD*. When warranted and properly designed, a traffic signal helps to:

- ✓ Reduce crashes.
- ✓ Improve traffic movement.
- ✓ Allow other vehicles and pedestrians to cross a heavy traffic stream.
- ✓ Control traffic better than non-automated methods.

Unjustified, ill-designed, improperly operated, or poorly maintained traffic signals may cause:

- ✓ Increased crash frequency.
- ✓ Excessive delay.
- ✓ Disregard of signal indications.
- ✓ Circuitous travel by alternate routes.

9.1.1. Basic Design Guidelines

The *MUTCD* sets basic guidelines for the design and construction of traffic signal installations. Furthermore, many state DOTs have specific guidance regarding the design and implementation of traffic signals. The design of traffic signals requires the expertise of a qualified traffic engineer. Exhibit 9.1 illustrates some basic design concepts.

Exhibit 9.1: Basic Traffic Signal Design Guidelines

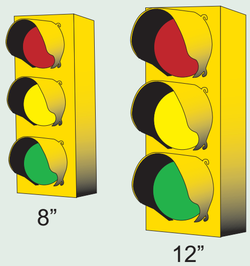
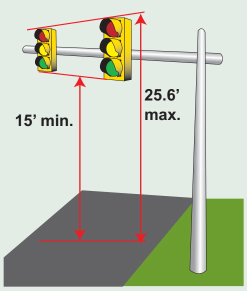
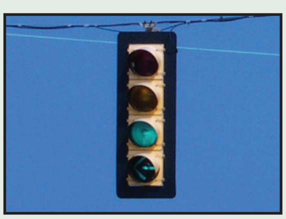
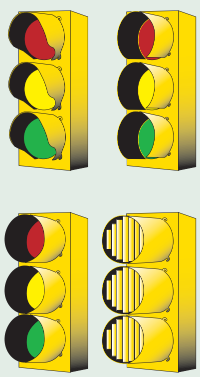
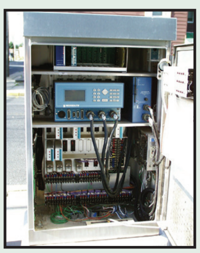
DESIGN ELEMENT	DESIGN CONSIDERATION/GUIDANCE
LENS SIZE  	✓ There are two nominal sizes for signal lenses: 8-inch and 12-inch. ✓ SDDCTEA recommends using 12-inch lenses in most cases, and always: • Where arrow signal indications are used. • When intersection approach speeds exceed 40 mph. • Where signals are over 120 feet from the stop line. • For approaches where signals might be unexpected or sight distance is limited. • For locations where there is a significant percentage of elderly drivers.
SIGNAL DISPLAY REQUIREMENTS 	✓ A minimum of two signal faces for the major traffic movement must be continuously visible on an approach to a signalized intersection. ✓ Provide adequate sight distance of the signal display. The sight distance varies with approach speed, as shown in MUTCD Table 4D-2. ✓ Locate signals between 40 and 180 feet from the stop bar. ✓ Required signal faces for any one approach must be mounted no less than 8 feet apart, measured horizontally perpendicular to the approach and between the centers of the signal faces.
SIGNAL MOUNTING HEIGHT  	✓ The bottom of the signal housing and any related attachments to a vehicular signal face located over a roadway shall be at least 15 feet above the pavement. ✓ The top of the signal housing of a vehicular signal face located over a roadway shall not be more than 25.6 feet above the pavement.
BACKPLATES 	✓ Provide backplates on signal heads to improve their visibility by making the head stand out from the surroundings. ✓ Backplates also help to prevent confusion due to advertising signs and the rising or setting of the sun. ✓ Backplates shield the signal face from sunlight, particularly for east- and west-facing signals. ✓ A yellow retroreflective strip can be placed on the backplate for additional visibility.

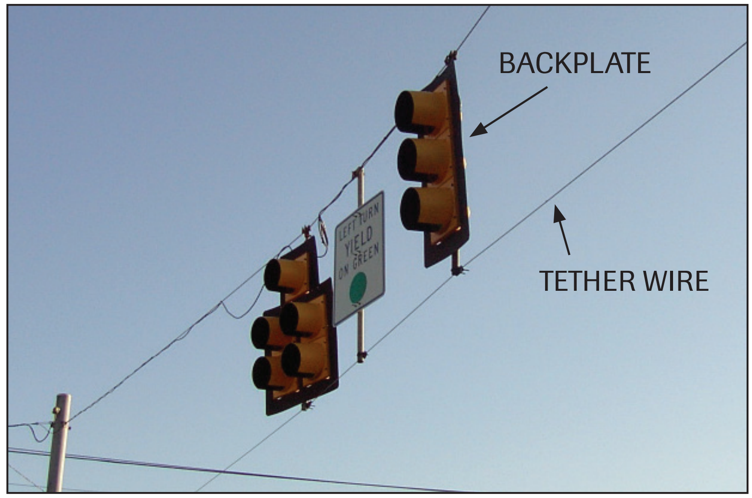
Exhibit 9.1: Basic Traffic Signal Design Guidelines (Continued)

DESIGN ELEMENT	DESIGN CONSIDERATION/GUIDANCE
LATERAL PLACEMENT OF SUPPORTS 	✓ Where speeds are less than 40 mph, signal poles should be placed at least 2 feet (but preferably more) beyond the edge of vertical curb or at least 2 feet (but preferably more) beyond the usable shoulder if no curb exists. ✓ Generally, if no curb exists and where speeds exceed 40 mph, poles should be more than 10 feet from the edge of the roadway.
VISOR TYPE Cut-away Tunnel  Full Circle Louvered	✓ Equip all signal faces with visors to reduce reflected glare from the sun or other light, and to direct the signal indication to the approaching traffic. ✓ Cut-away visors are the most commonly used type. ✓ Full circle, tunnel, and louvered type visors further reduce the possibility of signal indications being seen by opposing traffic.
CONTROLLER CABINET 	✓ A controller cabinet is used to store the equipment used to operate a traffic signal. ✓ Locate it as far from the roadway as practical. ✓ It should not be placed where it would be hazardous to pedestrians, joggers, or bicyclists, or where it blocks the view of motorists. ✓ Position it so that a person working on the cabinet will have a clear view of all intersection approaches.
OPTICALLY PROGRAMMED SIGNAL FACES 	✓ Use optically programmed signal faces when signal faces may be able to be viewed from another approach or adjacent intersection. ✓ Optically programmed signal faces limit visibility of signal faces to the area for which they are intended.

9.1.2. Signal Display and Design Configuration

Generally, provide the same number of overhead signal faces as approach lanes with a minimum of two. See Exhibit 9.2 for recommended number of signal faces per approach.

A traffic signal installation's effectiveness depends largely on the ease with which the signal heads can be seen and recognized. For this reason, certain standards have been developed to place signal faces within the motorist's cone of vision, and within a desirable mounting height and location within the intersection.



Signal Head Components

Signal heads may be mounted on posts or poles at the sides of the roadway or on raised islands in the roadway. They also may be suspended from span wires or mast arms over the roadway. The use of tether wire with span wire mountings reduces the movement of signal heads due to wind. Post-mounted signals are not recommended for use as the primary control of left-turn and through-traffic movements due to visibility issues.

The *MUTCD* requires that at least one signal face (but preferably two) be located within a cone of 20 degrees to the left or to the right of the "center of the approach lanes extended." Signals should be located between 40 and 120 feet from the stop bar. When a 12-inch signal face is used, signals can be installed up to 180 feet from the stop bar without installation of a near-side supplemental signal face. Required distances are illustrated in Exhibit 9.3.

Exhibit 9.2: Recommended Minimum Number of Primary Signal Faces[1]

NUMBER OF THROUGH LANES ON APPROACH	TOTAL NUMBER OF PRIMARY THROUGH SIGNAL FACES FOR APPROACH[2]	MINIMUM NUMBER OF OVERHEAD-MOUNTED PRIMARY THROUGH SIGNAL FACES FOR APPROACH
1	2	1
2	2	1
3	3	2[3]
4 or more	4 or more	3[3]

Notes:

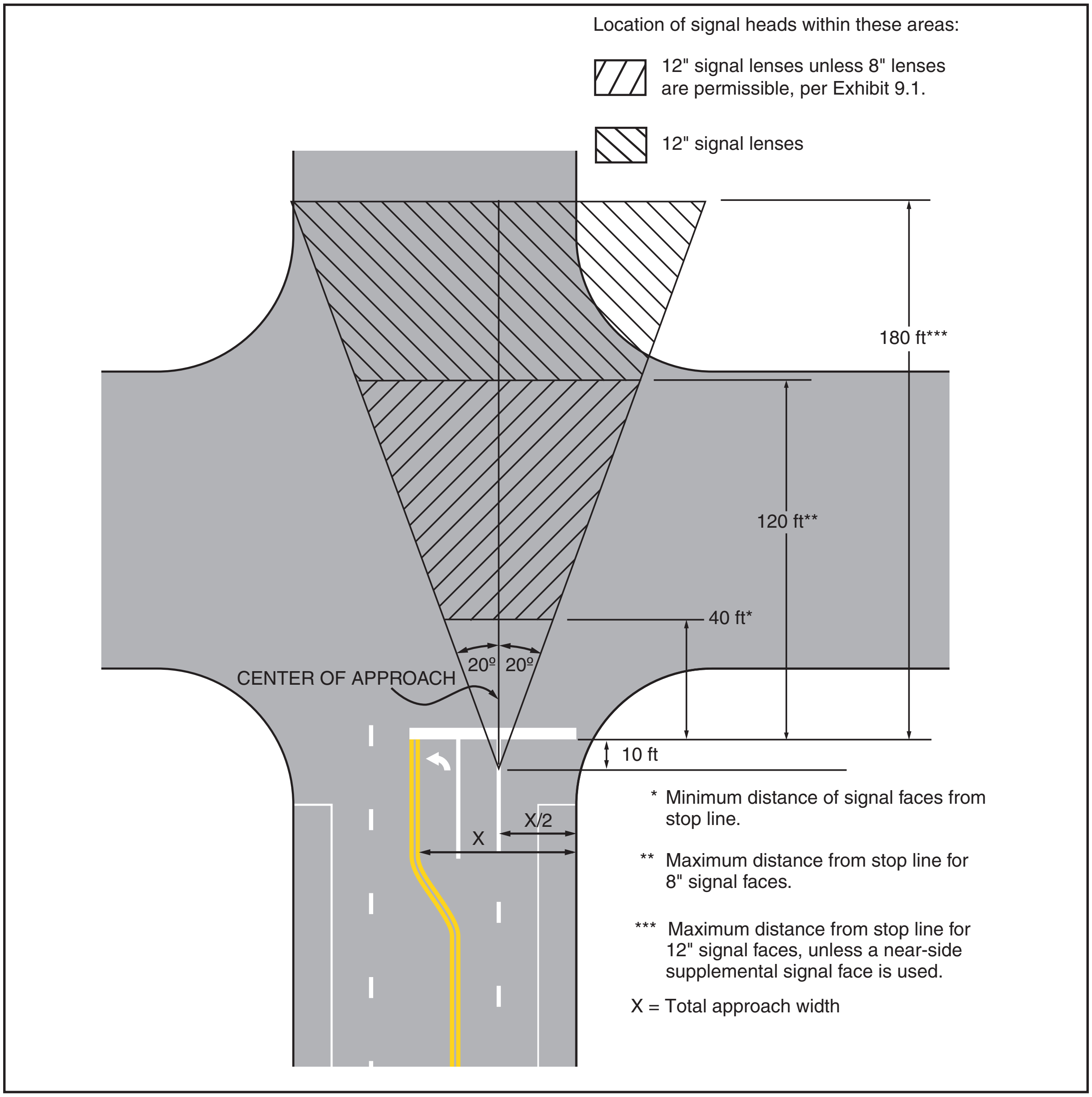
[1] *This table applies for through traffic on approaches with posted, statutory, or 85th-percentile speed of 45 mph or higher.*

[2] *A minimum of two through signal faces is always required. These recommended numbers of through signal faces may be exceeded. Also, see cone of vision requirements on the next page.*

[3] *If practical, all of the recommended number of primary through signal faces should be located overhead.*

Source: MUTCD *Table 4D-1*

Exhibit 9.3: Horizontal Location of Signal Faces



Source: Figure 4D-4, *MUTCD*

9.1.3. The Basics of Signal Timing and Operations

Proper timing and phasing of signalized intersections is critical in promoting safety and efficiency. There are four elements that make up the operation of a signalized intersection: interval, timing, phase, and cycle. These are defined in Exhibits 9.4 and 9.5.

The interval is the basic element of signal operations. All-red (clearance) and yellow (change) intervals must be calculated based on the speed, grade, and geometry of the intersection in order to ensure safe clearance of vehicles before a conflicting movement begins.

Green intervals proportionally distribute the total available green time based on the number of lanes and demand on each approach.

Exhibit 9.4: Signal Operation Elements

ELEMENTS	DESCRIPTION
INTERVAL	✓ The part of a signal cycle during which signal indications do not change. For example, red indication for one movement is considered an interval.
TIMING	✓ The period of time assigned to each signal interval. For example, the time given to the yellow indication is the timing for that interval.
PHASE	✓ The portion of a signal cycle when a single movement or a group of non-conflicting movements have the right-of-way. Typically, three intervals (green, yellow, red) make up a phase.
CYCLE	✓ A complete sequence of all signal indications. Typically, two or more phases make up a cycle.

Exhibit 9.5: Signal Phasing Intervals

INTERVAL	DESCRIPTION AND PURPOSE
GREEN INTERVAL	✓ Green times can be determined by several means. The basic principle for all methods is that green times should be proportional to the amount of traffic demand and the number of lanes on each approach. ✓ Green times should be recalculated periodically, especially when changes to traffic patterns occur.
YELLOW (CHANGE) INTERVAL	✓ The purpose of the yellow indication is to “warn” drivers that the green interval is ending and that a red interval will follow. In most jurisdictions, vehicles may legally enter the intersection while the yellow indication is displayed. ✓ Yellow intervals should have a duration of 3 to 6 seconds, which varies by speed.
ALL-RED (CLEARANCE) INTERVAL	✓ An all-red clearance interval will safely clear all vehicles from the intersection before an opposing flow of traffic begins. ✓ The all-red interval should not exceed 6 seconds, which varies by intersection width and speed.

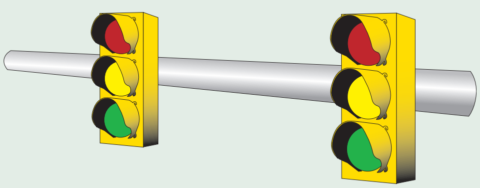
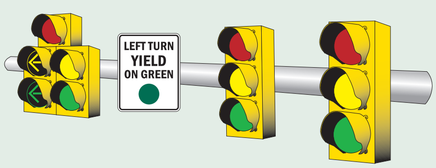
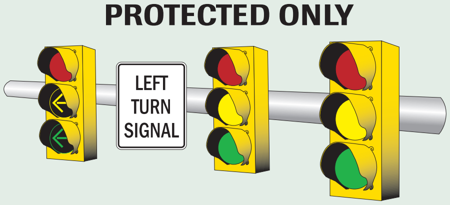
> **KEY POINT**
>
> More signal phases are generally needed as traffic volumes and number of lanes increase.

Phasing can be simple or complex. To work effectively, a traffic signal system needs an appropriate signal phasing plan. A low-volume intersection normally operates with two phases, one for the main street, and one for the minor street. As traffic volumes and number of lanes increase, more phases may be required to give protected right-of-way to left-turn movements. Each phase added to the signal operation takes time away from existing phases.

Additional phases are sometimes added to accommodate left turns. In general, as left-turn volumes and opposing through traffic volumes increase, a point is reached where it is difficult for left-turning traffic to find adequate gaps in opposing traffic. Providing a separate left-turn lane alleviates the problem somewhat by providing storage space. However, a left-turn signal phase may still be warranted. Exhibit 9.6 describes the three types of left-turn phasing: Permissive, Protected/Permissive, and Protected Only.

When the number of phases required at an intersection is determined, the goals of safety and capacity may conflict. The added phases may result in longer cycle lengths and increased vehicle delays.

Exhibit 9.6: Left-Turn Phasing Options

TYPE OF LEFT-TURN PHASING	DESCRIPTION
PERMISSIVE 	✓ This is the simplest mode. ✓ No special phase or protection is included for left-turn movements. ✓ Left turns are permitted to turn against the opposing through-movement during acceptable gaps in traffic.
PROTECTED/PERMISSIVE 	✓ A special left-turn phase is provided, usually before the through movement of the opposing direction. ✓ During the through-movement phase, left turns are permitted to turn against the opposing through-movement during acceptable gaps in traffic. ✓ An exclusive left-turn lane is not required, however one is recommended in most cases for efficiency. ✓ The 2009 *MUTCD* now allows the use of a flashing yellow arrow during permissive portion of this phase. Before using this, check with your state's DOT to see if they have adopted this practice.
PROTECTED ONLY 	✓ A special protected left-turn phase is provided. ✓ Left turns can proceed only during the protected phase and are prohibited from turning during the through phase. ✓ An exclusive left-turn lane is required.

9.1.4. Maximizing Operations and Efficiency

KEY POINT

Traffic signals should be evaluated periodically to maximize efficiency.

In California, 1,535 traffic signals were retimed at a total cost of $2 million ($1,300 per signal). Delay was reduced by 14 percent and fuel consumption decreased by 6 percent, saving California motorists nearly $8 million ($5,200 per signal) annually in delay and fuel costs resulting in a benefit-to-cost ratio of 4:1.

Efficient operation of traffic signals requires the correct operation as well as periodic evaluations.

There are two primary types of traffic signal operation: pretimed operations (i.e., fixed) and actuated signal operations. Pretimed is the simplest type of operation. With pretimed signals, during each period of the day (a.m., midday, and p.m.) the amount of green time provided for each signal phase remains fixed within the specified time period. For example, if a left-turn lane is provided with a separate left-turn phase and that lane is free of vehicles, the green phase would still occur even with no vehicles present. Pretimed signals are effective where there is little fluctuation in volumes. Actuated signal operations use some form of detection, including loops beneath pavement, video cameras, or pedestrian push-buttons, to provide green time for a particular phase only if vehicular or pedestrian demand is present. Actuated signals are effective where traffic volumes vary throughout the day.

A more advanced form of signal operation is dynamic signalization. With this, the cycle length is variable in extreme traffic conditions. Full detection is required. If a phase detects constant traffic through the entire length of the phase, it will provide more green time, usually ten seconds, to that phase during the next cycle. It will continue to do this as long as constant traffic is detected up to a maximum. It will progressively decrease the maximum time as demand is not present at the end of the phase.

This type of signalization is beneficial where large events, such as graduation ceremonies, occur on occasional intervals and release large amounts of traffic in short amounts of time.

Exhibit 9.7 shows several features that should be considered in the design or upgrade of a traffic signal. These enhancements, along with periodic evaluations, can reduce intersection delay and fuel consumption by as much as 20 percent. Traffic signals should be evaluated periodically to maximize efficiency.

Exhibit 9.7: Maximizing Traffic Signal Operations and Efficiency

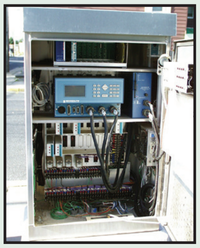
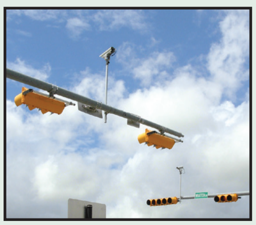
STRATEGY	CONSIDERATIONS	BENEFITS	COSTS
PERIODIC RETIMING 	✓ Traffic flow patterns change over time due to land use or other changes. ✓ Typically, traffic signals should be retimed about every 3 years. ✓ Traffic signals adjacent to new facilities, such as Commissaries and exchanges, should be retimed.	✓ An ITE article gave eight examples where retiming reduced delay by 8-40%.	✓ For analyses and implementation, signal retiming costs range from $1,300 to $2,500 per intersection.
ACTUATION  	✓ Actuated signals respond to variations of traffic to maximize operations. ✓ Actuation is accomplished through the use of detectors which can consist of inductive loops, radar, or video. ✓ Video detection costs are now almost equivalent to loop detector costs, while maintenance costs are greatly decreased. ✓ Video detection is non-intrusive, meaning there is no cutting into pavement. Video detection can function the same in rutted or damaged pavement whereas pavement in poor condition can damage loops. ✓ Actuation should be reviewed periodically (6 months or less) to ensure detectors are functioning properly and are not falsely calling phases, thus wasting green time from other movements.	✓ Actuation can reduce delay by 25 to 40% over pretimed signals.	✓ Analysis and implementation costs depend on the number of lanes, type of technology, and the amount of detection, but should range from $5,000 to $20,000 per intersection.

Exhibit 9.7: Maximizing Traffic Signal Operations and Efficiency (Continued)

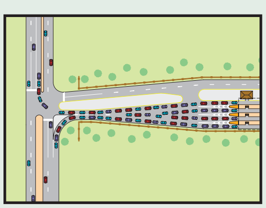
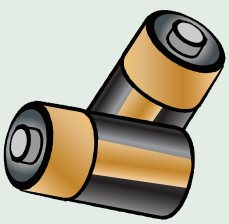
STRATEGY	CONSIDERATIONS	BENEFITS	COSTS
COORDINATION 	✓ A coordinated traffic signal system consists of two or more traffic signals interconnected and timed such that platoons of traffic traveling at the design speed get green indications through successive intersections. ✓ Coordination can be achieved through hardwire methods (copper or fiber) or through wireless solutions (spread spectrum radio, cellular, or GPS communications). ✓ Spread spectrum radio communication may offer the most flexible communication method while minimizing connection fees and monthly utility charges. ✓ If considering spread spectrum, since this uses radio wavelengths, verify that there will be no interference with installation radio wavelength requirements.	✓ FHWA estimates that coordination can reduce delay by as much as 25%.	✓ Cost is estimated at $2,000 to $10,000 per intersection to provide physical interconnection between intersections and software upgrades.
PREEMPTION 	✓ Emergency vehicle preemption allows traffic signal timing to be altered to provide priority for selected (emergency) vehicles thus improving response times. ✓ Emergency preemption gives immediate priority to emergency vehicles by providing a green indication for the emergency vehicle once vehicular and pedestrian clearances have been satisfied.	✓ FHWA found that emergency vehicle response times decreased between 16% and 23%.	✓ Cost is estimated at $8,000 to $10,000 per intersection.
GATE COORDINATION 	✓ Gate operations and the overall processing capacity should be considered when timing internal and external signalized intersections adjacent to gates.	✓ Traffic congestion is reduced, thus promoting safer operations.	✓ For analyses and implementation, signal retiming costs range from $1,300 to $2,500 per intersection.

Exhibit 9.7: Maximizing Traffic Signal Operations and Efficiency (Continued)

STRATEGY	CONSIDERATIONS	BENEFITS	COSTS
LIGHT EMITTING DIODES (LEDS) 	✓ LEDs represent a different technology than traditional incandescent signal bulbs. ✓ LEDs use less energy and burn out gradually. ✓ LEDs should be used on all new signal designs. LED inserts can replace incandescent bulbs on existing signals.	✓ California Energy Commission concluded that LEDs result in a 40% energy savings. ✓ With this energy savings, it is possible for traffic signals to be operated by solar power.	✓ Cost is estimated at approximately $5,000 per intersection, but have lower life cycle costs due to maintenance and energy savings.
BATTERY BACKUP SYSTEMS 	✓ Key intersections are vulnerable to higher crash rates during power outages. ✓ Battery backup systems can allow key intersections to function normally.	✓ Reduced crashes	✓ $5K per intersection

SDDCTEA performed a study at a large Army installation and found that by simply retiming the 50 traffic signals and adding detection where it was lacking yielded the following annual measures of effectiveness:

MEASURE OF EFFECTIVENESS	ANNUAL SAVINGS	FINANCIAL SAVINGS*
Total Delay	4,374,000 hr	$64,243,125.00
Fuel Consumed	3,396,600 gal	$10,189,800.00
CO Emissions	237,474 kg	
NOx Emissions	46,224 kg	
VOC Emissions	55,044 kg	

** Note: 1. Delay savings were equated to monetary value using $14.6875 per hour identified in Engineering News Record and NCHRP Report 133*
2. $3 per gallon was used for fuel savings.

9.2. HYBRID BEACONS

A hybrid beacon is a special type of beacon that is used to warn and control traffic at locations that are otherwise not signalized. There are several areas where hybrid beacons should be used: pedestrian hybrid beacons, hybrid beacons for emergency vehicle access, hybrid beacons for active vehicle barriers, and hybrid beacons for low flying aircraft. Hybrid beacons have three signal sections, with a circular yellow section centered beneath two horizontally aligned circular red signal indications. At least two hybrid beacon faces shall be installed for each approach of the major street and a stop line shall be installed for each approach of the major street.

9.2.1. Pedestrian Hybrid Beacons

Pedestrian hybrid beacons are intended to assist pedestrians in crossing the street or highway at a marked crosswalk. They can be installed to facilitate pedestrian crossings where signal warrants are not met, or where signal warrants are met but the decision is made to not install a traffic signal. Refer to Chapter 13 for additional information.

9.2.2. Emergency Vehicle Hybrid Beacons

An emergency vehicle traffic control signal is a special traffic control signal that assigns right of way to an authorized emergency vehicle. A type of emergency vehicle signal is a hybrid beacon. Emergency-vehicle hybrid beacons shall be used only in conjunction with signs to warn and control traffic at an unsignalized location where emergency vehicles enter or cross a street or highway. Emergency-vehicle hybrid beacons shall be actuated only by authorized emergency or maintenance personnel.

As with pedestrian hybrid beacons, emergency vehicle hybrid beacons are dark when not activated. Upon actuation by an emergency vehicle, the beacon displays a flashing circular yellow indication, followed by a solid circular yellow. The red indications then alternate during the egress of the emergency vehicles, then return to dark until the next actuation. An optional steady red clearance interval may be used after the steady yellow and before the alternating red interval.

Stop lines and EMERGENCY SIGNAL—STOP WHEN FLASHING RED (R10-14 or R10-14a) signs shall be used with emergency-vehicle hybrid beacons.

9.2.3. Active Vehicle Barrier Hybrid Beacons

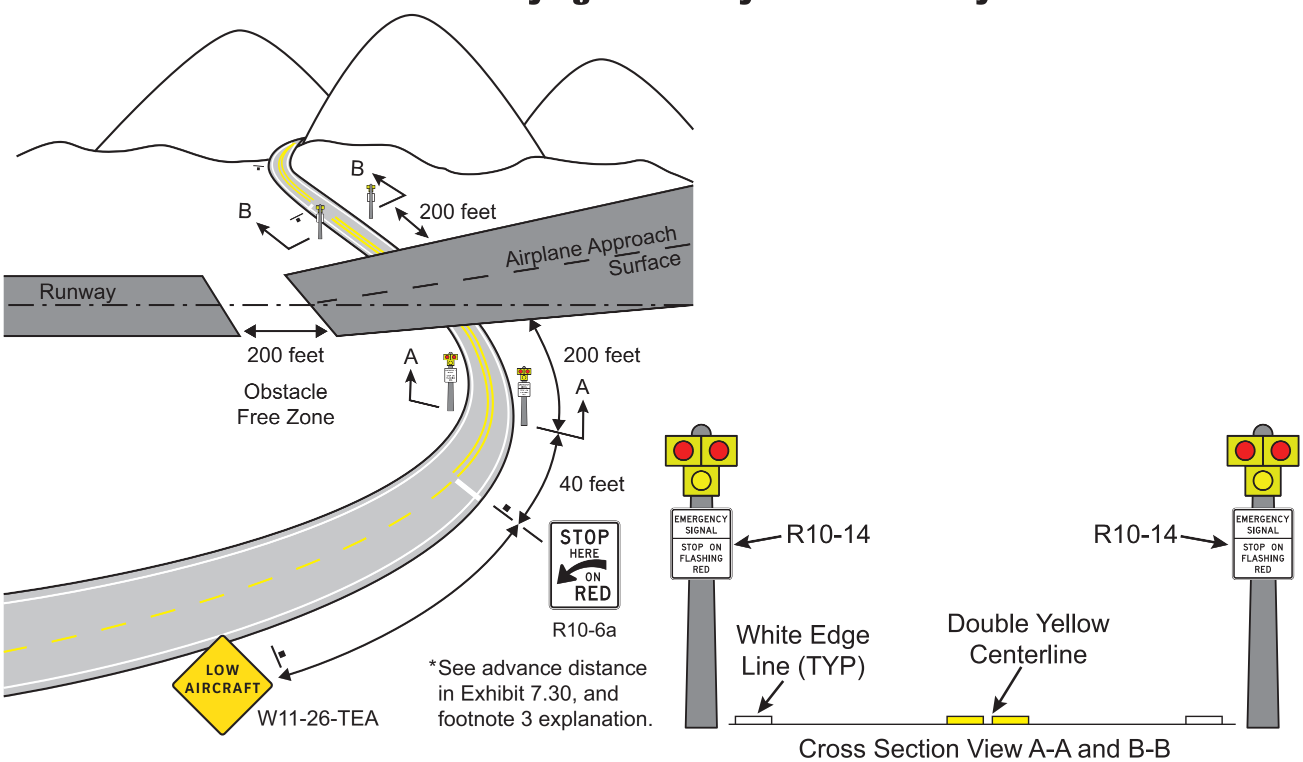
Hybrid beacons are now preferred for use at active vehicle barriers when signals are required for an AVB Safety Scheme, and operate similarly to emergency vehicle hybrid beacons. See SDDCTEA Pamphlet 55-15 for more guidance.

9.2.4. Low Flying Aircraft Hybrid Beacons

There are occasionally roadway conflicts with low-flying aircraft when a roadway crosses the end of a runway. In cases when the roadway must be closed for planes taking off and landing, use a hybrid beacon with appropriate signing. The hybrid beacon must be located 200 feet in advance of the runway clear zone (approach surface) in both directions. The R10-14, EMERGENCY SIGNAL—STOP ON FLASHING RED sign should be installed at the location of the beacon. The stop bar should be 40 feet in advance of the face of the beacons. The LOW AIRCRAFT (W11-26-TEA) sign should be used in advance of the stop bar. A STOP HERE ON RED sign, (R-10-6a) should be located adjacent to the stop bar. The LOW AIRCRAFT (W11-26-TEA) sign should be used in advance of the stop bar. See Exhibit 7.30 for the appropriate distance for the placement of this sign. The sign should be located per footnote 3 in that figure, based on a potential stop situation.

This hybrid beacon assembly should only be used when the roadway must be closed for flights. When the roadway crosses the end of the runway but it is not necessary that the roadway be closed, the LOW AIRCRAFT sign can be installed alone. Refer to Section 7.3.7 for additional signing details.

Exhibit 9.8: Low Flying Aircraft Hybrid Beacon Layout



9.3. PEDESTRIAN ACCOMMODATIONS AT SIGNALS

Many traffic signals lack the appropriate pedestrian accommodations to allow pedestrians to safely cross. When designing or upgrading a signalized intersection, consider the basic needs of pedestrians including those with special needs.

Typically, pedestrians can cross concurrently with the green phase for traffic travelling in the same direction as the crosswalk. However, in downtown areas where pedestrian activity is much more frequent and comprises a considerably higher proportion of roadway users, signal phasing that offers more safety to pedestrians can be considered. Specifically, there are two types of phasing: All Pedestrian phase, and Lead Pedestrian Interval. Exhibit 9.9 summarizes these two options.

In addition to phasing, other approaches and technologies exist that can promote pedestrian safety at signalized intersections.

Countdown pedestrian indications are now required on all new signal designs where the DONT WALK interval exceeds 7 seconds. Countdown signals are preferred since, in addition to seeing traditional WALK and DONT WALK symbols, the pedestrian also sees how much time is left in the flashing DONT WALK interval.

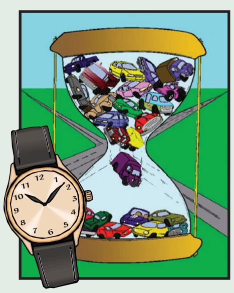
Audible pedestrian tones can assist the visually impaired in locating pedestrian push buttons, and assist them in knowing when to cross. This tone emitting device is referred to as an Accessible Pedestrian Signal. There are no warrants or requirements for the use of these; they are based solely on community need and desire. Depending on device, the tone can come from either the pushbutton or the pedestrian signal head, but it is not necessary that both emit tones on the same signal design. When part of the pushbutton, they often vibrate and emit vocal directions for the crosswalk that it controls.

Exhibit 9.10 shows features of pedestrian signals.

Exhibit 9.9: Pedestrian Phasing Considerations

CONCEPT	ALL PEDESTRIAN PHASE	LEAD PEDESTRIAN INTERVAL (LPI)
DESCRIPTION	Pedestrians receive a dedicated phase which is typically timed to allow them to cross at least one leg and in some cases diagonally.	Traffic signals are programmed to allow the pedestrian to begin crossing before the vehicle traffic on the parallel street is given the green light. This is commonly referred to as a lead pedestrian interval (LPI) which lasts for 3-4 seconds. Pedestrians and motor vehicles are separated in time by providing a LPI, which permits pedestrians to gain a head start before turning vehicles are released.
PEDESTRIAN IMPACTS	✓ Pedestrian movements occur when vehicular traffic is halted. ✓ Pedestrian delays can actually increase versus LPIs if the pedestrian arrives just after the all pedestrian phase. ✓ Pedestrians may become impatient and cross with concurrent traffic.	Pedestrians enter traffic early before vehicular traffic to promote visibility; however, they move concurrently after the LPI expires.
TRAFFIC IMPACTS	✓ Traffic is delayed while pedestrian movements take place. ✓ At typical intersections this can be in the range of 25 seconds. ✓ If a pedestrian crosses before the phase comes up, the time will appear to be "wasted."	Traffic is delayed for 3-4 seconds per direction (E/W and N/S) for LPI.
OTHER CONSIDERATIONS	Pedestrians are able to cross diagonally across the intersection; however, they may not if there are no diagonal crosswalks and signal heads.	Research has shown that this treatment is associated with a decrease in pedestrian/motor vehicle conflicts and an increase in the percentage of motorists that yield right-of-way to pedestrians. This study examined the influence of a three-second LPI on pedestrian behavior and conflicts with turning vehicles (Van Houten, Retting, Farmer, Van Houten, & Malenfant, 2000).

Exhibit 9.10: Pedestrian Signal Features

FEATURE	CONSIDERATIONS
INFRASTRUCTURE  	✓ Intersections that are used by pedestrians should have sidewalks that are at least 4 feet wide. ✓ Ramps between sidewalks and crosswalks must be ADA compliant – a minimum width of 36 inches, a maximum slope of 8.3%, and a detectable warning surface immediately before entering the roadway. ✓ Crosswalks should be clearly marked in accordance with the *MUTCD*.
INDICATIONS 	✓ The use of pedestrian signals is encouraged to provide pedestrians a clear understanding when they should cross the roadway. New indications should be either a white WALKING PERSON or an orange UPRAISED HAND. ✓ Consider including countdown timer displays to show the pedestrian how many seconds until the termination of the pedestrian change interval (flashing UPRAISED HAND). ✓ Countdown pedestrian signals are now required per the 2009 *MUTCD* for all locations where the flashing DONT WALK interval exceeds 7 seconds. ✓ Where there is a significant amount of visually impaired pedestrians, consider the use of accessible pedestrian signals, or pedestrian signals that emit audible tones when the WALK indication is active. These are an option per ADA.
TIMING NEEDS 	✓ It is essential to provide adequate time for pedestrians to enter the intersection, and to cross the street safely. • Generally, 3.5 feet per second is used under normal conditions and 3 feet per second is used where there is significant child or elderly pedestrian activity. • The minimum walk time is generally at least 7 seconds. • A flashing DONT WALK indication must be displayed long enough to allow any pedestrians that have left the curb to complete their crossing. This can be calculated by dividing the width of the crossing by the assumed walking speed.
PUSH BUTTONS 	✓ Where pedestrian activity is frequent or where pedestrian timing requirements do not impact traffic operations, pedestrian phases should be displayed without requiring activation. ✓ At locations where pedestrian activity is infrequent and pedestrian phasing is not warranted at all times, the use of pedestrian push buttons may be justified. ✓ In general, buttons should be within 10 feet of the ADA landing area, and be no farther than 10 inches from the edge of sidewalk. ✓ The large mushroom-plunger style (pictured at left) is preferred for ADA accessibility.

9.4. COMMON OPERATIONAL AND MAINTENANCE ISSUES

KEY POINT

Proper maintenance is critical to a traffic signal's efficiency and safety.

Maintenance of traffic signals is a very important topic. The *Traffic Signal Installation and Maintenance Manual*, published by ITE, discusses the maintenance of traffic signals in much detail.

A simple preventative maintenance program requires:

- ✓ Regularly replacing lamps before the end of their rated life.
- ✓ Overhauling the parts of controller units.
- ✓ Repainting equipment and hardware.
- ✓ Routine checking of voltage.
- ✓ Regular inspection of the equipment.

Traffic signal timings should be re-evaluated every 3 to 5 years or when significant changes to traffic flow patterns occur.

SDDCTEA Can Help!

One of SDDCTEA's services is an Operational Audit for Traffic Signal Sustainability (OATSS) study. With this type of study, the following is performed:

- ✓ Collect traffic data at 4 to 6 signalized locations
- ✓ Identify existing signal equipment and operational deficiencies
- ✓ Conduct traffic analyses to determine delay and levels of service
- ✓ Develop optimized traffic signal timings

Special Features

- ✓ Conduct traffic data collection, traffic analyses, and field implementation of new signal timings
- ✓ Record deficient signal equipment
- ✓ Enter new signal timing parameters into controllers.

This type of study can be completed in 1 week.

Traffic signal maintenance is either preventive or in response to an identified need. Poor traffic signal maintenance leads to frequent breakdowns resulting in motorist complaints and discredit to the responsible authority.

Based on ITE data, an average intersection requires 52 hours of signal maintenance annually. Too often, traffic signal maintenance becomes a secondary, noncritical responsibility.

Military installations not able to fully staff and operate a signal maintenance shop should consider hiring a contractor for signal maintenance work.

Exhibit 9.11 explains the problems, symptoms, and remedies of traffic signal maintenance. The lay person can see a traffic signal cycle between green, yellow, and red and believe that everything is operating acceptably. However, there are other symptoms to watch for, including malfunctioning loops, improper signal timing, and malfunctioning equipment.

Proper maintenance is critical to a traffic signal's efficiency and safety.

Exhibit 9.11: Traffic Signal Maintenance Issues

PROBLEM	SYMPTOMS	WHY IS IT A PROBLEM	REMEDIES
MALFUNCTIONING LOOPS	At an actuated signal, a side street or mainline left-turn phase will always be called for its maximum time, regardless of demand.	Actuated signals are intended to be more efficient than pretimed signals, but when phases are called unnecessarily, they lose that efficiency.	Contact a signal technician to repair or replace the loop. If the pavement condition is so poor that it cannot support loops, consider using video detection.
IMPROPER SIGNAL TIMING	Traffic on side streets must wait for unnecessarily long periods of time for the green light, and/or does not get sufficient green time to accommodate demand. One approach may have frequent queuing while other approaches are free flowing.	Whether actuated or pretimed, traffic signals generally use preprogrammed timing plans. If the timing plans are not appropriate for the traffic demand, the traffic signal operates inefficiently. Additionally, whenever any improvement occurs that changes traffic demand through an intersection, the signal must be retimed.	Contact a signal technician to retime the traffic signal. To properly design the timings that should be used, a turning movement count should be conducted at the intersection, along with using software such as *HCS* or *Synchro* to calculate timings.
MALFUNCTIONING EQUIPMENT	Deteriorating equipment often includes missing or broken tunnel visors or signal heads; burnt or broken lenses, or even bulbs that are burned out.	Problems with equipment can detract from the signal's visibility. Missing visors prevent shading from the sun; broken or burned lenses lack visibility; and burned out bulbs do not give any information to the motorist. Malfunctioning equipment can cause crashes.	All of these can often be fixed fairly easily once the signal head can be accessed. A bucket truck is necessary to access overhead signal heads. Screws attach visors and lenses onto the signal head. Although bulbs can be replaced easily, consider using LED indications which use less power, are brighter, and require less maintenance.

9.4.1. Maintenance Checklist

The table below shows a listing of maintenance items to perform on a traffic signal on a regular basis. ITE recommends that preventative maintenance be scheduled at least once a year. They should also be inspected after severe weather to ensure that they are operating normally.

Exhibit 9.12: Traffic Signal Maintenance Checklist

CHECK	COMPONENT
VEHICULAR SIGNAL HEADS	
	Clean and inspect all visors. Tighten screws as necessary. Replace those missing or broken.
	Clean and inspect all lenses. Replace those damaged.
	Inspect traffic signal housing for cracks or damage.
	Check gaskets and mounting hardware. Retighten as necessary.
	Check signal head alignment.
	Replace incandescent signals.
	Clean reflectors on inside of signal housing (for incandescent signals)
	Clear branches or other vegetation potentially blocking visibility to signal heads.
	Check underclearances for span wire mounted signal heads; adjust height as necessary.
	Check bushings on cable outlets; replace as necessary.
	Check for damaged mounting brackets.
	Clean backplates; check for cracks and missing screws.
PEDESTRIAN SIGNAL HEADS	
	Clean and inspect all visors.
	Clean and inspect all lenses.
	Inspect signal housing for cracks or damage.
	Check gaskets and mounting hardware. Retighten as necessary.
	Check head alignment relative to their crosswalk.
	Replace incandescent bulbs.
	Clean reflectors on inside of signal housing (for incandescent signals).
PEDESTRIAN PUSHBUTTONS	
	Check housing for damage or signs of vandalism.
	Check for tightness.
	Verify operation.
	Check accompanying sign; repair or replace as necessary.

Exhibit 9.12: Traffic Signal Maintenance Checklist (Continued)

CHECK	COMPONENT
SIGNAL POLES AND MAST ARMS	
	Check Anchorage.
	Check tightness of mounting hardware.
	Re-tighten bolt covers.
	Check poles and arms for warping and other damage.
	Replace missing pole base access handhole covers.
	Clear drainage holes in base.
	Check for missing pole caps and mast arm end caps.
	Check condition of grout at pole base.
	Check condition of varmint screen at pole base.
SPAN WIRE INSTALLATIONS	
	Visually inspect each upper and lower tether span wire for damage.
	Visually inspect each upper and lower tether span wire for excess sag.
	Inspect all connecting span hardware.
	Inspect guy anchors for proper attachment.
	Visually inspect pole condition for cracks.
LOOP DETECTORS	
	Verify operation areas of detection.
	Visually inspect loop installation; reseal saw cuts if necessary.
	Check loop detector splices.
	Retune loop detector amplifiers.
VIDEO DETECTORS	
	Verify operation areas of detection.
	Check video camera positioning.
	Inspect camera head for damage.
	Clean camera lens.
BATTERY BACK-UP	
	Verify automatic transfer switch operation.
	Verify incoming line voltage.
	Verify DC output to batteries.
	Verify AC Output on inverter.
	Check electrical connections.
	Test system with a simulated power outage.

Exhibit 9.12: Traffic Signal Maintenance Checklist (Continued)

CHECK	COMPONENT
CONTROLLER CABINET	
	Vacuum interior.
	Change cabinet filter.
	Check operation of fan and thermostat.
	Check operation of light and switch.
	Check and tighten terminal connections.
	Verify operation of detector and panel relays.
	Check police functions.
	Lubricate hinges and locks.
	Check cabinet door gaskets.
	Test circuit breakers.
	Check GFCI receptacle.
	Seal all conduit.
	Verify that all conductors are tagged or otherwise identified.
	Seal around cabinet base with silicone caulk.
CONTROLLER ASSEMBLY	
	Scan conflict monitor for logged events.
	Perform conflict monitor test.
	Run internal diagnostic routine on controller.
	Verify vehicle and pedestrian calls.
	Verify correct date and time.
	Place user manuals, operational and wiring diagrams if missing.

Developed with information from ITE's Traffic Signal Maintenance Handbook

9.5. FLASHING BEACONS

9.5.1. Warning Beacons

A Warning Beacon (*MUTCD* Section 4L.03) shall consist of one or more signal sections of a standard traffic signal face with a flashing CIRCULAR YELLOW signal indication in each signal section. A Warning Beacon shall be used only to supplement an appropriate warning or regulatory sign or marker. Warning Beacons, if used at intersections, shall not face conflicting vehicular approaches. If Warning Beacons have more than one signal section, they may be flashed either alternately or simultaneously.

Use warning beacons to call a driver's attention to an appropriate warning or regulatory sign or marker. Typical applications of this driver-aid treatment include:

- ✓ At obstructions in or immediately adjacent to the roadway.
- ✓ As supplemental emphasis to regulatory or warning signs.
- ✓ As emphasis for mid-block crosswalks.
- ✓ On approaches to intersections where additional warning is required, or where special conditions exist.
- ✓ As supplements to regulatory signs, except STOP, YIELD, DO NOT ENTER, and Speed Limit signs.

Vertically Arranged Warning beacon example

9.5.2. Stop Beacons

A Stop Beacon (*MUTCD* Section 4L.05) shall be used only to supplement a STOP sign, a DO NOT ENTER sign, or a WRONG WAY sign. A Stop Beacon shall consist of one or more signal sections of a standard traffic signal face with a flashing CIRCULAR RED signal indication in each signal section. If two horizontally aligned signal indications are used for a Stop Beacon, they shall be flashed simultaneously to avoid being confused with grade crossing flashing-light signals. If two vertically aligned signal indications are used for a Stop Beacon, they shall be flashed alternately.

9.5.3. Rectangular Rapid Flash Beacons

The use of yellow RRFBs to enhance the conspicuity of various pedestrian crossing and school crossing signs is not yet in the *MUTCD*, but has been given interim approval (see IA-11 at http://mutcd.fhwa.dot.gov/res-interim_approvals.htm). Refer to Section 13.7.3. 'Additional Crosswalk Enhancements' for information on RRFBs at crosswalks.

The use of red RRFBs is not compliant with the *MUTCD*. However, FHWA is currently conducting official experimentation with red RRFBs is in conjunction with WRONG WAY signs on freeway exit ramps that activate only when a wrong way vehicle is detected.

9.6. ITS STRATEGIES

KEY POINT Consider opportunities for ITS, particularly at entry control facilities.

Intelligent Transportation Systems (ITS) involve the application of technologies and innovative practices to improve all aspects of transportation service. Common examples of ITS include dynamic message signs (DMS), detection devices, closed circuit televisions (CCTV), highway advisory radio (HAR), and over-height detection.

DMS example

Dynamic Message Signs

DMS offers the ability to change the information being provided to motorists. A DMS can advise motorists of the security level, roadway status, or other information. DMS messages should be clear and concise, with no more than three alternating screens. Ideally, a DMS should be placed such that a driver can select an alternate route to their destination if necessary. A good example of DMS use is off base, where signs could inform motorists of relative congestion of several ECFs.

Closed Circuit Televisions

CCTV offers security benefits and also provides a mechanism to monitor traffic conditions. They can monitor congested roadways and intersections. In ECF applications they can be used to monitor ID check areas, inspection areas, visitor's centers, ECF approach and departure zones, and neighboring intersections and roadways that may be impacted by ECF operations.

CCTV example

Highway Advisory Radio

HAR informs motorists of traffic conditions. They can be used to inform of roadway incidents, closures, which ECFs are open or closed, or to direct visitors and trucks to the appropriate ECF.

HAR example

Variable Speed Limits

It is sometimes desired to post variable speed limits. A roadway that is prone to effects of fog, snow, or ice may be a candidate for a variable speed limit. Variable speeds could also be used for advisory conditions. In this type of use, use it with an advisory speed sign.

Drop Arms

Drop arms can be used at ECFs approaching the active vehicle barriers (refer to the SDDCTEA AVB Safety Schemes shown in Pamphlet 55-15) and at railroad crossings. When these are used, they must consist of a drive mechanism and a fully retroreflectorized red- and white-striped gate arm with lights. When in the down position, the gate arm shall extend across the approaching lanes of highway traffic. Gates can be used in conjunction with flashing light signals.

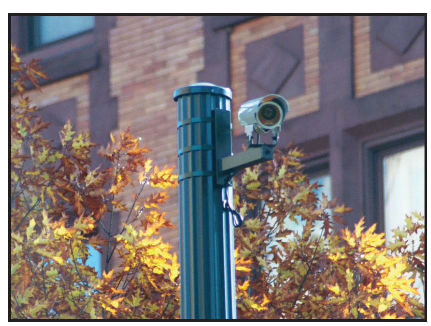
Variable speed limit sign example

Detection Devices

Detection devices can monitor speed, volume, direction, and classification of traffic. Types of detection devices include video, loop detectors, radar detectors, and infrared systems. Loops, video, and radar detectors are commonly used for traffic signal and congestion detection. Other example benefits include several ECF-related uses, such as monitoring approach speeds, monitoring traffic conditions and queuing, monitoring illegal entry on outbound lanes, and detection of over-height vehicles.

Loop Detector

Radar Detector



Video Detector

Detection device examples

Bluetooth Detection

Bluetooth systems are becoming more viable for vehicular detection. They detect Bluetooth signals from vehicles, cellular phones or other devices. They are often used for travel time information to obtain travel time from two locations, versus actual detection since not all vehicles are equipped with this type of signal.

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CHAPTER 10—ROUNDABOUTS

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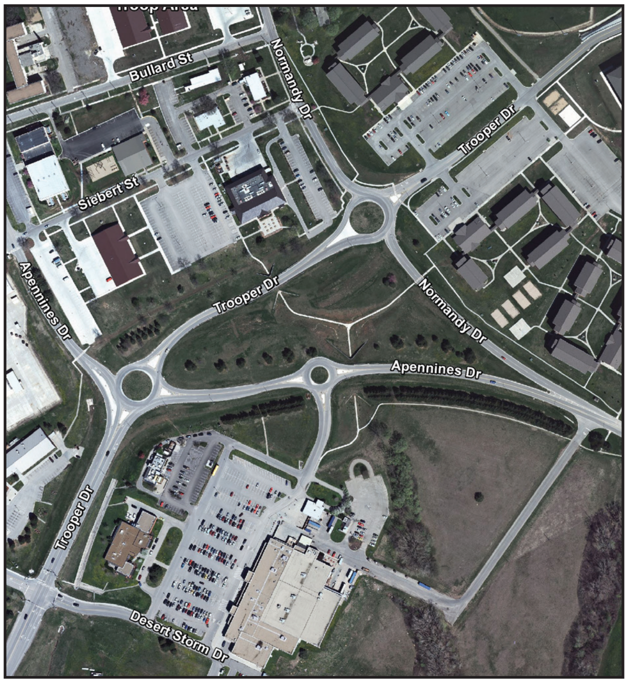
Traffic circles have been used in the United States for over 100 years, but there have been very few new installations in the last 50 years because traffic circles are not especially safe or efficient. However, the modern circular intersection, hereafter referred to as a “roundabout,” was developed in the United Kingdom in the 1960s to address the problems with traffic circles.



Multiple roundabouts in a small area

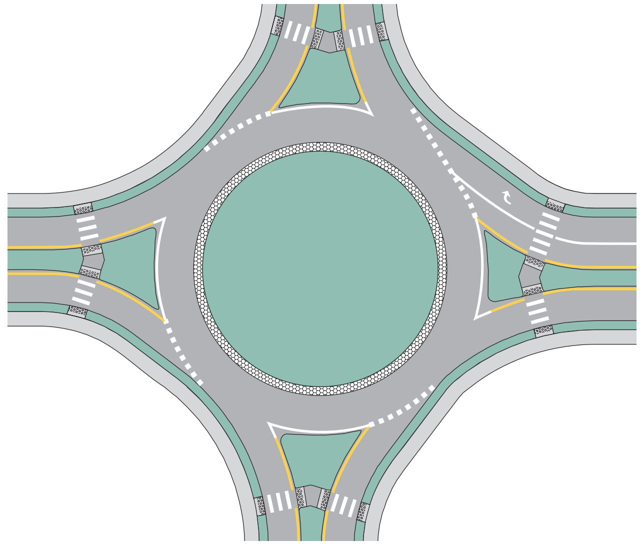
Two key characteristics of any roundabout include:

- ✓ Entering traffic must yield to circulating traffic.
- ✓ Each approach has a splitter island designed to slow traffic and to ensure that all vehicles travel in the proper direction around the central island.

Many studies have shown that roundabouts are safe and effective, and they are now widely used internationally. Perhaps because traffic circles did not work well in the United States, there has been some reluctance from the public to use roundabouts.

However, roundabouts are addictive because after an initial installation, local communities typically ask for more. As a result, there are clusters of roundabouts scattered around the United States. Ten years ago, there were about 1,000 roundabouts in the United States, 20,000 in France, and 10,000 in the United Kingdom. Now, it is estimated that there are about 30,000 in France, and many more in the United States since many state departments of transportation have been more favorable to building roundabouts. [1]

1 *Q&As: Roundabouts. Insurance Institute for Highway Safety, Highway Loss Data Institute. Arlington, VA, January 2009.*



When asked about roundabouts, most unfamiliar drivers in the United States say that they do not like them; but, after one is constructed locally, the majority of drivers in that area like the roundabout and want more of them.

A roundabout is defined as a circular intersection with yield control at entry, which permits a vehicle on the circulatory roadway to proceed, and with deflection of the approaching vehicle counter-clockwise around a central island. Further, it is a modified traffic circle that conforms to specific geometric design criteria that promotes driver awareness, reduced traffic speeds, and improved traffic flow. Roundabouts reduce traffic congestion by eliminating left turns. Since each approach to the roundabout is essentially an intersection with a one-way street, the driver is not delayed by traffic flow from two directions. Only right turns are allowed.

Roundabouts eliminate angle and head-on crashes. Roundabouts promote slower speeds due to the diversion in travel path. Crashes that occur at roundabouts are at a much lower speed than at traditional intersections, and are, therefore, less severe.

Roundabouts can range from a very simplistic single-lane design to complex multilane configurations. Single-lane designs are rather straightforward, but today's multilane configurations are designed so that, if drivers enter a roundabout in the correct approach lane they should be able to follow the lane lines to their intended exit roadway without crossing any solid lane lines.

10.1. ROUNDABOUTS VS. TRAFFIC CIRCLES

KEY POINT

Roundabouts are generally the safest intersection design available.

Roundabouts are generally smaller than traffic circles and they always have a splitter island to help channelize vehicles and force drivers to travel at a slower speed.

In addition, roundabouts always require entering vehicles to yield to traffic within the circle, which is similar to merging with traffic at a freeway on-ramp.

Traffic within a traffic circle frequently has to weave across high-speed travel lanes, whereas a properly designed roundabout is more structured to avoid lane changing. The bottom line from a driver's point-of-view is that the design and operation of roundabouts are much more consistent than the design and operation of traffic circles. Additional differences are included in Exhibit 10.1.

Exhibit 10.1: Differences Between Roundabouts and Traffic Circles

ELEMENT	ROUNDABOUT	TRAFFIC CIRCLE
TRAFFIC CONTROL	YIELD signs are used on all approach roadways; circulating vehicles always have the right of way. Merging is similar to a freeway on-ramp, but at a much slower speed.	Some circles use STOP signs on some approaches and no control on other approaches, and some use STOP or YIELD signs within the circle.
DEFLECTION	A splitter island is used on all approaches to slow traffic and to ensure that traffic goes to the right.	Traffic typically enters the circle at a right angle.
PEDESTRIANS	Pedestrians can only cross the approach legs, at a distance of at least one car length from the circulatory roadway.	Some circles have sidewalks across or on the outer edge of the central island.
PARKING	Parking is not allowed within the circulatory roadway or near the splitter islands.	Parking is sometimes allowed within a circle.

10.2. ADVANTAGES OF ROUNDABOUTS

KEY POINT

A traffic circle is NOT a roundabout.

Roundabouts are designed to meet the needs of all road users—drivers, pedestrians, pedestrians with disabilities, and bicyclists. In contrast to traditional intersections, roundabouts eliminate many of the traffic conflicts, such as left turns and crossing conflicts, both of which are significant contributors to the number and severity of crashes. Because traffic enters and exits only through right turns, the number of severe crashes at roundabouts is substantially reduced. Small-angle collisions that may occur as a result of a right-hand turn are typically less severe than other types of collisions.

A list of advantages and disadvantages of roundabouts is included as Exhibit 10.2.

Traditionally, in the United States, about 45 percent of all crashes have occured at intersections. However, research shows that converting an existing intersection to a roundabout typically results in a 35 percent reduction in the number of crashes and a 76 percent reduction in the number of injury crashes.

Studies show that roundabouts:

- ✓ Are safe and efficient.
- ✓ Are environmentally friendly.
- ✓ Reduce travel speeds.
- ✓ Provide for landscaping and beautification.
- ✓ Are contagious.

Exhibit 10.2: Roundabouts vs. Other Types of Intersections

Advantages:

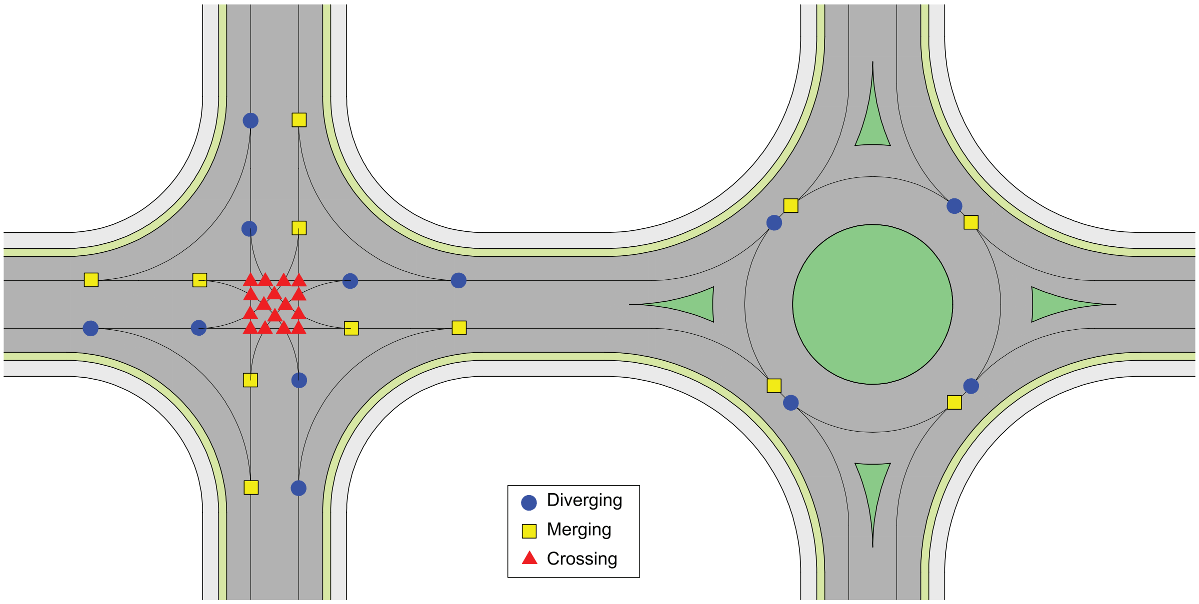
- ✓ Fewer and less serious crashes.
- ✓ Improves safety for pedestrians—the splitter island provides a refuge for pedestrians to allow a two-stage crossing, with each stage crossing a one-way roadway.
- ✓ Can be used for speed control, especially speed mitigation at ECFs.
- ✓ Improves traffic flow with fewer stops.
- ✓ Resolves issues with not obeying traffic signals.
- ✓ When traffic is light, no wasted time for drivers as you would have with a signal.
- ✓ Accommodates U-turns, even for larger trucks.
- ✓ Safely operates during power outages.
- ✓ No overhead traffic signals to hinder over-height loads.
- ✓ Facilitates the junction of more than four roadway approaches.
- ✓ Issues with left turns are eliminated.
- ✓ Can easily be designed to prohibit exiting at an intersection leg with turn prohibitions.
- ✓ Unlike signalized intersections, storage lanes are not required.
- ✓ Simplifies the driver decisions required when entering the intersection (i.e., the roundabout) because all traffic is coming from the left (this is especially helpful for older drivers).
- ✓ From an environmental standpoint—improves air quality, reduces energy consumption, requires fewer travel lanes, and provides more landscaping opportunities.
- ✓ Has considerably less maintenance costs versus traffic signals.

Disadvantages:

- ✓ May require a larger intersection footprint.
- ✓ May require pedestrians to walk a greater distance.
- ✓ Cannot assign a priority to a specific roadway—roundabouts treat all approaches equally.
- ✓ Unfamiliar drivers may find roundabouts confusing.
- ✓ It may cost more to convert a stop-controlled intersection to a roundabout than to a signalized intersection, unless a signalized intersection requires a lot of widening for turning and storage lanes.
- ✓ With too many roundabouts in close proximity to each other, drivers may get disoriented or dizzy.

As illustrated in Exhibit 10.3, the number of vehicle-to-vehicle conflict points for a single-lane roundabout is only 25 percent of the number at a conventional intersection. Perhaps even more important, the roundabout does not have any crossing conflicts—the type of conflict that causes the dangerous, side-impact type crashes. Therefore, the safety record for roundabouts is not a fluke.

Exhibit 10.3: Comparison of Conflict Points



The number of conflict points for pedestrians is also reduced by at least 50 percent, and pedestrians only need to cross one direction of traffic at a time. Therefore, safety benefits are not just for vehicles, but also for pedestrians.

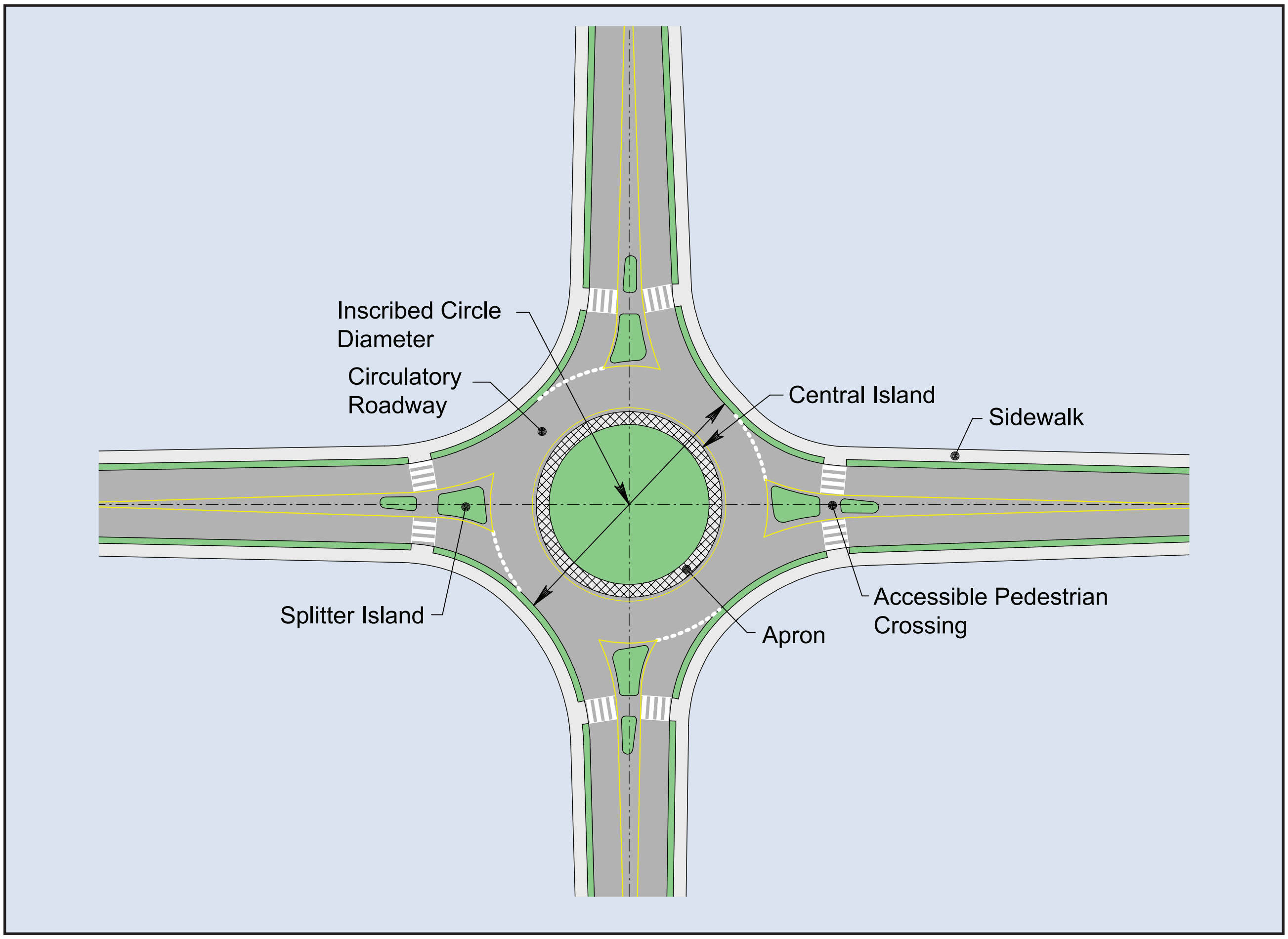
The only intersection traffic control that is approximately as safe as a roundabout is a multiway stop intersection. However, multiway stop intersections have less capacity, more delay, many negative environmental consequences due to stopped traffic, and create disrespect for STOP signs.

In addition to safety, efficiency is another major benefit of roundabouts. Many studies have documented reductions in delay, unnecessary stops, fuel consumption, emissions, and energy usage.

10.3. DESIGN CONSIDERATIONS

The design of a roundabout is essentially an iterative process that should only be done by a professional with a thorough knowledge of roundabouts. Among other references, the designer should consult the publication entitled *Roundabouts: An Informational Guide, Second Edition [published as TRB's National Cooperative Highway Research Program (NCHRP) Report 672], 2010*. As discussed in the following sections, refer to Exhibit 10.4 which illustrates key features of a roundabout.

Exhibit 10.4: Key Roundabout Features



Size—The basic term used to reflect the size of a roundabout is the inscribed circle diameter, which is the measurement between opposite outer edges of the circulatory roadway. This diameter is based on the design speed and the number of lanes in the circulatory roadway—as the design speed or the number of circulatory lanes increase, the inscribed circle diameter should also increase. The circulatory roadway is the curved path available for use by vehicles to travel in a counterclockwise direction around the central island.

The recommended design speed within the circulatory roadway is a function of the speed of approaching vehicles when they are 300 or 350 feet from the center of the roundabout. For vehicles approaching at about 45 mph, the design speed should be about 50 percent of the approach speed (or 22.5 mph), and for vehicles approaching at 25 mph the design speed should be about 62 percent of the approach speed (or about 15.5 mph). If the approach roadways have different approach speeds, the roundabout should be designed for the higher speed. Design speeds for the merge point and at the exit point may be slightly higher than the design speed on the circulatory roadway.

The capacity of a one-lane roundabout is approximately 20,000 vehicles per day; therefore, if the volumes are greater than that, additional lanes generally will be required. However, the capacity is highly dependent upon the traffic volumes during the peak hours, specifically the distribution of the volumes across the approaches and whether vehicles are making left-turns, right-turns, U-turns, or straight-through movements.

In an urban environment, the inscribed circle diameter typically would be about 100 to 130 feet for a single-lane roundabout, and 150 to 180 feet for a double-lane roundabout. Additional area is also needed outside of the inscribed circle for sidewalks.

Alignment—Ideally, the centerline of each roadway leg should pass through the center of the inscribed circle so that entry and exiting speeds are balanced and the central island is conspicuous to approaching drivers.

The splitter island is the raised island on an approach to the circulatory roadway that separates entering traffic from exiting traffic, deflects and slows entering traffic, and provides a refuge for pedestrians.

The splitter island must be of sufficient length to accommodate pedestrians, curved to slow and deflect approaching traffic, and aligned with the central island. The width of the splitter island should not be so wide that it encourages high speeds. Moreover, traffic signs and pavement markings must act in concert to ensure safety.

Central Island Shape—The central island is the raised area in the center of the roundabout, around which traffic circulates. Although most central islands are round, other shapes include:

- ✓ Elliptical.
- ✓ Tear-shaped, especially if one-way roads are involved.
- ✓ Turbo-shaped with push-outs to emphasize the beginning of left-turn lanes.

Things that may affect the shape of the central island include: the number and alignment of the approach roadways; the number of lanes on each approach; the presence of exclusive left-turn or right-turn lanes; and the presence of one-way roads.

Pedestrians—Pedestrians should be accommodated on the outside of the circulatory roadway and across the splitter island. The most common crossing is a bent crosswalk to make the crossing as short as possible (as illustrated on Exhibit 10.4). The *MUTCD* states that crosswalks should be located a minimum of 20 feet from the edge of the circulatory roadway. Additionally, SDDCTEA recommends a minimum of 25 feet in advance of any yield line.

The capacity of a roundabout is directly related to the turning movements. The highest capacity would occur if all approaches had the same volume and everyone wanted to make a right turn. On the other hand, the worst scenario would be if everyone wanted to make a U-turn.

Bicyclists—Cycling through a roundabout should be safer than through a conventional intersection because:

- ✓ Travel speeds are generally lower, and
- ✓ Cyclists can normally merge with other traffic without stopping.

Trucks and Other Large Vehicles—It is important to design roundabouts to accommodate the largest trucks, buses, and tractor-trailers that will be using the intersection. These vehicles can be accommodated by using an apron on the outer portion of the central island. To help prevent smaller vehicles from driving on this part of the central island, the surface of the apron can be raised. The apron is the outer portion of the central island that is designed for off-tracking of the rear wheels of trucks, buses and tractor trailers. This portion of the central island must be able to physically accommodate these large vehicles, but it should be raised above the roadway and have a rough texture to discourage other vehicles from using it.

Signs and Markings—Signs and pavement markings on the approaches and on the circulatory roadway should be compatible with each other to provide a consistent message. Due to the number of signs often used in a relatively short distance, ensure that signs do not obscure each other. Specifically, be careful to not obscure the view of the YIELD signs with the optional Pedestrian signs. See Sections 2B.43, 2B.44, 2B.45 and 2D.38, and Chapter 3C of the *MUTCD* for additional design details. Exhibit 10.5 shows a roundabout that lacks correctly designed features.

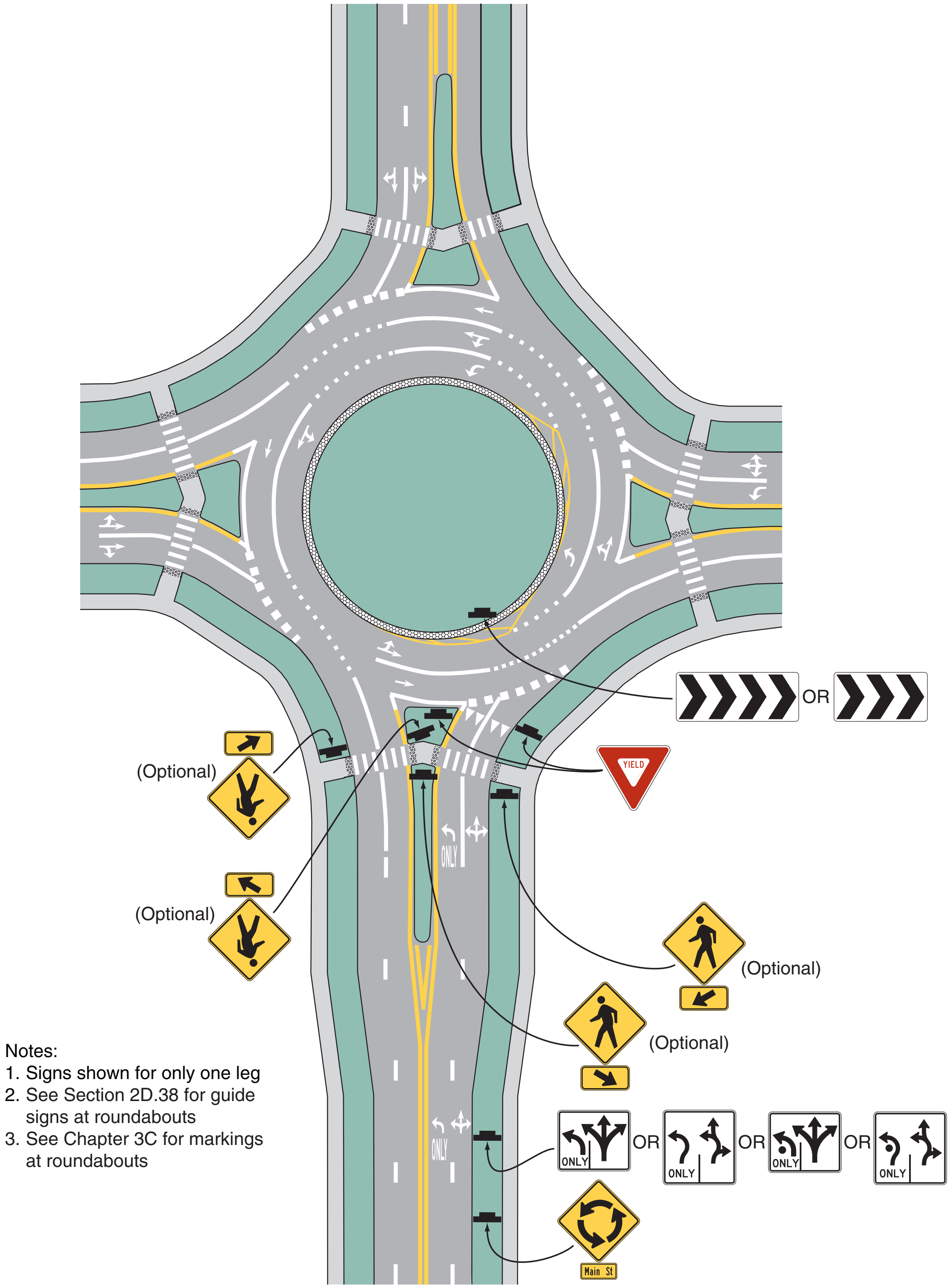
Exhibit 10.5: What's Wrong With This Roundabout?

- ✓ The splitter islands are too wide, which encourages higher speeds.
- ✓ Sidewalks should be continuous and crosswalks should cross each splitter island.
- ✓ Ideally, pavement markings should define the islands and the merge point.
- ✓ Missing signs include an advance Circular Intersection (W2-6) symbol sign, and the new black-and-white Roundabout Directional Arrow within the central island as included in the 2009 MUTCD (see Exhibit 10.6).
- ✓ A Keep Right (R4-7) sign is also desirable at the beginning of the splitter island because there are no center line pavement markings.

Multilane Roundabouts—The design of multilane roundabouts is more critical than the design of single-lane roundabouts. Specifically, it is essential that the roundabout be designed so that, if drivers enter the roundabout in the correct approach lane, they will be able to follow the lane lines to their exit roadway without crossing any solid lane lines. To help guide vehicles entering a multilane roundabout, provide a short section of tangent after the splitter island at the entrance to the actual circular roadway. This would help line traffic up with their correct lane in the circulatory roadway.

Exhibit 10.6 illustrates a multilane roundabout with several different lane assignments. Lane assignments should be custom designed for each intersection, based on the design-hour traffic volumes. The lanes on each approach should always line up with the lanes in the circulatory roadway.

Exhibit 10.6: Sample Design for a Multilane Roundabout



Source: Figure 2B-23 of the MUTCD

10.4. GEOMETRIC DESIGN BASICS

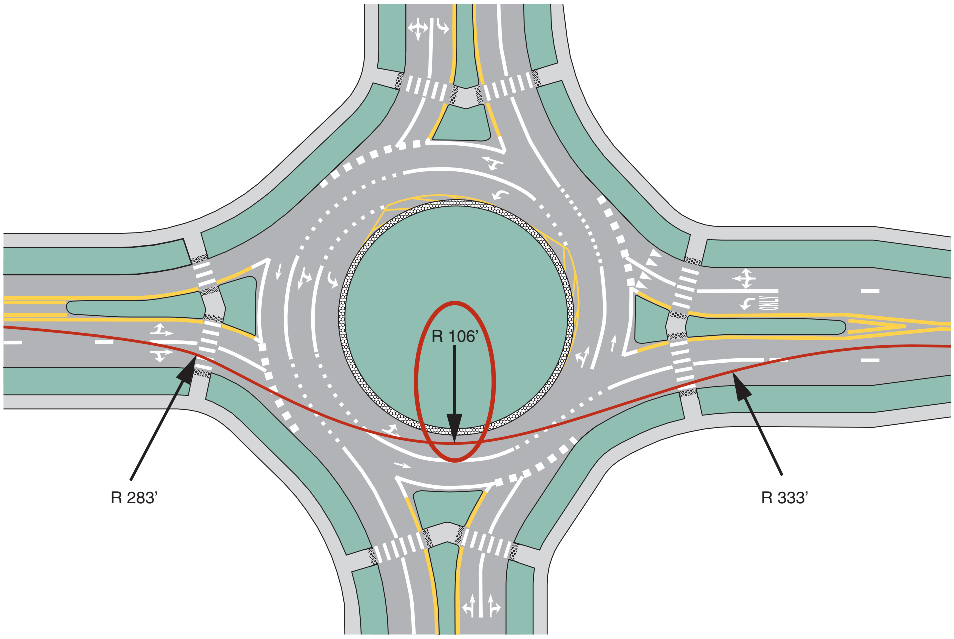
Roundabouts should be designed by qualified professionals, since there are many aspects to consider. These aspects include accommodation of the design vehicle, drainage, fastest travel path, entry and exit overlap, and constructability. The intent of this section is not to provide comprehensive knowledge of these aspects, but to provide an awareness of these aspects to assist with a design review. It is assumed that other design references would be available for roundabout designers.

Roundabout constructability is very important when the intersection must remain open to traffic through construction. It is ideal for a contractor to have an entire intersection closed for construction, but if no alternate routes are available for traffic, the construction must be phased to build sections of the roundabout.

Drainage must be specially designed. Existing drainage systems usually need to be reconfigured since the roundabout extents are beyond those of a traditional intersection. If tying into existing drainage systems, inlets located at the edges of a roundabout may be shallower since they are located farther from where they would have been with the original intersection layout. It is critical that roundabouts not have areas that pond.

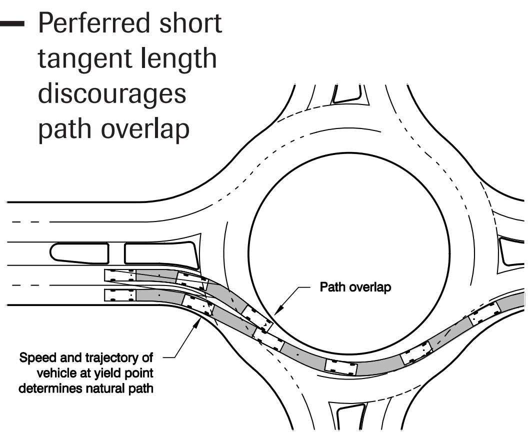
An advantage of roundabouts is they have a traffic calming effect when properly designed. However, the fastest path of travel through a roundabout must be evaluated to verify that the geometry will encourage the design vehicle to stay in its intended travel path through the roundabout, as well as to verify that the roundabout's design speed is appropriate. The maximum theoretical entry design speed is recommended to be 25 mph for a single lane roundabout, and 25 to 30 mph for a multi-lane roundabout. Roundabout speed is determined by the fastest path allowed by the geometry. Through movements are usually the fastest path, but sometimes right-turn paths are more critical. Poor deflection results in the fastest path yielding undesirable high speeds. If the central island diameter is too short compared to the inscribed circle diameter, less deflection is required, and a higher fastest path results. Two-lane roundabouts can have especially higher fastest paths since a path can overlap both lanes. As a general rule, the deflection should result in a speed differential of at least 10 mph. An undesirable path overlap example is illustrated in Exhibit 10.7. The red line represents the fastest path; the roundabout has a wide circulatory roadway with no geometric features to encourage the vehicle to remain in its lane. This lane encroachment can increase the potential for sideswipe crashes.

Exhibit 10.7: Fastest Path Through a Multilane Roundabout



Entry and exit path overlap is a poor result of a design that does nothing to discourage, or even promotes, vehicles crossing paths. This occurs at multilane roundabouts that lack certain geometric features that discourage path overlap. Specifically, path overlap occurs when the natural path of the adjacent lanes one another. It is most common at the entry to the roundabout. For entries, it occurs where the geometry of the right (outside) lane tends to lead vehicles into the left (inside) circulatory lane. For exits, the geometry tends to lead vehicles from the left-hand lane into the right-hand exit lane. Path overlap results in sideswipe crashes by vehicles off-tracking into an adjacent lane while traveling into, out of, or through the roundabout. At multilane roundabouts, to avoid path overlap, provide a short length of tangent between the center of the entry lanes and the center of the circular path lanes. (Refer to Exhibit 6-30 in NCHRP Report 672.) This can be accomplished by ending the entry curvature prior to the yield line. Exhibit 10.8 shows a preferred roundabout design with this short tangent length on entry.

Exhibit 10.8: Preferred Design to Avoid Path Overlap



Source: http://teachamerica.com/RAB11/RAB1109Vorisek/player.html & Exhibit 6-28, NCHRP Report 672

Driver's view when approaching the roundabout entry point

The design vehicle must be accommodated through the roundabout. Usually, it must be possible for a WB-67 truck to travel through the roundabout, and a truck apron can provide the room needed for off-tracking for through or left-turns. Right turns should not require the use of a truck apron, since this would require the cab driving onto the apron. When reviewing roundabout designs, request that the designer provide the turning template analysis for the design vehicle, such as an Autoturn analysis. SDDCTEA is also available to review designs to verify proper design vehicle geometry.

CHAPTER 11—ROADSIDE SAFETY

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11.1. ROADSIDE SAFETY FACTS

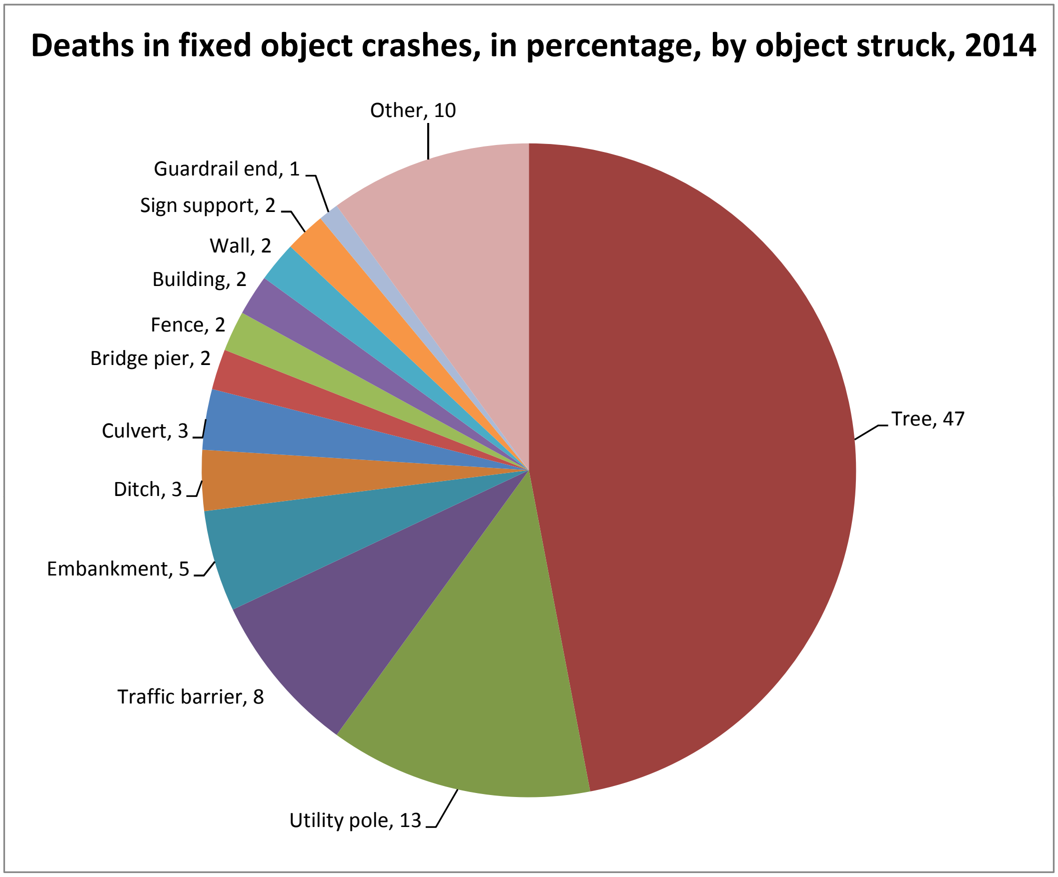
KEY POINT

A "forgiving roadside" reduces the seriousness of run-off-the-road crashes.

In a typical year, according to the National Highway Traffic Safety Administration (NHTSA), one-quarter of motor vehicle deaths involve vehicles leaving the roadway and hitting fixed objects such as trees or utility poles along the road.

- ✓ 60 percent of roadside fatalities involve trees and utility poles.
- ✓ 44 percent of roadside fatalities occur between 9:00 p.m. and 6:00 a.m.
- ✓ 43 percent of drivers killed in roadside crashes have a blood alcohol content at or above 0.08 percent.
- ✓ 35 percent of drivers killed in roadside crashes are men younger than 35 years old.

The chart below shows deaths in fixed object crashes by type of object struck by percentage for the year 2014.



Source: Insurance Institute for Highway Safety Highway Loss Data Institute

Regardless of the reason for a vehicle leaving the road, a roadside that is free of fixed objects such as trees and poles, with stable, flattened slopes, helps to reduce the frequency and/or severity of crashes. The concept of the “forgiving roadside” accounts for errant vehicles that leave the roadway, and supports a roadside design where serious consequences of such incidents are reduced. Reasons why vehicles leave the travel way and encroach on the roadside include:

Severe crash example

- ✓ Driver fatigue and inattention
- ✓ Driving under the influence of drugs or alcohol
- ✓ Excessive speed
- ✓ Roadway conditions
- ✓ Bad visibility, possibly due to deficient roadway delineation
- ✓ Collision avoidance
- ✓ Vehicle failure

Crashes caused by driver error, such as driving under the influence of alcohol, speeding, or falling asleep, can be addressed by educational and enforcement programs. Contact your safety office for more information about these educational programs.

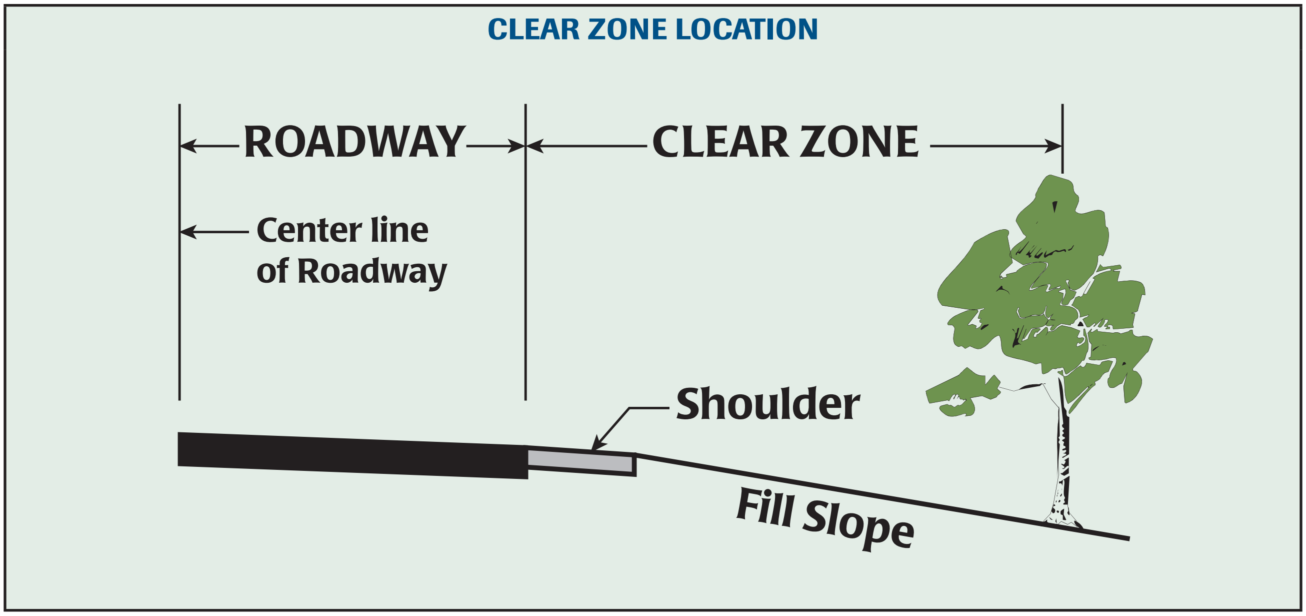
11.2. FORGIVING ROADSIDE CONCEPT, CLEAR ZONE AND LATERAL CLEARANCE

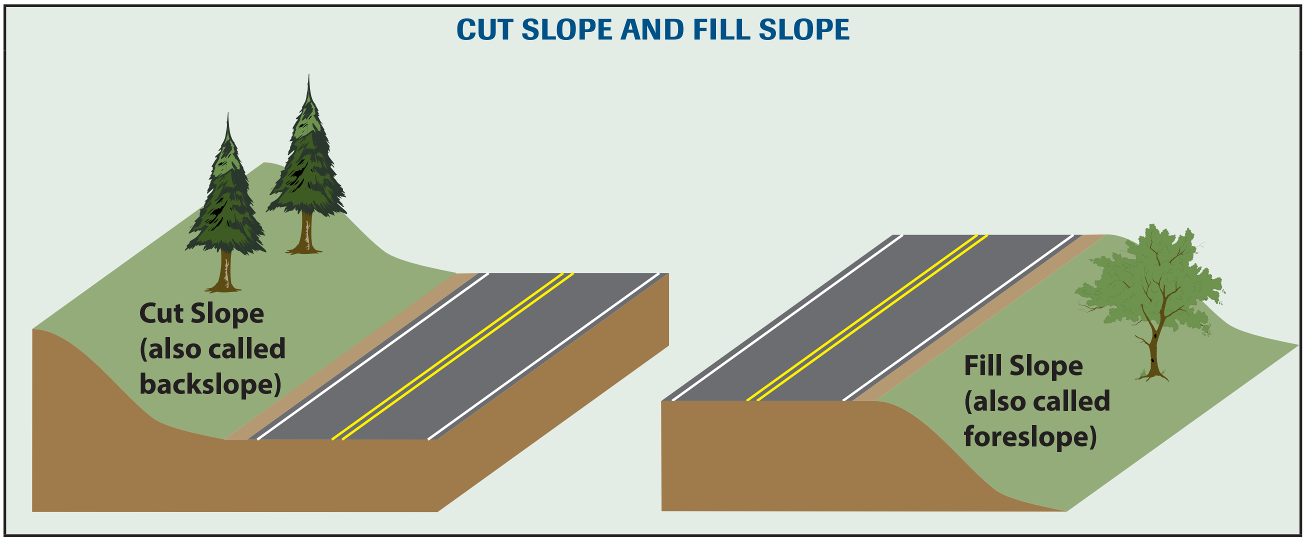
KEY POINT

Clear zone is a measured distance from the edge of the travel way that should be free from obstructions.

A clear zone is the total roadside border area from the edge of the travel way that is available for safe use by errant drivers. Providing adequate clear zones can enhance roadway safety by providing motorists with certain levels of expectation.

The needed clear zone distance is a function of the design speed of the adjacent roadway, the ADT volumes, and roadside geometry (i.e., side slope).





The values presented in Exhibit 11.1 suggest the approximate center of a range to be considered for clear zone, and generally apply to rural highways and controlled access facilities (such as freeways and interstates). **Nonetheless, in urban environments, the values given in Exhibit 11.1 should be used if practical.** However, for arterials and other non-controlled access facilities in an urban environment, where the right-of-way is often extremely limited, it may be impractical to establish a clear zone using the guidance presented in this section. For this situation, refer to Section 11.3.

Exhibit 11.1: Clear Zone Distances (In feet from edge of travel way)

DESIGN SPEED	DESIGN ADT	FILL SLOPES			CUT SLOPES		
		6:1 OR FLATTER	5:1 TO 4:1	3:1	3:1	4:1 TO 5:1	6:1 OR FLATTER
40 MPH OR LESS	Under 750	7-10	7-10	*	7-10	7-10	7-10
	750-1500	10-12	12-14	*	12-14	12-14	12-14
	1500-6000	12-14	14-16	*	14-16	14-16	14-16
	Over 6000	14-16	16-18	*	16-18	16-18	16-18
45–50 MPH	Under 750	10-12	12-14	*	8-10	8-10	10-12
	750-1500	14-16	16-20	*	10-12	12-14	14-16
	1500-6000	16-18	20-26	*	12-14	14-16	16-18
	Over 6000	20-22	24-28	*	14-16	18-20	20-22

** Since recovery is less likely on the unshielded, traversable 3:1 slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Determination of the width of the recovery area at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through travel lane and the beginning of the 3:1 slope should influence the recovery area provided at the toe of the slope.*

Source: AASHTO Roadside Design Guide, Table 3-1

The clear zones described in Exhibit 11.1 are appropriate for tangent sections and the inside of horizontal curves. On the outside of horizontal curves, a correction factor from Exhibit 11.2 should be applied to the value shown in Exhibit 11.1. For curves with a radius greater than 2,900 feet, a correction factor for the outside of the curve is not necessary.

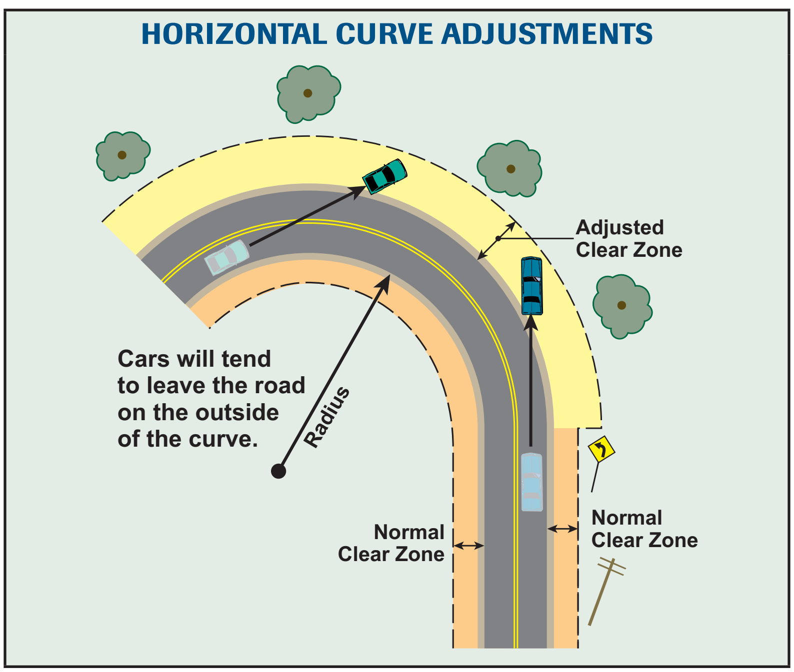


Exhibit 11.2: Horizontal Curve Adjustments*
(Clear zone curve corrections)

RADIUS (FEET)	DESIGN SPEED (MPH)		
	40	45	50
2950	1.1	1.1	1.1
2300	1.1	1.1	1.2
1970	1.1	1.2	1.2
1640	1.1	1.2	1.2
1475	1.2	1.2	1.3
1315	1.2	1.2	1.3
1150	1.2	1.2	1.3
985	1.2	1.3	1.4
820	1.3	1.3	1.4
660	1.3	1.4	1.5
495	1.4	1.5	
330	1.5		

**Multiply the clear zone distance derived from Exhibit 11.1 by the curve correction factor derived from Exhibit 11.2 to obtain the proper clear zone on the outside of the curve in feet. This factor applies only to the outside of curves. Curves flatter than 2950 feet do not require an adjusted clear zone.*

Source: AASHTO Roadside Design Guide, Table 3-2

11.3. LATERAL OFFSETS FOR URBAN AREAS

Urban environments are characterized by sidewalks beginning at the face of the curb, enclosed drainage, numerous fixed objects (e.g., signs, utility poles, luminaire supports, fire hydrants, etc.), and frequent traffic stops. In these constrained settings, it is frequently not possible to obtain the appropriate clear zone described in Section 11.2 due to the limited right of way for roadside features, since urban areas are often more developed. This section presents considerations to enhance safety on uncontrolled access highways in urban or restricted environments. As stated in AASHTO, *"Typical conditions for these types of roads or streets include lower speeds, dense abutting development, limited right-of-way, closely spaced intersections and accesses to properties, higher traffic volumes, and the presence of special users, including mass transit vehicles, delivery trucks, bicycles, and pedestrians."* In this type of environment, where the clear roadside concept cannot be achieved, a lateral offset to vertical obstructions (i.e., fixed objects) is needed to accommodate motorists driving on the roadway.

Urban areas often use curbing. With curbing, fixed objects should never be located closer than 1.5 feet from the face of curbing, with 3 feet provided at intersections. This minimum lateral offset distance is intended only to provide sufficient clearance for the overhang of a truck to avoid striking an object, and should not be misconstrued as satisfying the clear roadside concept. However, per the AASHTO

Roadside Design Guide, *"Research has shown that in an urban environment, approximately 80 percent of roadside crashes involved an object with a lateral offset from the curb face equal to or less than 4 feet and more than 90 percent of urban roadside crashes have a lateral offset less than or equal to 6 feet."*

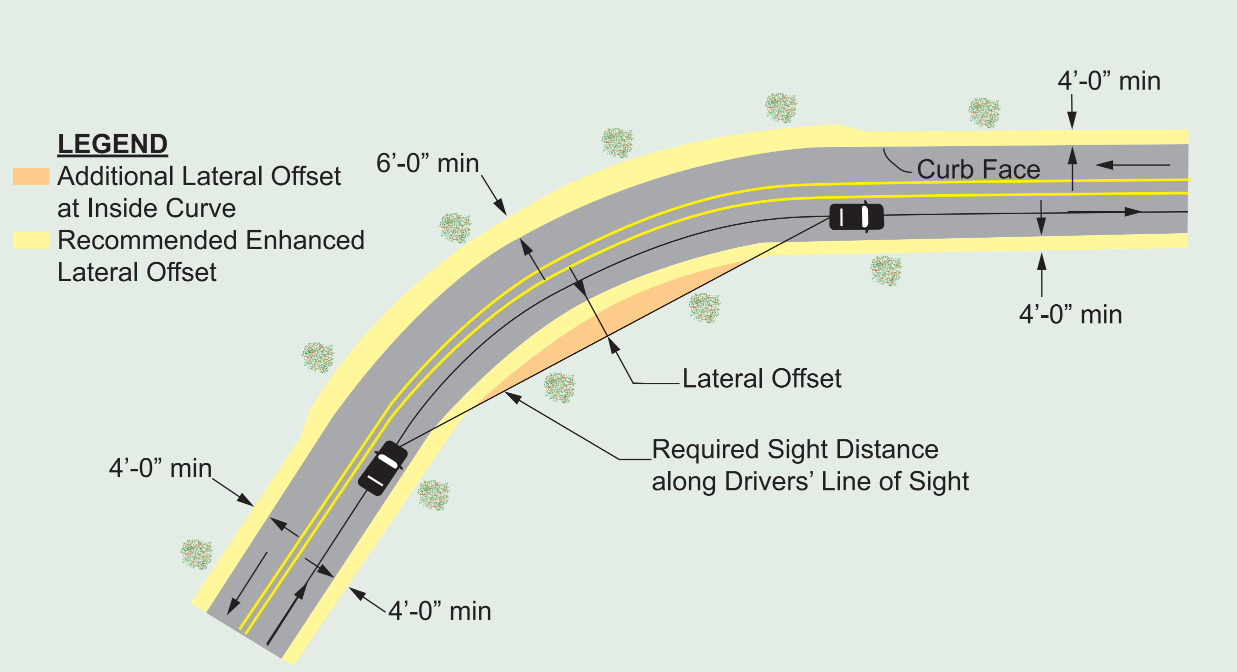
Considering this, an enhanced lateral offset of 4 to 6 feet is more appropriate for this type of environment. AASHTO has identified the critical urban roadside locations that are more prone to crashes and, as illustrated in Exhibit 11.3, established specific lateral offsets for these unique locations. However, it is important to remember that these are reasonable goals when the clear zone widths suggested in Section 11.2 cannot be achieved, and again should not be misconstrued as satisfying the clear roadside concept. Illustrations, taken from the AASHTO Roadside Design Guide, follow Exhibit 11.3 to assist in understanding the given offsets.

Exhibit 11.3: Urban Lateral Offset Distances

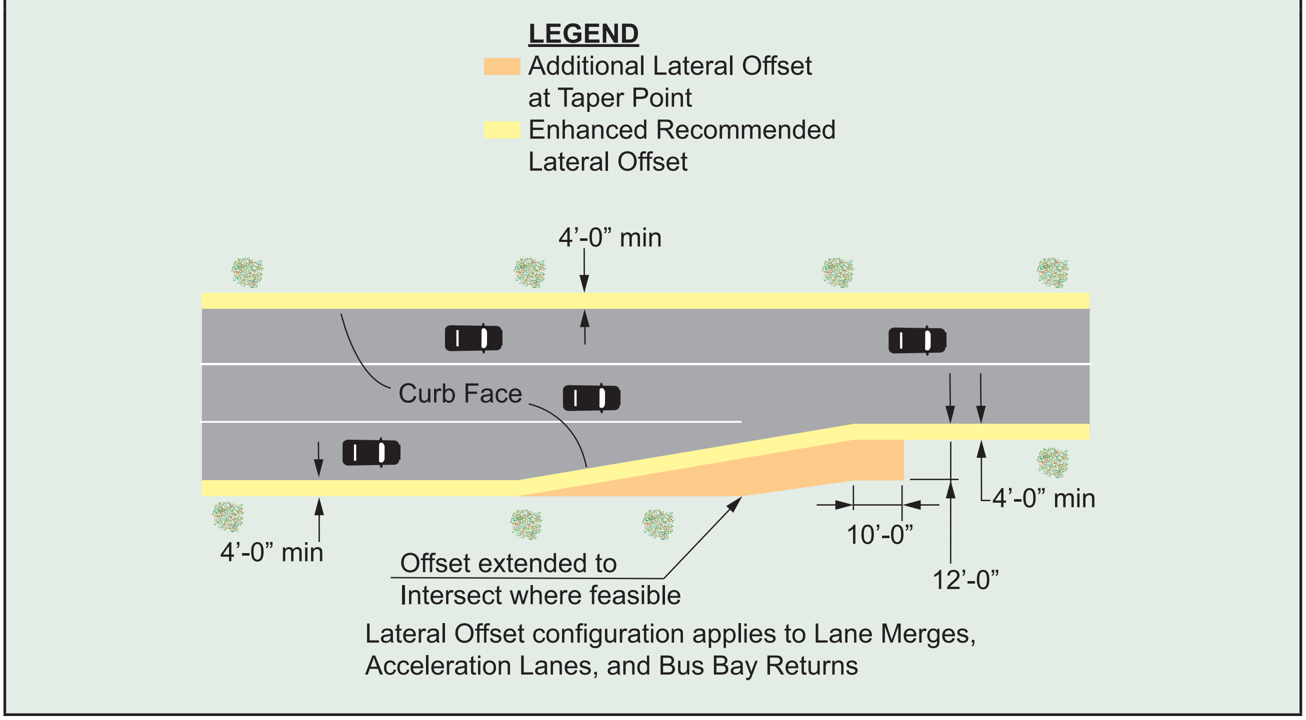
URBAN ROADWAY CONDITION	*MINIMUM LATERAL OFFSET (FEET)
Urban Roadway, Curbed Section	4
Urban Roadway, Curbed Section, Outside of Curves	6
Urban Roadway, No Curbing Present	8
Urban Roadway, No Curbing Present, Outside of Curves	12
Urban Roadway, Curbed Section, In Area of Merge	12
Urban Roadway, Curbed Section, In Area of Driveways	10–15

* measured from the face of the curb, if applicable

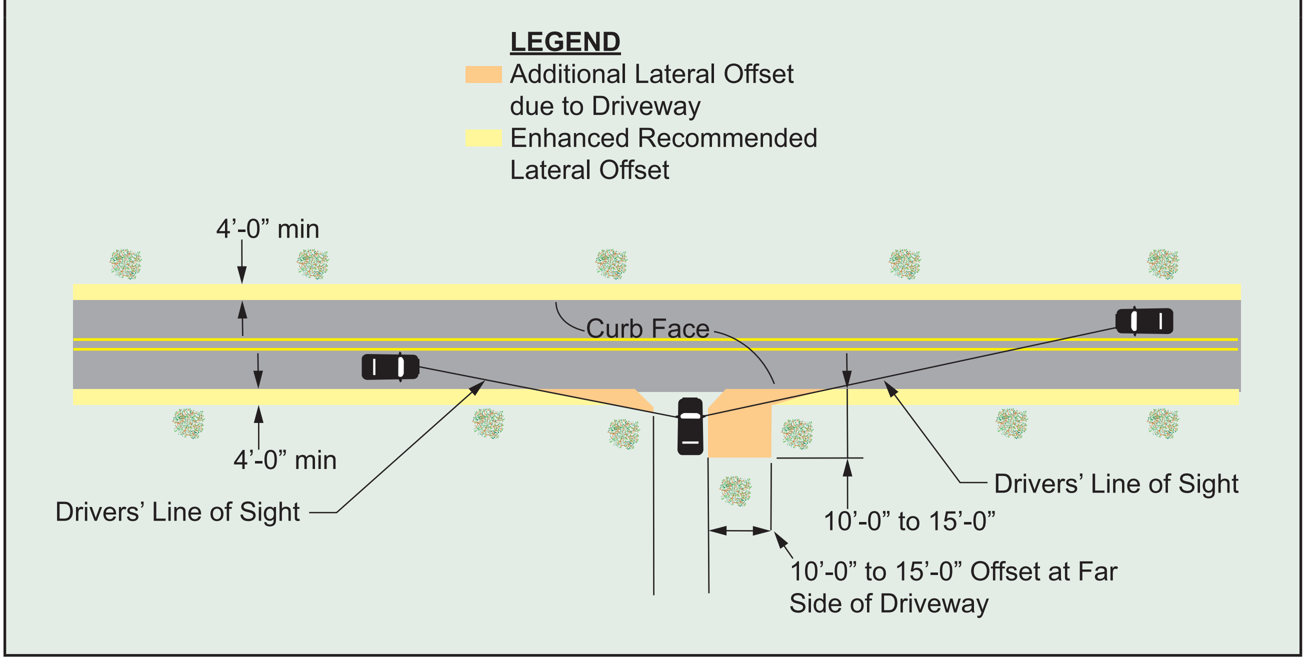
LATERAL OFFSET FOR OBJECTS AT HORIZONTAL CURVES ON CURBED FACILITIES



ENHANCED LATERAL OFFSETS AT MERGE POINTS



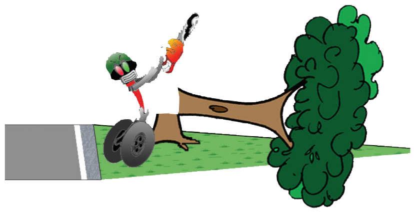
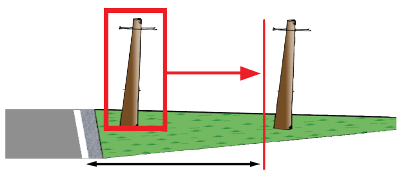
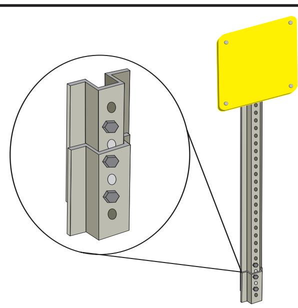
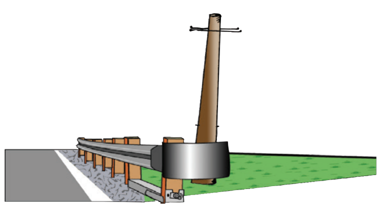
ENHANCED LATERAL OFFSETS AT DRIVEWAYS



11.4. COMMON ROADWAY HAZARDS AND MITIGATION STRATEGIES

When a roadside hazard, such as a tree or utility pole, is in the clear zone, there are five options to mitigate the hazard. These options, shown in Exhibit 11.4, should be considered in the order in which they are presented.

Exhibit 11.4: Options to Mitigate Hazards

OPTION 1		Remove the hazard.
OPTION 2		Relocate the hazard (outside the clear zone).
OPTION 3		Reduce the impact severity (breakaway support).
OPTION 4		Shield the hazard with a traffic barrier (guardrail).
OPTION 5		Delineate the hazard with an object marker.

11.4.1. Trees

Trees are involved in approximately 47 percent of roadside (fixed object) fatalities. Essentially there are two methods to address the problem of roadside trees.

Driver-aid treatments—Help to keep the motorist on the road.

- ✓ **Rumble strips**—A series of intermittent, narrow, transverse areas of rough-textured, slightly raised, or depressed road surface that are installed on the center line or edge line of the roadway to warn road users and help prevent roadway departure.
- ✓ **Pavement markings**—Center line and edge line pavement markings, in good condition, provide a particularly effective method of defining roadway edges.
- ✓ **Delineators and signs**—Installing advance warning signs and roadway delineators can help to alert motorists where extra caution is advised.
- ✓ **Roadway improvements**—Improvements to the roadway itself can help reduce run-off-the-road crashes.

Forgiving roadside—Protect motorists if they do leave the road.

- ✓ **Remove**—Removal of trees should be considered when those trees are determined both to be obstructions and to be in a location likely to be hit.
- ✓ **Shield**—Roadside barriers should only be used when the severity of striking the tree is greater than the severity of striking the barrier; and when removal is not a viable option.

In general ALL plantings within a clear zone should consist of shrubs and other plantings that will not grow into fixed objects. Consider any planting with an expected mature trunk size of greater than 4 inches in diameter as a fixed object.

11.4.2. Utility Poles

Utility poles pose the same problems as trees and are involved in approximately 13 percent of roadside (fixed object) fatalities. Measures to alleviate utility pole hazards include:

- ✓ Bury utility lines.
- ✓ Increase the lateral offset of utility poles from the roadway edge. Ideally, utility poles should be located outside the clear zone.
- ✓ Reduce the number of utility poles. Often the number of utility poles can be reduced by combining uses such as telephone and electricity on one pole. Also, in many cases the number of poles can be reduced by increasing spacing between the poles.
- ✓ Install breakaway utility poles. This method is designed to decrease the severity, not the frequency of roadside crashes.

Example of wide clear zone

ROADWAY SAFETY

- ✓ Install guardrails in front of utility poles. This method is designed to decrease the severity, not the frequency of roadside crashes.

Since utility poles are generally privately owned and installed devices, improvements can often be complicated. Installations should encourage cooperation with utility companies in making improvements. Implementing these suggestions will greatly help to reduce injuries and fatalities on installation roadways.

11.4.3. Breakaway Supports

Removing or relocating a roadside hazard from the clear zone is not always feasible. Some objects must be mounted near the roadway, and some objects may have been mounted close to the roadway long before the clear zone concept was considered. Man-made objects such as signs, mailboxes, light poles, utility poles, bollards, etc., are often mounted within the clear zone.

One-quarter of motor vehicle deaths involve vehicles leaving the roadway and hitting fixed objects. In cases where these objects cannot be removed or relocated, using an appropriate breakaway support will reduce the impact severity.

A breakaway support refers to all types of devices that yield when hit by a vehicle. They yield because the design of the support purposely incorporates a weak spot. Three criteria dictate that these supports fail in a predictable manner:

- ✓ AASHTO's *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*
- ✓ *National Cooperative Highway Research Program (NCHRP) Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features*
- ✓ AASHTO *Manual for Assessing Safety Hardware (MASH)*

The AASHTO MASH is the most current criteria, however the methodologies of the other criteria are still valid. While it is not important to memorize these publications, it is critical to understand that strict specifications exist for the performance of breakaway supports. Since most states have a standard design for breakaway supports that have been crash tested and approved, consult your state's standards for an appropriate design.

Breakaway supports are available for objects such as:

- ✓ Post mounted signs (refer to Section 7.8.12 for additional information)
- ✓ Luminaires
- ✓ Traffic signals
- ✓ Fire hydrants
- ✓ Mailboxes
- ✓ Utility poles

Give special care and consideration to breakaway supports for luminaries, traffic signals, and utility poles. If not designed or constructed properly, a falling support can be hazardous to other vehicles on the roadway.

11.4.4. Drainage Features

As shown in Exhibit 11.5, many of the drainage structures on military installations were installed before roadside safety was considered an important topic.

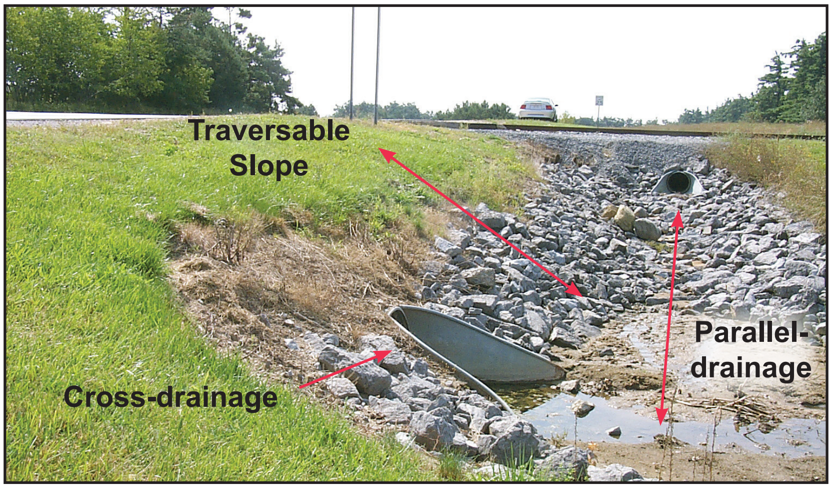
Exhibit 11.5: Common Deficiency Examples

Protruding endwalls for cross-drainage structure

Endwalls too close to roadway edge for cross-drainage structures

Parallel-drainage ditches within the clear zone
Note: Parallel ditches are not an obstacle if properly designed.

Two types of drainage structures exist along roadways: cross-drainage structures and parallel-drainage structures. Cross-drainage structures are designed to carry water underneath the roadway, while parallel-drainage structures are designed to carry water parallel to the roadway.



Culvert with end section

11.4.4.1. Cross-drainage Structures

For cross-drainage structures, consider the following options to minimize their impact on safety:

- ✓ **Use a traversable slope**—For smaller diameter culverts (40" or less), the end of the culvert should match the slope of the surrounding embankment. This design can be accomplished with the use of end sections or wingwalls and the use of safety end treatments. For larger culverts (greater than 40" in diameter), consider treatments such as extending, shielding, or delineating the structure.
- ✓ **Extend the structure so it is less likely to be hit**—If the end of a culvert cannot be made traversable, it should be moved to a location outside of the clear zone.
- ✓ **Shield the structure**—Sometimes a structure cannot be made traversable or moved beyond the clear zone. This is especially true for larger structures. In those cases, consider installing a barrier such as guardrail.
- ✓ **Delineate the structure**—If the above alternatives are not appropriate, the structure should be delineated as shown below.

Traversable culvert grate
[Source: Courtesy of IA DOT]

Delineate the structure

11.4.4.2. Parallel-Drainage Structures

For parallel-drainage structures, the following options should be considered to minimize their impact on safety:

✓ **Eliminate the structure**—In some cases parallel-drainage structures can be eliminated. For example, at a crossroad, the water can be carried over the cross street rather than underneath it.

Eliminate parallel-drainage structures

✓ **Use a traversable design**—Use of a rounded flat-bottom ditch (Exhibit 11.6) provides the best combination for safety and drainage.

✓ **Move the structure**—Structures should be moved laterally, preferably to a location outside the clear zone.

✓ **Shield the structure**—Sometimes a structure cannot be removed or relocated outside the clear zone. This is especially true for large structures. In those cases, consider installing a barrier such as guardrail.

✓ **Delineate the structure**—If the above alternatives are not appropriate, the structure should be delineated.

Exhibit 11.7 compares different ditch designs with respect to safety and drainage. Refer to Exhibit 11.7 for a summary of drainage feature mitigation measures.

Exhibit 11.6: Ditch Designs

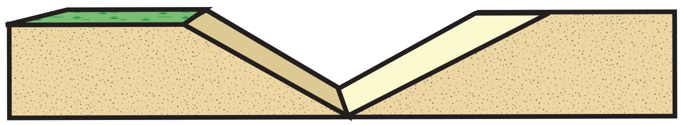
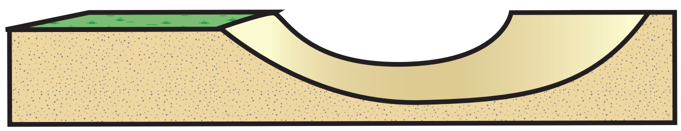
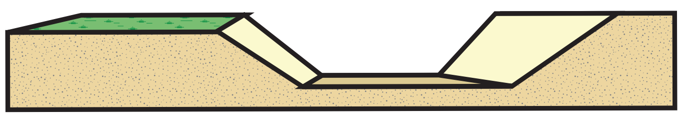
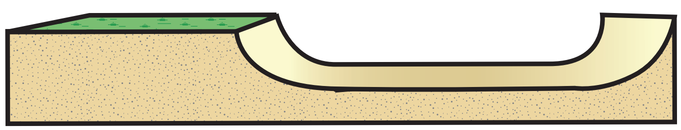
BEST FOR SAFETY		BEST FOR DRAINAGE
	V-DITCH 	
✔	**ROUNDED DITCH** 	
	FLAT BOTTOM DITCH 	✔
✔	**ROUNDED/FLAT BOTTOM DITCH** 	✔

Exhibit 11.7: Drainage Feature Mitigation Measures

TYPE OF DRAINAGE STRUCTURE	DEFICIENCY	POTENTIAL MITIGATION MEASURES
CROSS-DRAINAGE STRUCTURE	Non-traversable slope at the end of a culvert	✓ Install metal end section. ✓ Install concrete wingwalls. ✓ For larger culverts (>40 inches in diameter), consider extending the culvert or installing barrier.
	Protruding headwall (>4 inches)	✓ Remove headwall and install end section or wingwalls. ✓ Remove the top of the headwall. ✓ Regrade the area around the headwall.
	Culvert end close to edge of roadway	✓ Extend the culvert laterally outside the clear zone. ✓ If culvert extension is not possible, shield or delineate the end of the culvert.
PARALLEL-DRAINAGE STRUCTURE	Non-traversable parallel ditch	✓ Convert the drainage system to a "closed" system (i.e., installing pipes and inlets). ✓ If a "closed" system is not feasible, regrade the ditch to a rounded flat-bottom ditch.
	Culvert underneath a cross street within the clear zone	✓ Relocate the culvert outside the clear zone. ✓ If relocation is not feasible, flatten the slope around the end of the culvert as much as possible. The use of an end section or wingwalls may be necessary.

11.4.5. Guardrail Basics

A roadside barrier is a longitudinal device used to shield motorists from natural or manmade obstructions located along a roadway. Remember, barriers are themselves hazards. They are intended to reduce the severity, not the frequency of crashes. Use barriers only where the result of striking the object or leaving the roadway would be more severe than the consequences of striking the barrier. Guardrails are the most common type of barrier. Another common type is a concrete jersey barrier.

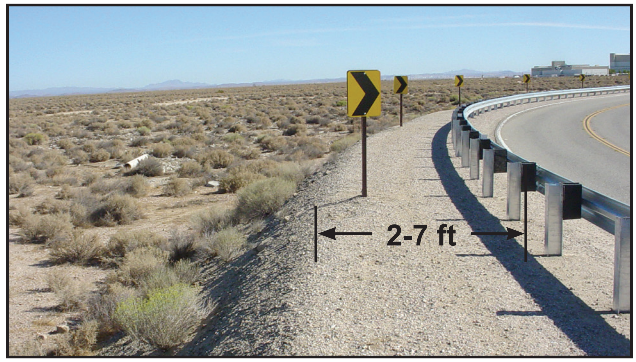
11.4.5.1. Guardrail Design

When designing or choosing a guardrail system, consider the following:

- ✓ Lateral placement and deflection
- ✓ Length of need
- ✓ End treatment

Lateral Placement and Deflection

The type and design of a guardrail used depends on the maximum deflection and the location of the roadside obstacle. The minimum lateral distance between a guardrail and an obstruction varies between 2 and 7 feet, depending on the type of guardrail used.



Lateral placement and deflection

For barrier application on steep slopes, provide a minimum of 2 feet of barrier-to-embankment distance to prevent the posts from coming out of the side slope upon impact.

Place roadside barriers as far from the road edge as possible. At a minimum, place beyond the “shy line,” or the distance from the edge of the travel way that an obstacle will not be perceived as an immediate hazard by a typical driver. The distance between the barrier and obstruction must always allow for maximum barrier deflection.

On high speed roads, avoid using guardrail-curb combinations due to the potential for vehicle vaulting. Where curbing is absolutely necessary to control drainage, the curb should be no higher than 4 inches and the guardrail should be semi-rigid. The face of the guardrail and the face of the curb should align. The use of guardrail with curbs should be evaluated by a qualified engineer.

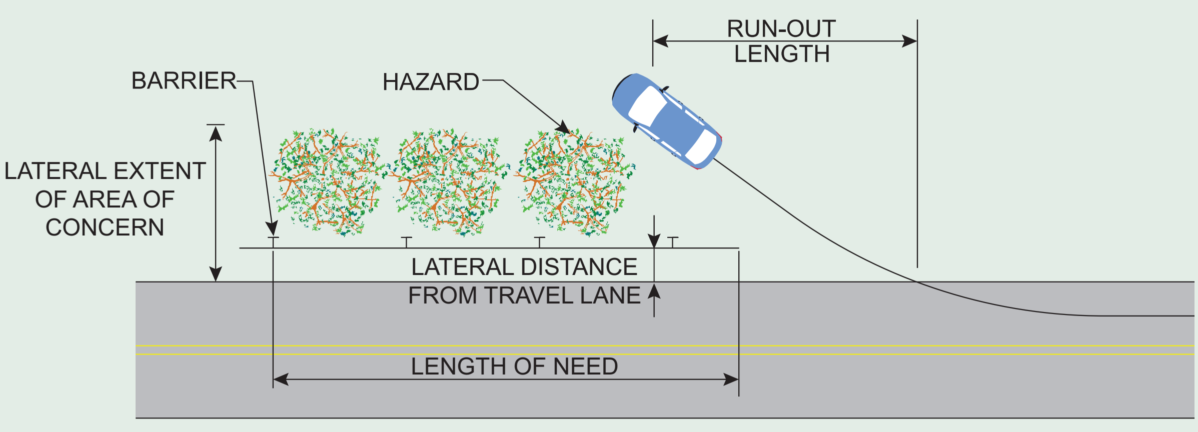
In some instances where a barrier is warranted, installing guardrail may appear to be a less expensive option than removing or relocating the hazard. Consider the life cycle costs of maintaining the guardrail.

Length of Need

To prevent a vehicle from striking an obstacle, install a guardrail in front of, and for a distance in advance of, the obstruction. The distance that guardrail should be installed in advance of the obstruction is called the length of need. Length of need should be determined by a qualified engineer and depends on flare, run-out length, and the offset between the obstacle and the guardrail.

The AASHTO runout length, is the theoretical off-road distance needed for a vehicle that has encroached on the roadside to come to a stop. This distance is measured from the upstream end of the roadside hazard, along the roadway, to the point at which the vehicle is assumed to leave the roadway. AASHTO provides recommended runout lengths, based on the design speed of the roadway and the given traffic volume, to use in determining the barrier length-of-need. Once runout length and lateral extent of the area of concern are known, the AASHTO length of need depends on the tangent length needed upstream of the hazard, its lateral distance from the travel lanes, and the flare rate, designed for the installation.

RUN-OUT LENGTH



End Treatments

Guardrail runs that end within the clear zone require an end treatment. An end treatment should provide a "forgiving" apparatus for the exposed ends of a guardrail system. On two-lane, two-way highways, both ends require an appropriate end treatment.

NCHRP Report 350 outlines minimum crash performance criteria that roadside hardware should meet. *NCHRP Report 350* approved devices are required on:

- ✓ National Highway System (NHS) roads.
- ✓ Roads where daily traffic volumes exceed 6,000 vehicles.
- ✓ Roads where the design speed is greater than 50 mph.

NCHRP Report 350 approved devices are considered crashworthy.

Crashworthy end treatments can be categorized by their application and characteristics. Some end treatments are gating, meaning they allow a vehicle to pass through on impact. Others are nongating, meaning they will gradually stop or redirect a vehicle. End treatments can also be categorized as flared or parallel, depending on whether they are installed parallel with the roadway or flared away from the roadway. An anchored backslope terminal is the most desirable end treatment.

Turned-down end treatments are not crashworthy and should be avoided. Although less expensive than other types of end treatments, turned-down end treatments may cause vehicles to vault or flip. Exhibit 11.8 shows examples of guardrail end treatments.

Exhibit 11.8: Guardrail End Treatment Examples

	Turned-down end treatment
	Guardrail with no end treatment
	Proper end treatment
	Proper end treatment

11.4.5.2. Common Mistakes

Some common mistakes of guardrail installation include those in Exhibit 11.9.

Exhibit 11.9: Common Guardrail Mistakes

	Obstacles in front of a barrier
	Inadequate guardrail lengths
	Gaps in guardrail (gaps that are less than 200 feet should be avoided)

11.4.6. Roadway Shoulders

> **KEY POINT**
> A contributing factor in crashes is often poorly maintained shoulders.

Too often, improper shoulder maintenance leads to crashes. The story is common: a car's wheels drop off the edge of the pavement of a highway; the driver attempts to bring the vehicle back into the travel lane, but the rear wheel catches the shoulder drop-off; the driver oversteers and the vehicle swings into the opposing lane of traffic. Usually this situation can be avoided by controlling shoulder erosion.

Roadway shoulder maintenance should include:

- ✓ **Erosion control**—Proper construction and grading of shoulders and road edges is critical for controlling erosion. Proper construction provides lateral support for the shoulder and prevents the edges from cracking and eroding. Proper grading allows water to flow from the roadway and into the drainage system, rather than standing and eroding the shoulder or pavement edge.
- ✓ **Removal of build-up**—Remove vegetation and dirt build-up along roadway shoulders and edges to expedite the drainage of water from the roadway surface.
- ✓ **Control of shoulder cracking**—Apply a seal coat to the roadway shoulders to control cracking and assist in maintaining its structural integrity.

Poorly maintained shoulder

11.5. DRIVER-AID TREATMENTS

Driver-aid treatments minimize highway crashes by helping to keep the road user on the travel way. Many severe crashes occur in curves and turns due to driver fatigue or impairment. The most common driver-aid treatments are:

- ✓ Rumble strips
- ✓ Signs and pavement markings
- ✓ Roadway improvements/ITS
- ✓ Delineators and object markers
- ✓ Warning beacons

11.5.1. Rumble Strips

Rumble strips are a series of various type surface textures used on paved roads and shoulders that produce noise and vibration to alert road users of a traffic condition or hazard (see Exhibit 11.10).

A rumble strip becomes a “rumble stripe” when an edge line or center line pavement marking is placed on it. The contour of the rumble strip drains water, and provides a reflective back wall that allows the pavement marking to maintain its retroreflectivity at night during rain and post-rain events (when normal pavement markings lose their function).

Application of Rumble Strips

- ✓ **Shoulder**—rumble strips effectively alert drivers if they leave the travel way, thus reducing run-off-the-road crashes.
- ✓ **Center line**—rumble strips are useful in areas with undivided, two-way traffic roads where there is a history of head-on crashes.
- ✓ **Transverse**—or travel-lane rumble strips, are a useful tool for alerting motorists of an upcoming unsafe condition, such as an unexpected intersection or a tight curve.

Different DOTs locate shoulder edge line rumble strips at different points with respect to the actual travel lane edge. To accommodate bicyclists, avoid rumble strips unless a minimum of 4 feet of paved shoulder is available. Also, common modifications to shoulder rumble strips include:

- ✓ Leaving a periodic gap in the rumble line to allow bicycles to travel between the shoulder and travel lane
- ✓ Modifying the depth and width of the rumble cut to make traversing the rumble strips safer for cyclists.

Exhibit 11.10: Pavement Marking Detail for Rumble Strips and Stripes

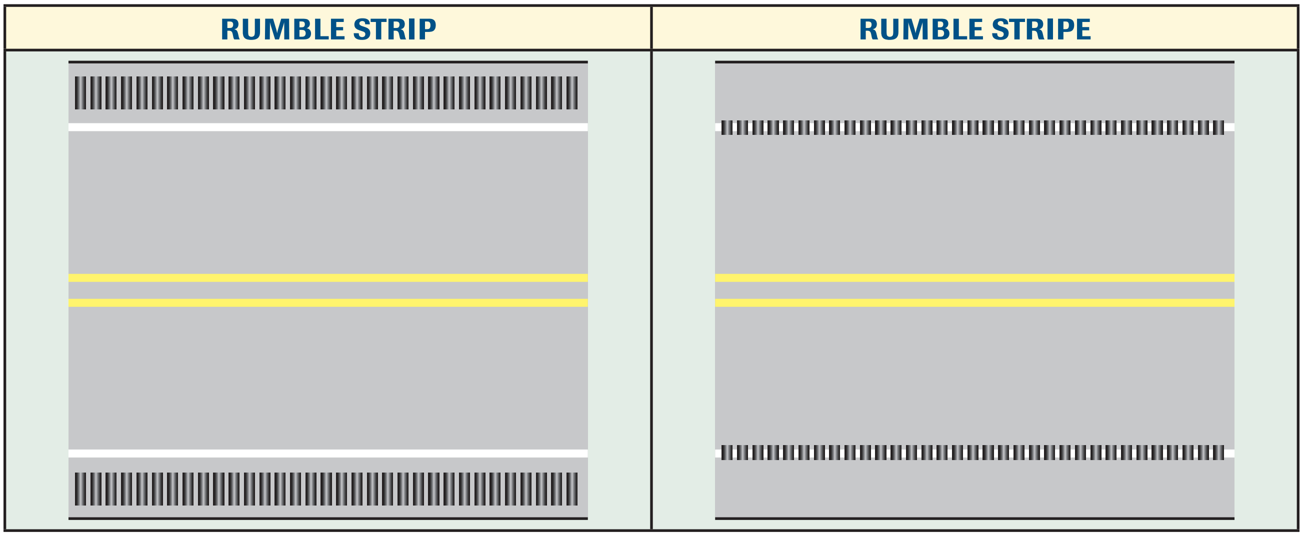


Exhibit 11.11: Common Types of Rumble Strips*

TYPE	DESCRIPTION	COMMENTS
MILLED 	✓ Machine-milled ✓ Longitudinal width of 7 inches ✓ Transverse width of 16-17 inches ✓ Offset 12-16 inches from travel lane ✓ Tires drop ½ inch into groove	✓ Favorite type of most states because they are easy to install ✓ Do not affect pavement integrity ✓ Produce greater noise and vibration than other types of rumble strips
ROLLED/FORMED  	✓ Made by a roller with steel pipes welded to drums ✓ 1¼ inches deep ✓ 1½ inches wide ✓ 8 inches between grooves	✓ Do not create the same feel of noise and vibration as milled rumble strips

**The type of rumble strip and the exact dimensions vary from state to state. Contact your State DOT for further guidance.*

Shoulder and center line rumble stripes

Related Concerns

- ✓ **Noise**—Noise is both a benefit and a concern with rumble strips. Noise serves as a benefit when it alerts motorists. However, when installed near residential areas, the noise is often perceived as a nuisance. A solution to this concern may be to move the rumble strips farther away from the travel way, reducing the likelihood of them being traveled on. However, this may also reduce their effectiveness.
- ✓ **Bicycles**—Rumble strips pose problems for bicycles. On facilities that have bicycle traffic, redesign roadway and shoulders when possible to accommodate both rumble strips and bicycles. Many states have, or are in the process of developing, bicycle-friendly rumble strips. Check out www.fhwa.dot.gov for more information on states' rumble strip details and specifications.
- ✓ **Maintenance**—Rumble strips cause little, if any, deterioration in roadway surfaces. By their design, rumble strips are self-cleaning since passing vehicles create a wind force that blows debris from the rumble strips.

Costs vs. Benefits

- ✓ The 350+ mile Pennsylvania Turnpike system experienced a 70 percent reduction in run-off-the-road crashes after rumble strips were installed.
- ✓ California experienced an average reduction of 33 percent in run-off-the-road crashes statewide with rumble strip installation.
- ✓ The cost of milled shoulder rumble strips is about $0.35 per linear foot of shoulder.
- ✓ New York State Thruway data indicate a benefit/cost ratio ranging from 66:1 to 182:1.
- ✓ Nevada DOT calculated a benefit/cost ratio ranging from 30:1 to 60:1 for interstate rumble strips.

11.5.2. Signs and Pavement Markings

Signs

Signs are another effective driver-aid treatment. Examples of warning sign treatments for horizontal alignment changes include Turn, Curve, Reverse Turn, and Reverse Curve signs. These signs are very helpful but are commonly misused. Use the criteria in the *MUTCD* as the basis for deciding what type of sign to install. Chapter 7 in this pamphlet also discusses signage for horizontal alignment changes, and Chapter 15 provides information regarding Advisory Speed postings.

Pavement Markings

Pavement markings make up the primary delineation and control for road users to navigate the highway system. Markings have an enormous impact on highway safety since they regulate and guide the movement of traffic. Markings provide the best system of roadway delineation for the least cost. Cost is about $0.50 per linear foot for a four-inch wide solid pavement marking line using paint and glass beads. Chapter 8 in this pamphlet discusses the different types of pavement markings, as well as the different types of marking material.

11.5.3. Roadway Improvements and Intelligent Transportation Systems

Roadway improvements can also be effective driver-aid treatments. Many times common improvements can yield the highest reduction in crashes.

- ✓ Realign unconventional roadway conditions.
- ✓ Improve roadway drainage by improving roadway crown and superelevation.
- ✓ Reconstruct deteriorated roadway surface.

ITS has become mainstream and has greatly decreased in cost. Because of its use of technology, these systems can yield reductions in crashes that other improvements cannot.

- ✓ Horizontal alignment warning systems are used to warn motorists if they are traveling too fast for the impending change in horizontal alignment.
- ✓ "RED WHEN FLASHING" signs are used to warn of a red indication at nearby traffic signals where sight distance is limited.
- ✓ Weather sensors and signs are used to provide advance warning of conditions such as black ice on a bridge.
- ✓ Collision countermeasure systems are used to warn of approaching, conflicting traffic at intersections with insufficient sight distance.

11.5.4. Delineators and Object Markers

Delineators

Delineators provide all-weather delineation of roadway edges and are beneficial at locations where alignment may be confusing, such as lane reductions or curves. The color of the delineator must conform to the color of line it is supplementing.

- ✓ 30% reduction in crashes
- ✓ Benefits outweigh costs on roadways with greater than 1,000 vehicles daily

Proper use of delineators

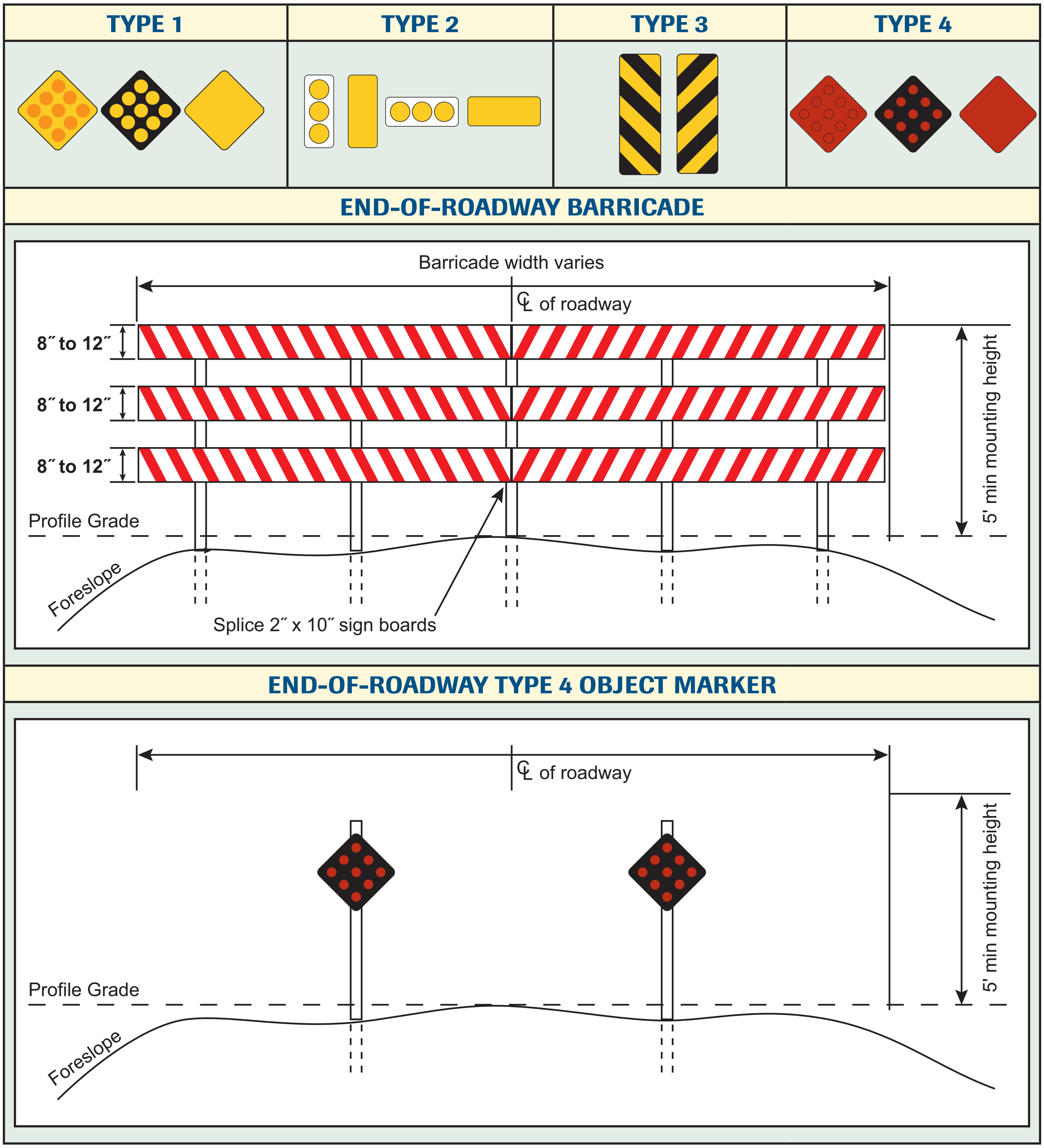
Object Markers

Use object markers to mark obstructions within or adjacent to the roadway. Mark obstructions with a Type 1 or Type 3 marker. Type 3 markers have stripes sloping downward on the side traffic should pass.

Mark roadside hazards adjacent to the roadway with Type 2 or Type 3 markers. This includes items located within the clear zone, or so close to the edge of the road that they need a marker. This includes a variety of items, such as underpass piers, bridge abutments, handrails, and culvert headwalls. In some cases they may be used to mark roadside conditions such as narrow shoulder drop-offs, gores, small islands, and abrupt changes in roadway alignment.

Type 4 markers are typically used at the end of a dead-end roadway, in other than construction or maintenance areas. The Type 4 object marker may be used in instances where there are no alternate vehicular paths. Where conditions warrant, more than one marker, or a larger marker with or without a Type 3 Barricade (see *MUTCD* Section 2B.67), may be used at the end of the roadway. They can be supplemented with an end-of-roadway barricade when conditions warrant. The end-of-roadway barricade can be supplemented with a ROAD CLOSED (R11-2) sign as illustrated in Exhibit 7.23 on page 7-63. The advantage of this type of marker is that they delineate the entire roadway width. These markers are shown in Exhibit 11.12. See section 7.3.15 for additional discussion on object markers.

Exhibit 11.12: Object Markers



CHAPTER 12—ROADWAY SAFETY IMPROVEMENT PLAN

It is well known that safety on our public roadways is regulated and documented and methods of improving safety are constantly being investigated. It is just as important that roadway safety on military bases is addressed, and all military roadways should provide safe traveling for motorized and nonmotorized traffic. Providing for a safe travelway includes educating the roadway users on safe driving habits, providing a roadway that is designed for the posted speed limit, intersections consisting of the proper traffic control devices and sight distance requirements, and maintaining safe travel through work zone areas.

Importance of safety—motorized and nonmotorized traffic sharing the same roadway

12.1. VEHICULAR CRASHES

> **KEY POINT**
> Vehicular accidents can occur due to a variety of reasons including: inclement weather, driver distraction or error, road debris or animal obstruction, or substandard roadway geometrics or traffic control devices.

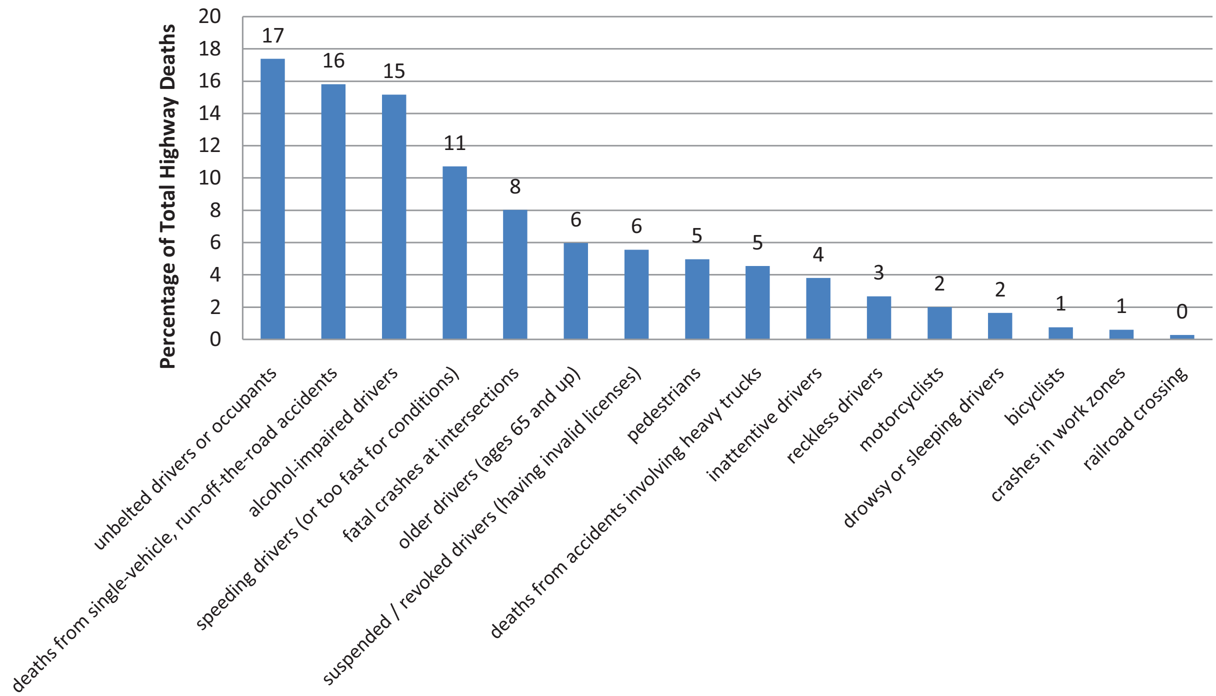
Since vehicular crashes fall into multiple categories, maintaining records of crashes that have occurred can be very helpful for determining safety upgrades. Exhibit 12.1 shows several different crash types.

Exhibit 12.1: Common Crash Types

TYPE OF CRASH	
REAR IMPACT	
SIDE IMPACT/SIDESWIPE/ANGLE	
HEAD-ON COLLISION	
ROLLOVER	
SINGLE CAR INCIDENT/RUNOFF	

Exhibit 12.2 displays the major categories that cause or are associated with deaths on highways. Additionally, from the ITE Journal of July 2010, an analysis of crashes in Great Britain between 2005 and 2009 reveals that human factors play a large role in crashes at all levels of severity. In fact, the top 10 contributory factors were "human factors," such as: failing to look properly; being careless, being reckless, or in a hurry; failing to correctly judge the other vehicle's path or speed; travelling too fast for conditions; braking too suddenly; following too close; and being impaired by alcohol.

Exhibit 12.2: Major Categories of Highway Deaths in 2009



ITE Traffic Safety Toolbox, Chapter 1 on Safety Management, Table 1-1

12.2. CRASH RECORDS

As discussed in Section 12.1, it is important to maintain vehicular crash records in order to develop methods to increase safety on military base roadways.

12.2.1. Military Crash Records

✓ **Current System**—Many bases currently do not maintain adequate crash records. Crash forms are currently tied into general personal, property, and vehicular information and are mainly used to quantify and track monetary damage. These forms do not give specific information on the crash itself. Generally, military security forces are in charge of crash data, and the data is not readily given to engineering personnel or agencies performing transportation studies. Thus it is very difficult to use existing military base crash data for engineering purposes. Refer to SDDCTEA Pamphlet 55-8 for additional information regarding crash reports as well as a copy of the DA 3946 Military Police Traffic Accident Report.

✓ **Improvements to Current System**—Potential improvements that could be implemented on military bases include:

- Make the crash reports accessible for engineering safety improvement analysis.
- Make the current form more detailed to include information about the crash itself. It is less important to obtain all of the personal information that is being done now. An example of a crash and its associated form is shown in Exhibit 12.3.

Exhibit 12.3: Crash Form

CRASH FORM	
Date and Time:	5/18/08, 1032
Roadway Number or Name:	Base parking lot
Collision Type:	Rear end
Intersection Type:	N/A
Urban or Rural:	Urban
Number of Vehicles Involved:	1
Number of People Involved:	2
Severity of Accident:	Minor
Number of Fatalities:	0
Number of Injuries:	0
Illumination within the Accident Area:	Some daylight, parking lot lights
Weather Conditions:	Raining
Road Surface Conditions:	Wet
Short Description of the Accident:	While pulling out of parking spot, car struck pole.

Car pulled out of parking spot and hit pole

Traffic signals can be warranted, and roadway improvements can be justified based on a history of crash experience at a certain location. But what if you haven't had a crash recently, or have no documented history of crashes, but instead have had lots of "near misses" and complaints about a problem location? Is some number of near misses or complaints equal to a crash with respect to recommending or justifying a solution? In 1931 a book by H.W. Heinrich entitled "Industrial Accident Prevention" discussed that there was a relationship between major injury accidents and near misses or incidents. The relationship was a pyramid model where for every 300 or so near misses a major accident would result. We don't know what the relationship would be for traffic crashes, but if one is interested in preventing a crash, then one could draw a conclusion that a crash is more likely and perhaps inevitable when a number of near misses occur.

12.2.2. Crash Record Resources

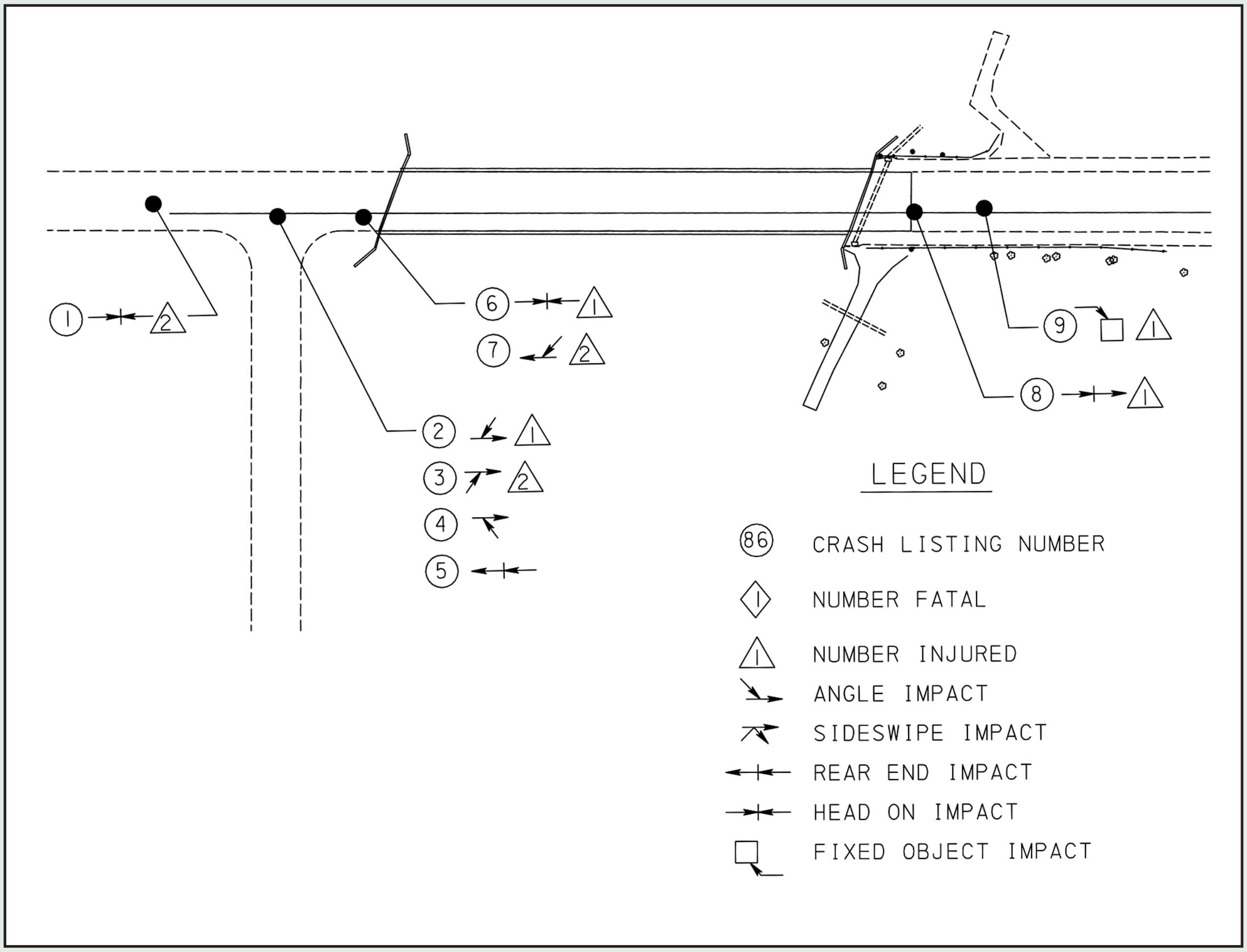
There are multiple national and local safety organizations that compile transportation accident data, are continuously developing new technology for improving safety, and offer resources to assist in improving safety at all levels.

- ✓ The NHTSA compiles a vast array of accident data, including state specific crash information. Individual state crash data and forms can be obtained through the NHTSA.
- ✓ The Safety section of the FHWA references multiple resources listed in this chapter, and also contains information on crash tested hardware.
- ✓ The *Model Minimum Uniform Crash Criteria (MMUCC) Guideline* is a document that provides a dataset for describing motor vehicle accidents that can be used to improve highway safety within each State and nationally.
- ✓ The Transportation Safety Planning Working Group developed the *Transportation Planner's Safety Desk Reference* which contains general crash data, and gives an overview on what safety improvements can be implemented and the resources that can be used to develop a Safety Improvement Plan.

12.2.3. Crash Diagrams

Once crash reports are obtained, they can be summarized by creating crash diagrams. As shown below, crash diagrams are graphical representations of the crash pattern at a particular location. Typically, crash diagrams are drawn by the designer or engineer conducting the study using arrows to represent the movement of the vehicles involved and how the vehicles impacted each other. Crash diagrams can quickly illustrate the situation where concentrations of crashes are located. Refer to SDDCTEA Pamphlet 55-8 for additional information on creating a crash diagram.

CRASH DIAGRAM EXAMPLE



12.3. IMPROVING ROADWAY SAFETY

The two key elements to increasing safety on military roadways are to educate roadway users on elements of safety and implementing roadway safety improvements.

12.3.1. Roadway User Safety Considerations

While engineers strive to improve the safety of the roadway itself, there are safety aspects that lie on the roadway users. These include the driver, the vehicle, as well as pedestrians and bicyclists. Temporary work zones are also areas that can be targeted with highway safety, but these can be influenced by the roadway owning agency through proper specification and oversight of contractors. Exhibit 12.4 shows issues and safety improvement recommendations for those elements.

There are many factors that can improve highway safety that lie on the road user, which can be improved with enforcement, education, as well as vehicular technology. These include:

- ✓ Maximizing seatbelt use by driver and all passengers.
- ✓ Eliminated drug and alcohol impaired driving.
- ✓ Obeying properly-applied speed limits, and driving even slower when road conditions demand it.
- ✓ Eliminating distracted driving, particularly cell phone use, and texting.
- ✓ Practicing safer driving techniques, such as limiting lane changing, and only when it safe to do so, maximize turn signal use, obeying traffic control devices, regulatory and warning signs.

Exhibit 12.4: Roadway User Safety Considerations

ELEMENT	COMMON ISSUES	SAFETY IMPROVEMENT RECOMMENDATIONS
DRIVER	✓ Impairments—drug or alcohol use ✓ Distractions—eating, cell phones, radio, GPS ✓ Speeding ✓ Not obeying traffic control devices ✓ Not wearing seatbelts ✓ Not using turning signals ✓ Motorcyclists not wearing helmets	✓ Enforce DUI regulations ✓ Educate on the importance of not being distracted while driving ✓ Enforce Executive Order 13513, no texting while driving a government vehicle, or driving for government business ✓ Enforce traffic violations
VEHICLE	✓ Vehicle not in good operating condition or with clear vision ✓ Vehicle lights not operational ✓ Vehicle's windshield wipers or tires are in need of replacement	✓ Educate on the importance of keeping vehicle in good condition ✓ Consider requiring proof of annual vehicle inspections
PEDESTRIANS/ BICYCLISTS	✓ Bicyclists not wearing helmet ✓ Not wearing high visibility safety apparel ✓ Not using retroreflective vests at nighttime ✓ Bicyclists not following traffic control devices ✓ Not using sidewalks or crosswalks	✓ Educate on the importance of practicing safe bicycling ✓ Designate and enforce the use of cross walks within high volume areas ✓ Reduce motor vehicle speed in high pedestrian accident areas ✓ Create or designate pedestrian/ bicyclist pathways to keep them off of roadways
TEMPORARY WORK ZONE	✓ Does not have the proper temporary traffic control devices ✓ Workers not wearing the proper safety apparel	✓ Enforce the use of a Temporary Traffic Control plan that is designed to current standards (see *MUTCD* Part 6) ✓ Enforce driver compliance to work zone traffic controls ✓ Enforce workers to practice standard safety precautions

12.3.2. Roadway Safety Improvement

KEY POINT

The Knowledge Official Safety Magazine of the U.S. Army frequently has advice, tips, and statistics on safe driving. See: https://safety.army.mil.

In addition to addressing safety issues involving the drivers, vehicles, pedestrians/bicyclists, and work zones, the transportation network that these elements utilize can also be improved from a safety standpoint.

12.3.2.1. FHWA-Recommended Improvements

According to the FHWA's Safety department, there are nine proven crash countermeasures that can be incorporated into a transportation facility to help increase safety as summarized in Exhibit 12.5.

Exhibit 12.5: FHWA-Recommended Crash Countermeasures

CRASH COUNTERMEASURE	GUIDANCE
ROUNDABOUT	Roundabouts have demonstrated substantial safety and operational benefits compared to most other intersection forms and controls, with especially significant reductions in fatal and injury crashes. ✓ By converting from a two-way stop control mechanism to a roundabout, a location can experience an 82 percent reduction in severe (injury/fatal) crashes and a 44 percent reduction in overall crashes. ✓ By converting from a signalized intersection to a roundabout, a location can experience a 78 percent reduction in severe (injury/fatal) crashes and a 48 percent reduction in overall crashes. ✓ Roundabouts should be considered when rehabilitating existing intersections that have been identified as needing major safety or operational improvements. ✓ Roundabouts have also proven to be effective at freeway interchange ramp terminals and at rural high-speed intersections.
CORRIDOR ACCESS MANAGEMENT	Access management is a set of techniques that agencies use to control access to highways, major arterials, and other roadways. The benefits of access management include improved movement of traffic, reduced crashes, and fewer vehicle conflicts. Access management techniques are designed to manage the frequency and magnitude of conflict points at intersections and driveways by altering access patterns. Several of the more common access management treatments include: ✓ Driveway closure, consolidation, or relocation, ✓ Restricted-movement designs for driveways (such as right-in/right-out only), ✓ Restricted-movement and alternative designs for intersections (such as J-turns, median U-turns and quadrant roadways), ✓ Raised medians that prevent cross-roadway movements and focus turns and/or U-turns to key intersections, ✓ Adding auxiliary turn lanes (including exclusive left or right and two-way left), ✓ Constructing parallel, lower speed one-way or two-way frontage roads for access, and ✓ Using roundabouts or mini roundabouts to provided needed or desired access.

Exhibit 12.5: FHWA-Recommended Crash Countermeasures (Continued)

CRASH COUNTERMEASURE	GUIDANCE
BACKPLATES WITH RETROREFLECTIVE BORDERS	Backplates are added to a traffic signal indication in order to improve the visibility of the illuminated face of the signal by introducing a controlled-contrast background. The improved visibility of a signal head with a backplate is then made more conspicuous by framing the backplate with a retroreflective border. Taken together, a signal head equipped with a backplate with retroreflective border is made more visible and conspicuous in both daytime and nighttime conditions, which is intended to reduce unintentional red-light running crashes. ✓ Backplates with retroreflective borders should be considered as part of efforts to systemically improve safety performance at signalized intersections. Adding a retroreflective border to an existing signal backplate can be a very low-cost safety treatment, as the materials are simple strips of retroreflective sheeting.
LONGITUDINAL RUMBLE STRIPS AND STRIPES ON TWO-LANE ROADS	Longitudinal rumble strips are milled or raised elements on the pavement intended to alert inattentive drivers through vibration and sound that their vehicles have left the travel lane. There are a number of possible applications that can be used: ✓ Shoulder rumble strips are installed on a shoulder near the edge of the travel lane. They significantly reduce run-off-road (ROR) crashes. ✓ Edge line rumble strips are very similar to shoulder rumble strips, but placed at the edge of the travel lane, typically in line with the edge line pavement marking. ✓ Center line rumble strips are installed at or near the center line of an undivided roadway, and may be comprised of either a single or double line of rumbles. They reduce cross center line crashes such as head-on collisions and some run-off-road left crashes. ✓ Rumble stripes are either edge line or center line rumble strips where the pavement marking is placed over the rumble strip. This countermeasure increases nighttime visibility of the pavement marking.
SAFETY EDGE	The Safety Edge is a proven technology that shapes the edge of a paved roadway at approximately 30 degrees from the pavement cross slope during the paving process. The Safety Edge eliminates tire scrubbing, a phenomenon that contributes to losing control of a vehicle. It has been successfully constructed on both asphalt and concrete pavements. Consult the state DOT for standards for implementing the Safety Edge for asphalt or concrete paving projects without curbs.

Exhibit 12.5: FHWA-Recommended Crash Countermeasures (Continued)

CRASH COUNTERMEASURE	GUIDANCE
ENHANCED DELINEATION AND FRICTION FOR HORIZONTAL CURVES	Low-cost safety treatments vary by the severity of the curvature and the operating speed. Low-cost treatments typically include methods for warning the driver in advance of the curve, but treatments will vary by intensity of the warning. Implementing the recently published curve treatments included in the *MUTCD* should improve curve safety over past practices by providing consistency. However, additional enhancements can be made with post-mounted delineation in the curve or an enhanced signing treatment that may include larger chevron signs with enhanced retroreflectivity. For more challenging curves, dual indicated advance signs with constant flashing beacons may be effective. Pavement markings are also an effective communication tool to indicate the alignment change. Pavement friction is critical for changing vehicle direction and ensuring the vehicle remains in its lane. Traditional friction courses or high friction surface treatments should be considered for curves with numerous wet weather crashes or severe curves with higher operating speeds.
PEDESTRIAN HYBRID BEACON	The pedestrian hybrid beacon is a pedestrian-activated warning device located on the roadside or on mast arms over midblock pedestrian crossings. The beacon head consists of two red lenses above a single yellow lens. Pedestrian hybrid beacons should only be used in conjunction with a marked crosswalk. In general, they should be used if gaps in traffic are not adequate to permit pedestrians to cross, if vehicle speeds on the major street are too high to permit pedestrians to cross, or if pedestrian delay is excessive. Transit and school locations may be good places to consider using the pedestrian hybrid beacon.
ROAD DIETS (ROADWAY RECONFIGURATION)	A Road Diet typically involves converting an existing four-lane, undivided roadway segment to a three-lane segment consisting of two through lanes and a center, two-way left-turn lane. The resulting benefits include a crash reduction of 19 to 47 percent, reduced vehicle speed differential, improved mobility and access by all road users, and integration of the roadway into surrounding uses that results in an enhanced quality of life. A key feature of a Road Diet is that it allows reclaimed space to be allocated for other uses, such as turn lanes, bus lanes, pedestrian refuge islands, bike lanes, sidewalks, bus shelters, parking or landscaping.

Exhibit 12.5: FHWA-Recommended Crash Countermeasures (Continued)

CRASH COUNTERMEASURE	GUIDANCE
MEDIANS AND PEDESTRIAN CROSSING ISLANDS IN URBAN AND SUBURBAN AREAS	A median is an area between opposing lanes of traffic, excluding turn lanes. Medians in urban and suburban areas can either be open (pavement markings only) or they can be channelized (raised medians or islands) to separate various road users. A median is an area between opposing lanes of traffic, excluding turn lanes. Medians in urban and suburban areas can either be open (pavement markings only) or they can be channelized (raised medians or islands) to separate various road users. Pedestrian crossing islands (or refuge areas)—also known as center islands, refuge islands, pedestrian islands, or median slow points—are raised islands placed on a street at intersections or midblock locations to separate crossing pedestrians from motor vehicles. There are several types of medians and pedestrian crossing islands, and if designed and applied appropriately, they improve the safety benefits to both pedestrians and vehicles in the following ways: ✓ They may reduce pedestrian crashes by 46 percent and motor vehicle crashes by up to 39 percent. ✓ They may decrease delays (by greater than 30 percent) for motorists. ✓ They allow pedestrians a safe place to stop at the mid-point of the roadway before crossing the remaining distance. ✓ They enhance the visibility of pedestrian crossings, particularly at unsignalized crossing points. ✓ They can reduce the speed of vehicles approaching pedestrian crossings. ✓ They can be used for access management for vehicles (allowing only right-in/right-out turning movements). ✓ They provide space for supplemental signage on multi-lane roadways. Medians/refuge islands should be at least 4 feet wide (preferably 8 feet wide to accommodate pedestrian comfort and safety) and of adequate length to allow the anticipated number of pedestrians to stand and wait for gaps in traffic before crossing the second half of the street.

12.3.2.2. AASHTO-Recommended Improvements

AASHTO has developed the *Highway Safety Manual (HSM)* which introduces the science behind safety analysis and provides roadway improvements for multiple types of crash conditions. The manual has the following goals:

- ✓ Identifying sites with the most potential for crash frequency or severity reduction;
- ✓ Identifying factors contributing to crashes and associated potential countermeasures to address these issues;
- ✓ Conducting economic appraisals of potential improvements and prioritizing projects;
- ✓ Evaluating the crash reduction benefits of implemented treatments; and
- ✓ Estimating potential effects on crash frequency and severity of planning, design operations, and policy decisions.

12.4. IMPLEMENTATION OF A ROADWAY SAFETY IMPROVEMENT PLAN

KEY POINT

Form a Roadway Safety Committee to implement a safety improvement plan.

In order to improve roadway safety on military bases, it may be necessary to form a Safety Committee. The committee could then pinpoint specific safety needs, and develop a Roadway Safety Improvement Plan in order to address those needs. Exhibit 12.6 outlines the steps to formulating the plan.

Exhibit 12.6: Steps to Formulating a Safety Improvement Plan

STEP 1	✓ Each installation should have a Safety Committee consisting of a multi-disciplinary team. • Members should include planners, traffic engineers, installation police, safety personnel, offbase police, and pedestrian/bicycle coordinators. ✓ The purpose of the committee is to develop a base-wide Traffic Safety Plan and a Roadway Safety Plan. • The safety committee will also be responsible for implementing Roadway Safety Improvement Plans, as well as Temporary Traffic Control plans as needed.
STEP 2	✓ The Safety Committee should organize a safety audit on existing or proposed roadways, which will include an analysis of existing crash data.
STEP 3	✓ For the Roadway Safety Improvement Plan, the committee should then identify through the safety audit, areas with safety concerns (high crash areas) and determine the potential causes for the accidents in that area.
STEP 4	✓ The committee could then identify potential safety improvements, the cost of the improvements, and potential reduction in accidents due to those improvements (see AASHTO *Highway Safety Manual*).
STEP 5	✓ The committee should use this data to develop the Roadway Safety Improvement Plan which can either address general base-wide roadway safety issues, or can be more specific to address a particular issue.
STEP 6	✓ Implement the plan. • Many safety-related improvements are low cost. • Higher cost improvements can be phased for implementation.

12.5. FIELD ASSESSMENTS

KEY POINT

Field assessments by knowledgeable personnel are crucial to fully analyze problem areas.

A field assessment was conducted to discover a safety problem at the intersection of two local residential streets. The crash pattern was such that eastbound and southbound vehicles were colliding at right angles, and the number of crashes was excessive for the low volumes on the two streets.

A review of crash diagrams immediately revealed that the probable cause of many of these crashes was the poor corner visibility at the northwest corner. However, several hours of field observation uncovered the more likely cause—extremely poor corner visibility at the southwest corner was forcing eastbound drivers to place all of their attention in that direction as they crossed the intersection, thus ignoring the southbound traffic.

Direct field observation by knowledgeable personnel is one of the most neglected techniques for problem identification. Such problems as pedestrian interference and conflicts from driveways; visibility constraints that are not necessarily shown on a condition diagram; and driver behavior patterns are usually identified only by field observation.

Field observation is also very valuable in the study of possible geometric enhancements to improve traffic operations. For example, proper channelization can be established through the observance of actual vehicle movements. The scouring of pavement by tires often gives a good clue as to the “natural path” being followed by most drivers. These natural paths can be studied in the field or from aerial photos before geometric improvements are designed. Exhibit 12.7 shows typical contributing factors for crash patterns that can be identified through a field assessment. General countermeasures to eliminate the causes are also provided.

Exhibit 12.7: General Crash Pattern

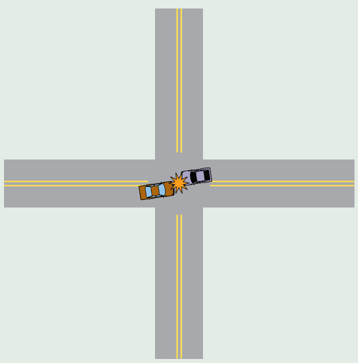
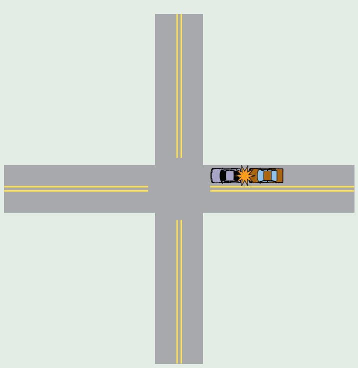
CRASH PATTERN	CONTRIBUTORY FACTOR	GENERAL COUNTERMEASURE
Left-turn head-on collisions 	✓ Large volume of left turns	✓ Create one-way street ✓ Widen road ✓ Provide left-turn signal phases ✓ Prohibit left turns ✓ Reroute left-turn traffic ✓ Channelize intersection ✓ Install STOP signs (see *MUTCD*) ✓ Revise signal sequence ✓ Provide turning guide lines (if there is a dual left-turn lane) ✓ Provide traffic signal if warranted by *MUTCD* ✓ Retime signals ✓ Add a roundabout
	✓ Restricted sight distance	✓ Remove obstacles ✓ Provide adequate channelization ✓ Provide special phase for left-turning traffic ✓ Provide left-turn lanes ✓ Install warning signs ✓ Reduce speed limit on approaches
	✓ Too short yellow phase	✓ Increase yellow intervals ✓ Provide all-red phase
	✓ Absence of special left-turning phase	✓ Provide special phase for left-turning traffic
	✓ Excessive speed on approaches	✓ Reduce speed limit on approaches
Rear-end collisions at unsignalized intersections 	✓ Driver not aware of intersection	✓ Install/improve warning signs
	✓ Slippery surface	✓ Overlay pavement ✓ Provide adequate drainage ✓ Groove pavement ✓ Reduce speed limit on approaches ✓ Provide Slippery When Wet signs
	✓ Large volume of turning vehicles	✓ Create left- and right-turn lanes ✓ Prohibit turns ✓ Increase curb radii
	✓ Inadequate roadway lighting	✓ Improve roadway lighting

Exhibit 12.7: General Crash Pattern (Continued)

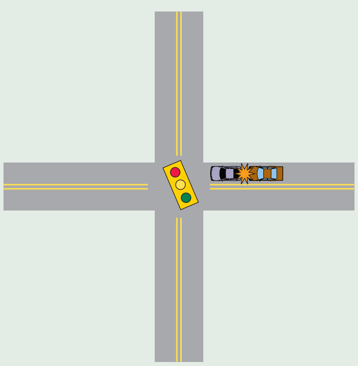
CRASH PATTERN	CONTRIBUTORY FACTOR	GENERAL COUNTERMEASURE
Rear-end collisions at unsignalized intersections (continued)	✓ Excessive speed on approaches	✓ Reduce speed limit on approaches
	✓ Inadequate gaps	✓ Provide traffic signal, if warranted by *MUTCD* ✓ Provide STOP signs ✓ Add a roundabout
	✓ Crossing pedestrians	✓ Install/improve signing or marking of pedestrian crosswalks
Rear-end collisions at signalized intersections 	✓ Slippery surface	✓ Overlay pavement ✓ Provide adequate drainage ✓ Groove pavement ✓ Reduce speed limit on approaches ✓ Provide Slippery When Wet signs
	✓ Large volume of turning vehicles	✓ Create left- and right-turn lanes ✓ Prohibit turns ✓ Increase curb radii ✓ Provide special phase for left-turning traffic ✓ Add a roundabout
	✓ Poor visibility of signals	✓ Install/improve advance warning devices ✓ Install overhead signals ✓ Install 12-inch signal lenses ✓ Install visors ✓ Install backplates ✓ Relocate signals ✓ Add additional signal heads ✓ Remove obstacles ✓ Reduce speed limit on approaches
	✓ Inadequate signal timing	✓ Adjust yellow interval ✓ Provide progression through a set of signalized intersections ✓ Add all-red clearance interval
	✓ Unwarranted signals	✓ Remove signals (see *MUTCD*)
	✓ Inadequate roadway lighting	✓ Improve roadway lighting
	✓ Crossing pedestrians	✓ Install/improve signing or marking of pedestrian crosswalks ✓ Provide pedestrian WALK phase

Exhibit 12.7: General Crash Pattern (Continued)

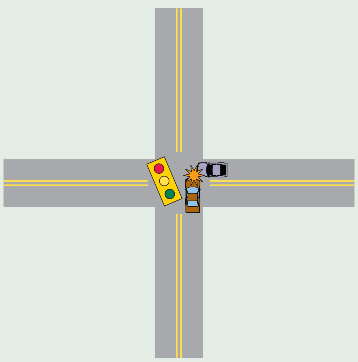
CRASH PATTERN	CONTRIBUTORY FACTOR	GENERAL COUNTERMEASURE
Right-angle collisions at signalized intersections 	✓ Restricted sight distance	✓ Remove sight obstructions ✓ Restrict parking near corners ✓ Install warning signs (see *MUTCD*) ✓ Reduce speed limit on approaches ✓ Channelize intersections ✓ Install advance markings to supplement signs
	✓ Excessive speed on approaches	✓ Reduce speed limit on approaches ✓ Increase yellow interval ✓ Install rumble strips ✓ Add a roundabout
	✓ Poor visibility of signal	✓ Install advance warning devices ✓ Install 12-inch signal lenses ✓ Install overhead signal ✓ Install visors ✓ Install backplates ✓ Improve location of signal heads ✓ Add additional signal heads ✓ Add illuminated street name signs
	✓ Inadequate signal timing	✓ Adjust yellow interval ✓ Provide all-red clearance interval ✓ Install actuated signal controller ✓ Retime signals ✓ Provide progression through a set of signalized intersections
	✓ Inadequate roadway lighting	✓ Improve roadway illumination
	✓ Inadequate intersection advance warning signs	✓ Install additional intersection advance warning signs
	✓ Large intersection volume	✓ Retime signals ✓ Add traffic lane

Exhibit 12.7: General Crash Pattern (Continued)

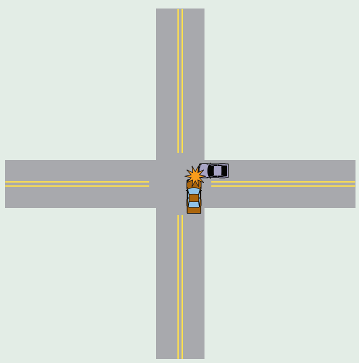
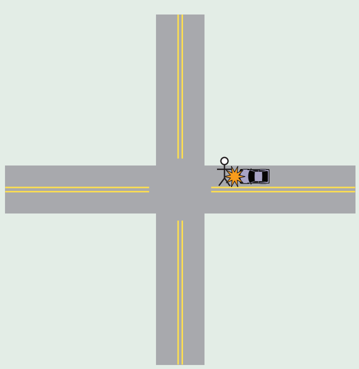
CRASH PATTERN	CONTRIBUTORY FACTOR	GENERAL COUNTERMEASURE
Right-angle collisions at unsignalized intersections 	✓ Restricted sight distance	✓ Remove sight obstructions ✓ Restrict parking near corners ✓ Install STOP signs (see *MUTCD*) ✓ Install warning signs (see *MUTCD*) ✓ Reduce speed limit on approaches ✓ Install signal (see *MUTCD*) ✓ Install YIELD signs (see *MUTCD*) ✓ Channelize intersection ✓ Install advance markings to supplement signs ✓ Install limit lines ✓ Add a roundabout
	✓ Large intersection volume	✓ Install signal (see *MUTCD*) ✓ Reroute through traffic
	✓ Excessive speed on approaches	✓ Reduce speed limit on approaches ✓ Increase yellow interval ✓ Install rumble strips
	✓ Inadequate roadway lighting	✓ Improve roadway illumination
	✓ Inadequate intersection advance warning signs	✓ Install intersection advance warning signs
	✓ Inadequate traffic control devices	✓ Upgrade traffic control devices ✓ Increase enforcement
Pedestrian-vehicular collisions 	✓ Restricted sight distance	✓ Remove sign obstructions ✓ Install pedestrian crossings ✓ Install/improve pedestrian crossing signs ✓ Reroute pedestrian paths ✓ Prohibit curb parking near crosswalks
	✓ Inadequate protection for pedestrians	✓ Add pedestrian refuge islands ✓ Install pedestrian barriers
	✓ School crossings	✓ Use guards at school crossings
	✓ Inadequate signals	✓ Install pedestrian signals (see *MUTCD*)
	✓ Inadequate phasing for signal	✓ Change timing of pedestrian phase
	✓ Driver inadequately warned of frequent mid-block crossings	✓ Prohibit parking ✓ Install warning signs ✓ Lower speed limit ✓ Install pedestrian barriers

Exhibit 12.7: General Crash Pattern (Continued)

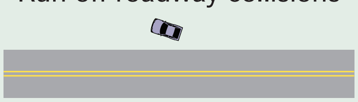
CRASH PATTERN	CONTRIBUTORY FACTOR	GENERAL COUNTERMEASURE
Pedestrian-vehicular collisions (continued)	✓ Inadequate pavement markings	✓ Install thermoplastic markings ✓ Supplement markings with appropriate signing (see *MUTCD*) ✓ Upgrade pavement markings (see *MUTCD*)
	✓ Inadequate gaps at unsignalized intersections	✓ Install traffic signal, if warranted (see *MUTCD*) ✓ Install pedestrian crosswalk and signs ✓ Install pedestrian WALK-DONT WALK signals
	✓ Inadequate roadway lighting	✓ Improve road lighting
	✓ Excessive vehicle speed	✓ Reduce speed limit ✓ Install proper warning signs ✓ Install pedestrian barriers ✓ Use enforcement
Run off roadway collisions 	✓ Slippery pavement	✓ Overlay existing pavement ✓ Provide adequate drainage ✓ Groove existing pavement ✓ Reduce speed limit ✓ Provide Slippery When Wet signs
	✓ Roadway design inadequate for traffic conditions	✓ Widen lanes ✓ Relocate islands ✓ Close curb lanes ✓ Install guardrails
	✓ Poor delineation	✓ Improve/install pavement markings ✓ Install roadside delineations ✓ Install advance warning signs
	✓ Inadequate roadway lighting	✓ Improve roadway lighting
	✓ Inadequate shoulders	✓ Upgrade roadway shoulders
	✓ Improper channelization	✓ Improve channelization
	✓ Inadequate pavement maintenance	✓ Perform road surface repair
	✓ Poor visibility	✓ Increase size of signs
	✓ Excessive speed on approaches	✓ Reduce speed limit

Exhibit 12.7: General Crash Pattern (Continued)

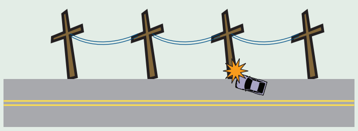
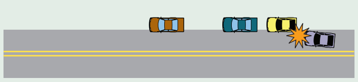
CRASH PATTERN	CONTRIBUTORY FACTOR	GENERAL COUNTERMEASURE
Fixed object collisions 	✓ Obstructions in or too close to roadway	✓ Remove obstacles ✓ Install barrier curbing ✓ Install breakaway features to light poles, signposts, and so forth ✓ Protect objects with guardrail ✓ Install crash cushioning devices
	✓ Inadequate roadway lighting	✓ Improve roadway lighting
	✓ Inadequate pavement marking	✓ Install reflectorized pavement lines
	✓ Inadequate signs, delineators, and guardrails	✓ Install reflectorized paint and/or reflectors on the obstruction
	✓ Inadequate road design	✓ Provide proper superelevation ✓ Improve superelevation at curve ✓ Install appropriate warning signs and delineators
	✓ Slippery surface	✓ Improve skid resistance ✓ Provide adequate drainage ✓ Provide Slippery When Wet signs ✓ Groove existing pavement
	✓ Excessive vehicle speed	✓ Reduce speed limit ✓ Use enforcement
Collisions with parked or parking vehicles 	✓ Improper pavement markings	✓ Stripe per recommended standards
	✓ Improper parking clearance at driveways	✓ Post parking restrictions near driveways
	✓ Angle parking	✓ Convert angle parking to parallel parking
	✓ Excessive vehicle speed	✓ Reduce speed limit if justified by spot speed studies
	✓ Illegal parking	✓ Use enforcement
	✓ Improper parking	✓ Prohibit parking ✓ Create off-street parking
	✓ Large parking turnover	✓ Create one-way streets ✓ Reroute through traffic

Exhibit 12.7: General Crash Pattern (Continued)

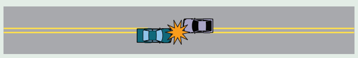
CRASH PATTERN	CONTRIBUTORY FACTOR	GENERAL COUNTERMEASURE
Sideswipe or head-on collisions 	✓ Inadequate roadway design	✓ Create one-way streets and provide wider lanes
	✓ Improper road maintenance	✓ Perform necessary road surface repairs
	✓ Inadequate shoulders	✓ Improve shoulders
	✓ Excessive vehicle speed	✓ Reduce speed limit ✓ Install median devices ✓ Remove constriction such as parked vehicles
	✓ Inadequate pavement markings	✓ Install or refurnish center lines, lane lines, and pavement edge lines ✓ Install reflectorized lines and edges
	✓ Inadequate channelization	✓ Install acceleration and deceleration lanes ✓ Channelize intersection ✓ Provide turning lanes
	✓ Inadequate signing	✓ Add illuminated street name signs ✓ Add advance street name signs ✓ Install lane use control signs at the beginning of turn lanes

Exhibit 12.7: General Crash Pattern (Continued)

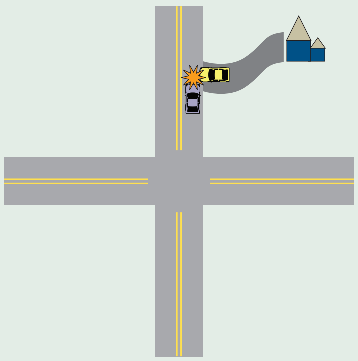
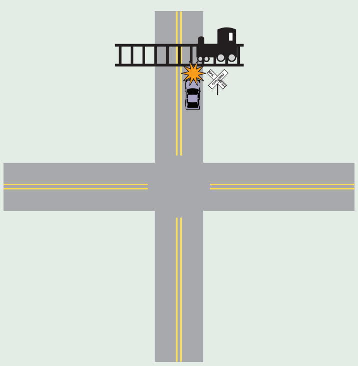
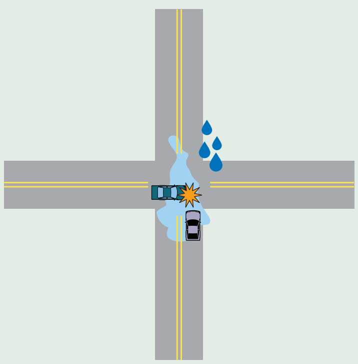
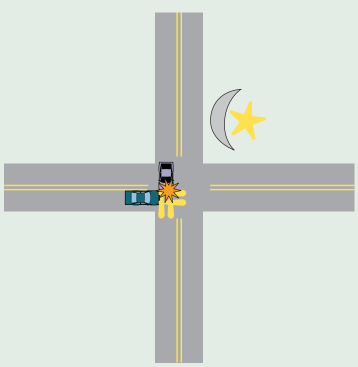
CRASH PATTERN	CONTRIBUTORY FACTOR	GENERAL COUNTERMEASURE
Driveway-related collisions 	✓ Left-turning vehicles	✓ Install median devices ✓ Install two-way left-turn lanes
	✓ Improperly located driveway	✓ Regulate minimum spacing of driveways ✓ Move driveway to side street ✓ Install curbing to define driveway location ✓ Consolidate adjacent driveways
	✓ Right-turning vehicles	✓ Provide right-turn lanes ✓ Restrict parking near driveways ✓ Widen driveways ✓ Widen through lanes ✓ Increase curb radii
	✓ Large volume of through traffic	✓ Move driveway to side street ✓ Construct a local service road ✓ Reroute through traffic
	✓ Restricted sight distance	✓ Remove sight obstructions ✓ Restrict parking near driveway ✓ Install/improve street lighting ✓ Reduce speed limit
	✓ Inadequate roadway lighting	✓ Improve roadway lighting
Train-vehicle crashes 	✓ Restricted sight distance	✓ Remove sight obstructions ✓ Reduce grade ✓ Install train-actuated signals (see *MUTCD*) ✓ Install STOP sign (see *MUTCD*) ✓ Install advance warning signs (see *MUTCD*) ✓ Install automated flashers and gates
	✓ Poor visibility	✓ Improve roadway lighting ✓ Increase size of signs
	✓ Improper traffic signal preemption timing	✓ Retime traffic signals
	✓ Excessive vehicle speeds on approaches	✓ Revise speed limit

Exhibit 12.7: General Crash Pattern (Continued)

CRASH PATTERN	CONTRIBUTORY FACTOR	GENERAL COUNTERMEASURE
Train-vehicle crashes (continued)	✓ Inadequate pavement markings	✓ Install advance markings to supplement signs ✓ Install limit lines ✓ Install/improve pavement markings
	✓ Slippery surface	✓ Skidproof roadway
	✓ Improper preemption of railroad signals or gates	✓ Retime railroad signals and gates
	✓ Rough crossing surfaces	✓ Improve crossing surfaces
	✓ Sharp crossing angle	✓ Rebuild crossing with proper angle
Wet-pavement crashes 	✓ Slippery pavement	✓ Overlay existing pavement ✓ Groove existing pavement ✓ Reduce speed limit ✓ Provide Slippery When Wet signs ✓ Skidproof roadway
	✓ Inadequate drainage	✓ Provide adequate drainage
	✓ Inadequate pavement markings	✓ Upgrade pavement markings
Night crashes 	✓ Poor visibility or lighting	✓ Install/improve street lighting ✓ Install/improve delineation markings ✓ Install/improve warning signs
	✓ Poor sign quality	✓ Upgrade signing ✓ Provide illuminated signs
	✓ Inadequate channelization or delineation	✓ Install pavement markings ✓ Improve delineation markings ✓ Provide raised markers ✓ Upgrade advance warning signs

12.6. BICYCLE SAFETY

Bicycles are vehicles and are able to travel on a wide variety of roadway types. It should be assumed that bicyclists will want to ride, and plans should be made to accommodate them on new infrastructure or renovation projects. The Federal Highway Administration (FHWA) has encouraged routine accommodation for bicyclists (and pedestrians) for many years, and the concept has been embraced by many state and local departments of transportation (DOTs).

Bicycling can be encouraged by reallocating space on existing streets that bicyclists are known to frequent. This could involve removing parking, narrowing travel lanes to slow motor vehicle speeds, and using the space added from lane narrowing to accommodate bike lanes, paved shoulders, or wide curb lanes.

Often there is an opportunity to integrate bicycle facilities into the site design. For example, roadway shoulder should be paved and designed to be wide enough to accommodate a potentially striped bike lane. The normally accepted roadway shoulder width to accommodate bicycle travel is four feet. As a short term method in locations where bicycle accommodation is desired, shoulders can be evaluated to ensure that their condition is such that bike travel is safe and that cyclists can expect some measure of protection from traffic resulting from distance from the travel lanes. Pavement markings to designate bike lanes add a measure of safety by serving as a visual deterrent for motorists and defining roadway space identified for cyclists. The minimum width required to provide a bike lane in both directions on a 2-lane roadway is 32 feet. This would allow for two 12-foot lanes and two 4-foot shoulders. If at least 28 feet is available, a bike lane could be provided in one direction; however, there is the potential that some bicyclists would use this lane traveling against the direction of traffic, which would be hazardous.

Design Guidance

AASHTO's Guide for the Development of Bicycle Facilities provides these guidelines for accommodating bicyclists on shared roadways:

- ✓ Shoulders may be used where provided. Shoulders should be paved with a minimum desirable width of four feet, or five feet where there is a guardrail, curb, or other longitudinal barrier. If significant bicycle traffic is expected, shoulders should be wider.
- ✓ In urban areas, a wide curb lane, 14 feet, can be provided in the absence of a shoulder.
- ✓ Where on-street parking exists, 12 feet for combined bicycle travel and parking width should be provided.
- ✓ Provide bicycle-safe inlets
- ✓ Ensure that traffic signal detection is also designed for bicycles.

Additionally, FHWA's publication: Bicycle Road Safety Audit Guidelines and Prompt Lists (http://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa12018/) can be used to assess bicycle facilities.

Bike Share Programs

Bike share programs are not really new but have not received much publicity. Cities such as Hoboken, NJ; Washington, D.C.; and Boulder, CO have used these programs with success. The way the program works differs in each city, but the basic concept is that people can use bicycles for free or for a small charge at various pick-up and drop-off points. The concept could work on military bases as well.

CHAPTER 13—PEDESTRIAN SAFETY

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CHAPTER 13—PEDESTRIAN SAFETY

KEY POINT

Pedestrian crashes are of particular concern and can best be reduced through engineering, education, and enforcement.

Crosswalk example

According to FHWA traffic safety statistics for 2013, 4,675 pedestrian fatalities occurred nationwide. This represents 14 percent of total fatalities occurring in crashes in 2013. On average, a pedestrian is killed every 2 hours, and injured every 8 minutes in traffic crashes. More crashes fatal to pedestrians occurred at non-intersections (69%) than at intersections (20%). More occurred in the dark (72%) than in daylight (25%), dawn (2%), and dusk (2%). More occurred in urban areas (73%) than rural areas (27%). The average age of pedestrians killed in traffic crashes was 46. The estimated average age of those injured in traffic crashes was 36. More than two-thirds (3,247 of 4,735 or 69%) of the pedestrians killed in traffic crashes were males.

13.1. SIDEWALKS

KEY POINT

Provide sidewalks along any roadway that does not have shoulder.

Sidewalks are one of the most basic forms of pedestrian accommodations. Sidewalks are generally used significantly more in urban areas than in rural areas. Built-up portions of military bases generally have an urban feel. More open areas of bases have a rural feel. Therefore, there are areas on bases where sidewalks are more appropriate versus where they may not be necessary. As a general rule, provide sidewalks anywhere along a roadway that does not have shoulder, regardless of pedestrian demand. If there are two separate areas on a base located close to each other which generate significant pedestrian traffic, they should be connected by sidewalk or other pedestrian walking facility. Worn paths adjacent to a roadway are an indication of pedestrian demand. Such locations generally indicate the need for sidewalk.

Sidewalk width can vary from four feet to eight feet, depending on pedestrian demand. For ADA reasons, if a four-foot wide sidewalk is used, a 5-foot by 5-foot wheelchair passing area must be provided every 200 feet. Provide some form of a buffer between the roadway and the sidewalk. This can be a planted strip or curb. If the sidewalk is adjacent to the roadway curb, provide an additional two-feet of sidewalk width.

When locating sidewalk, locate it with respect to the adjacent roadway, not with respect to a building. For example, if sidewalk is being added in conjunction with a building project, the sidewalk should be located such that it clearly appears to be a sidewalk intended for all pedestrians, versus a pedestrian access to the building.

When placing sidewalk, it should be continuous. Sidewalks should not have gaps. For example, a case where sidewalk is provided in front of one building and not in front of an adjacent building is not desirable. When sidewalk ends, end it at a logical location that is ADA compliant.

Worn path indicates need for sidewalk

Example of undesirable sidewalk termination

13.1.1. PT Accommodations

Physical Training (PT) is a key part of military training. PT is frequently performed during morning hours, which frequently coincides with peak vehicular traffic. This results in an increased potential for vehicle-pedestrian conflicts if conditions are not favorable. The ideal location for PT is on sidewalks, as opposed to roadways. When planning for PT routes, it is ideal to have routes that travel adjacent to barracks buildings. This reduces the need for personnel to drive to PT locations. Exhibit 13.1 summarizes preferred PT locations in order of preference.

Exhibit 13.1: Preferred PT Locations, by order of preference

LOCATION	CONSIDERATIONS
1. Sidewalk	Sidewalks are generally located in built-up parts of a base. Barracks are also generally located in built-up parts of a base. If PT routes are located on sidewalks, it may eliminate the need to drive to PT.
2. Jogging/walking trails	Trails should be used to keep PT routes away from roadways. This is advantageous because it minimizes vehicle-pedestrian conflicts.
3. Low-volume roadways	If roadways are used for PT, they should be low-volume roads which can be closed to vehicular traffic. Station crossing guards at cross roads in order to maximize awareness of pedestrian traffic by vehicular traffic.
4. Moderate Volume Roadways	If roadways with higher traffic volumes are used, it is preferred for the safety of troops to close the roadway. If this is not possible, post a low speed limit which applies when troops are present. Also, use flaggers or even a vehicular escort to clearly indicate the presence of troops on the roadway.
5. High Volume Roadway	PT routes located on high volume roadways is not recommended. If key roadways through an installation are closed to traffic, particularly in the morning peak period, adjacent roadways, often lower classification, must accommodate the diverted traffic. This results in degraded traffic operations.

13.1.2. Pedestrian-Related ADA Considerations

KEY POINT

If you cannot meet PROWAG standards, contact SDDCTEA.

The Americans with Disabilities Act of 1990 (ADA) is a major civil rights law that prohibits discrimination against persons with disabilities and sets design requirements for construction or alteration of facilities. It applies to state and local government and private sector facilities. The Department of Justice and Department of Transportation maintain standards under the ADA.

It is the goal of the Department of Defense (DoD) to make its facilities accessible to persons with disabilities. To achieve that goal, the Department intends to go beyond the minimum requirements of law. Even if a facility is exempt from coverage under the Architectural Barriers Act of 1968 (ABA), compliance with the standards identified in this memorandum is recommended to the maximum extent that is reasonable and practicable without degrading the facility's military utility.

Source: DEPUTY SECRETARY OF DEFENSE; 10-31-2008: http://www.access-board.gov/ada-aba/dod-memorandum.htm.

The Architectural Barriers Act of 1968 (ABA) requires that buildings and facilities that are designed, constructed, or altered with Federal funds, or leased by a Federal agency, comply with Federal standards for physical accessibility. The ABA applies to Federal facilities including those on military installations. The DoD maintains standards under the ABA.

Per the October 31, 2008 Deputy Secretary of Defense (DepSECDEF) Memo, Subject: Access for People with Disabilities, the DoD accessibility standards are based on the 2004 "Americans with Disabilities Act and Architectural Barriers Act Accessibility Guidelines" (ADA-ABA Guidelines) developed by the U.S. Access Board (http://www.access-board.gov/ada-aba/final.pdf). Specifically, DoD's adopted standards are included in ABA Chapters 1 and 2, and Chapters 3 through 10 of the guidelines, which specify what has to be accessible and how to achieve access. Although ADA-ABA are written as guidelines, the October 31, 2008 DepSECDEF Memo states that the ADA-ABA Guidelines are adopted by the DoD. Therefore, since DoD adopted the guidelines, they are now standards with which DoD must comply.

In an effort to address design elements found in public rights-of-way and not covered by the ADA and ABA guidelines, the United States Access Board published "Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way" (PROWAG) in July 2011 and provided a public comment period. SDDCTEA recommends that DoD installations utilize the PROWAG for transportation elements (such as sidewalks along roadways and parking lots), in addition to Unified Facilities Criteria (UFC) 3-201-01 Civil Engineering.

According to the ADA "All new construction and modifications must be accessible to individuals with disabilities. For existing facilities, barriers to services must be removed if readily achievable."

According to "Designing Sidewalks and Trails for Access" published by the FHWA, the type of provisions needed vary by location. Different types of curb ramps are needed at sidewalks and crosswalk locations.

Detectable warning surfaces must also be provided at the road edge in order to give blind pedestrians the message that they are about to enter a roadway. The detectable warning surface must differ in color from the sidewalk, must be at least two feet deep measured parallel to the direction of the sidewalk, and should not be diagonal to the crosswalk.

In addition to the detectable warning surface, a turning space at least 4-foot by 4-foot intended for wheelchair mobility is to be provided at the top of the ramp. The maximum cross-slope of this 'landing area' should be no greater than two percent, the minimum for drainage.

At signalized intersections where pedestrian push buttons are used, it must be located no greater than 10 inches from the landing area. Sometimes, in order to achieve this, pedestrian push button stub poles are needed. The pedestrian push button should be mounted at 42 inches from the elevation of the sidewalk. These features are illustrated in the photo on the following page.

Examples of common deficiencies related to detectable warning surfaces are shown in Exhibit 13.2.

Pedestrian Features at Signalized Intersections

Exhibit 13.2: Detectable Warning Surface Examples

	Crosswalk lacks curb ramps.
	Detectable warning surface is diagonal to the crosswalks. This alignment directs the pedestrian into the center of the intersection.
	Detectable warning surface not adjacent to roadway.
	Correctly designed curb ramps.

In general, when designing for ADA, Exhibit 13.3 shows several design considerations.

Exhibit 13.3: ADA Design Considerations

DESIGN ELEMENT	ADA CONSIDERATIONS
Sidewalks	✓ Firm, stable, and slip resistant ✓ Separated from travel lanes ○ Curbs ○ Planting strips ○ Other barriers ○ Should be out of clear zone ✓ 2% maximum cross slope ✓ Preferred width of 60 inches, but if not possible, provide 48 inch minimum width, with 60 inch by 60 inch passing zone provided every 200 feet. ✓ Maximum grade is the higher of 5% or the grade of the adjacent street
Curb Ramps	✓ 8.3% maximum gradient ✓ 11% maximum change in gradient ✓ Toe of curb must be flush with pavement ✓ Detectable warning surface required at ramp / roadway interface, 24 inches in length for the entire width of the ramp. ✓ $15 to $35 per square foot
Turning Space (Ramp Landings)	✓ Needed at changes in direction ✓ Minimum 4' x 4' (5' x 5' desirable) ✓ 2% max cross-slope in all directions
Traffic Signals	✓ Where pedestrian activity is frequent or where pedestrian timing requirements do not impact traffic operations, pedestrian phases should be displayed without requiring activation. ✓ At locations where pedestrian activity is infrequent and pedestrian phasing is not warranted at all times, the use of pedestrian push buttons may be justified. ✓ Pedestrian signals are required for all new signals ✓ Accompanied by signage explaining their purpose and use ✓ Push buttons must be accessible ○ Firm, stable, slip resistant landing - 4' x 4' - 2% max cross slope ○ 10" maximum reach ○ 42" mounting height ○ 10' maximum distance from waiting area ✓ Accommodation for the visually impaired as warranted, to include accessible pedestrian signals which emit audible tones.

13.2. PEDESTRIAN CRASH MITIGATION

ITE recognizes that reduction of pedestrian crashes can only be accomplished through engineering, education, and enforcement; otherwise known as the 3 E's. The 3 E's are interrelated and only successful if all three are addressed.

Stop for Pedestrians

Engineering and Maintenance

It is the engineering and maintenance staff's responsibility to provide the appropriate pedestrian accommodations and to ensure that these accommodations are properly maintained.

Education

Education of motorists and pedestrians alike can help ensure that everyone understands their responsibilities. A common method to educate motorists and pedestrians is through periodic articles or ads in installation newspapers. Additionally, school-based education campaigns can promote pedestrian safety to children. The FHWA Web site is an excellent source of free educational sources, located at http://safety.fhwa.dot.gov/ped_bike/ped_cmnity/ped_walkguide/ch3_edu.cfm.

Enforcement

Proper enforcement can ensure compliance with laws and traffic control devices. Because Security Forces' responsibilities are numerous, their ability to routinely patrol crosswalk compliance is limited. However, even occasional (once a month) enforcement will result in improved compliance.

Pedestrian crashes are of particular concern and can best be reduced through engineering, education, and enforcement.

13.3. PEDESTRIAN-VEHICLE RIGHT-OF-WAY

> **KEY POINT**
>
> Vehicles shall yield to pedestrians in a crosswalk, but pedestrians shall not enter the path of a vehicle to constitute an immediate hazard.

The Uniform Vehicle Code and Model Traffic Ordinances is the model traffic ordinance for most states; however, each state may have its own traffic ordinances, which may vary. The traffic model ordinance states that pedestrians have certain rights and duties.

So what does that mean? Regarding unsignalized crosswalks, both drivers and pedestrians have responsibilities. The driver must yield to pedestrians; however, pedestrians should use caution when entering crosswalks. At unmarked, non-intersection locations, the pedestrian should always yield to motorists. State codes may vary; therefore, consult your state's vehicle code for exact language.

EXCERPT FROM ARTICLE V—PEDESTRIAN'S RIGHTS AND DUTIES

11-502-Pedestrians' right-of-way in crosswalks

(a) When traffic-control signals are not in place or not in operation, the driver of a vehicle shall yield the right-of-way, slowing down or stopping if need be to yield to a pedestrian crossing the roadway within a crosswalk when the pedestrian is upon the half of the roadway upon which the vehicle is traveling, or when the pedestrian is approaching so closely from the opposite half of the roadway as to be in danger.

(b) No pedestrian shall suddenly leave a curb or other place of safety and walk or run into the path of a vehicle which is so close as to constitute an immediate hazard.

11-503-Crossing at other than crosswalks

(a) Every pedestrian crossing a roadway at any point other than within a marked crosswalk or within an unmarked crosswalk at an intersection shall yield the right-of-way to all vehicles upon the roadway.

(b) Any pedestrian crossing a roadway at a point where a pedestrian tunnel or overhead pedestrian crossing has been provided shall yield the right-of-way to all vehicles upon the roadway.

(c) Between adjacent intersections at which traffic-control signals are in operation pedestrians shall not cross at any place except in a marked crosswalk.

(d) No pedestrian shall cross a roadway intersection diagonally unless authorized by official traffic-control devices; and when authorized to cross diagonally, pedestrians shall cross only in accordance with the official traffic-control devices pertaining to such crossing movements.

Source: Uniform Vehicle Code and Model Traffic Ordinances

13.4. CROSSWALKS

What is a crosswalk?

A crosswalk is the connection of two sidewalks or designated pedestrian crossing across a roadway.

Crosswalks serve the purpose of collecting pedestrians into one location, and encouraging platoons of pedestrian crossings at that location.

Definition: The *MUTCD* defines the term Crosswalk: (a) that part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or in the absence of curbs, from the edges of the traversable roadway, and in the absence of a sidewalk on one side of the roadway, the part of a roadway included within the extension of the lateral lines of the sidewalk at right angles to the center line; (b) any portion of a roadway at an intersection or elsewhere distinctly indicated as a pedestrian crossing by pavement marking lines on the surface, which might be supplemented by contrasting pavement texture, style, or color.

Where should crosswalks be used?

Crosswalks should not be used where speeds exceed 45 mph at unsignalized intersections, and where sight distance is not adequate. Generally, crosswalks should be marked based on the following guidelines:

- ✓ All signalized intersections with pedestrian signal heads;
- ✓ All locations where a school crossing guard is normally stationed to assist children in crossing the street; and
- ✓ All intersections and mid-block crossings satisfying minimum vehicle and pedestrian volume guidelines.

Crosswalks are essentially implied at intersections, even when not marked. The most likely location for a pedestrian to cross is at an intersection.

What about mid-block crosswalks?

The use of marked mid-block crosswalks is highly debated on military installations. Some proponents argue that marked mid-block crosswalks enhance safety while others argue that they give pedestrians a false sense of security. When developing plans for new facilities, avoid situations such as locating the primary parking area on the opposite side of a busy street. Also, marking mid-block crosswalks at every location where pedestrians cross results in disrespect of crosswalks, including those that truly are warranted.

Should marked or unmarked crosswalks be used?

FHWA published a study entitled Safety Effects of Marked vs Unmarked Crosswalks at Uncontrolled Locations (www.tfhrc.gov/safety/pubs/04100/04100.pdf). The study results reveal that under no condition was the presence of a marked crosswalk alone (absent of other improvements including signing, special pavement, flashing lights, or geometric improvement) at an uncontrolled location associated with a significantly lower pedestrian crash rate, as compared to an unmarked crosswalk.

However, the study notes that this is not justification to do nothing. Pedestrian needs in crossing streets should routinely be identified and appropriate solutions should be selected to improve pedestrian safety and access. In some cases crosswalks should be marked in association with other improvements.

13.4.1. Crosswalks at Midblock Locations and on Uncontrolled Approaches to Intersections

Crosswalk lines legally define a crosswalk and should not be used indiscriminately. An engineering study should be performed before they are installed at uncontrolled locations. Uncontrolled refers to the absence of traffic control (yield, stop or signals) on the approach to a crosswalk. This section provides criteria for marking a pedestrian crossing at a midblock location or on an uncontrolled approach to an intersection. If warrants are met and a crosswalk is marked, additional enhancements will be required. Warrants and recommended enhancements, within this document, apply to school zones; however, refer to Part 7 of the *MUTCD* for specific signs to use at school crosswalks.

For a proposed crosswalk at a midblock or on an uncontrolled approach to an intersection, the following two criteria shall be satisfied in conjunction with the proposed marked crosswalk:

- ✓ The crosswalk shall provide adequate sight distance; to include vertical, horizontal, and intersection stopping sight distance.
- ✓ The crosswalk shall not cross any part of an auxiliary lane and its transition. Auxiliary lanes include left turn, right turn, acceleration and deceleration lanes. Two-way left-turn lanes are not considered auxiliary lanes.

Locations being considered for a crosswalk (midblock or an uncontrolled approach to an intersection) should have a minimum level of traffic and pedestrian volumes. All of the following four criteria should be satisfied prior to installation:

- ✓ Location of midblock crossings should be a minimum of 300 feet (200 feet with an engineering study) from any controlled intersection (all-way signal/stop/yield control or pedestrian overpass).
- ✓ Pedestrian crossing volumes should meet one of the following conditions:
  - 20 pedestrians in an hour, or
  - 15 elderly, disabled and/or children in an hour, or
  - 60 pedestrians total for the highest consecutive pedestrian 4-hour period.

  Pedestrian counts should only include pedestrians crossing within 100 feet either side of the proposed crosswalk location in an attempt to capture only potential users of the proposed crosswalk.
- ✓ The two-way traffic volume should meet the minimum of 1500 vehicles for the average daily traffic (ADT) or 150 vehicles in the pedestrian count hour.
- ✓ The current pedestrian crossing is not due to a correctable gap in the sidewalk system.

After determination is made that a crosswalk is warranted, Exhibit 13.4 provides enhancements that should be added when a crosswalk at a midblock or an uncontrolled approach to an intersection is implemented. The enhancements contained in Exhibit 13.4 are for guidance purposes and should be applied with engineering judgment. Major improvements, such as pedestrian hybrid beacons and pedestrian signals, must meet *MUTCD* guidelines and warrants; and be justified by an engineering study.

> As an example, if it is determined that an uncontrolled/midblock crosswalk is warranted, review Exhibit 13.4 for the given vehicle volume and roadway configuration to determine the number of the applicable **SDDCTEA-developed** drawing. All drawings (14 total) have been included in subsequent sections of this chapter based upon the recommended improvements.

Exhibit 13.4: Guidelines for Enhancements of Crosswalks at Midblock Locations and on Uncontrolled Approaches to Intersections

X = Required Treatment ✔ = Recommended Treatment	Vehicle Volume 1,500 ≤ ADT ≤ 12,000 OR 150 ≤ 1-Hour Volume ≤ 1,200												Vehicle Volume ADT > 12,000 OR 150 1-Hour Volume > 1,200											
	2-Lanes Two-Way			3-Lanes Two-way (TWLTL)			≥ 4-Lanes Divided With Raised Median			≥ 4-Lanes Undivided			2-Lanes Two-Way			3-Lanes Two-way (TWLTL)			≥ 4-Lanes Divided With Raised Median			≥ 4-Lanes Undivided		
Enhancement Type	≤ 30 mph	35 mph	≥ 40 mph	≤ 30 mph	35 mph	≥ 40 mph	≤ 30 mph	35 mph	≥ 40 mph	≤ 30 mph	35 mph	≥ 40 mph	≤ 30 mph	35 mph	≥ 40 mph	≤ 30 mph	35 mph	≥ 40 mph	≤ 30 mph	35 mph	≥ 40 mph	≤ 30 mph	35 mph	≥ 40 mph
Pavement Marking																								
Crosswalk Marking: Section 3B.18	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Added Visibility Crosswalk Marking: Section 3B.18, Para 13									✔			✔			✔		✔	✔	✔	✔	✔	✔	✔	✔
Signing and Lighting																								
Pedestrian Crossing (W11-2) warning sign W/Downward Diagonal Arrow (W16-7P) Plaque: Section 2C.50	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Yield Here To (Stop Here For) Pedestrians (R1-5, R1-5a, R1-5b, or R1-5c) signs with Yield (Stop) Line marking: Section 2B.11 & 3B.16 (Yield or Stop scenario is dictated by local state law)							✔	✔	✔	✔	✔	✔							✔	✔	✔	✔	✔	✔
An advance Pedestrian Crossing (W11-2) warning sign with Ahead (W16-9P) plaque: Section 2C.50			✔			✔			✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Lighting	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Midblock Drawing #	1	1	2	1	1	2	3	3	4	4	4	4	2	2	2	2	2	2	4	4	4	4	4	4
Uncontrolled Approach to Intersection Drawing #	5	5	6	5	5	6	7	7	8	8	8	8	6	6	6	6	6	6	8	8	8	8	8	8
Major Improvements	Traffic Engineering Study is required to determine applicability of Hybrid Beacons, Pedestrian Signals or a Pedestrian Overpass																							
Pedestrian Actuated Signals (Section 4C.05) Drawing # 9, 12 OR Pedestrian Hybrid Beacons (Section 4F.01) Drawing # 10, 11, 13, 14 OR Pedestrian Overpass (based on ITE Design and Safety of Pedestrian Facilities Manual)			✔			✔			✔			✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
FHWA PUBLICATION: HRT-04-100 *	C	C	P	C	P	P	C	P	N	P	P	N	C	P	N	P	N	N	N	N	N	N	N	N

* The letters (C,P, or N) describe the baseline minimum enhancements for midblock crosswalks according to FHWA publication number HRT-04-100. SDDCTEA's recommendations contained in this table are based on this publication's minimum criteria.

C = Candidate sites for marked crosswalks. Marked crosswalks must be installed carefully and selectively. Before installing new marked crosswalks, an engineering study is needed to determine whether the location is suitable for a marked crosswalk. For an engineering study, a site review may be sufficient at some locations, while a more in-depth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, and other factors may be needed at other sites. It is recommended that a minimum utilization of 20 pedestrian crossings per peak hour (or 15 or more elderly and/or child pedestrians) be confirmed at a location before placing a high priority on the installation of a marked crosswalk alone.

P = Possible increase in pedestrian crash risk may occur if crosswalks are added without other pedestrian facility enhancements. These locations should be closely monitored and enhanced with other pedestrian crossing improvements, if necessary, before adding a marked crosswalk.

N = Marked crosswalks alone are insufficient, since pedestrian crash risk may be increased by providing marked crosswalks alone. Consider using other treatments, such as traffic calming treatments, traffic signals with pedestrian signals where warranted, or other substantial crossing improvement to improve crossing safety for pedestrians.

If the existing speed limit is > 40 mph and pedestrian signals/hybrid beacons are not warranted, consider reducing the roadway speed limit prior to placement of crosswalk.
Unless otherwise stated, all section references are to the 2009 National *MUTCD*
TWLTL = Two-Way Left-Turn Lane **Speed Limit** = Posted Speed Limit **ADT** = Average Daily Traffic (total of both directions)

Crosswalks should not be installed at locations that could present an increased safety risk to pedestrians without first providing adequate design features and/or traffic control devices. “Adding crosswalks alone will not make crossings safer, nor will they increase vehicles stopping for pedestrians. Whether or not marked crosswalks are installed, it is important to consider other pedestrian facility enhancements (e.g., signing, raised median, traffic signal, roadway narrowing, enhanced overhead lighting, traffic-calming measures, curb extensions), as needed, to improve the safety of the crossing.” Good engineering judgment should be used in individual cases for deciding where to install crosswalks. (FHWA PUBLICATION # HRT-04-100)

13.5. MARKING CROSSWALKS

Crosswalks (at midblock locations and on uncontrolled approaches to intersections) that meet the installation criteria given in Section 13.4.1. and therefore are determined to be warranted, must at a minimum be marked on the roadway with pavement marking material. Refer to Section 8.2.15. for information regarding crosswalk pavement markings.

However, per Exhibit 13.4 - Guidelines for Enhancements, it is recommended that some crosswalks (depending on the vehicle volume and number of travel lanes) be marked with added visibility markings. For added visibility, the area of the crosswalk may be marked with white diagonal lines at a 45-degree angle to the line of the crosswalk or with white longitudinal lines parallel to traffic flow. When diagonal or longitudinal lines are used to mark a crosswalk, the transverse crosswalk lines may be omitted. This type of marking may be used at locations where substantial numbers of pedestrians cross without any other traffic control device, at locations where physical conditions are such that added visibility of the crosswalk is desired, or at places where a pedestrian crosswalk might not be expected.

If used, the diagonal or longitudinal lines should be 12 to 24 inches wide and separated by gaps of 12 to 60 inches. The design of the lines and gaps should avoid the wheel paths if possible, and the gap between the lines should not exceed 2.5 times the width of the diagonal or longitudinal lines.

13.6. SIGNING CROSSWALKS

Because pedestrian crossings on uncontrolled unapproaches and at mid-block locations are generally unexpected by the road user, a Pedestrian Crossing warning sign (W11-2) should be installed and adequate visibility should be provided by parking prohibitions.

Corridors with several crossings can be signed at the start of the corridor to make motorists aware of pedestrian activity. It is important to be consistent in sign placement. If signing a group of crosswalks, take care to ensure that either all of them are signed at the crossing location or none of the intermediate crosswalks are signed (and advance signing only is used).

When used in advance of a crossing, warning signs shall be supplemented with one of the following plaques:

- ✓ AHEAD (W16-9P)
- ✓ XX FEET (W16-2P)
- ✓ NEXT XX FEET (W16-4P)

Typical pedestrian crossing signs with downward pointing arrow plaque

These plaques provide advance notice to road users of crossing activity. When used at the crossing location, warning signs shall be supplemented with a diagonal downward pointing arrow (W16-7P) plaque. Designated school crossings are signed in a similar fashion, but require a specific type of sign. Refer to Section 7.3.6 for additional information regarding the W11-2 Pedestrian Crossing sign.

KEY POINT

Signing requirements for school crosswalks have changed with the 2009 version of the MUTCD.

Pedestrian and school signs, and their related supplemental plaques, may utilize a fluorescent yellow-green background with a black legend and border instead of the traditional yellow background. Avoid mixing the two colors within a selected site area.

In addition to providing correct crosswalk signing, it is equally important to provide correct crosswalk markings. Refer to Section 8.2.15 for pedestrian crossing markings.

The following pages contain the SDDCTEA-developed Signing and Striping Layouts (i.e., non-signalized) that correspond to Drawings #1–#8, as recommended enhancements given in Exhibit 13.4.

CROSSWALK SIGNING FOR NORMAL ACTIVITY

SIGNING AND STRIPING LAYOUTS (NON-SIGNALIZED)

GENERAL NOTES (APPLICABLE TO DRAWINGS 1-8):

1) ALL REFERENCES ARE TO THE 2009 NATIONAL MUTCD, UNLESS OTHERWISE NOTED.

2) STOP AND YIELD LINES SHALL BE IN ACCORDANCE WITH SECTION 3B.16

3) CROSSWALK MARKINGS SHALL BE IN ACCORDANCE WITH SECTION 3B.18

4) LOCAL STATE LAW WILL DICTATE WHETHER STOP OR YIELD TO PEDESTRIANS SHOULD BE USED.

5) YIELD (STOP) LINES AND YIELD HERE TO (STOP HERE FOR) PEDESTRIANS SIGNS SHOULD NOT BE USED IN ADVANCE OF CROSSWALKS THAT CROSS AN APPROACH TO OR DEPARTURE FROM A ROUNDABOUT. (SECTION 2B.11)

6) UNLESS OTHERWISE NOTED, INTERSECTION PARKING RESTRICTIONS SHALL BE IN ACCORDANCE WITH SECTION 3B.19

7) SIGNING SHOWN FOR ONE APPROACH ALSO APPLIES TO OPPOSITE APPROACH UNLESS SHOWN OTHERWISE.

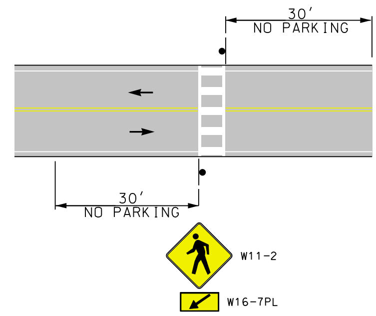
8) SIGN HEIGHT SHALL BE A MINIMUM OF 7FT MEASURED TO THE BOTTOM OF THE SIGN PANEL. SIGN OFFSET SHALL BE IN ACCORDANCE WITH SECTION 2A.16 AND 2A.19

SIGN SPACING DISTANCE
TABLE 2C-4

POSTED OR 85TH PERCENTILE SPEED	"X" DISTANCE
35 MPH OR LESS	100 FT
40 MPH	125 FT
45 MPH	175 FT
50 MPH	250 FT
55 MPH	325 FT

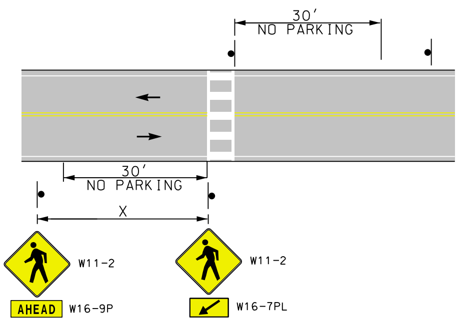
SIGNING AND STRIPING LAYOUTS (MIDBLOCK)

PEDESTRIAN CROSSING LAYOUT



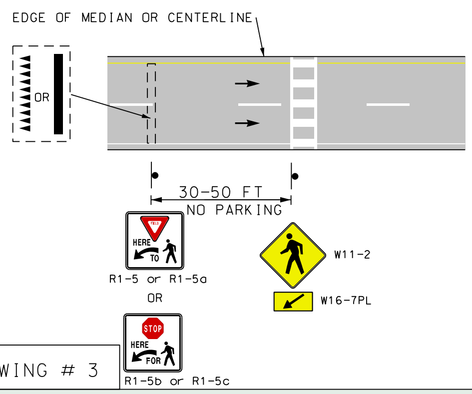
DRAWING # 1

PEDESTRIAN AHEAD CROSSING LAYOUT



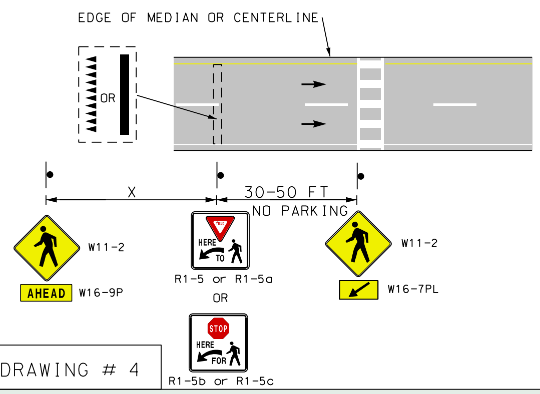
DRAWING # 2

YIELD TO (STOP FOR) PEDESTRIANS CROSSING LAYOUT
(USE FOR MULTILANE APPROACHES ONLY)



DRAWING # 3

YIELD TO (STOP FOR) PEDESTRIANS CROSSING LAYOUT WITH ADVANCE PEDESTRIAN CROSSING SIGN
(USE FOR MULTILANE APPROACHES ONLY)

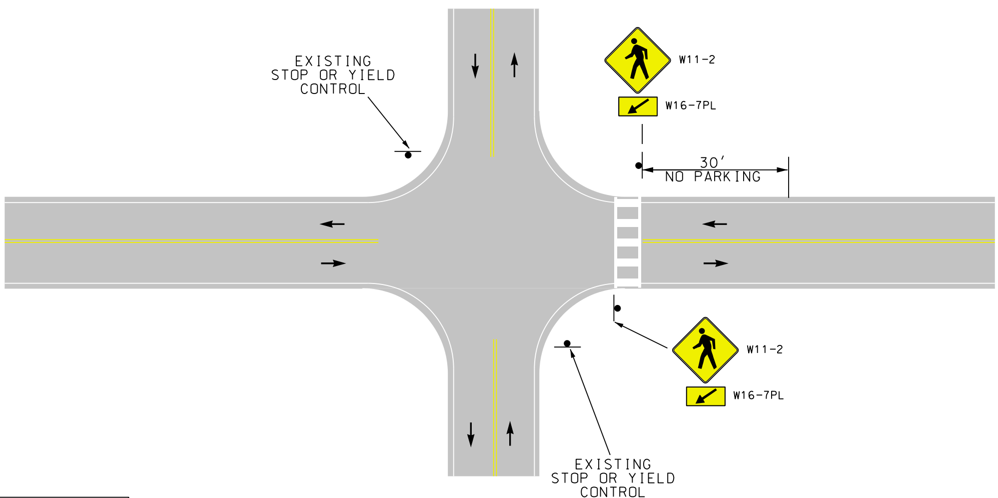


DRAWING # 4

CROSSWALK SIGNING FOR NORMAL ACTIVITY (Continued)

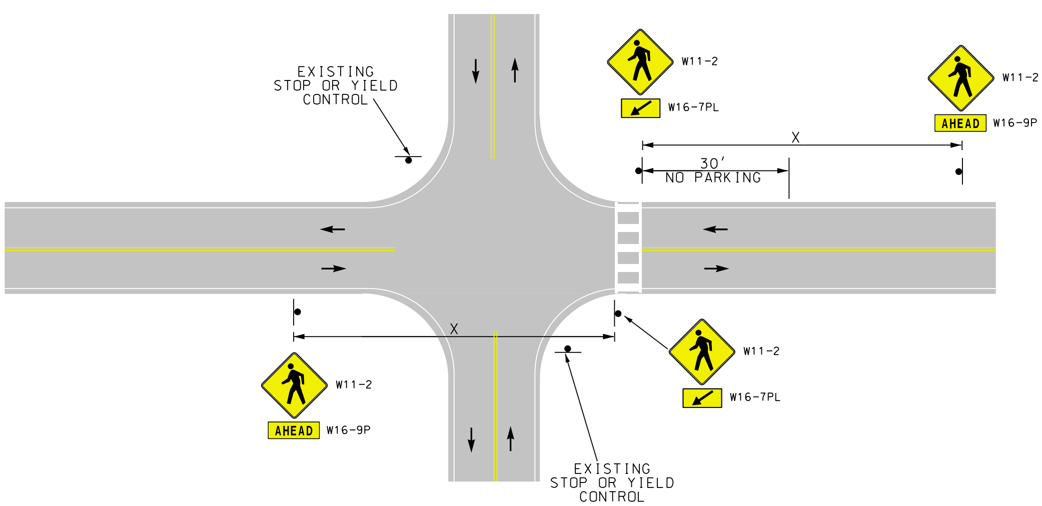
SIGNING AND STRIPING LAYOUTS
(UNCONTROLLED APPROACHES TO INTERSECTIONS)

PEDESTRIAN CROSSING LAYOUT



DRAWING # 5

PEDESTRIAN AHEAD CROSSING LAYOUT



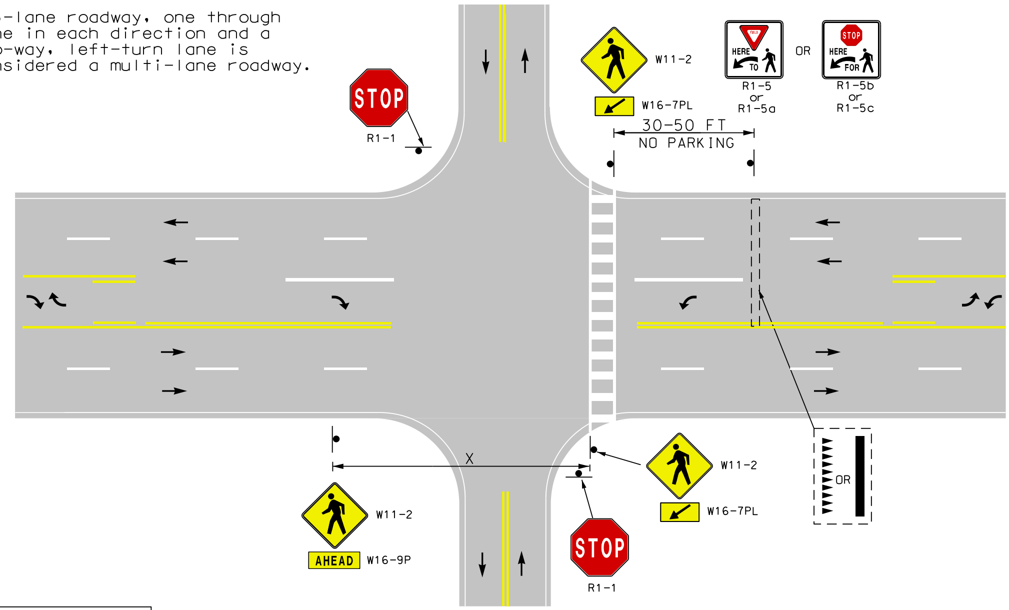
DRAWING # 6

CROSSWALK SIGNING FOR NORMAL ACTIVITY (Continued)

SIGNING AND STRIPING LAYOUTS
(UNCONTROLLED APPROACHES TO INTERSECTIONS)

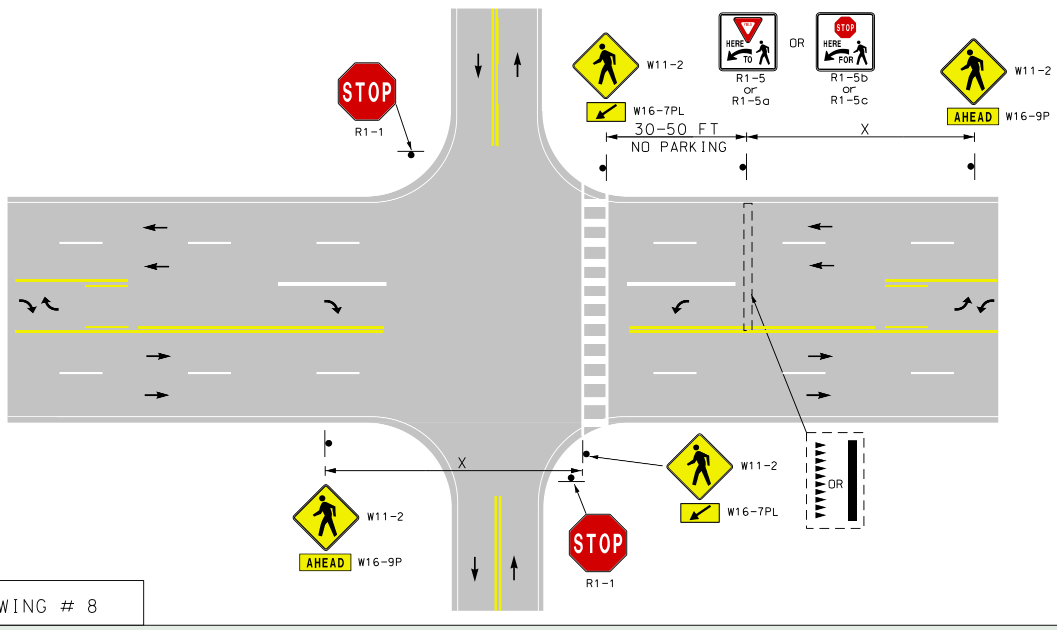
YIELD TO (STOP FOR) PEDESTRIANS CROSSING LAYOUT
(USE FOR MULTILANE ONLY*)

* A 3-lane roadway, one through lane in each direction and a two-way, left-turn lane is considered a multi-lane roadway.



DRAWING # 7

YIELD TO (STOP FOR) PEDESTRIANS CROSSING LAYOUT
WITH PEDESTRIAN AHEAD SIGN
(USE FOR MULTILANE ONLY*)



DRAWING # 8

13.7. USE OF TRAFFIC SIGNALS FOR PEDESTRIAN ACCOMMODATIONS

KEY POINT

A traffic signal, even when used for pedestrians, must meet at least one traffic signal warrant.

Another perceived cure-all is the installation of traffic signals to accommodate pedestrians. Although properly designed and equipped traffic signals can better accommodate pedestrians, a traffic signal must satisfy one of the warrants contained in the *MUTCD* for installation. The *MUTCD* contains several warrants for traffic signal installation, including criteria based on traffic volumes and crash history. Signal Warrants 4 and 5 directly correspond to pedestrian activity.

WARRANT 4, PEDESTRIAN VOLUME

The Pedestrian Volume signal warrant is intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street.

The need for a traffic control signal at an intersection or mid-block crossing shall be considered if an engineering study finds that the pedestrian and traffic volume data falls above the curves shown in the *MUTCD*.

WARRANT 5, SCHOOL CROSSING

The School Crossing signal warrant is intended for application where the fact that school children cross the major street is the principal reason to consider installing a traffic control signal. The *MUTCD* limits school children to elementary through high school levels.

The need for a traffic control signal shall be considered when an engineering study of the frequency and adequacy of gaps in the vehicular traffic stream, as related to the number and size of groups of school children at an established school crossing across the major street, shows that:

- ✓ The number of adequate gaps in the traffic stream during the period when the children are using the crossing is less than the number of minutes in the same period; and
- ✓ There is a minimum of 20 schoolchildren during the highest crossing hour.

Before a decision is made to install a traffic control signal, consideration shall be given to the implementation of other remedial measures, such as warning signs and flashers, school speed zones, school crossing guards, or a grade-separated crossing.

In both cases the signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 300 feet, unless the proposed traffic control signal will not restrict the progressive movement of traffic.

Exhibit 13.5 shows proper signal timing. Proper timing of pedestrian signal phases is critical in ensuring safe pedestrian crossings. Install pedestrian signal heads at any signalized location meeting one or more of the following conditions:

1. If a traffic control signal is justified by an engineering study and meets Warrant 4 or Warrant 5
2. If an exclusive signal phase is provided or made available for pedestrian movements with all conflicting vehicular movements being stopped;
3. At an established school crossing at any signalized location; or
4. Where engineering judgment determines that elaborate signal phasing would tend to confuse or cause conflicts with pedestrians.

Exhibit 13.5: Pedestrian Signal Timing

	The WALK interval should be at least 7 seconds in length so that pedestrians have adequate opportunity to leave the curb or shoulder before the pedestrian clearance time begins. However, if pedestrian volumes and characteristics do not require a 7-second WALK interval, WALK intervals as short as 4 seconds may be used.
	The pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk to travel at a walking speed of 3.5 feet per second, to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. Where children, elderly, or disabled populations are present, walking speeds of 3 feet per second should be considered.
	All pedestrian signal heads used at crosswalks where the pedestrian change interval (i.e., flashing don't walk interval) is more than 7 seconds shall include a pedestrian change interval countdown display in order to inform pedestrians of the number of seconds remaining in the pedestrian change interval. These are commonly referred to countdown pedestrian signals.
The pedestrian clearance time may be entirely contained within the vehicular green interval, or may be entirely contained within the vehicular green and yellow change intervals. However, there must be a minimum 3-second buffer between the end of the DONT WALK interval and the beginning of an opposite direction's green phase. See Section 9.3 for additional information on pedestrian accommodations at signalized intersections.	

Refer to Exhibit 13.4 (Guidelines for Enhancements of Crosswalks at Midblock locations and on Uncontrolled Approaches to Intersections) to determine if a pedestrian signal is a recommended treatment for your crossing location. The SDDCTEA-developed Traffic Control Signal Layouts that correspond to Drawings #9 and #12, as recommended enhancements given in Exhibit 13.4, have been included in Section 13.7.2.

Nonetheless, a pedestrian signal must meet *MUTCD* warrants and be justified by an engineering study.

13.7.1. Pedestrian Hybrid Beacons

Pedestrian hybrid beacons are intended to assist pedestrians in crossing the street or highway at a marked crosswalk. They can be installed to facilitate pedestrian crossings where signal warrants are not met, or where signal warrants are met but the decision is made to not install a traffic signal. Per the *MUTCD*, a pedestrian hybrid beacon shall only be installed at a marked crosswalk. Minimum warrants must be met for the pedestrian hybrid beacon to be installed, as shown in the *MUTCD*. The design of the pedestrian hybrid beacon shall conform to Section 4D.03 of the *MUTCD*.

Pedestrian beacons are dark when not activated. Upon actuation by a pedestrian, the beacon displays a flashing circular yellow indication, followed by a solid circular yellow. Both steady circular red indications are then displayed during the walk indication. The red indications then alternate during the flashing don't walk interval, then return to dark after the end of the flashing don't walk interval.

Where signal warrants are not met, or where signal warrants are met but the decision is made to not install a traffic signal, pedestrian hybrid beacons can be installed to facilitate pedestrian crossings. Per the *MUTCD*, a pedestrian hybrid beacon shall only be installed at a marked crosswalk. Minimum warrants must be met for the pedestrian hybrid beacon to be installed, as shown in the *MUTCD*. The design of the pedestrian hybrid beacon shall conform to Section 4F.02 of the *MUTCD*.

13.7.2. Traffic Control Signal and Pedestrian Hybrid Beacon Layouts

The following figures show the layout of a pedestrian hybrid beacon.

TRAFFIC CONTROL SIGNAL AND PEDESTRIAN HYBRID BEACON LAYOUTS
(MIDBLOCK AND UNCONTROLLED APPROACHES TO INTERSECTIONS)

GENERAL NOTES (APPLICABLE TO DRAWINGS 9-14):

1) ALL REFERENCES ARE TO THE 2009 NATIONAL MUTCD, UNLESS OTHERWISE NOTED.

2) PEDESTRIAN HYBRID BEACONS SHALL BE IN ACCORDANCE WITH WITH SECTION 4F.

3) MIMIMUM WARRANTS AND GUIDELINES MUST BE MET PRIOR TO HYBRID BEACON AND TRAFFIC SIGNAL INSTALLATION - SEE SECTION 4F.01 FOR PEDESTRIAN HYBRID BEACON INSTALLATION GUIDELINES OR SECTION 4C.05 FOR THE PEDESTRIAN VOLUME SIGNAL WARRANT.

4) STOP AND YIELD LINES SHALL BE IN ACCORDANCE WITH SECTION 3B.16.

5) CROSSWALK MARKINGS SHALL BE IN ACCORDANCE WITH SECTION 3B.18.

6) CROSSWALKS SHALL NOT BE SIGNALIZED IF THEY ARE LOCATED WITHIN 300 FT FROM THE NEAREST TRAFFIC CONTROL SIGNAL, UNLESS THE PROPOSED TRAFFIC CONTROL SIGNAL WILL NOT RESTRICT THE PROGRESSIVE MOVEMENT OF TRAFFIC.(SECTION 4D.01).

7) THE "CROSSWALK - STOP ON RED (SYMBOLIC CIRCULAR RED)" (R10-23) SIGN SHALL BE USED WITH PEDESTRIAN HYBRID BEACONS. (SECTION 4F.02). IT SHALL NOT BE SUBSTITUTED WITH A PEDESTRIAN CROSSING (W11-2) WARNING SIGN.

8) THE "CROSSWALK - STOP ON RED (SYMBOLIC CIRCULAR RED)" (R10-23) SIGN SHALL ONLY BE USED WITH PEDESTRIAN HYBRID BEACONS. (SECTION 2B.53). IT SHALL NOT BE USED FOR OTHER APPLICATIONS.

9) IF A PEDESTRIAN HYBRID BEACON IS INSTALLED AT OR IMMEDIATELY ADJACENT TO AN INTERSECTION WITH A SIDE ROAD OR DRIVEWAY, VEHICULAR TRAFFIC ON THE SIDE ROAD OR DRIVEWAY SHALL BE CONTROLLED BY A STOP SIGN.

10) TRAFFIC CONTROL SIGNAL FEATURES; SUCH AS THE DESIGN/SIZE OF SIGNAL INDICATIONS, NUMBER/LOCATION OF SIGNAL FACES, AND SEQUENCING; SHALL BE IN ACCORDANCE WITH CHAPTER 4D.

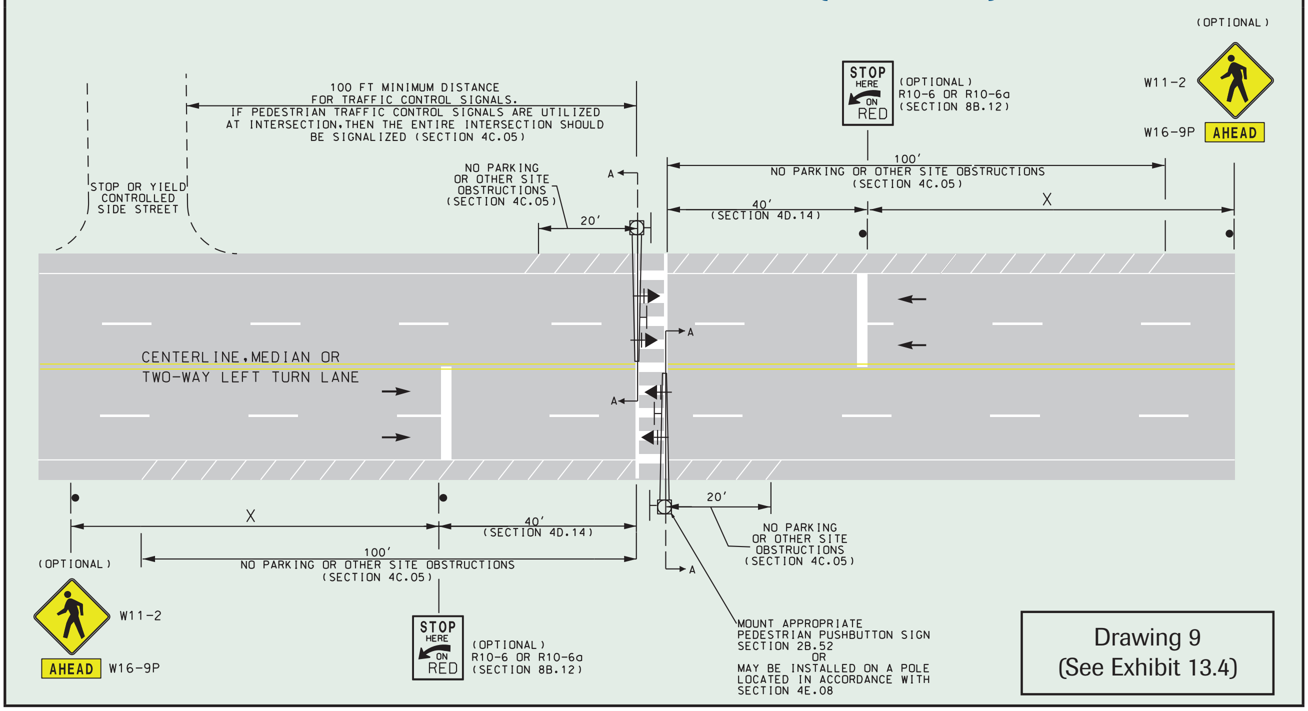
11) PEDESTRIAN SIGNAL HEADS AND DETECTORS SHALL COMPLY WITH CHAPTER 4E AND SECTION 4D.03 OR CHAPTER 4F FOR PEDESTRIAN HYBRID BEACONS.

12) UNLESS OTHERWISE NOTED, INTERSECTION PARKING RESTRICTIONS SHALL BE IN ACCORDANCE WITH SECTION 3B.19.

SIGN SPACING DISTANCE
TABLE 2C-4

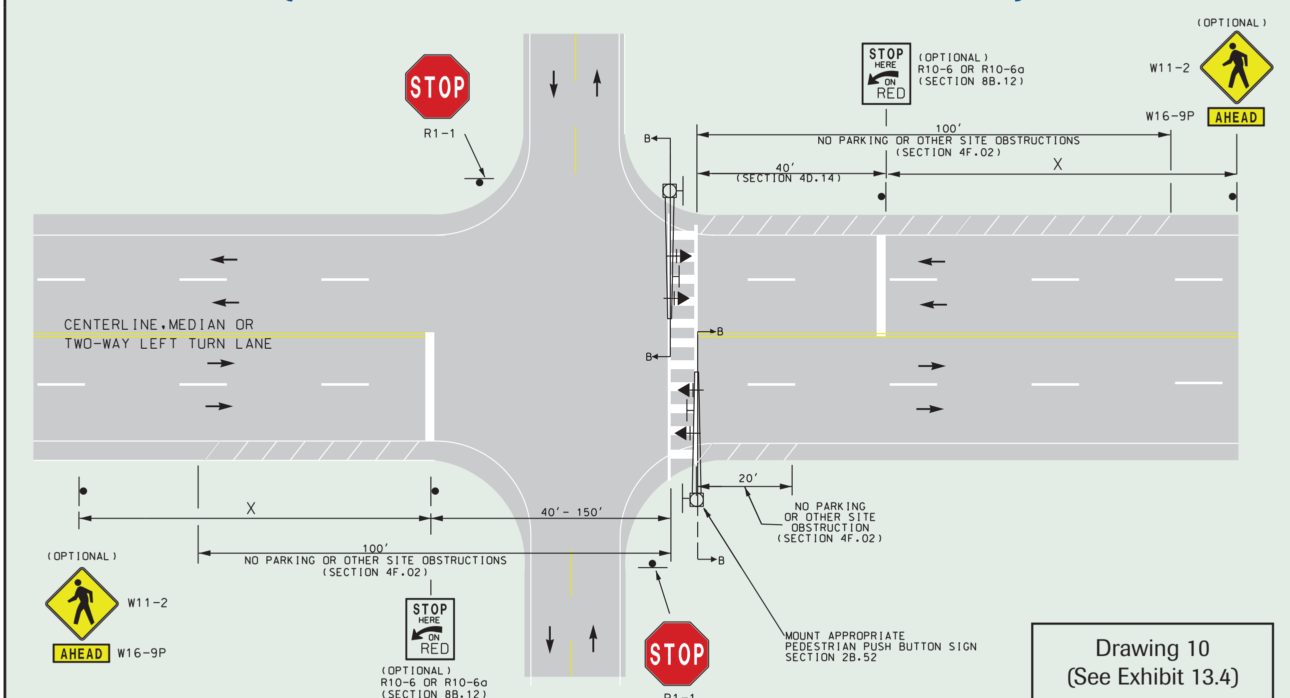
POSTED OR 85TH PERCENTILE SPEED	"X" DISTANCE
35 MPH OR LESS	100 FT
40 MPH	125 FT
45 MPH	175 FT
50 MPH	250 FT
55 MPH	325 FT

TRAFFIC CONTROL SIGNAL LAYOUT (MIDBLOCK)



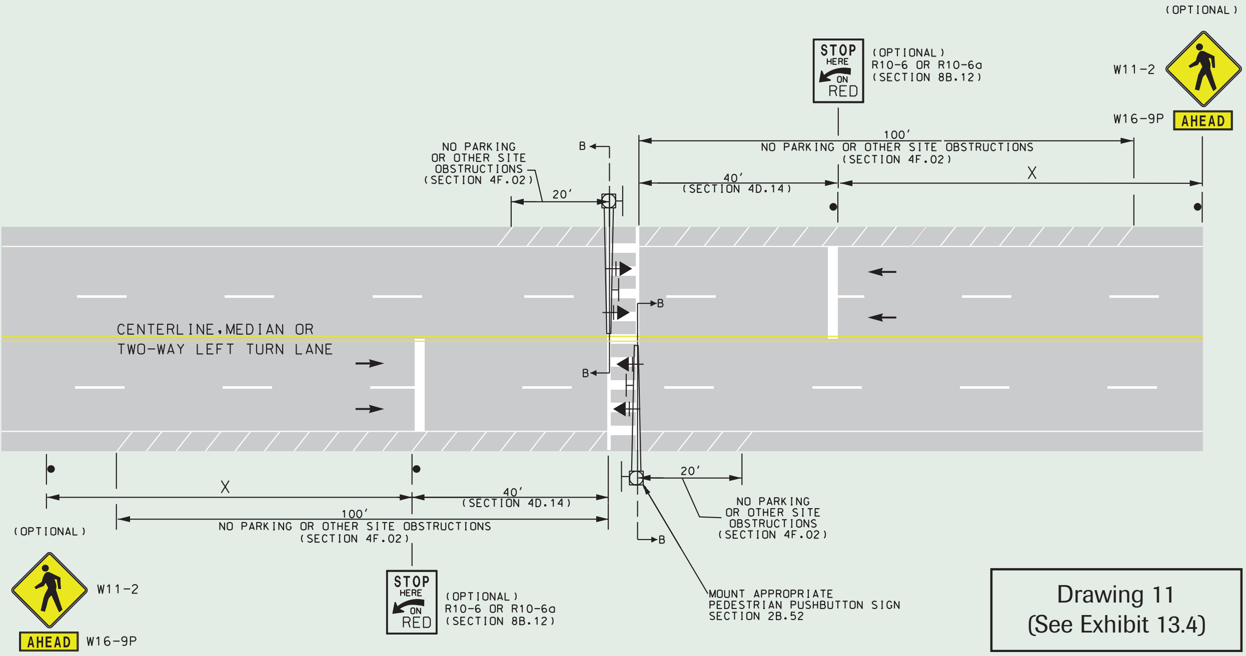
Drawing 9
(See Exhibit 13.4)

PEDESTRIAN HYBRID BEACON LAYOUT (UNCONTROLLED APPROACHES TO INTERSECTIONS)



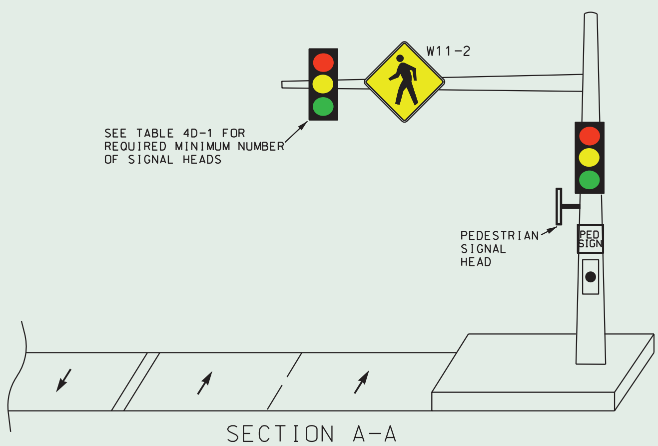
Drawing 10
(See Exhibit 13.4)

PEDESTRIAN HYBRID BEACON LAYOUT (MIDBLOCK)



Drawing 11
(See Exhibit 13.4)

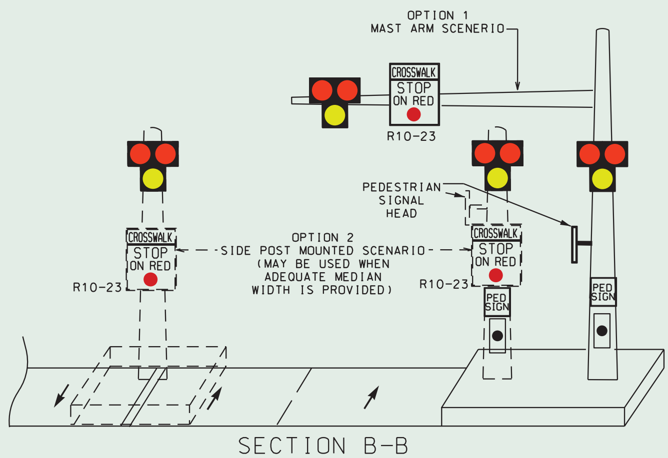
TRAFFIC CONTROL SIGNAL APPLICABLE FOR ALL SPEEDS (WITH OR WITHOUT MEDIAN)



Drawing 12
(See Exhibit 13.4)

PEDEDSTRIAN HYBRID BEACON SPEEDS ≤ 35 MPH

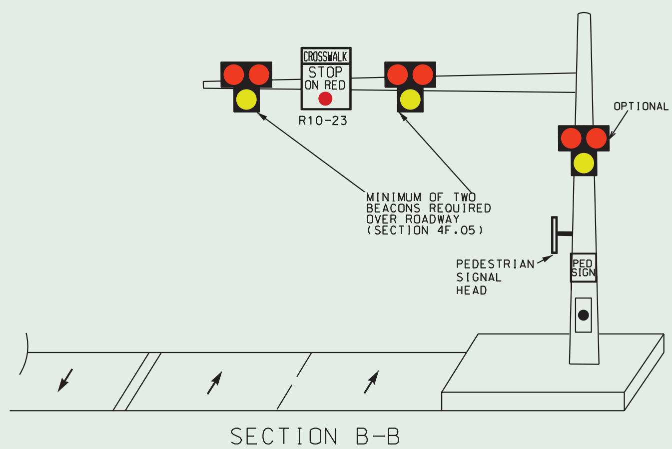
(IF APPROACH LANES EQUAL 3 OR MORE PER DIRECTION, UTILIZE OPTION 1—MAST ARM LAYOUT)



Drawing 13
(See Exhibit 13.4)

PEDEDSTRIAN HYBRID BEACON SPEEDS > 35 MPH

(WITH OR WITHOUT MEDIAN)



Drawing 14
(See Exhibit 13.4)

13.7.3. Additional Crosswalk Enhancements

In-Roadway Warning Lights

In-roadway warning lights at crosswalks are a form of active warning devices. These have high-intensity, bi-directional in-pavement lights that are activated by a push button or microwave sensor at either curb. Once activated, the lights emit a rapidly flashing yellow light in both directions of traffic. The advantage to using these is that they only are activated when a pedestrian is in the crossing. Studies show that when flashing crosswalks are used, drivers tend to yield to pedestrians more frequently, and the advanced warning leads to slower approach speeds.

Currently, there are no “warrants” in the *MUTCD* regarding the use of in-roadway warning lights; therefore, it is left to engineering judgment as to where these devices should be considered. Additionally, be sure to check with your state Department of Transportation to verify that these are acceptable for use in your state.

Rectangular Rapid Flash Beacons

Rectangular Rapid Flash Beacons (RRFB) can enhance safety by reducing crashes between vehicles and pedestrians at unsignalized intersections and mid-block pedestrian crossings by increasing driver awareness of potential pedestrian conflicts. The use of yellow RRFBs to enhance the conspicuity of various pedestrian crossing and school crossing signs is not yet in the *MUTCD*, but has been given interim approval (see IA-11 at http://mutcd.fhwa.dot.gov/res-interim_approvals.htm).

RRFBs are user-actuated amber LEDs that supplement warning signs at unsignalized intersections or mid-block crosswalks. They can be activated by pedestrians manually by a push button or passively by a pedestrian detection system. RRFBs use an irregular flash pattern that is similar to emergency flashers on police vehicles. RRFBs may be installed on either two-lane or multi-lane roadways.

RRFBs are a lower cost alternative to traffic signals and hybrid signals, and are shown to increase driver yielding behavior at crosswalks significantly when supplementing standard pedestrian crossing warning signs and markings.

When used, install the beacons between the W11-2 pedestrian warning sign and the W13-1P downward-pointing arrow placard. The sign assembly should be mounted at the regular height.

Note that RRFBs do not refer to flashing LEDs in the border of a sign.

RRFB example

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CHAPTER 14—TEMPORARY TRAFFIC CONTROL

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Temporary traffic control (TTC) is an all-encompassing term used for traffic control requirements for work zones, ECF lane closures, roadway incidents, utility work, maintenance operations, and other reasons for a temporary closure of part or all of a roadway.

14.1. WORK ZONE SAFETY

Work zones are areas on installations that are under construction or receiving maintenance. These areas require special attention in order to provide safety to the travelling public (vehicular, pedestrian, bicyclists and persons with disabilities), and to the workers involved with the activities. It is essential that work zones have the proper traffic control regardless of the volume of traffic, lack of funding, or properly written specifications.

Work zone lacking proper tapers, signing, and temporary pavement markings

Work zone involving a closed roadway with no signing to indicate the closure of the roadway

Part 6 of the *MUTCD* puts work zone traffic control under the umbrella of TTC. Part 6 of the *MUTCD* covers many TTC scenarios and devices in depth. These topics are summarized in this chapter and cover important points more commonly encountered on military installations.

When designing TTC plans, be sure to investigate for any local and state DOT TTC standards. There may be state-specific laws related to speed limits, cell phone use in work zones, and special signing needed in work zones.

The lack of appropriate traffic control is considered to be an OSHA violation, violating the General Duty Clause.

29 U.S.C. § 654, 5(a)1: "Each employer shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees."

The lack of *MUTCD*-compliant work zone traffic control for roadway work is a recognizable hazard for the workers. It is imperative that installations and their contractors provide proper TTC in work zones.

14.2. FUNDAMENTAL TEMPORARY TRAFFIC CONTROL PRINCIPLES

The *MUTCD* identifies seven basic principles of TTC, as summarized in Exhibit 14.1. These apply not only to the civilian world, but to military projects as well.

Exhibit 14.1: Basic Principles of Temporary Traffic Control

1. General plans or guidelines should be developed to provide safety for motorists, bicyclists, pedestrians, workers, enforcement/emergency officials, and equipment. The basic safety principles governing the design of permanent roadways and roadsides should also govern the design of TTC zones.	✓ A TTC plan should be developed that is appropriate to the complexity of the work project. ✓ This applies to all types of projects regardless of contracting mechanism. Design-Bid-Build projects should include TTC plans which the contractor is required to follow. Design-build projects should require the development of TTC plans.
2. Road user movement should be inhibited as little as practical. When designing TTC, assume that drivers will only reduce their speeds if they clearly perceive a need to do so.	✓ Avoid abrupt changes in geometrics such as lane narrowing, dropped lanes, or main roadway transitions that require rapid maneuvers. Schedule the work such that the need for lane closures or alternate routes is minimized, while still getting the work completed quickly.
3. Motorists, bicyclists, and pedestrians should be guided in a clear and positive manner while approaching and traveling through TTC zones. Provide adequate warning, delineation, and channelization to assist in guiding road users in advance of and through the TTC zone.	✓ TTC devices inconsistent with intended travel paths through TTC zones should be removed or covered. ✓ If flagging procedures are used, they should provide positive guidance to road users traversing the TTC zone.
4. To provide acceptable levels of operations, routine day and night inspections of TTC elements should be performed. Individuals who are knowledgeable in the principles of proper TTC should be responsible for safety in TTC zones. The most important duty should be to check that all TTC devices are consistent with the TTC plan.	✓ As the work progresses, TTCs can be modified, if appropriate, in order to provide better mobility and positive guidance to the road user and to provide worker safety. ✓ Monitor TTC zones under varying conditions of road user volumes, light, and weather to check that applicable TTC devices are effective, clearly visible, clean, and in compliance with the TTC plan. ✓ Crash records in TTC zones should be monitored and studied to identify the need for changes in the TTC zone. ✓ Maintenance of the TTC devices is equally as important as initial installation of the correct devices.

Exhibit 14.1: Basic Principles of Temporary Traffic Control (Continued)

5. Attention should be given to the maintenance of roadside safety during the life of the TTC zone. To accommodate run-off-the-road incidents, disabled vehicles, or emergency situations, unencumbered roadside recovery areas or clear zones should be provided whenever possible.	✓ Channelization should be accomplished by the use of pavement markings, signing, and crashworthy, detectable channelizing devices. ✓ Work equipment, workers' private vehicles, materials, and debris should be stored in such a manner to reduce the probability of being impacted by run-off-the-road vehicles.
6. Each person whose actions affect TTC zone safety, from the upper-level management to the field workers, should receive training appropriate to the job decisions each individual is required to make.	✓ Only those individuals who are trained in proper TTC practices and have a basic understanding of the principles should supervise the selection, placement, and maintenance of TTC devices used for TTC zones.
7. Maintain good public relations. Consider the needs of all road users such that appropriate advance notice is given and alternative paths are provided.	✓ Use basewide PR to identify the existence of and reasons for TTC zones to assist in keeping the road users well informed. ✓ The needs of emergency service providers (law enforcement, fire, and medical) should be assessed and appropriate coordination and accommodations made. ✓ The needs of operators of commercial vehicles such as buses and large trucks should be assessed and appropriate accommodations made.

14.3. TEMPORARY TRAFFIC CONTROL PLANS

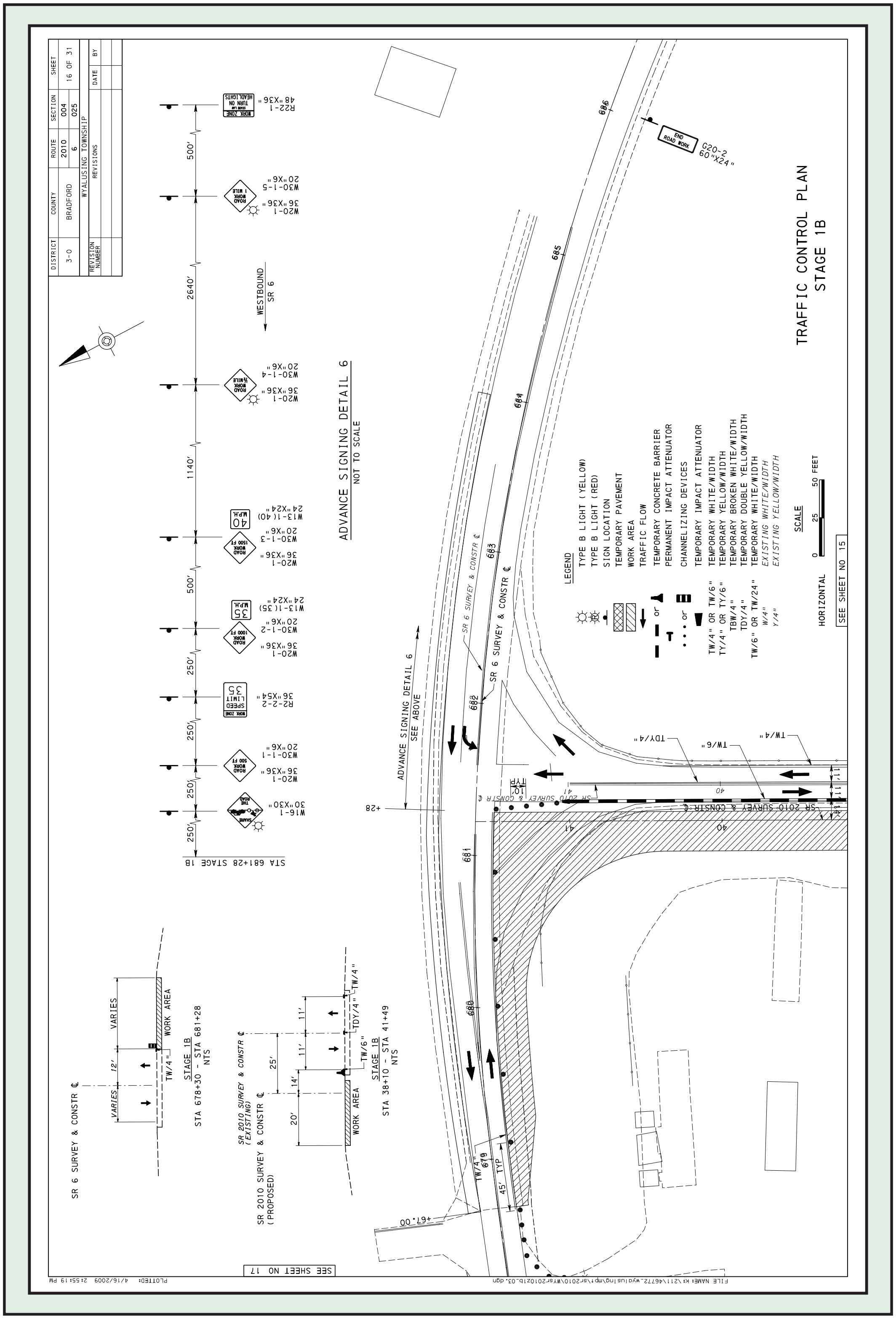
TTC plans should describe the TTC measures that are to be used for safely facilitating roadway users through a work zone or incident area.

TTC plans should be developed by an experienced individual, and should follow design criteria set forth by the *MUTCD* or other documented design criteria. TTC plans can be developed in multiple types of formats, including:

- Written in a TTC plan project specification
- Referencing by citation to other policies or documents (such as your state DOT Highway Standards)
- Displayed graphically on the construction project plans
- Developing a standalone TTC plan, including graphics and written narrative

An example of a TTC plan is shown as Exhibit 14.2.

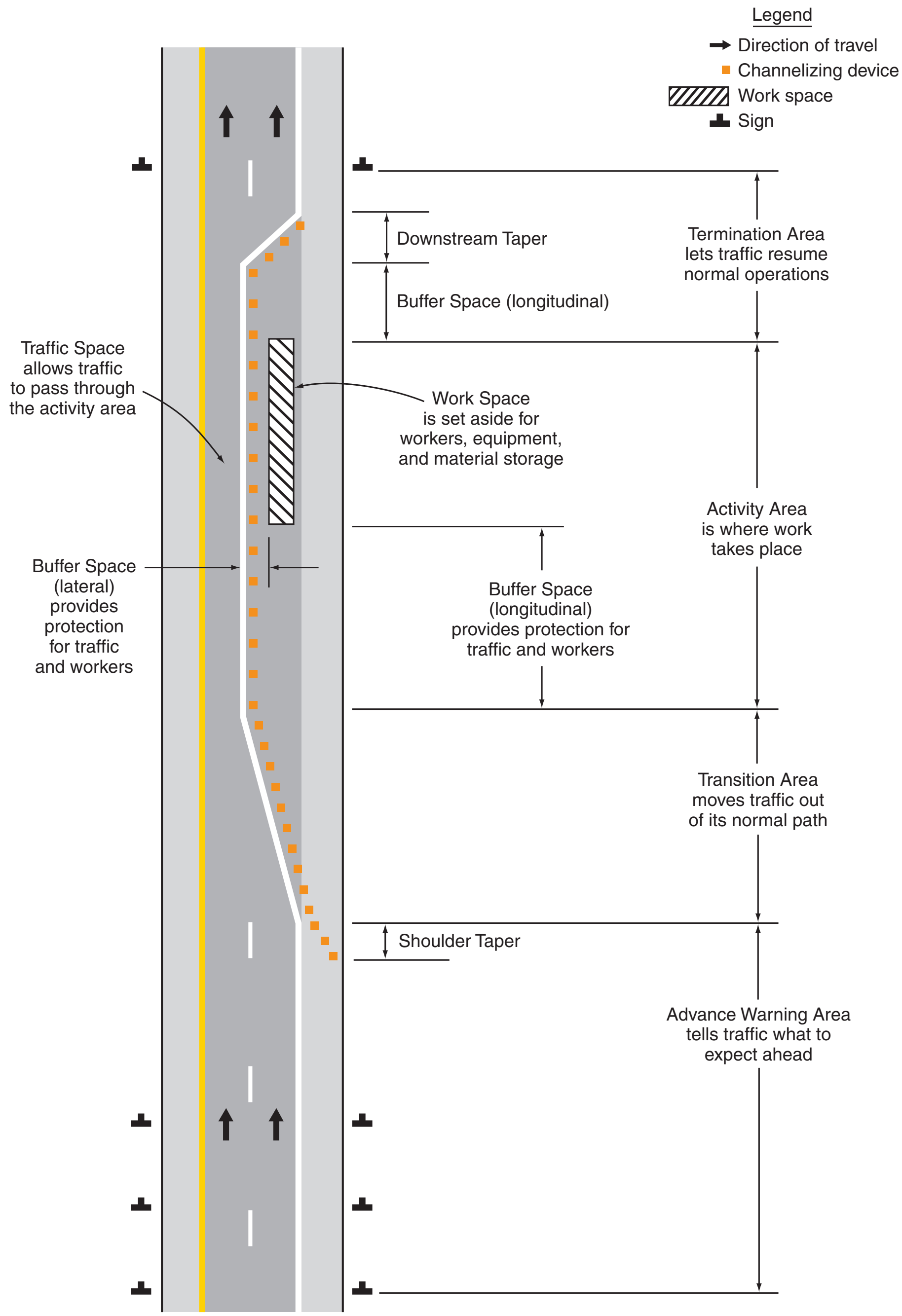
Exhibit 14.2: Example Temporary Traffic Control Plan



14.4. TEMPORARY TRAFFIC CONTROL ZONES

A TTC zone is an area where construction activities, an unplanned incident, or a planned special event requires modifications to the expected traffic pattern. Most TTC zones are divided into four areas as shown in Exhibit 14.3.

Exhibit 14.3: TTC Zones



Source: MUTCD *Figure 6C-1*

14.4.1. Advance Warning Area

The advance warning area is the zone located in advance of the construction or unplanned incident area, where road users are informed about the upcoming work zone.

Advance warning of the work zone is critical. Mainly this is accomplished through the use of advance signing, but can also consist of a vehicle with warning beacons for short-term work zones. As a motorist approaches a typical work zone, there are several steps in providing important information. The first step is to inform the roadway user of the changing condition through a "ROAD WORK AHEAD" sign. The second step should inform the roadway user of what traffic flow changes are occurring, such as "LANE CLOSED AHEAD," or "DETOUR AHEAD" signs. The last step should inform the roadway user of the immediate situation, which could include "Merge Left" or "STOP HERE ON RED" signs. Exhibit 14.8 on page 14-12 shows recommended sign spacing.

The distances given in Exhibit 14.8 should be applied with engineering judgment as they are approximate and intended for guidance purposes. Per the *MUTCD* Section 6C.04, "On urban streets, the effective placement of the first warning sign in feet should range from 4 to 8 times the speed limit in mph, with the high end of the range being used when speeds are relatively high. When a single advance warning sign is used (in cases such as low-speed residential streets), the advance warning area can be as short as 100 feet. When two or more advance warning signs are used on higher-speed streets, such as major arterials, the advance warning area should extend a greater distance." On the contrary, "Since rural highways are normally characterized by higher speeds, the effective placement of the first warning sign in feet should be substantially longer—from 8 to 12 times the speed limit in mph. Since two or more advance warning signs are normally used for these conditions, the advance warning area should extend 1,500 feet or more for open highway conditions." Refer to the *MUTCD* Chapter 6C and *MUTCD* Table 6C-1 (included in this pamphlet as Exhibit 14.8) for more information.

14.4.2. Transition Area

The transition area is where roadway users are redirected from the typical traffic pattern. Commonly, the transition area consists of tapering the roadway, as illustrated on Exhibit 14.3. Due to the importance of the tapers in this zone, they are discussed separately in Section 14.5. Possible transition area signs include: "BE PREPARED TO STOP" and "Merge Right."

14.4.3. Activity Area

The activity area is where the work activity or incident is located and consists of the work space, traffic space, and buffer space (see Exhibit 14.3). This area can involve direct interaction of motorized and nonmotorized traffic with the work area, workers, and equipment which can pose as a safety risk. It is important that sufficient lateral and/or longitudinal buffer space is allowed in order to separate road user flow from the work space or an unsafe area. The required stopping sight distance for the roadway may be used to determine the length of the longitudinal buffer space, as given in Exhibit 14.4. The width of a lateral buffer space should be determined by engineering judgment.

Exhibit 14.4: Stopping Sight Distance as a Function of Speed

SPEED*	DISTANCE
20 MPH	115 feet
25 MPH	155 feet
30 MPH	200 feet
35 MPH	250 feet
40 MPH	305 feet
45 MPH	360 feet
50 MPH	425 feet
55 MPH	495 feet
60 MPH	570 feet
65 MPH	645 feet
70 MPH	730 feet
75 MPH	820 feet
*Posted speed, off-peak 85th-percentile speed prior to work starting, or the anticipated operating speed.	

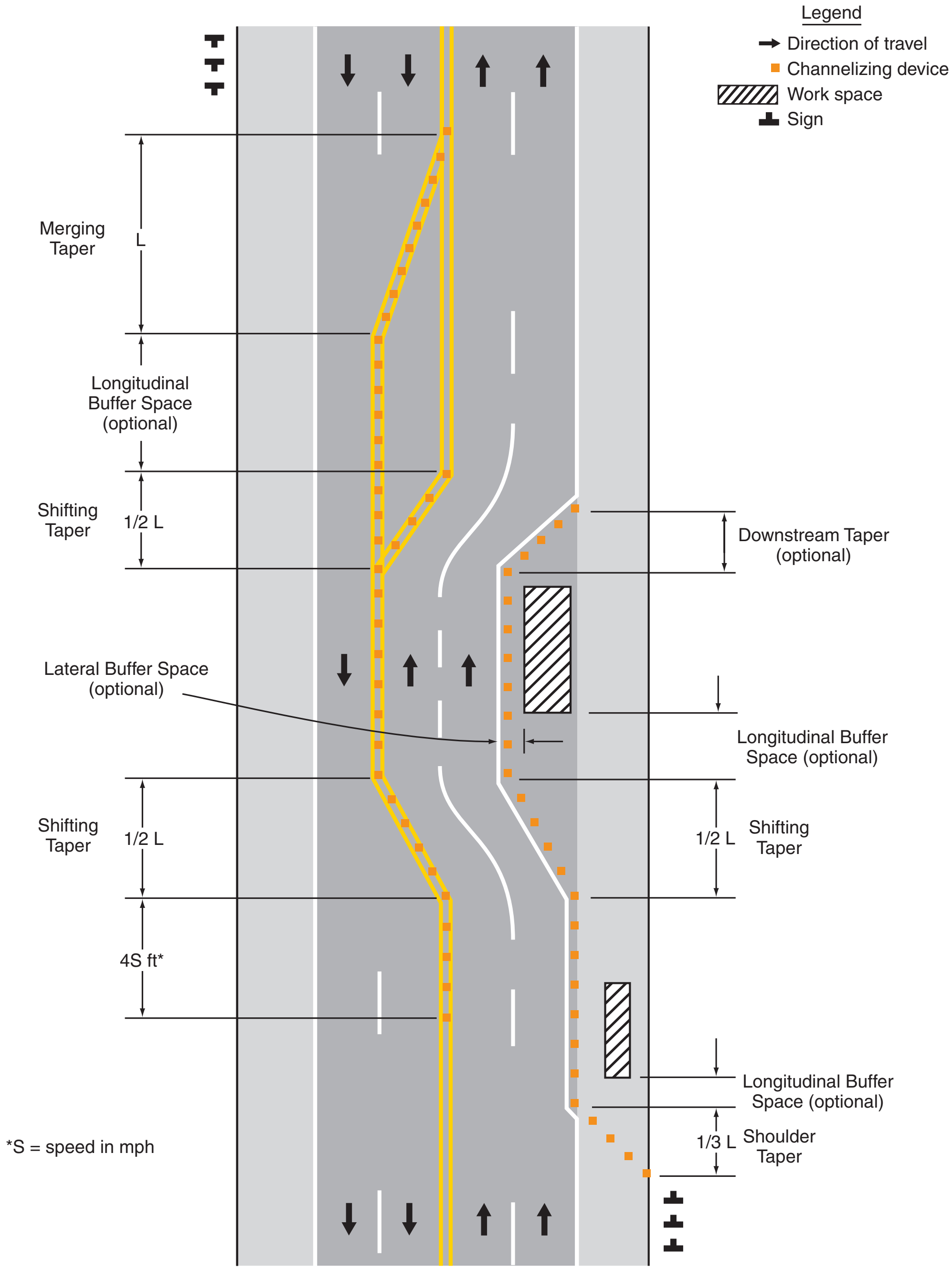
Source: MUTCD *Table 6C-2*

14.4.4. Termination Area

The termination area is the portion of the TTC zone where roadway users are returned to their normal driving pattern. A typical sign used in this area is an “END ROAD WORK” sign.

14.5. TAPER DESIGN

Tapers are required to safely shift roadway users to a new traffic pattern. They can be used in both the transition and termination areas, and are typically delineated by channelizing devices or temporary pavement markings. Use Exhibits 14.5 and 14.6 to determine the length of the taper.



Source: MUTCD *Figure 6C-2*

Exhibit 14.5: Taper Length Criteria for Temporary Traffic Control Zones

TYPE OF TAPER	TAPER LENGTH
MERGING TAPER	at least L
SHIFTING TAPER	at least 0.5 L
SHOULDER TAPER	at least 0.33 L
ONE-LANE, TWO-WAY TRAFFIC TAPER	50 feet minimum, 100 feet maximum
DOWNSTREAM TAPER	50 feet minimum, 100 feet maximum
Note: Use Exhibit 14.6 to calculate L	

Exhibit 14.6: Formulas for Determining Taper Length

SPEED (S)	TAPER LENGTH (L) IN FEET
40 MPH OR LESS	$L = \frac{WS^2}{60}$
45 MPH OR MORE	$L = WS$
Where: L = Taper length in feet W = Width of offset in feet S = Posted speed limit, or off-peak 85th-percentile speed prior to work starting, or the anticipated operating speed in mph	

Source: MUTCD *Tables 6C-3, 6C-4, and 6H-4*

14.6. TYPICAL TTC APPLICATIONS

Every TTC zone is unique. The needs can be variable due to the work location and duration, traffic volumes, and roadway usage. The types of work durations and work locations common to military installations are summarized within this section. More detailed information is located in Part 6 of the *MUTCD*.

14.6.1. Work Duration

Long-term stationary—Construction occupies a location for longer than 3 days. This duration will extend into the nighttime; therefore, retroreflective and/or illuminated devices must be used. Traffic control devices required could include temporary pavement markings, temporary signals, signed detour route, or diversion.

Intermediate-term stationary—Construction that occupies a location from 1 to 3 days, or nighttime work longer than 1 hour. Commonly this includes maintenance or utility operations.

Short-term stationary—Construction or incident that occupies the location from 1 hour to 1 day (daylight hours only).

Short duration—Construction or incident that occupies the location up to 1 hour. Vehicles with appropriate signing and lighting, and channelizing devices that are easy to install and remove should be used in lieu of numerous signs or temporary pavement markings that take longer to install.

Mobile—Work that is continuously moving such as pothole patching, roadway cleaning, or some utility operations. TTC devices that could be used for mobile operations include: flaggers, shadow vehicle with appropriate signing and devices (high-intensity rotating, flashing, oscillating, or strobe lights).

Long-term, stationary work zone

14.6.2. Flagger Stations

Flagger stations shall be located such that approaching road users will have sufficient stopping distance (see Section 14.4.3 for distance requirements based on speed and stopping sight distance). Except in emergency situations, flagger stations shall be preceded by an advance warning sign or signs and should be illuminated at night.

W20-7 and W16-2P

14.6.3. Work Location

The figures shown on the subsequent pages show typical work zone applications for various scenarios. These scenarios are those deemed to be most applicable to military installations. The *MUTCD* contains additional scenarios beyond those that are shown in this section.

Exhibit 14.7 shows the legend for symbols used within this section. Exhibit 14.8 shows the distances referred to with letters shown as dimensions within the figures. Note that the distances shown are minimum distances. In order to provide additional warning time, the distances can be increased.

Use Exhibits 14.5 and 14.6 to determine the length of the tapers.

Exhibit 14.7: Symbol Legend for Work Location Drawings

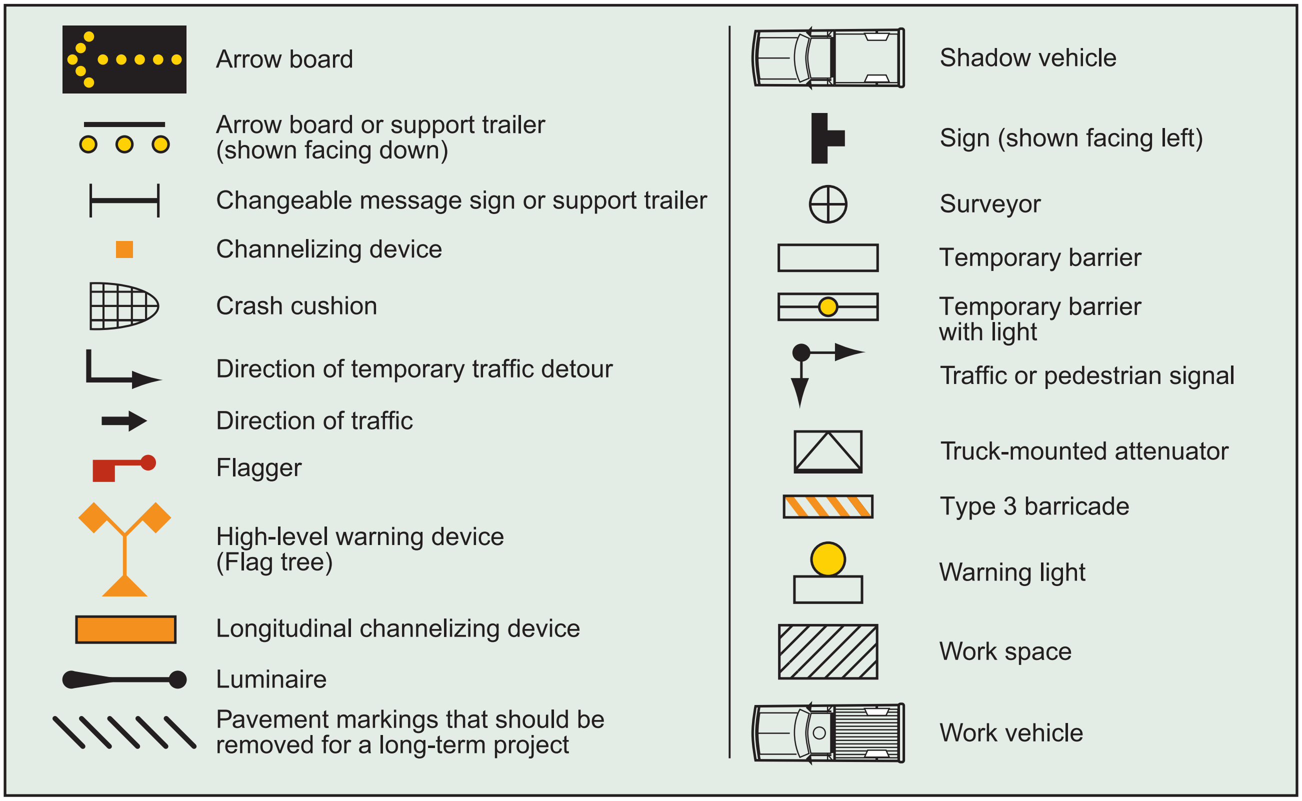


Exhibit 14.8: Recommended Advance Warning Sign Minimum Spacing (Reference for Letter Code Designations on Work Location Drawings)

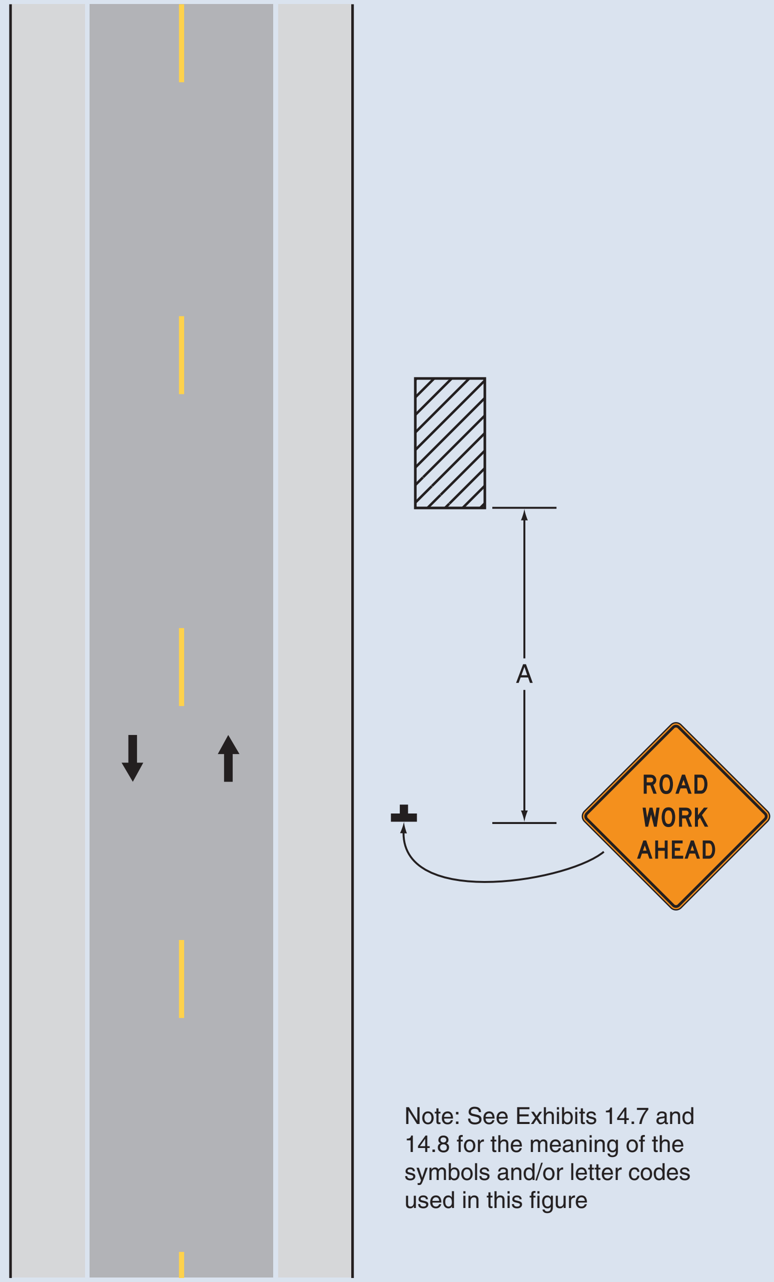
ROAD TYPE	DISTANCE BETWEEN SIGNS**		
	A	B	C
URBAN (LOW SPEED)*	100 feet	100 feet	100 feet
URBAN (HIGH SPEED)*	350 feet	350 feet	350 feet
RURAL	500 feet	500 feet	500 feet
EXPRESSWAY/FREEWAY	1,000 feet	1,500 feet	2,640 feet

* Speed category to be determined by the highway agency

** The column headings A, B, and C are the dimensions shown in *MUTCD* Figures 6H-1 through 6H-46, some of which are shown on the following page. The A dimension is the distance from the transition or point of restriction to the first sign. The B dimension is the distance between the first and second signs. The C dimension is the distance between the second and third signs. (The "first sign" is the sign in a three-sign series that is closest to the TTC zone. The "third sign" is the sign that is furthest upstream from the TTC zone.)

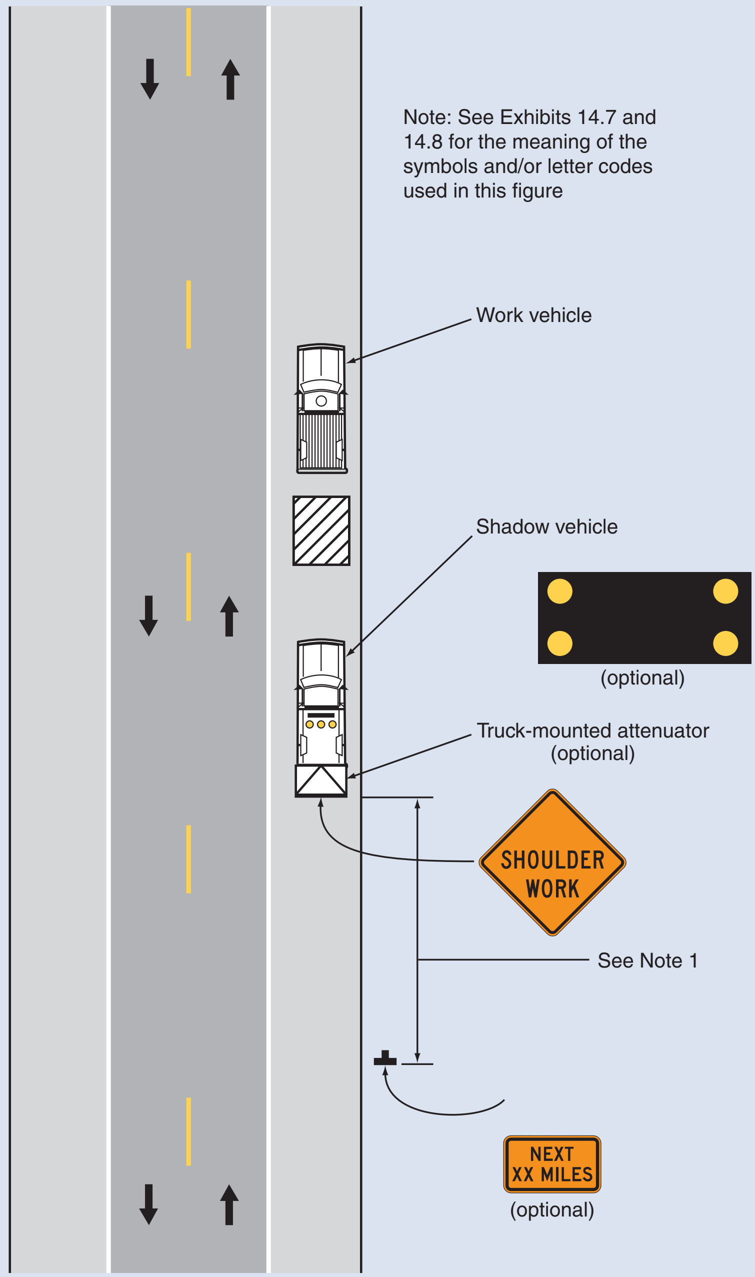
Source: MUTCD *Tables 6C-1 and 6H-3*

Work Beyond Shoulder—TTC needed if vehicles will be parked on the shoulder or travelling the roadway. TTC is generally not needed if all work and vehicles are located more than 15 feet from the edge of the travel way. Vehicle hazard lights shall not be used in lieu of high intensity rotating, flashing, oscillating, or strobe lights.



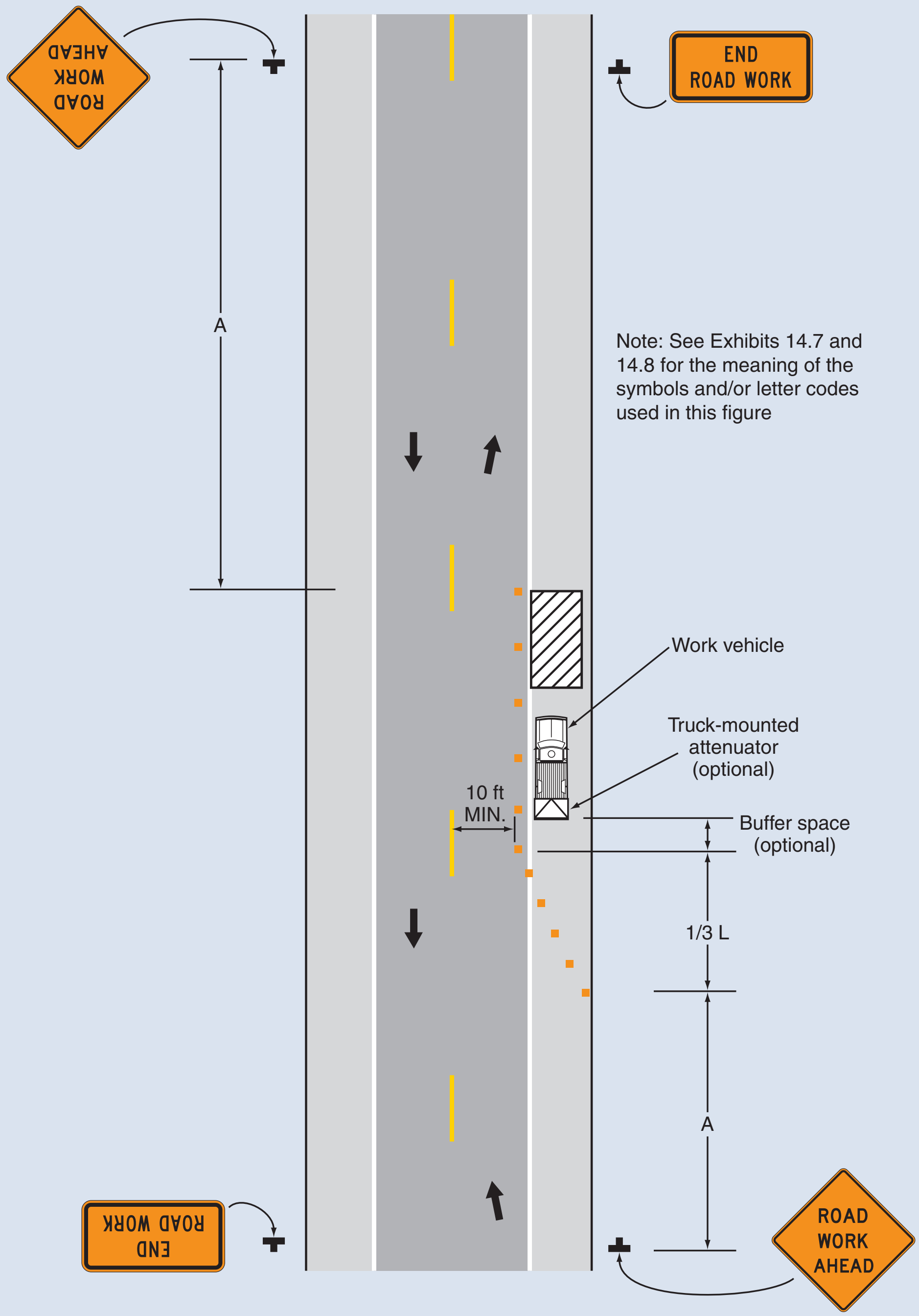
Source: MUTCD *Figure 6H-1*

Work on Shoulder with no encroachment—At least one advance warning sign shall be used if a paved shoulder 8 feet or wider is closed. Channelizing devices shall also be used to provide the road user with advance warning to stay in the travel way. Vehicle hazard lights shall not be used in lieu of high intensity rotating, flashing, oscillating, or strobe lights. Vehicle mounted signs should not be obstructed by equipment, and arrow boards shall use the caution mode.



Source: MUTCD *Figure 6H-4*

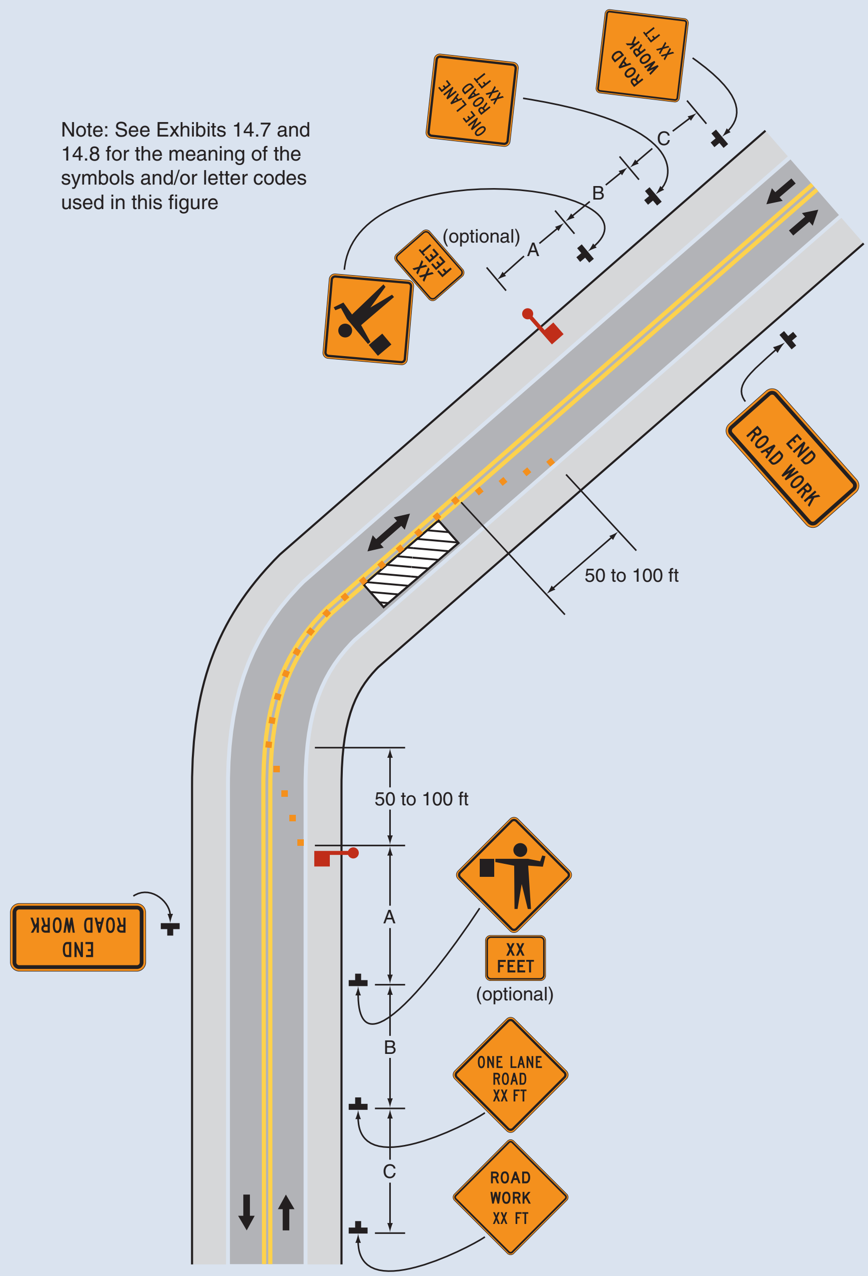
Work on Shoulder with minor encroachment—If the encroachment doesn't allow for at least a ten-foot travel way, then the lane should be closed. A nine-foot lane could be used in certain situations.



Source: MUTCD *Figure 6H-6*

Work within Traveled Way—One-Lane Closure on Two-Way Roadway –This involves lane closure for a limited distance, and the movements at each end of the closure need to be coordinated. This coordination can occur through the following methods:

Flagger Method—Flaggers located at both ends of closure, and are coordinated.

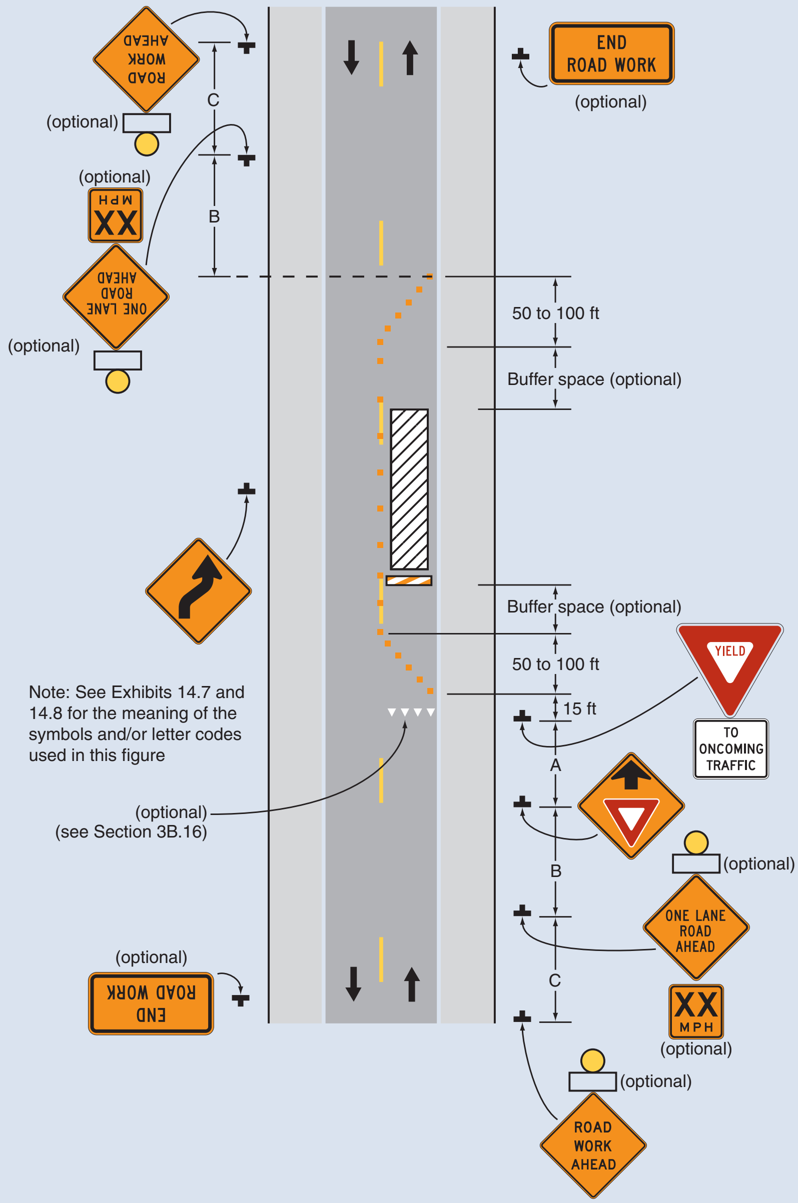


Source: MUTCD *Figure 6H-10*

Lane closure on a two-lane road with low traffic volumes

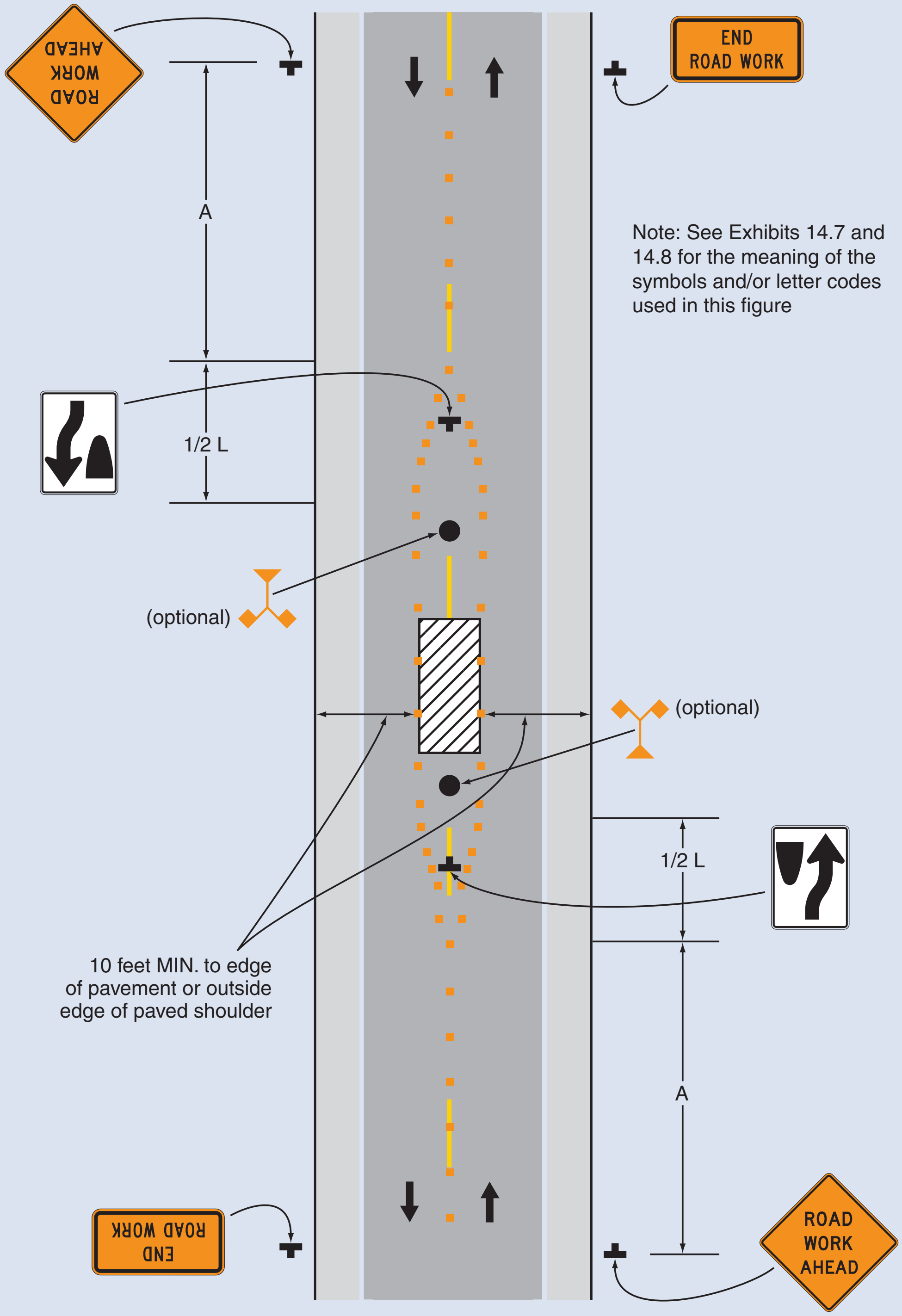
Flag Transfer Method—Vehicles at each end of closure are given a flag to signify the upcoming flagger that the lane is clear.

Stop or Yield Control—If sight distance permits, STOP or YIELD signs can be used to coordinate traffic through the single lane.



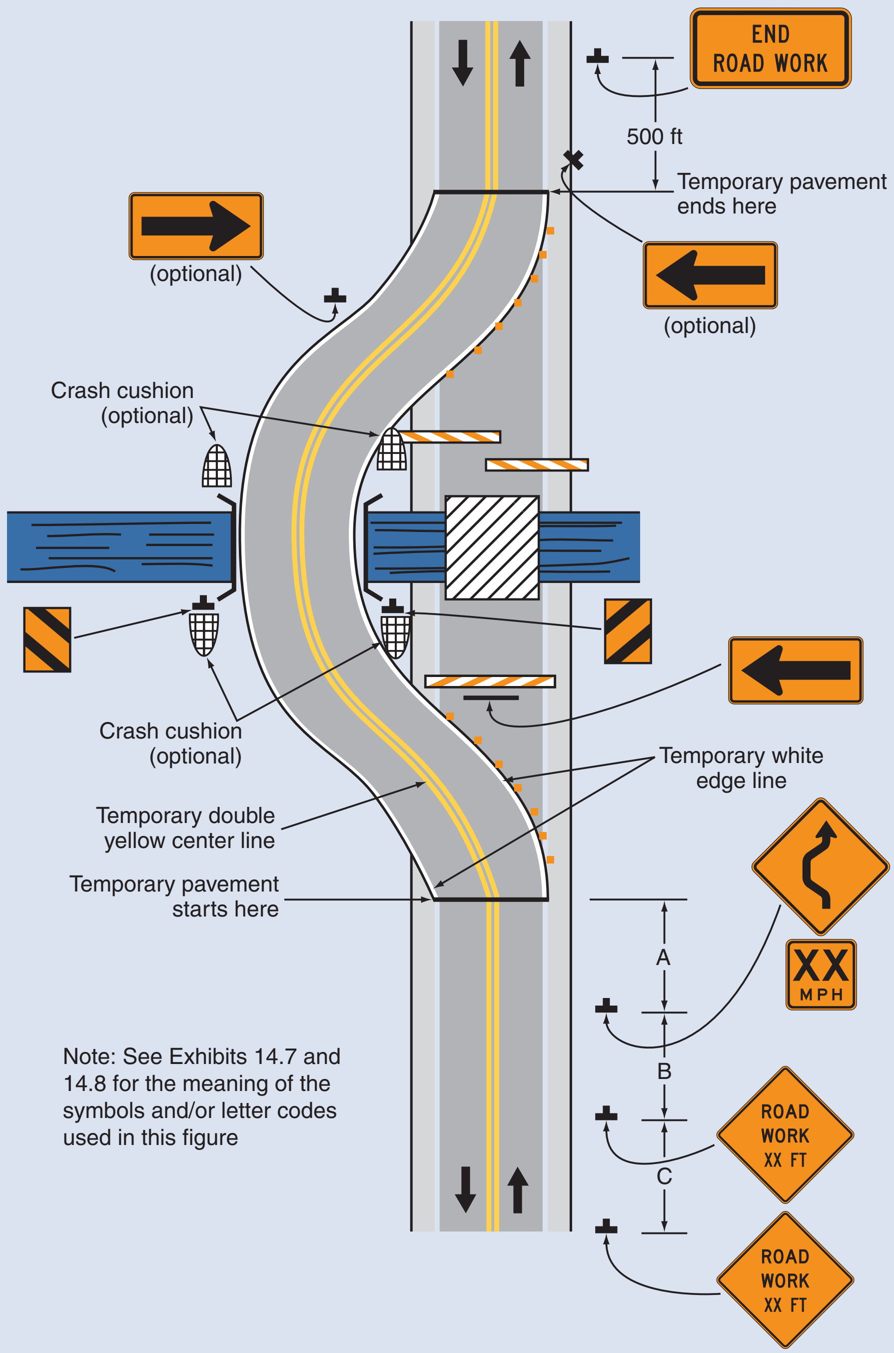
Source: MUTCD *Figure 6H-11*

Work in center of road—A minimum of 10-foot lanes shall be maintained around the work zone.



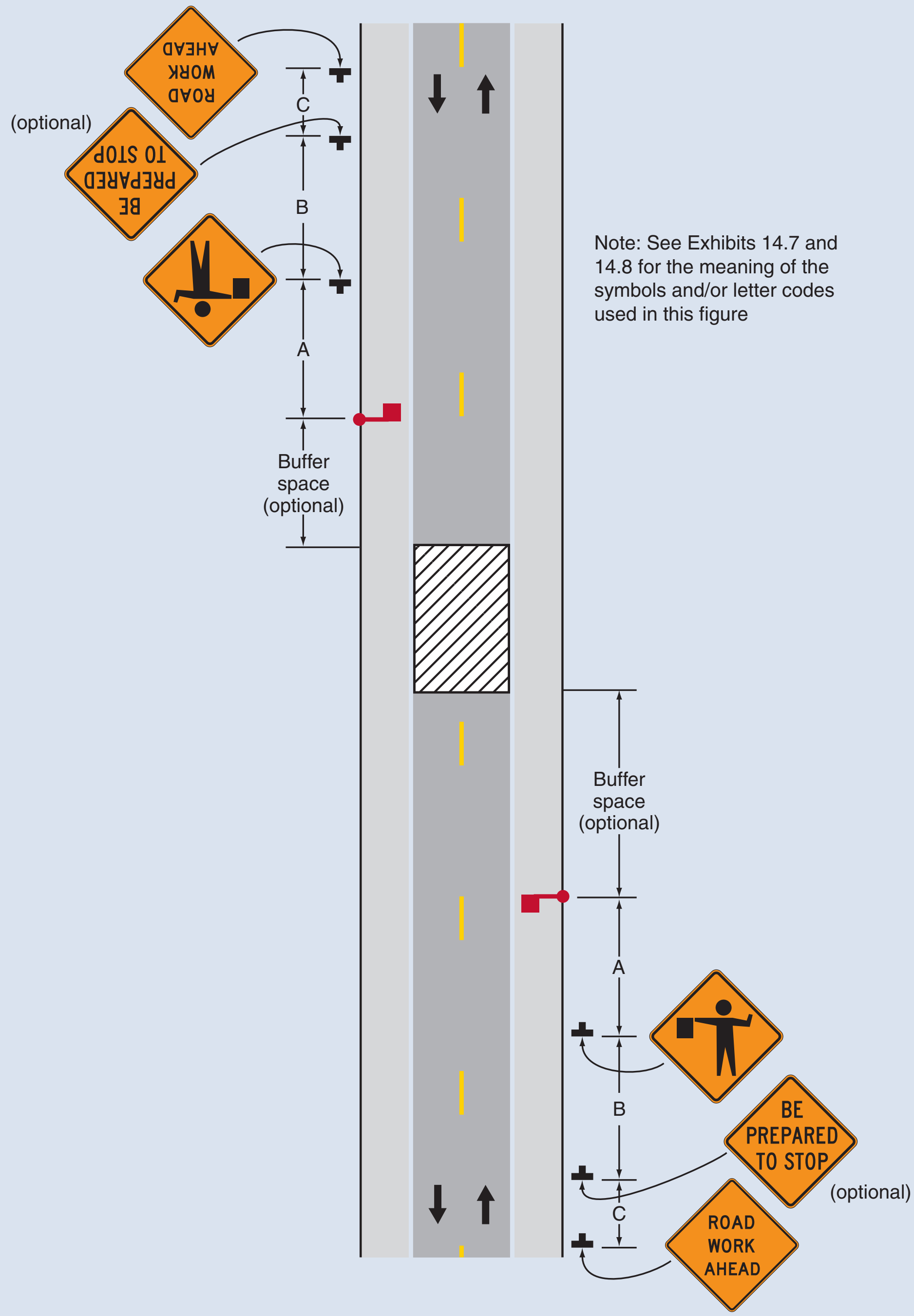
Source: MUTCD *Figure 6H-15*

Temporary Diversion—Temporary alignment used to divert road users around TTC zone. Pavement markings that do not apply shall be removed, and temporary barriers and end treatments shall be crashworthy.



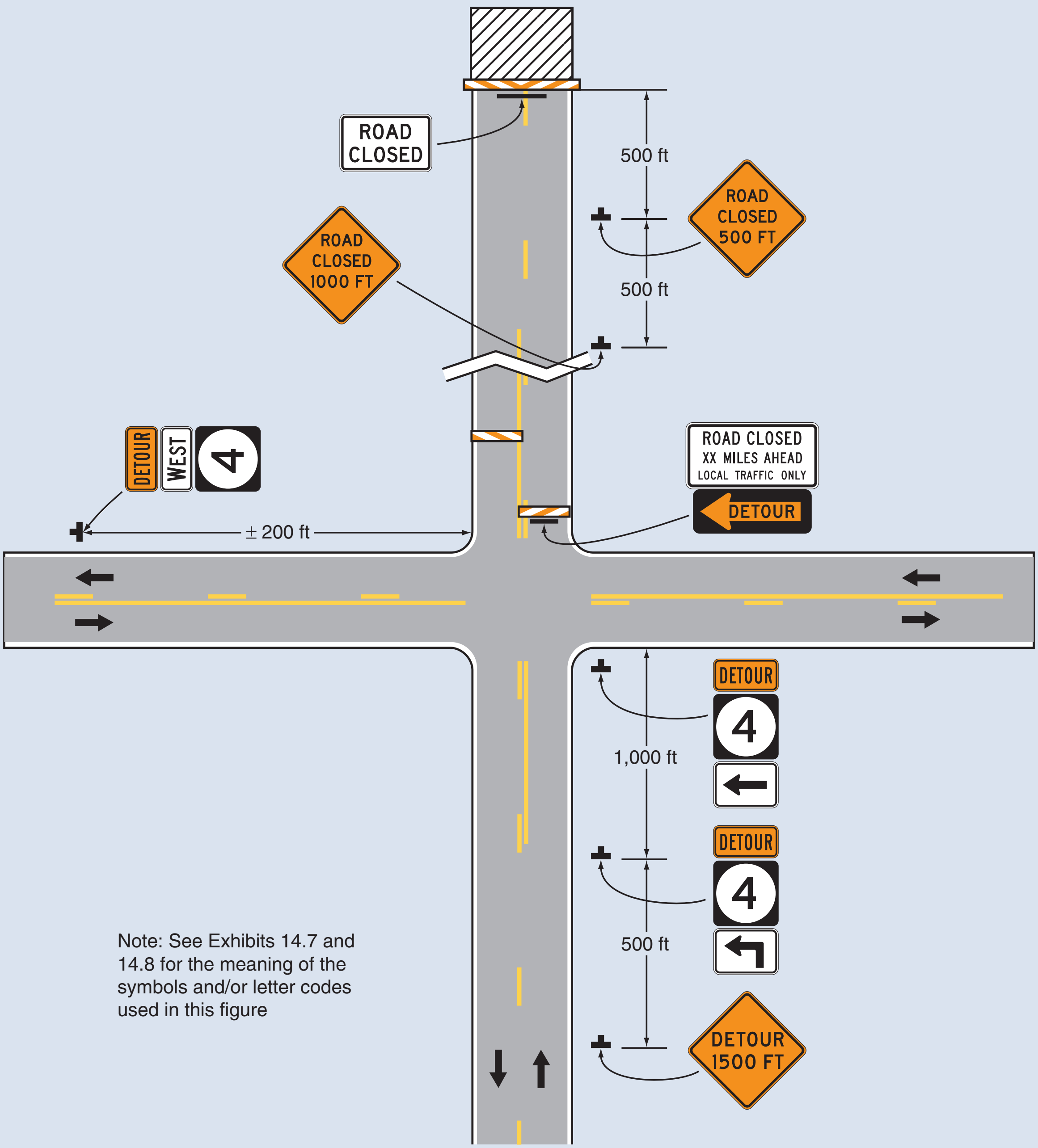
Source: MUTCD *Figure 6H-7*

Temporary Road Closure—Complete closure of the roadway. A flagger or other enforcement officer shall be used for this application.



Source: MUTCD *Figure 6H-13*

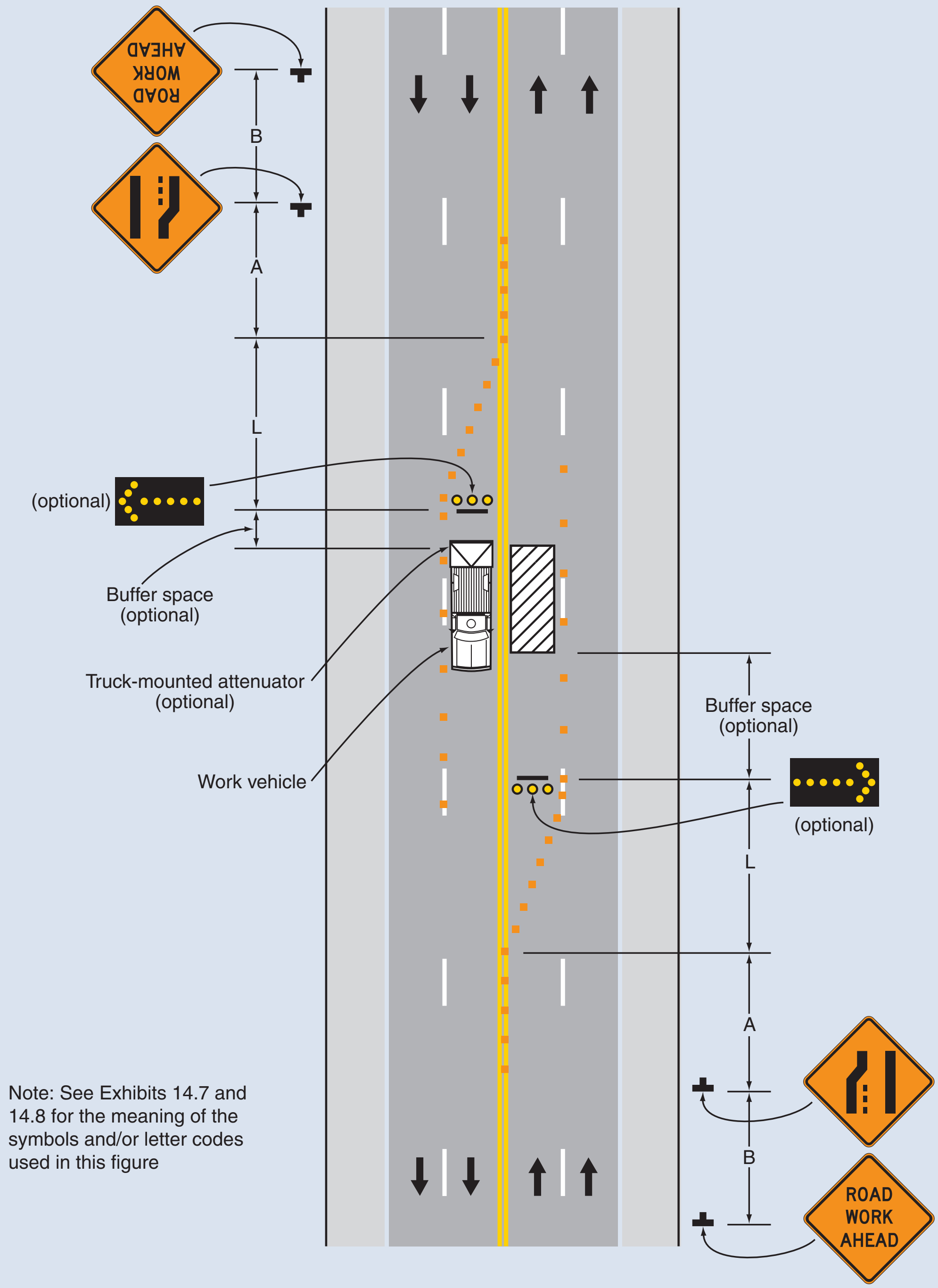
Detour Route—Used to temporarily reroute roadway users around a TTC zone onto existing roadways. Detour routes should be clearly marked to allow the road users to safely traverse the route, and return to the original roadway.



Note: See Exhibits 14.7 and 14.8 for the meaning of the symbols and/or letter codes used in this figure

Source: MUTCD *Figure 6H-8*

Closure on Multi-Lane Street—Additional signing may be needed then what is shown if there is a high speed limit or traffic volume.



Source: MUTCD *Figure 6H-30*

14.7. TTC DEVICES

The *MUTCD* defines traffic control devices as all signs, signals, markings, channelizing devices and other devices used to regulate, warn, or guide road users, placed on, over, or adjacent to a roadway open to public travel.

All traffic control devices used within TTC zones on a street, highway, or private road open to public travel shall comply with the applicable provisions of the *MUTCD*. This section summarizes the typical TTC devices utilized on military installations.

14.7.1. Signs

TTC zone signs convey both general and specific messages by means of words, symbols, and/or arrows and have the same three categories as all road user signs: regulatory, warning, and guide.

The colors for regulatory signs shall follow standards for other regulatory signs. Warning signs in TTC zones shall have a black legend and border on an orange background, with the following exceptions:

- ✓ The Grade Crossing Advance Warning sign (W10-1) must keep the yellow background.
- ✓ Signs required to have the fluorescent yellow-green background (School Crossing (S1-1) for example) must keep the fluorescent yellow-green background

Colors for guide signs shall follow the standard colors identified in the *MUTCD*. Refer to Part 6 of the *MUTCD* for a comprehensive listing of signs, installation and location criteria, sign size, and maintenance requirements.

R11-4

Regulatory Sign

W20-1*

Warning Sign

M4-10

Guide Sign

14.7.2. Channelizing Devices

> **KEY POINTS**
> Channelizing devices are typically used to close areas off from travel which are normally open to travel.

Channelizing devices are used for delineation of traffic patterns, or to channelize pedestrians. These include drums; tubular markers; vertical panels; cones; and Type I, II, or III barricades. Traffic cones and markers can be used effectively for temporary channelization of traffic during lane reversal and lane closures. These devices are convenient since, unlike steel drums, they can be quickly placed and removed and, if struck, will not damage vehicles.

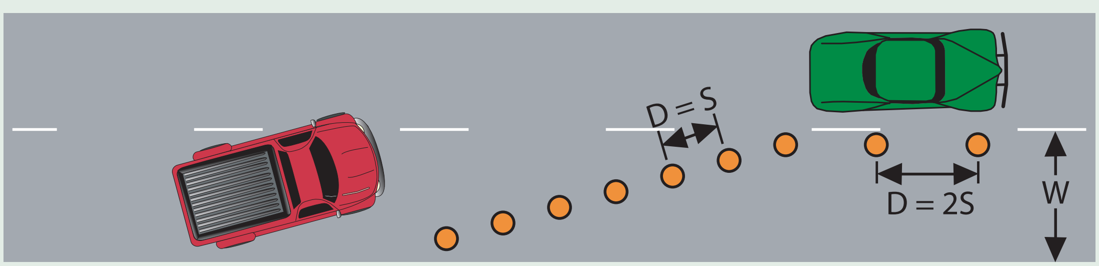
All traffic cones shall be orange in color and a minimum of 28 inches high with white retroreflective bands per *MUTCD*.

Within transitions (i.e., taper channelization), the distance between cones in feet should not exeed the posted speed limit in miles per hour. For example, if the posted speed limit is 25 mph, the maximum cone spacing is 25 feet. At other locations (i.e., tangent channelization), such as adjacent to closed lanes, the distance between cones in feet may be double the speed limit in miles per hour.

The use of traffic cones should follow standard transition requirements and should not result in an abrupt change in traffic patterns. As a general rule, the taper length (for merging lanes) in feet should at least equal $WS^2/60$ for a speed limit of 40 mph or less, or WS for speed limits equal to or greater than 45 mph (where W is the width of the shift in feet and S is the posted speed in miles per hour) or 100 feet, whichever is greater. Refer to Section 14.6 for additional information regarding the design of tapers in work zones.

The next page shows different channelizing devices.

LANE REDUCTION TAPER LENGTHS

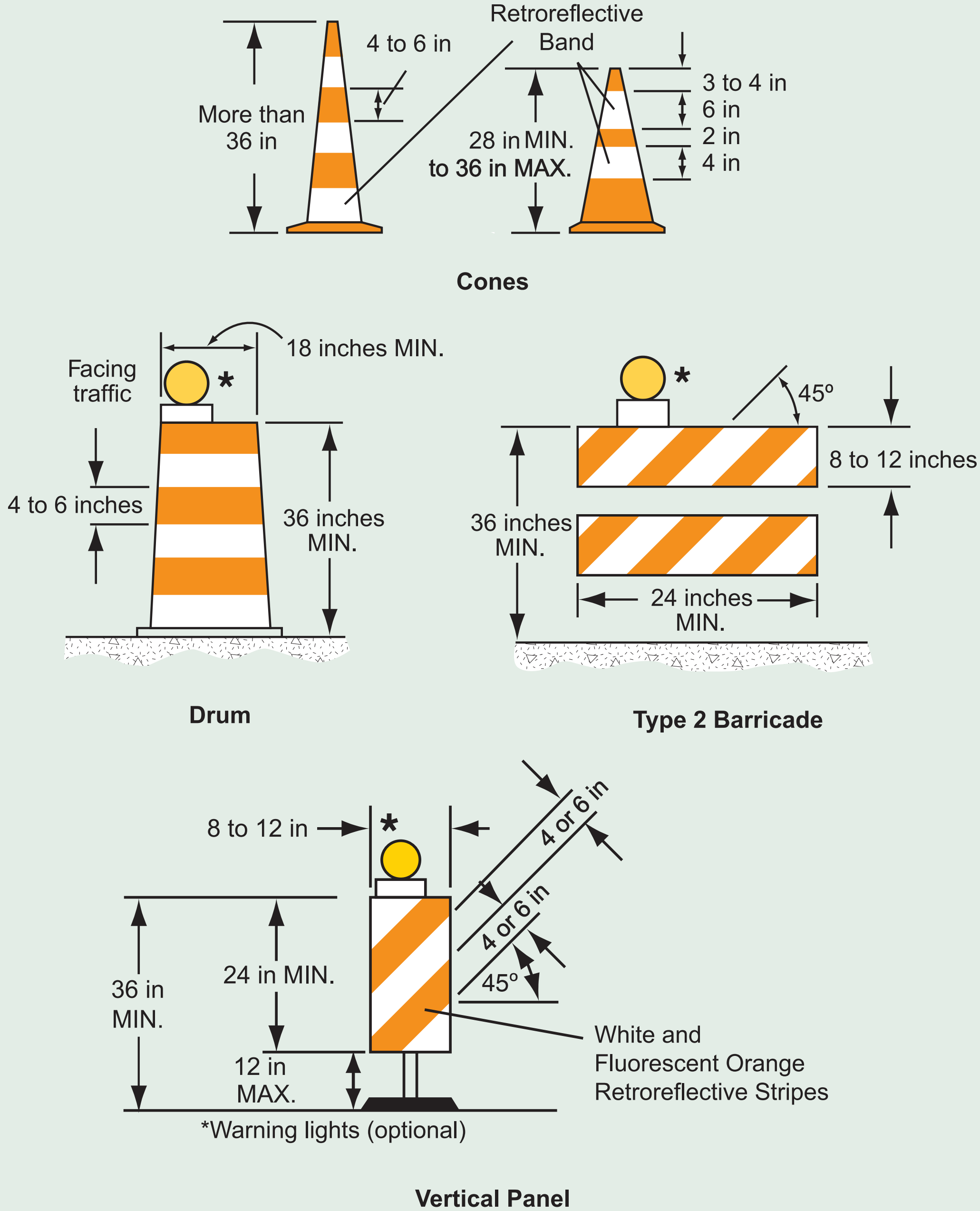


W = Width of Transition (feet)
S = Speed Limit (mph)
L = Length of Transition (feet)
D = Distance Between Channelizing Devices (feet)

$L = \frac{WS^2}{60}$ (For $S \leq 40$ mph)

$L = WS$ (For $S \geq 45$ mph)

TYPICAL CHANNELIZING DEVICES



Source: MUTCD *Figure 6F-7*

14.7.3. Flagger Devices

The most common device used by flaggers is a Hand-Signaling Device, such as a STOP/SLOW paddle. When used at night, the paddle shall be retroreflectorized.

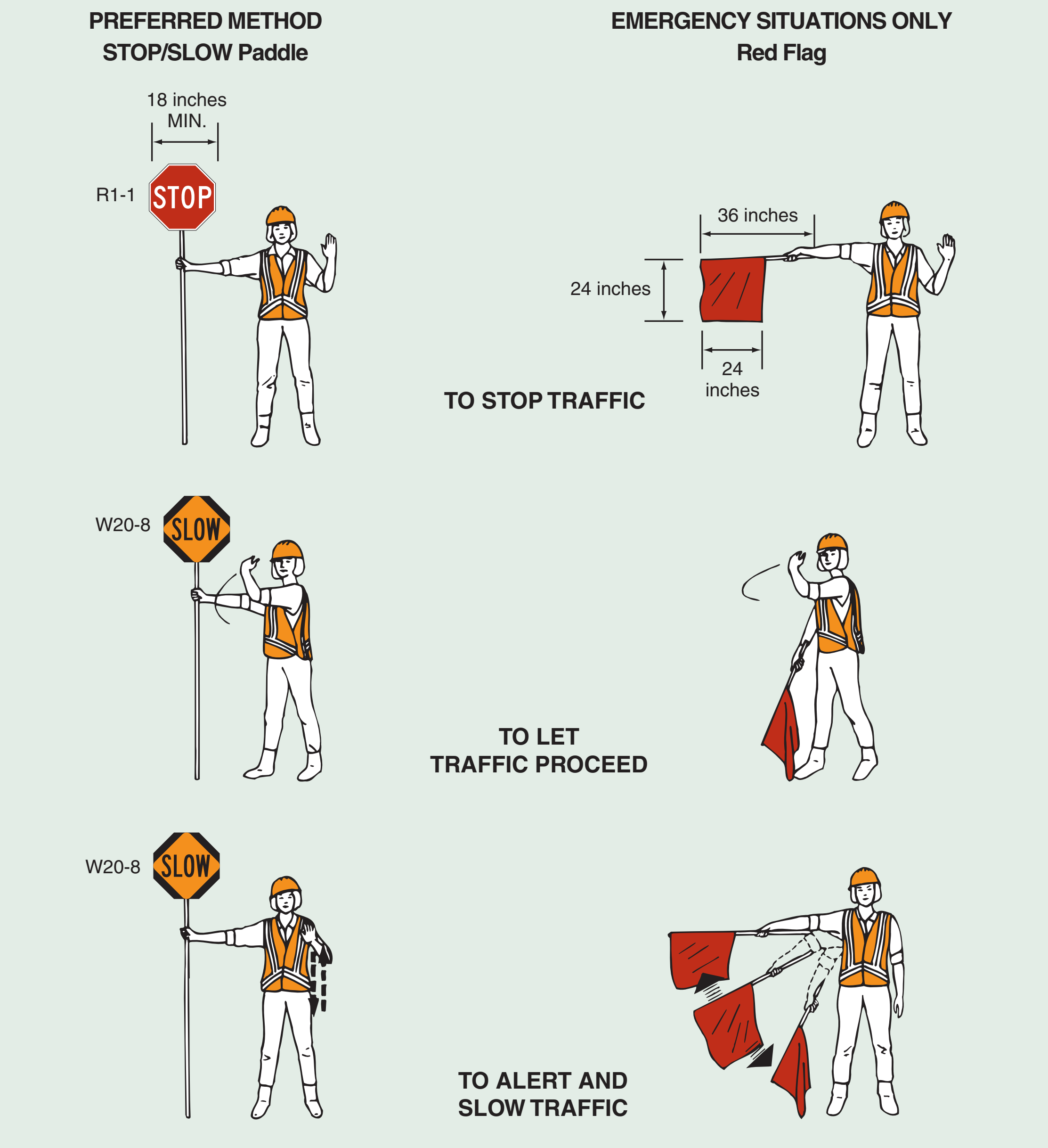
Flaggers in TTC zones should use special equipment to supplement hand signals. This can include a STOP/SLOW paddle, a flag, or a lighted baton. Typically, flaggers use a STOP/SLOW paddle, or flag, as shown in Exhibit 14.9. The *MUTCD* Part 6 describes other less common automated devices, and the detailed procedures for safely controlling traffic. Exhibit 14.9 shows common flagger hand signals.

A disadvantage of the paddle is that the messages are limited to those which are contained on the paddle. The flag offers more versatility compared to the STOP/SLOW paddle, but does not have reflectivity. Flags are made of a fluorescent orange vinyl material. This offers good visibility during daylight hours, but without retroreflectivity, it cannot be used at night. The actual flag can vary in size. Larger sizes are preferred for maximum visibility.

A lighted baton offers the advantage of nighttime visibility. Since it is not reflective, and does not have as much surface area visibility, it is not as effective during the day. For this reason, the use of a baton should be limited to nighttime.

In order to assist with audio signals, a flagger could have a whistle for use as needed.

Exhibit 14.9: Use of Hand-Signaling Devices by Flaggers



Source: MUTCD *Figure 6E-3*

14.7.4. Additional TTC Devices

Portable Changeable Message Sign—Can be used to display a variety of messages including information about an upcoming detour or road or lane closure. These shall only display traffic operational, regulatory, warning, or guidance information. Never use these for advertising messages.

Arrow Boards—Shall be a sign with a matrix of elements capable of either flashing or sequential displays.

Temporary Pavement Markings—Can consist of temporary painted pavement markings or temporary raised pavement markers

Lighting Devices—Can be used to supplement retroreflectorized signs, barriers, and channelizing devices.

Floodlights—Can be used when night work is required. Floodlighting shall not produce a disabling glare condition for approaching road users, flaggers, or workers.

Warning Lights—Consist of Type A, B, C, and D and are portable, powered, yellow, lens-directed, enclosed lights. These are mounted on channelizing devices or signs in a manner that, if hit by an errant vehicle, they will not be likely to penetrate the windshield.

Temporary Traffic Control Signals—Can be used to control road user movement through TTC zones.

Temporary Traffic Barriers—Shall be supplemented with standard delineation for improved visibility if used for channelizing. Temporary traffic barriers and their end treatments shall be crashworthy.

Crash Cushions—Shall be crashworthy and designed for each application to stop or redirect errant vehicles under prescribed conditions. They should be inspected periodically, and if damaged, shall be promptly repaired or replaced.

TTC Device Use

14.8. WORKER SAFETY CONSIDERATIONS

KEY POINTS

People working in traffic must always at a minimum wear an ANSI-approved reflective vest.

The safety of the workers within the TTC zone is equally as important as maintaining safety to the travelling public. The workers are vulnerable due to their close proximity to roadway users traversing through a change in traffic patterns. The elements shown in Exhibit 14.10 should be considered in order to improve worker safety.

Exhibit 14.10: Worker Safety Elements

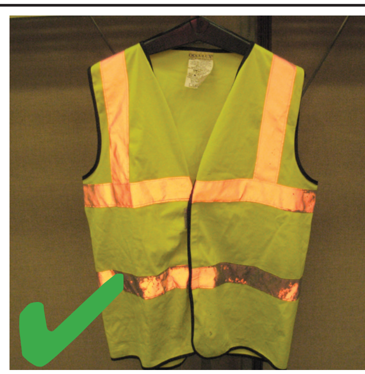
TRAINING	All workers should be trained on how to safely work next to motorized traffic.
TEMPORARY TRAFFIC BARRIERS	Should be placed along the work zone depending on factors such as lateral clearance or workers from adjacent traffic, speed of traffic, duration and type of operations, time of day and traffic volume.
SPEED REDUCTION	Reducing the speed of vehicular traffic, mainly through regulatory speed zoning, funneling, lane reduction, or the use of flaggers should be considered.
ACTIVITY AREA	Minimize exposure to risk by planning internal work area to minimize backing-up maneuvers of construction vehicles.
WORKER SAFETY PLANNING	A trained person should conduct a basic hazard assessment for worksite and job classifications required in the activity area.
SAFETY APPAREL	All workers, including flaggers and emergency responders, who are exposed to traffic or work vehicles/construction equipment within the TTC zone shall wear high-visibility safety apparel that meets proper classification for day and night work.
ROAD CLOSURE	If a detour route is available, the road may be closed temporarily which will reduce worker vulnerability.
LIGHTING	For nighttime work, the TTC zone may be lighted.

All daytime and nighttime workers, including flaggers and emergency responders, shall wear high-visibility safety apparel (meets ANSI 107-2004, Class 2 or 3 risk exposures).

- ✓ ANSI Class 2 apparel—required as a minimum for all workers within the highway right-of-way. Typical use is on lower speed, lower volume, and secondary road environments. Proper Class 2 apparel consists of a retroreflective fluorescent yellow-green sleeveless vest.
- ✓ ANSI Class 3 apparel—offers the greatest visibility and is recommended for high-risk environments including, but not limited to, high speed roadways, highly congested areas, complex lane shifts, bad weather, and/or in complex work zones. Class 3 vests are required to have sleeves, but retroreflective pants may be worn in addition to a Class 2 vest to also meet Class 3 standards.

Per the *MUTCD*, all workers, including flaggers and emergency responders, within the right-of-way who are exposed either to traffic (vehicles using the highway for purposes of travel) or to work vehicles and construction equipment within the TTC zone shall wear high-visibility safety apparel that meets the Performance Class 2 or 3 requirements of the ANSI/ISEA 107–2004 publication entitled “American National Standard for High-Visibility Safety Apparel and Headwear” (see Section 1A.11), or equivalent revisions, and labeled as meeting the ANSI 107-2004 standard performance for Class 2 or 3 risk exposure. A person designated by the employer to be responsible for worker safety shall make the selection of the appropriate class of garment. Proper safety apparel is required, in part, for OSHA compliance. The lack of proper safety apparel would be a “recognized hazard” as used in OSHA’s General Duty Clause, and would therefore be an OSHA violation.

Exhibit 14.11: Safety Apparel Classes

CLASS 1	
CLASS 2	
CLASS 3	

- ✓ ANSI Class 1 apparel is obsolete (although commonly available). This apparel is the incorrect color and lacks sufficient surface area.
- ✓ ANSI Class 2 apparel—required as a minimum for all workers within the highway right-of-way. Typical use is on lower speed, lower volume, and secondary road environments.
- ✓ ANSI Class 3 apparel—offers the greatest visibility and is recommended for high-risk environments including, but not limited to, high speed roadways, highly congested areas, complex lane shifts, bad weather, and/or in complex work zones. Class 3 vests are required to have sleeves, but retroreflective pants may be worn in addition to a Class 2 vest to also meet Class 3 standards.

A fluorescent hat or hard hat is also recommended for head gear for additional visibility. Hard hats are usually needed in work zones.

Workers within an active work zone

14.8.1. Flagger Considerations

It is important that flaggers have the proper training and qualifications due to their responsibility for public safety and because they have the most exposure to vehicles than other roadway workers. Flaggers should have the ability to receive and communicate specific instructions clearly, to move and maneuver quickly from danger, to control signaling devices, to understand and apply safe traffic control practices, and to recognize dangerous traffic situations and warn workers in time to avoid injury.

14.9. PEDESTRIAN CONSIDERATIONS

If pedestrian traffic will be interrupted by a TTC zone, then adequate temporary pedestrian access and walkways shall be provided. This includes maintaining accessibility and detectability if it exists at the affected area. When planning for pedestrians in a TTC zone, consider the following:

- ✓ Pedestrians shall not be led into conflicts with vehicles, equipment, and operations including vehicles moving through or around the worksite.
- ✓ Pedestrians shall be provided with a comparable temporary pathway to the existing condition, including width of walkway.
- ✓ A smooth, continuous hard surface shall be provided throughout the entire length of the temporary facility.
- ✓ Temporary pedestrian facilities must meet PROWAG requirements for accessibility, and must be designed to the same accessibility standards as a permanent facility.
- ✓ If pedestrians with disabilities are expected, then blocked routes, alternate crossings and sign and signal information should be communicated through devices such as audible information devices, accessible pedestrian signals or barrier or channelizing devices that are detectable to the disabled.
- ✓ If channelization is used to delineate a pathway, a continuous detectable edging should be provided for the disabled.
- ✓ If considered to be a shared-use path, objects are prohibited from overhanging or protruding into any portion of a shared use path, at or below 8 feet measured from the finished surface such that a minimum of 8 feet of vertical clearance is provided above the finished surface.

Undesirable example of temporary pedestrian accommodations

CHAPTER 15—SPEED LIMITS

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Speed limit signs are one of the most common types of traffic signs, but research shows that speed limits have little effect on the actual speed that motorists drive their vehicles. Moreover, the presence of an inappropriate speed limit increases the probability of crashes.

15.1. SPEED LIMIT BASICS

KEY POINT

Research shows that the safest speed limit approximates the 85th-percentile speed.

Speed limit sign example

Most motorists select a speed that will allow them to arrive at their destination in the shortest time possible but without endangering themselves and others. As drivers, we select our speed by considering the roadway width and alignment, presence of intersections and driveways, roadside conditions, parked vehicles, pedestrian traffic, mix and density of vehicular traffic, weather, and other conditions. The posted speed limit is the numerical speed limit noted on regulatory signs placed along the roadway to which it applies. Drivers pay almost no attention to posted speed limits, and studies have repeatedly proven that raising or lowering the speed limit has little effect on most drivers. All states have a law that requires a driver to operate his or her vehicle at a speed that is reasonable and prudent for existing conditions, regardless of the presence of a posted speed limit.

Speed differences between vehicles increase crash potential, and the greater the speed differences, the greater the damage when vehicles collide with one another. In a perfect world, everybody would drive at exactly the same speed at any given location.

Research shows that the safest speed limit approximates the 85th-percentile speed, which is the speed that 85 percent of the free-flowing vehicles are traveling at or below. In reality, it is necessary to round the speed limit to the nearest 5-mph multiple at or below the 85th-percentile speed.

Studies repeatedly show that establishing the speed limit below the 85th-percentile speed increases the number of crashes. The cause of this increase in crashes may be the direct result of a few drivers who actually attempt to obey the speed limit, which in turn frustrates other drivers, causes traffic queues and congestion, and contributes to increased tailgating and passing.

The basic reason to have a posted speed limit is to encourage speed uniformity and to provide a means to prosecute the few drivers that travel at excessive speeds and jeopardize the safety of others.

15.2. WHAT IS SPEED ZONING?

KEY POINT

Consult your state's vehicle code to ensure that all posted speed limits are enforceable.

Speed zoning is the process used to determine the proper speed limit. Every state uses the 85th-percentile speed as a major factor in selecting the appropriate speed limit. This is usually based on an engineering and traffic study. However, other factors such as roadside conditions, crash experience, and design speed are often considered.

All states have at least one statutory speed limit that may or may not require speed limit signs to make them enforceable. For example, a state may have statutory speed limits such as:

- ✓ 25 mph in urban business districts.
- ✓ 35 mph in residential districts.
- ✓ 70 mph on rural freeways.
- ✓ 55 mph on all other roadways.

However, agencies generally may revise these speed limits if they perform traffic engineering studies that document that the speed limit should be higher or lower than the statutory provisions. Therefore, it is essential that installations know the specifics for their state to ensure that all posted speed limits are enforceable under your state's vehicle code. For example, you should know:

- ✓ Statutory speed limits.
- ✓ Required engineering and traffic studies.
- ✓ Maximum spacing intervals for speed limit signs.

The statutory speed limit is a speed limit established by law that applies to a specific class or category of road; such as, rural freeway, residential streets, business district, and so on, and in some cases does not even require speed limit signs to make it legally enforceable. Statutory speed limits are specific to each state. Information regarding speed laws for your state is available via the Massachusetts Institute of Technology at: http://www.mit.edu/~jfc/laws.html. This site is good to provide a basic summary of states' codes. Another reference to utilize is the Summary of State Speed Laws (currently Twelfth Edition) distributed by the U.S. Department of Transportation, National Highway Traffic Safety Administration (NHTSA). Nonetheless, individual state vehicle codes should always be reviewed to verify the information retrieved. Additionally, the MIT site is not all-inclusive, and generally geared towards maximum speed limits by state versus lower speed limit codes by state.

Generally, most states require engineering and traffic studies to determine the following:

- ✓ Prevailing vehicle speeds.
- ✓ Physical features of the roadway.
- ✓ Crash locations and crash rates.

Any special safety concerns that may not be readily apparent to drivers; for example, limited sight distance.

15.3. SPOT SPEED STUDIES

KEY POINT

Use a spot speed study to determine the 85th-percentile speed.

Spot speed studies determine the speed distribution of vehicular traffic at a specific location. The most common method to determine vehicle speeds is with a radar speed gun.

To establish a regulatory speed limit, perform the spot speed study on a straight section of roadway, away from intersections where congestion may slow traffic. Design the study to avoid influencing the speeds; for example, a technician with a radar gun should not be visible to passing motorists, if possible. Perform speed studies under ideal weather, road and traffic conditions, and without the presence of police vehicles or any restriction that could influence speeds.

As a rule-of-thumb, spot speed studies should include a minimum of 100 free-flowing vehicles; however, if traffic volumes are very light you may reduce the sample to about 50 vehicles or a 2-hour sample. If there is a platoon of traffic, record only the speed of the first vehicle in the platoon since other vehicles are not free-flowing vehicles.

Use a data sheet, as shown in Exhibit 15.1, to annotate the spot speed information. One advantage of recording the speeds of exactly 100 vehicles is the simplicity of determining the 85th-percentile speed. By examination, the 85th-percentile speed in Exhibit 15.1 is between 35 and 36 mph because 83 vehicles traveled at or below 35 mph and 90 vehicles traveled at or below 36 mph.

Exhibit 15.1: Radar Spot Speed Data Example

SPEED (MPH)	RECORD	NO.	CUMULATIVE TOTAL
23			
24			
25	//	2	2
26			
27	//	2	4
28	////	4	8
29	//	2	10
30	~~////~~ ~~////~~ //	12	22
31	~~////~~	5	27
32	~~////~~ ~~////~~	10	37
33	~~////~~ ~~////~~ ~~////~~ ////	19	56
34	~~////~~ ~~////~~ ~~////~~	15	71
35	~~////~~ ~~////~~ //	12	83*
36	~~////~~ //	7	90*
37	~~////~~	5	95
38	///	3	98
39			
40	//	2	100
41			
42			
TOTALS		100	

** Note: The cumulative total column indicates that the 85th-percentile speed is between 35 and 36 mph.*

The *MUTCD* indicates that the speed limit should be within 5 mph of the 85th-percentile speed. However, some states make provisions for reductions below the 85th-percentile speed if crash rates are abnormally high or if special safety concerns exist that may not be readily apparent to drivers. For example, drivers may be unaware of limited stopping sight distance or restricted sight distance from a side road.

See SDDCTEA Pamphlet 55-8 for more information on speed studies.

15.4. SPEED LIMIT SIGNS

The standard Speed Limit (R2-1) sign is 24 by 30 inches. On roads with more than one travel lane in the same direction, it is beneficial to use a larger size such as 30 by 36 inches. You may also use larger sizes for additional emphasis at other locations. Refer to Chapter 7 for additional information regarding Speed Limit signage.

Place speed limit signs at every location where the speed limit changes, beyond major intersections, and at other locations where it is necessary to remind the road users of the applicable speed limit. However, try to avoid placing a sign immediately in advance of a curve or turn.

The *MUTCD* does not contain any maximum spacing requirements for Speed Limit signs, but many states have unique requirements that must be followed in order to enforce speed limits. Therefore, speed limit signs should also be placed at intermediate locations as necessary to comply with any state requirements. In the absence of any specific state spacing requirements, installations are encouraged to use maximum 1-mile spacing for speed limits of 35 mph or lower, and maximum 3-mile spacing for higher speed limits.

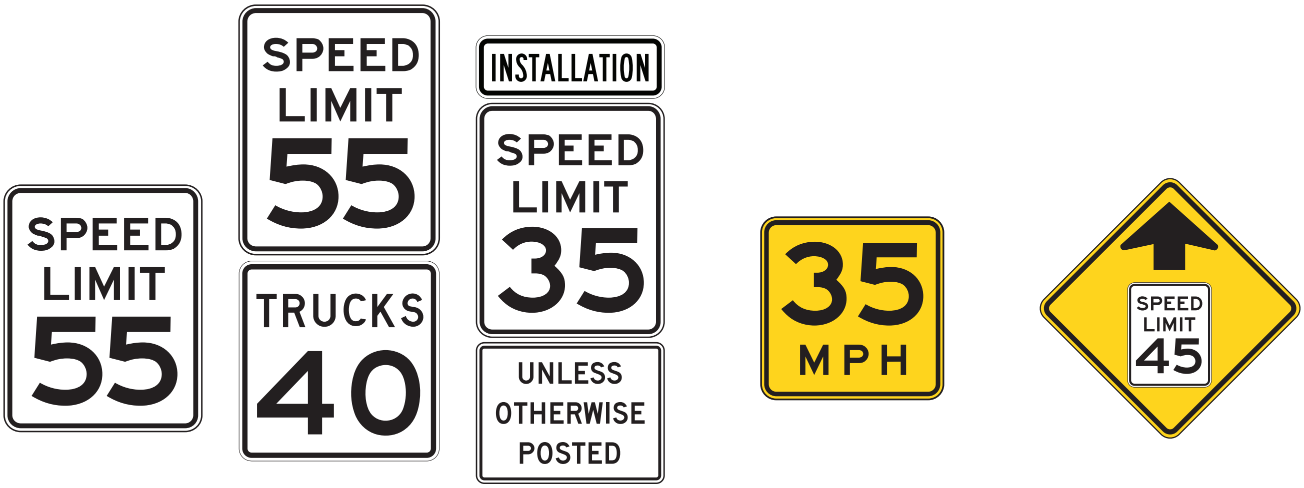
There may often be the desire to post lower speed limits for certain types of vehicles. These vehicle types may be trucks or any other slow-moving heavy vehicles. When this different speed limit is desired, use the Truck Speed Limit Plaque (R2-2P) to display the lower speed limit. This plaque would be mounted beneath a regular speed limit sign displaying the speed limit for the remainder of traffic. If trucks are not the appropriate vehicle to which the lower speed limit would pertain, the legend can be modified as appropriate.

Most states require advance signs to inform drivers of speed reductions, especially if the reduction is over 10 mph. The type of sign may vary from state to state, but the trend is to use the new Speed Reduction (W3-5) sign as shown below. Therefore, it is important to know the specific requirements for your state.

Many installations post blanket speed limits. This is permitted based on the 2009 *MUTCD*. This could either be posted at the entrance of the installation after the ECF area, or at more localized areas such as at the entrance to a housing area. If this type of speed limit is used, it should be signed as shown below:

- ✓ One of the following:
    - R2-5iP-TEA, INSTALLATION
    - R2-5cP, RESIDENTIAL
- ✓ R2-1, SPEED LIMIT XX
- ✓ R2-5P, UNLESS OTHERWISE POSTED

SPEED LIMIT | ADVISORY SPEED | SPEED REDUCTION



R2-1 | R2-1 and R2-2P | R2-5iP, R2-1, R2-5P | W13-1P | W3-5

Common speed-related signs

15.5. SPEED LIMIT REDUCTIONS

A Reduced Speed Limit Ahead (W3-5 or W3-5a) sign should be used to inform road users of a reduced speed zone where the speed limit is being reduced by more than 10 mph, or where engineering judgment indicates the need for advance notice to comply with the posted speed limit ahead.

If used, Reduced Speed Limit Ahead signs shall be followed by a Speed Limit (R2-1) sign installed at the beginning of the zone where the speed limit applies. The speed limit displayed on the Reduced Speed Limit Ahead sign shall be identical to the speed limit displayed on the subsequent Speed Limit sign.

W3-5

W3-5a

SPEED LIMITS

15.6. ADVISORY SPEEDS

> **KEY POINT**
> An advisory speed is a recommended safe speed for a specific condition.

An advisory speed (or warning speed) is a recommended safe speed at a given location such as a curve, where the speed is shown on a warning sign. However, this speed is relative to the driver and the vehicle driven—a speed that is safe or comfortable for a driver of a car may not be safe or comfortable for a truck driver, and the safe or comfortable speed for a driver of a sports car may not be safe or comfortable for the driver of a family sedan.

Though the most common application of an advisory speed is with the Advisory Speed (W13-1P) plaque installed below the Turn (W1-1) sign or Curve (W1-2) sign (shown below), an advisory speed may be posted below any warning sign. An option other than the Advisory Speed plaque for displaying warning speeds on Turn or Curve signs is to include it on the actual Turn or Curve sign legend (see the W1-1a sign shown below). *[Note: A Turn (W1-1) sign shall be used instead of a Curve sign in advance of curves that have advisory speeds of 30 mph or less.]*

If a regulatory speed limit, as displayed by black and white signs, is not appropriate at a horizontal turn or curve, the appropriate advisory speed may be determined from the 85th-percentile speed on the curve. The advisory speed should be the nearest multiple of 5 mph that is at or below the 85th-percentile speed.

The safe speed on a curve or turn can be determined by one of the following methods:

- ✓ Drive the curve with a ball-bank indicator as discussed on the following page.
- ✓ Determine the 85th percentile speed of passenger cars on the curve or turn.
- ✓ Review the roadway as-built plans and determine the design speed of the curve based on the radius constructed.

W1-1 and W13-1P

Turn sign with an Advisory Speed plaque

W1-2 and W13-1P

Curve sign with an Advisory Speed plaque

W1-1a

Combination Turn/ Advisory Speed Sign

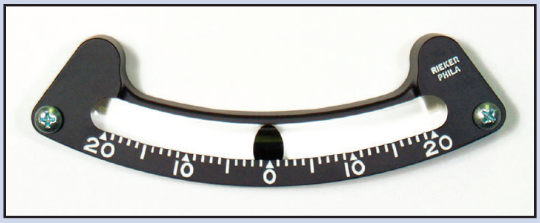
W3-10-TEA and W13-1P

ECF checkpoint sign with an advisory speed plaque

Regardless of the application or methodology, post an advisory speed only when the speed reduction necessary on the curve is 5 mph or greater as compared to the posted speed limit or the statutory speed limit. Refer to the chapter on Spot Speed Studies in Pamphlet 55-8 for more information on advisory speeds.

Ball-Bank Indicator

A ball-bank indicator measures the combination of centrifugal force and vehicle body roll in degrees. To determine the advisory speed with a ball-bank indicator, mount the instrument on the dash of a typical passenger vehicle and align it so that it provides a "zero reading" when the occupants are in the vehicle and the vehicle is on a perfectly level surface. Have a technician record the ball-bank reading as the vehicle travels at a uniform speed around the turn or curve in the center of the lane. The goal is to determine the highest multiple of 5 mph that produces a maximum ball-bank reading of 12 degrees at speeds of 35 mph or greater, 14 degrees at speeds of between 25 and 30 mph, and 16 degrees at speed of 20 mph or less (per criteria given in the *MUTCD* Section 2C.08). The curve advisory speed is set at the highest test speed that does not result in a ball-bank indicator reading greater than the acceptable level.



Model 1023W1 Ball Bank Indicator, Courtesy of Rieker, Inc., ©2002-2006 Rieker® All Rights Reserved.

As previously mentioned, the advisory speed plaque may be used to supplement any warning sign to indicate the advisory speed for a condition. For example, on the recommendation of a qualified traffic engineer, an advisory speed plaque may be posted beneath an intersection sign *[such as a Cross Road (W2-1) or Side Road (W2-2) sign]* or when determined that there may be a sight distance problem.

Another example of use of the advisory speed plaque, other than a horizontal turn or curve, is in the approach zone at an ECF where an advisory speed plaque can be posted with the CHECKPOINT (W3-10-TEA) warning sign. A sample sign layout for an ECF, which includes this sign assembly, is shown in the SDDCTEA Pamphlet 55-15.

CHAPTER 16—TRAFFIC CALMING

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> **KEY POINT**
> Traffic calming increases vehicle and pedestrian safety by reducing vehicle speeds.

Traffic calming is the use of physical measures to address speeding and high-volume cut-through traffic on neighborhood streets.

Speeding and cut-through traffic can create an atmosphere in which non-motorists are intimidated, or even endangered, by motor vehicle traffic. By addressing high speeds and cut-through volumes, traffic calming can improve both the real and perceived safety of pedestrians and bicyclists, and improve the quality of life within a neighborhood.

Generally, traffic calming measures are not appropriate on higher speed and higher volume streets such as arterial roadways. Traffic calming measures may be appropriate on the following roadway types:

- ✓ Local residential streets
- ✓ Collector streets with predominantly residential land uses
- ✓ Arterial roads within downtown districts or commercial areas (with posted speeds of 40 mph or less)

16.1. TOP FIVE RECOMMENDED TRAFFIC CALMING DEVICES

Speed humps—low cost and effective at reducing vehicle speeds.

Roundabouts—used to reduce vehicle conflicts at intersections with balanced approach volumes. They can be aesthetically pleasing, but are costly.

Raised crosswalks—elevated crosswalks that bring added attention to mid-block pedestrian crossings. They are also effective at reducing vehicle speeds. Often these devices are combined with bulb-outs to enhance pedestrian crossings.

On-street parking—reduces vehicle speeds in residential areas by psychologically narrowing the roadway. When used for traffic calming, it is important that roadway width and intersection sight distance requirements are satisfied. On-street parking on high volume, high-speed roadways can have a negative effect.

Diverters—devices that partially or completely prohibit traffic movements. They are excellent for eliminating residential "cut-through" movements. However, diverters also adversely impact emergency vehicle access and the access needs of local residents.

> **TRAFFIC CALMING OBJECTIVES INCLUDE:**
>
> - ✓ Achieving lower speeds for motor vehicles
> - ✓ Reducing collision frequency and severity
> - ✓ Increasing the safety and the perception of safety for non-motorized users
> - ✓ Reducing the need for police enforcement
> - ✓ Enhancing the street environment (e.g., street scaping)
> - ✓ Increasing access for all modes of transportation (motor vehicles, bicycles, pedestrians, etc.)
> - ✓ Reducing cut-through motor vehicle traffic

16.2. MULTI-WAY STOP CONTROL

KEY POINT

Multi-way stop control should never be used to reduce vehicle speeds.

A common request made by the general public is to use multi-way stop control as a means of reducing vehicle speeds. The *MUTCD* states that STOP signs should not be used for speed control. The decision to install multi-way stop control should be based on an engineering study. The following problems may occur if multi-way stop control is used where not warranted:

- ✓ Traffic will rarely come to a full stop.
- ✓ Motorists will increase their speed between STOP signs to make up for lost time.
- ✓ Residents will gain a false sense of security. The unwarranted control breeds disrespect for other multi-way stop-controlled intersections that are warranted.

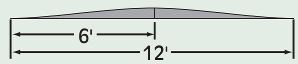
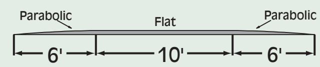
When implemented after a proper engineering study, multi-way stop control is an excellent tool to reduce right-angle crashes, but is not an effective tool at reducing vehicle speeds along a corridor.

Refer to Chapter 6 for additional information pertaining to multi-way stop control.

16.3. SPEED BUMPS VS. SPEED HUMPS

Exhibit 16.1 identifies reasons why speed humps are preferred over speed bumps.

Exhibit 16.1: Speed Bumps vs. Speed Humps

TYPE OF DEVICE	**SPEED BUMP**	**SPEED HUMP (WATTS PROFILE)**	**SPEED HUMP (SEMINOLE PROFILE)**
			
SIZE	✓ 1- to 3-feet long ✓ 3- to 6-inches high	✓ 12-feet long ✓ 3- to 4-inches high	✓ 22-feet long ✓ 3- to 4-inches high ✓ Also called speed tables
APPLICATION	✓ NOT RECOMMENDED ✓ Prohibited on Army installations	✓ Recommended only for local streets having an ADT of less than 3,500 vehicles, and a speed limit of 30 mph or less ✓ Not recommended for major emergency service routes	✓ Appropriate for streets with ADT volumes of up to 6,500 vehicles ✓ Many jurisdictions also permit the use of Seminole speed humps on emergency response routes
DESIGN SPEEDS	✓ NOT RECOMMENDED ✓ At low speeds, vehicle occupants feel a jolt ✓ At high speeds some vehicles can traverse speed bumps easily since the vehicle's suspension quickly absorbs the impact	✓ Designed to slow vehicles to 15-20 mph at each hump and 25-30 mph in between properly spaced humps ✓ Smoother to traverse when traveling at lower speeds than at higher speeds	✓ Because of its gentler profile, the Seminole speed hump has a design speed of 25-30 mph at the hump, and approximately 35 mph in between humps ✓ Smoother to traverse when traveling at lower speeds than at higher speeds
SPEED REDUCTION	✓ Dependent upon vehicle type and speed	✓ Reduces vehicle speeds by about 8 mph in the vicinity of humps	✓ Reduces vehicle speeds by about 6.5 mph ✓ Studies show that vehicle speeds at the hump and in between the humps are not significantly different
VOLUME REDUCTION	✓ Unknown	✓ Volumes are reduced, on average, by about 18%	✓ Volumes are reduced, on average, by about 12%

Note: Army Regulation 420-1 Section 2-17 states: "Hazardous features such as transverse ridges, speed bumps, or dips on pavement surfaces will not be installed or maintained as a means of controlling or reducing the speed of traffic." This regulation applies to speed bumps on Army installations. Speed humps can still be used.

16.4. SPEED HUMP APPLICATIONS

As detailed in Exhibit 16.2, there are several special considerations for speed hump applications.

Exhibit 16.2: Special Considerations for Speed Hump Applications

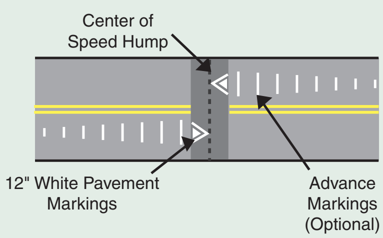
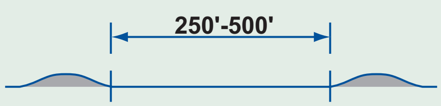
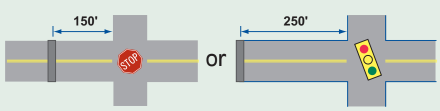
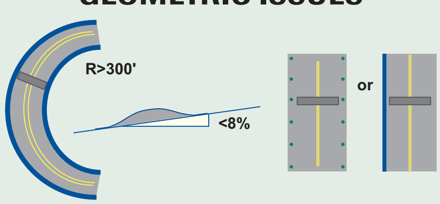
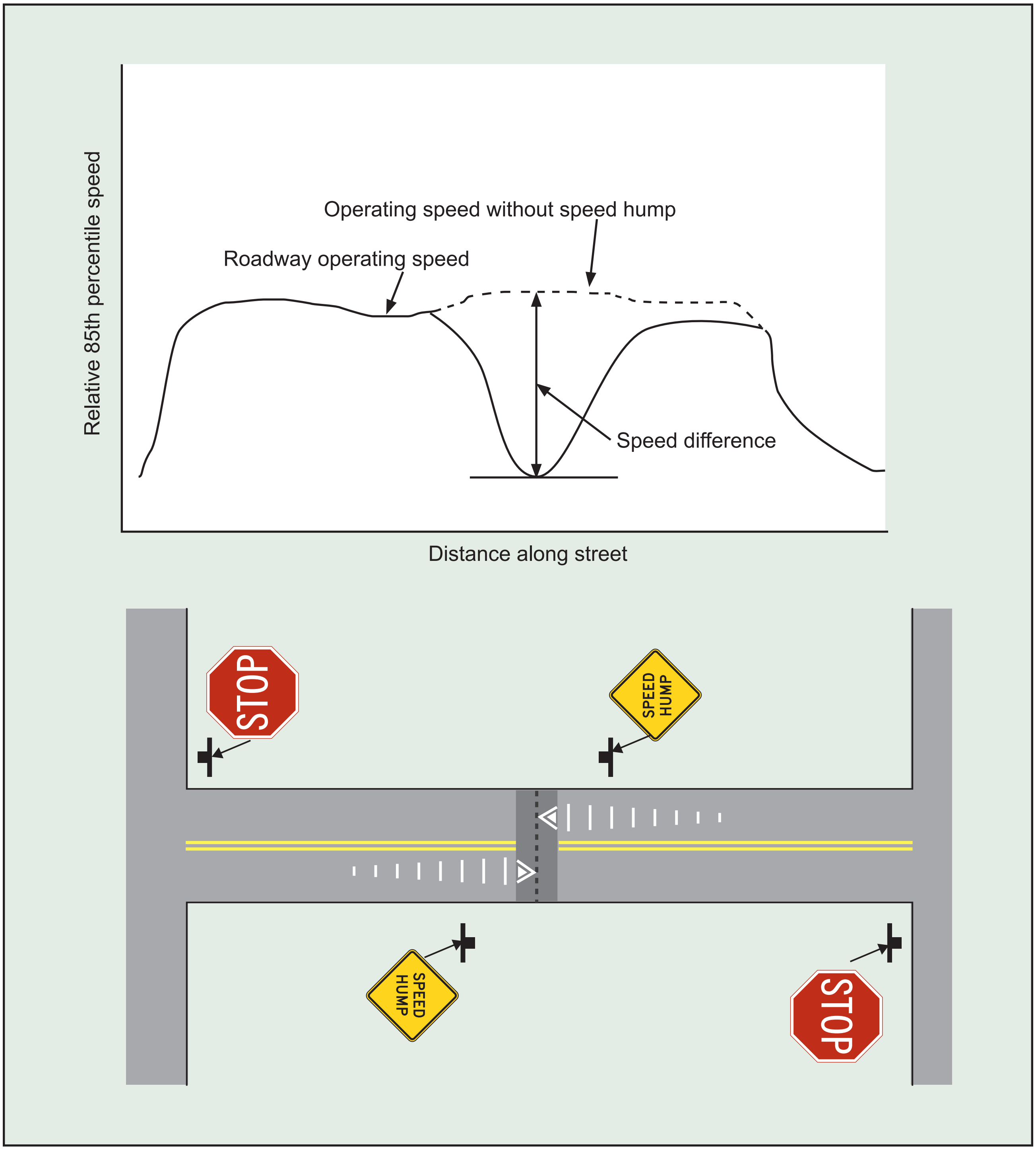
SIGNING 	✓ The SPEED HUMP (W17-1) sign should be used to give warning of a vertical deflection in the roadway that is designed to limit the speed of traffic. If used, the SPEED HUMP sign should be supplemented by an Advisory Speed plaque (W13-1). If a series of speed humps exists in close proximity, an Advisory Speed plaque may be eliminated on all but the first SPEED HUMP sign in the series.
PAVEMENT MARKINGS 	✓ Speed hump markings consist of 12-inch white markings as illustrated. Two other allowable configurations exist as shown in the *MUTCD*. Advanced speed hump markings, which shall be white, may be used in advance of a speed hump where added visibility is desired or where deflection is not expected.
NUMBER AND SPACING 	✓ A single hump will act as point speed control. To reduce speeds along an extended section of street, a series of humps is usually needed. Humps should be placed 250 to 500 feet apart. One study shows that placing speed humps at intervals of 275 feet resulted in 85th-percentile speeds of 25 mph; intervals of 550 feet resulted in 85th-percentile speeds of 30 mph.
PROXIMITY TO INTERSECTIONS 	✓ Normally, humps should not be placed within 150 feet of an unsignalized intersection, or 250 feet of a signalized intersection.
GEOMETRIC ISSUES 	✓ Curves—Speed humps should only be used on curves if the radius is greater than 300 feet. ✓ Grade—Humps should be installed on streets with a grade less than 8 percent. ✓ Curbing—Humps should only be installed on streets with curbing unless obstructions such as signing or flexible delineator posts prevent drivers from driving around a hump.

Exhibit 16.2: Special Considerations for Speed Hump Applications (Continued)

BICYCLES AND DRAINAGE 	✓ Ideally, speed humps should extend across the roadway from curb to curb. Bicyclists generally prefer this design, and it prevents motorists from driving with one wheel in the gutter. However, if drainage cannot be accommodated in the preferred design, the hump can be altered to allow drainage around the hump and to the nearest inlet.
EMERGENCY VEHICLES 	✓ Watts humps delay emergency vehicles anywhere from 1 to 10 seconds, with most delays in the range of 3 to 7 seconds. ✓ Seminole humps delay emergency vehicles by approximately 1 second.
NOISE  	✓ Although speed humps may create noise from vehicles passing over them, the overall noise levels on the street may be reduced because of reduced vehicle speeds.

Exhibit 16.3 shows a typical speed profile for a speed hump, as well as the speed differential if the speed hump was not used. Although this depicts a speed hump, it is similar to any traffic calming device.

Exhibit 16.3: Speed Profile for Speed Humps



16.5. BULBOUTS

Bulbouts are areas of expanded curbing, often used to facilitate pedestrian crossings by reducing pedestrian crossing distances. They can be located mid-block, or at intersections. They are appropriate for all street classifications. Common practice is to extend the curb 6 feet from the existing curb line, into width that would otherwise be used for on-street parking. Bulbouts also benefit pedestrians by improving visibility of pedestrians by traffic and of traffic by pedestrians.

When designing bulbouts at intersections, consider the appropriate design vehicle. If there are significant truck turning volumes, a bulbout may not be appropriate. If the intersection is narrow to begin with, bulbouts may not be appropriate regardless of design vehicle. Vehicle turning simulation must be run to ensure that turning movements through the bulbout will work with the design vehicle. Vertical curb is often used for bulbouts. Mountable curb can be used when needed at intersections for truck turning. However, if not properly designed structurally, this can deteriorate the curbing over time. When designing bulbouts, consider impacts to drainage. If not properly designed, a bulbout can impact water flow between curb inlets in a curb-gutter section, leaving an area prone to ponding.

Bulbouts located midblock have minimal impact on turning traffic, other than by impacting parking maneuvers. When designing bulbouts, use the following pointers:

- ✓ Use a width of 6 feet from the curb.
- ✓ Use an angle of 30 to 45 degrees from the original curb to taper the curb into the bulbout. Sharper angles result in the curb being hit head-on by parked vehicles which can result in damage to the curb.
- ✓ Verify that drainage will not be impacted. If so, it may result in the need for additional inlets right before the start of the taper on the uphill side.

In addition, check with the local DOT to obtain an applicable design manual and to obtain local design practice.

Bulb-out example

16.6. TRAFFIC CALMING TECHNIQUES

KEY POINT

FHWA has additional web resources on traffic calming: http://safety.fhwa.dot.gov/speedmgt/traffic_calm.cfm

Traffic calming techniques can be grouped into four major areas: horizontal deflection, vertical deflection, physical obstructions, and signing and pavement markings. These are detailed in the following sections.

16.6.1. Horizontal Deflection

Horizontal Deflection refers to two types of traffic calming measures. The first type hinders the driver's ability to drive in a straight line by creating a horizontal shift in the roadway. The shift forces drivers to slow their vehicles in order to safely navigate the measure. The second type of horizontal deflection measure is designed to narrow the width of the travel lane. Doing so reduces the usable surface of the roadway causing drivers to slow the vehicles to maintain an acceptable comfort level. Examples of the various techniques are shown in the photos to the right and options are outlined in Exhibit 16.4.

Bulb-out/Curb Extension—Areas of expanded curbing that extend across a parking lane, resulting in a narrower travel lane.

Chicane—Series of three bulb-outs, staggered at mid-block locations on alternating sides of the street.

Gateway—Entrance treatment, typically using physical and textural changes, which provides identity to an area.

On-Street Parking—Provisions for on-street parking reduce roadway width.

Raised Median Island/Pedestrian Refuge—Narrow islands, at mid-block or intersections, located between travel lanes with breaks in landscaping and curbing for pedestrians. These can often be constructed in the width otherwise used for a two-way left-turn lane when one is present. ADA-accessible curb ramps and sidewalks must be provided.

Roundabout—Raised island in the center of an intersection that requires vehicles to travel counterclockwise around the circle (in countries where vehicles travel on the right-hand side of the road).

Raised median island

Roundabout

Curb extension

Horizontal deflection examples

Exhibit 16.4: Horizontal Deflection Techniques

■ Significant Effect ◣ Moderate Effect □ Minimal or No Effect

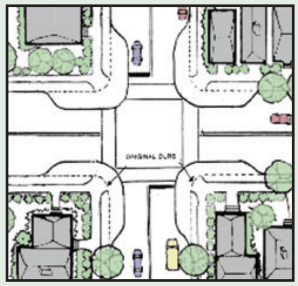
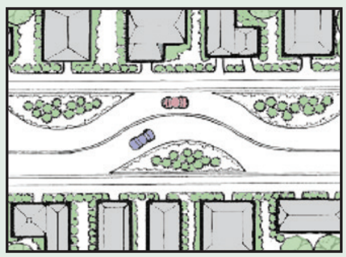
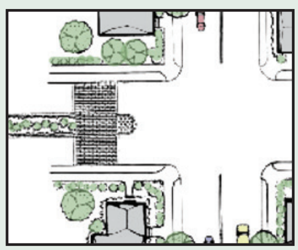
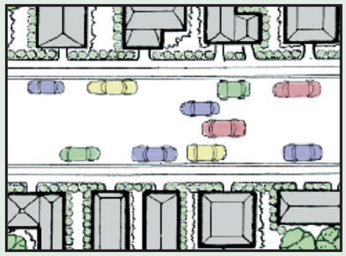
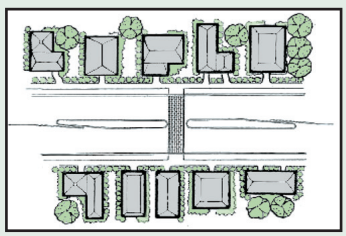
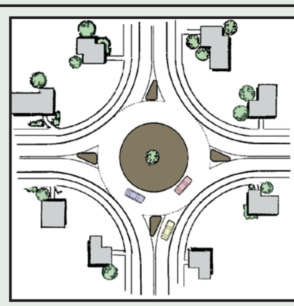
Technique	Illustration	VOLUME REDUCTION	SPEED REDUCTION	CONFLICT REDUCTION	EMERGENCY RESPONSE	ESTIMATED COST
BULB-OUT/CURB EXTENSION		□	◣	◣	◣	$7K–10K
CHICANE		◣	◣	□	◣	$6K–14K
GATEWAY		□	□	□	◣	$5K–20K

Exhibit 16.4: Horizontal Deflection Techniques (Continued)

■ Significant Effect ◣ Moderate Effect □ Minimal or No Effect

		VOLUME REDUCTION	SPEED REDUCTION	CONFLICT REDUCTION	EMERGENCY RESPONSE	ESTIMATED COST
ON-STREET PARKING		□	◣	□	◣	Varies
RAISED MEDIAN ISLAND/ PEDESTRIAN REFUGE		□	◣	◣	□	$5K-15K
ROUNDABOUT		◣	◣	■	■	$20K-120K

16.6.2. Vertical Deflection

KEY POINT

AR 420-1 prohibits the use of speed bumps to control or reduce vehicle speeds on Army installations. Although other services do not have a similar regulation, speed bumps are not recommended for use in any case.

Vertical deflection refers to traffic calming measures that create a change in the height of the roadway. When designed properly, vehicles must slow down over these measures in order to avoid unpleasant bumping sensations. Vertical deflection techniques are shown in Exhibit 16.5.

Raised Intersection—Intersections, including crosswalks, raised 3- to 6-inches above street grade.

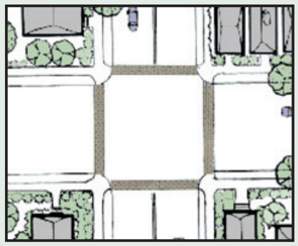
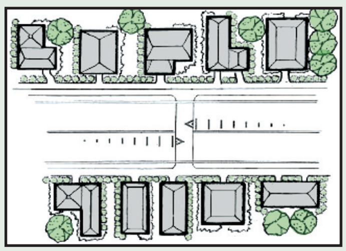
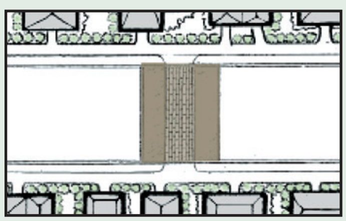
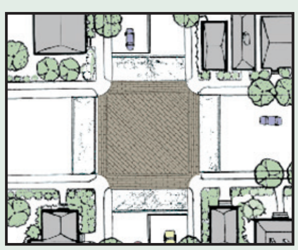
Textured Crosswalk—Use of pavers or other materials to define crosswalks and alert motorists that they are entering a pedestrian-friendly area.

Speed Humps—Raised humps in the roadway, typically 3-inches high and 12- to 22-feet long.

Raised Crosswalk—Marked pedestrian crossing elevated 3- to 6-inches above street grade at intersections or mid-block. Raised crosswalks can have similar effects as speed humps, but allow for pedestrian crossings. The reduction in speeds can have a benefit to pedestrian crossings that would not otherwise occur.

Exhibit 16.5: Vertical Deflection Techniques

■ Significant Effect ◣ Moderate Effect □ Minimal to No Effect

		VOLUME REDUCTION	SPEED REDUCTION	CONFLICT REDUCTION	EMERGENCY RESPONSE	ESTIMATED COST
TEXTURED CROSSWALK		□	□	□	□	$50-150/ sq. yd.
SPEED HUMPS		◣	■	◣	■	$1.5K-3.5K
RAISED CROSSWALK		◣	■	◣	■	$2K-10K
RAISED INTERSECTION		□	◣	◣	■	$15K-60K

16.6.3. Physical Obstruction

Physical obstruction refers to measures that prevent specific vehicle movements, thereby discouraging or eliminating cut-through traffic. The overall traffic volume reduction depends upon the nature of the traffic calming measure and the number of movements obstructed. Physical obstruction techniques are illustrated in Exhibit 16.6.

Semi-Diverter—Directional closure created by physically blocking half the street.

Diagonal Diverter—Physical barrier placed diagonally across a four-leg intersection to create two unconnected roadways.

Right-in/Right-out Island—Use of raised islands to prevent left turns and through movements, to and from side streets, at intersections with major streets.

Raised Median Through Intersection—Median barrier through an intersection that discourages through traffic in a residential area by restricting movements.

Street Closure—The use of a cul-de-sac to close a roadway by extending a physical barrier across the entire width, obstructing all traffic movements.

Exhibit 16.6: Physical Obstruction Techniques

■ Significant Effect ◣ Moderate Effect □ Minimal or No Effect

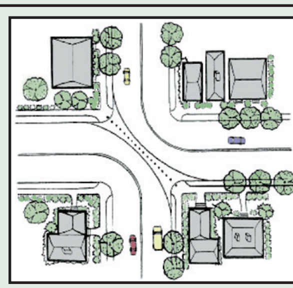
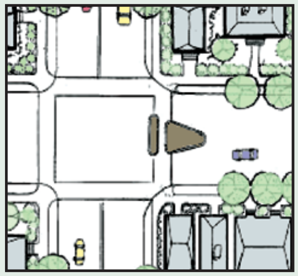
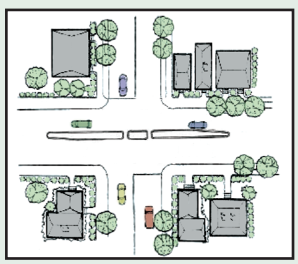
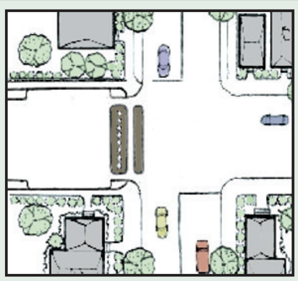
		VOLUME REDUCTION	SPEED REDUCTION	CONFLICT REDUCTION	EMERGENCY RESPONSE	ESTIMATED COST
SEMI-DIVERTER		■	◣	◣	◣	$1K-20K
DIAGONAL DIVERTER		■	◣	◣	◣	$7K-20K

Exhibit 16.6: Physical Obstruction Techniques (Continued)

■ Significant Effect ◣ Moderate Effect □ Minimal or No Effect

		VOLUME REDUCTION	SPEED REDUCTION	CONFLICT REDUCTION	EMERGENCY RESPONSE	ESTIMATED COST
RIGHT-IN/RIGHT-OUT ISLAND		◣	□	◣	◣	$3.5K-7.5K
RAISED MEDIAN THROUGH INTERSECTION		■	□	◣	■	$1.5K-20K
STREET CLOSURE		■	◣	■	■	$1.5K-25K

16.6.4. Signing and Pavement Markings

Signing and pavement markings can be used as traffic calming measures that regulate traffic movements in lieu of physical changes to the roadway. In certain applications, these measures may produce the same effect as the physical traffic calming measures. However, police enforcement is often required to ensure motorist compliance. Exhibit 16.7 shows the benefit of signing and pavement marking techniques.

Speed Limit Signing—Field investigations of citizen complaints of speeding on residential streets often reveal that very few, if any, speed limit signs are in place. While most states have statutory speed limits which can be enforced in the absence of speed limit signs, any other speed cannot be enforced. Statutory speed limits typically vary by state. Examples include: 25 mph in urban business districts, 35 mph in residential districts, 70 mph on urban freeways, or 55 mph on all other roadways. Therefore, residential streets must include speed limit signing if a speed limit other than the statutory speed limit is to be enforceable. However, a speed study must be conducted to establish the speed limits.

Turn Prohibitions—Turn prohibitions are an excellent “quick fix” that can be used for both 24-hour or part-time applications. One drawback is that the residents living in the area must also abide by the posted restriction. If the cut-through occurs only during certain peak hours, part-time applications should be used.

Roadway Narrowing With Edge Lines—A low-cost way of reducing speeds is to narrow the roadway lane through the use of edge lines and center lines. A number of jurisdictions across the country have installed this type of pavement marking application to create 10-foot-wide lanes. This pavement marking application is appropriate on local streets and low-volume minor collectors, but should not be used on major collectors or arterial streets.

Transverse Markings—Double-thick thermoplastic transverse pavement markings have been successful in slowing traffic in diverse areas such as school zones, hospitals, approaches to severe curves, and stop signs.

Exhibit 16.7: Signing and Pavement Markings Techniques

■ Significant Effect ◣ Moderate Effect □ Minimal or No Effect

	VOLUME REDUCTION	SPEED REDUCTION	CONFLICT REDUCTION	EMERGENCY RESPONSE	ESTIMATED COST
SPEED LIMIT SIGNING	□	◣	□	□	$250-400/sign
TURN PROHIBITIONS	◣	□	◣	□	$250-400/sign
ROADWAY NARROWING WITH EDGE LINES	□	◣	□	□	$0.30/linear foot
TRANSVERSE MARKINGS	□	◣	□	□	$2.00/linear foot

16.7. TRAFFIC CALMING PLANNING AND DESIGN CONSIDERATIONS

KEY POINT

A qualified traffic engineer should identify what traffic calming techniques are appropriate.

Traffic calming measures should typically be considered only after:

- ✓ Education and enforcement efforts have failed to produce the desired results.
- ✓ Existing traffic conditions have been thoroughly analyzed.
- ✓ The necessary approvals have been received by installation authorities and/or by the local DOT if the roadway is not owned by the installation.

A qualified engineer should gather the appropriate traffic data, analyze the data, and identify what (if any) traffic calming techniques are appropriate. Additionally, traffic flow diversions resulting from the installation of traffic calming devices should be studied.

Throughout the study and design process, the community should be engaged as much as possible to identify areas of concern, gather feedback on potential solutions, and provide feedback on the success of traffic calming improvements.

16.8. LEGAL ISSUES

Hundreds of local governments across the country have implemented traffic calming programs. Few have encountered liability issues. Almost all lawsuits that have arisen have been dismissed, denied, or withdrawn. Where lawsuits have succeeded, they have done so not because a traffic calming measure was found inherently unsafe, but because signs or pavement markings were poorly maintained. In order to minimize liability, installations should maintain documentation illustrating that their traffic calming programs are appropriate, and that the installation of traffic calming measures are based upon the recommendation of a qualified engineer.

CHAPTER 17—PARKING

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Lack of adequate parking presents a significant problem at many installations. Poorly designed and maintained parking facilities frustrate drivers and can increase crash potential. There are two basic categories of parking: on-street and off-street. This section will discuss common deficiencies with each and provide guidance on proper planning and design.

17.1. COMMON DEFICIENCIES

The ten most common parking deficiencies are discussed below.

- ✓ **On-street parking creates conflicts with traffic flow**—Perpendicular parking in particular is a major hindrance to traffic flow as drivers must slowly back their vehicles out of the parking spaces.

Perpendicular on-street parking

- ✓ **Poor parking lot circulation pattern and layout**—Poorly designed lots create conflicts between vehicles and cause unnecessary travel within parking lots.
- ✓ **Incorrect parking lot dimensions**—Narrow parking spaces and aisle widths make entering and exiting stalls difficult.
- ✓ **Parking areas do not conform to ADA guidelines**—Islands without curb cuts lengthen routes for physically challenged users and force them to circulate with vehicles.
- ✓ **Parking lots not properly maintained**—Broken pavement and excessive vegetative growth discourage driver utilization.
- ✓ **Absence of markings in on- and off-street parking areas**—Without marked parking stalls, inefficient use of space results as motorists park in a random fashion.
- ✓ **Lack of off-street parking areas**—When drivers cannot find an off-street parking space, they may park roadside and unknowingly become a hazard to other motorists.

Undesirable on-street parking

Example of too many access points

✓ **Poor lighting in parking areas**—Without adequate lighting, some drivers feel insecure and will be discouraged from parking.

✓ **Poor access design**—Unnecessary vehicular conflicts result when too many access points are provided. Conflicts between parking and circulation result.

✓ **Not enough buffer zone between parking lots and adjacent land uses**—Adequate buffer is necessary to provide room for landscaping.

17.2. OFF-STREET PARKING FACILITIES

KEY POINT

Because of lower crash rates, off-street parking is preferred over on-street parking.

During the initial planning process, off-street parking should be selected over on-street parking because of the associated lower crash rates.

Also important is the assumption that people are generally unwilling to walk more than 1,000 feet from their parking space to reach their destination.

Parking lots are not subject to *MUTCD* requirements with regards to signing and pavement markings. However, this does not mean that incorrect practices should be used in parking lots.

17.2.1. Demand

> KEY POINT
> When planning the area required for a parking lot, assume 350 square feet per parking space.

Site dimensions, topography, and vehicle type affect the design of parking lots. As a general rule, about 350 square feet is required per car to account for traffic aisles, space between adjacent cars, and entrance and exit lanes.

Future parking demand can be determined by using parking generation rates. A parking generation rate equates parking demand to a predictable characteristic, such as population, number of employees, or floor space. These rates have been developed for many types of facilities, and are published in ITE's *Parking Generation,* 2010.

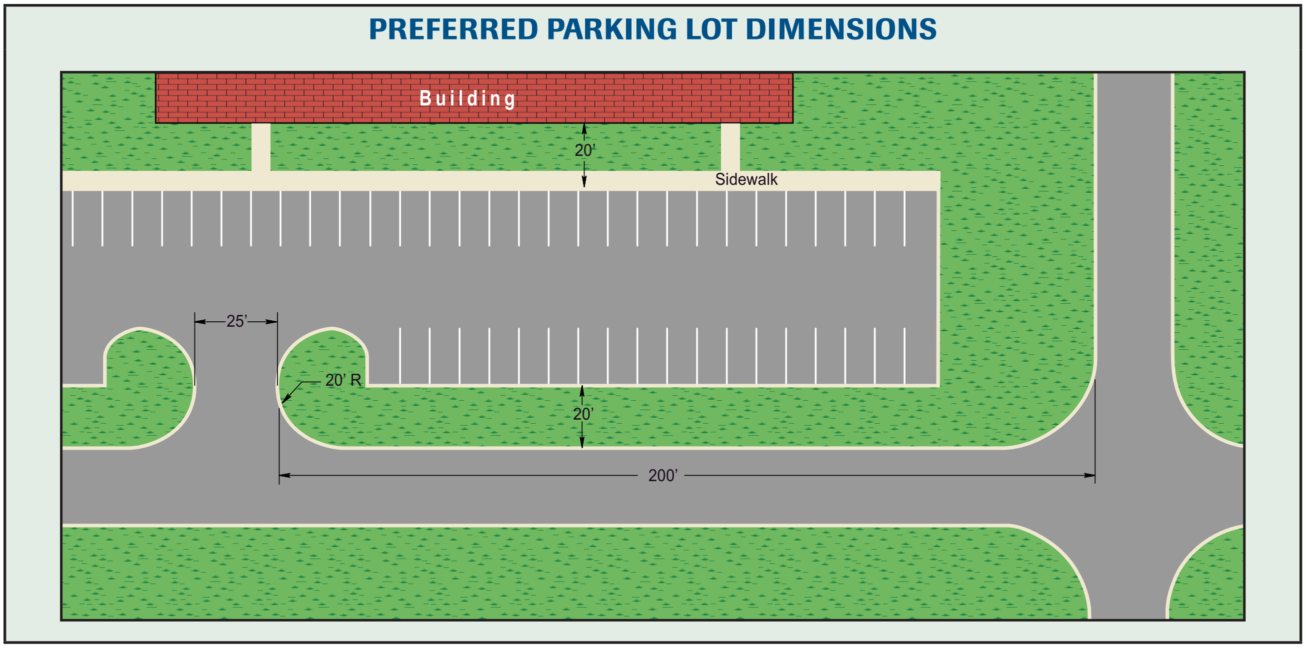
In addition, see UFC 3-201-01 "Civil Engineering" for military-specific parking design requirements. This UFC indicates the number of spaces required for several different types of military facilities. In addition to required spaces, reserved spaces are often provided in certain locations for higher-rank personnel, expecting mothers, or even fuel-efficient vehicles. If spaces of these types are provided, the number of spaces should be in addition to the minimum number of required spaces as calculated for a facility. This will avoid under-sizing the parking lot. Per ADA requirements, the number of ADA accessible spaces can be part of the number of required spaces. See SDDCTEA Pamphlet 55-8 for additional information on determining the required number of spaces.

For existing facilities, demand can be measured by performing a parking utilization study. This study compares the highest number of vehicles parked at each facility to the available parking supply. The survey should be conducted at 10:00 a.m. and again at 2:00 p.m. for long-term parking; and every 1 to 2 hours for short-term parking. As a general rule, short- and long-term parking areas should not be more than 85- and 90-percent full, respectively. If the parking utilization exceeds these figures, additional parking may be required.

17.2.2. Access Points

Factors such as pedestrians, traffic control, turning restrictions, and traffic volumes will affect the design of parking facilities, particularly the location of entry and exit points. As illustrated on the following page, a minimum driveway turning radius of 20 feet is recommended. A driveway width of 25 feet is recommended for two-way traffic flow. Also, as discussed in Chapter 18, try to locate driveways at least 200 feet from intersections, particularly for larger traffic generators. A qualified engineer should determine the exact spacing and location of access points.

When designing access points to parking lots, be sure to use the same design standards for signing and pavement markings as are used for adjacent roadways.



17.2.3. Setbacks

KEY POINT

See UFC 4-010-01 for information on standoff distances to parking areas.

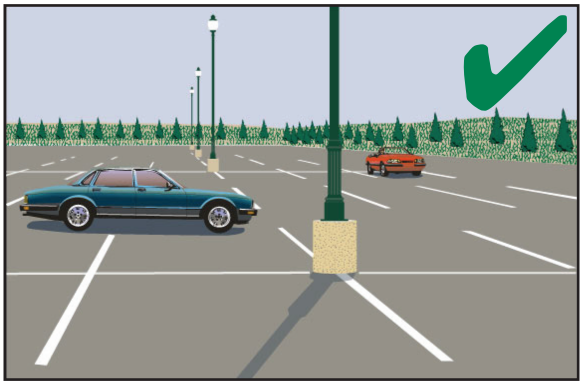
Parking adjacent to buildings should be avoided to allow a buffer space for plantings and sidewalks. This space, or setback, should be a minimum of 20 feet between the parking area and adjacent buildings. In addition, provide a minimum of 20 feet for the buffer strip separating the parking area from the street. Force protection concerns may require a larger buffer strip.

Force protection concerns often require a larger distance separating the parking area from an inhabited building. For parking within a controlled perimeter, which typically would include any installation that has entry control, the standoff distance requirements between a parking area and the building is 33 feet for an inhabited building, or 82 feet to a primary gathering building, billeting, or high occupancy family housing area. See UFC 4-010-01 for more information on standoff distances to parking areas.

Parking areas themselves are generally not considered to need standoff distance from other areas. For example, if a parking area is located adjacent to an installation perimeter fence, there is generally no need for standoff distance.

17.2.4. Lighting

Locate parking lot light fixtures away from traffic aisles and parking stalls. Light poles are ideally located in center or side islands, and protected by raised curbs. When light poles are within parking rows, locate the poles at the junctions of adjacent stalls as shown in the figure to the right. Poles and fixtures should be in scale, and accommodating to, the setting and surrounding area, while providing the desired level of nighttime illumination. Mounting height and spacing of luminaires should be sufficient to distribute the desired lighting intensity to the entire parking area. A normal lighting level is from 1.0 to 2.0 foot-candles.



Preferred light fixture location

See Chapter 21 for additional information on parking lot lighting.

17.2.5. Stall Layout

> **KEY POINT**
> For perpendicular parking, stalls for most vehicles should be 9 feet wide by 18.5 feet long.

Ideally, parking lots should be rectangular with parking on both sides of access aisles. For two-way traffic flow, parking spaces perpendicular (90°) to the aisles provide the most efficient design. The efficiency decreases as the parking angle decreases. Where a fast turnover rate is expected or where site limitations dictate, 60-degree or 45-degree angle parking with one-way aisles may be used. However, the advantage of easy pull-in and pull-out that angle parking provides is often offset by the inconvenience of one-way aisles, and the tendency of motorists to attempt to pull into a space from the wrong direction. Exhibit 17.1 provides stall layout dimensions for various parking angles.

SDDCTEA requires that all spaces be dimensioned according to the table in Exhibit 17.1, based on 9 feet by 18.5 feet for 90-degree angles. There have historically been different standards used for sizing parking spaces. Stall lengths have been shorter than 18.5 feet. SDDCTEA further requires the following of installations:

- ✓ In the event when a parking analysis is allowed or recommended, ITE’s Parking Generation manual should be used.
- ✓ When remarking an existing parking lot, use the same dimensions as are existing because changing them would impact drainage and light pole placement with respect to vehicles, as well as access aisles.
- ✓ If the dimensions shown in Exhibit 17.1 cannot be provided, a parking study shall be conducted to determine the appropriate design vehicle. A different design vehicle could reduce the required size of some or all parking spaces.
- ✓ Compact spaces could be provided if determined that there will be a consistent number of compact size vehicles accessing the facility on a regular basis. If providing compact car spaces, they can be as small as 8 by 16 feet. However, compact spaces should not be designed for if sufficient space is available for all spaces to be 9 by 18.5 feet. Frequent criticism of compact car spaces is that they are

generally not adhered to since they are not enforceable as handicapped spaces are. With smaller spaces, vehicles using these spaces are more prone to door dings, particularly if a non-compact vehicle uses it or parks in an adjacent space.

✓ Motorcycle spaces may be provided in the following scenarios:
  - If a parking study determines that there will be a consistent number of motorcycles regularly parking at the facility, motorcycle spaces may be a portion of the demand. However, if an observation demand-based parking study is performed, it must be performed in the most adverse weather timeframe where motorcycle travel is at the least (for example, during winter in northern climates). In this scenario, subtract motorcycle spaces from required regular spaces
  - At the installation's option for convenience of motorcyclists.

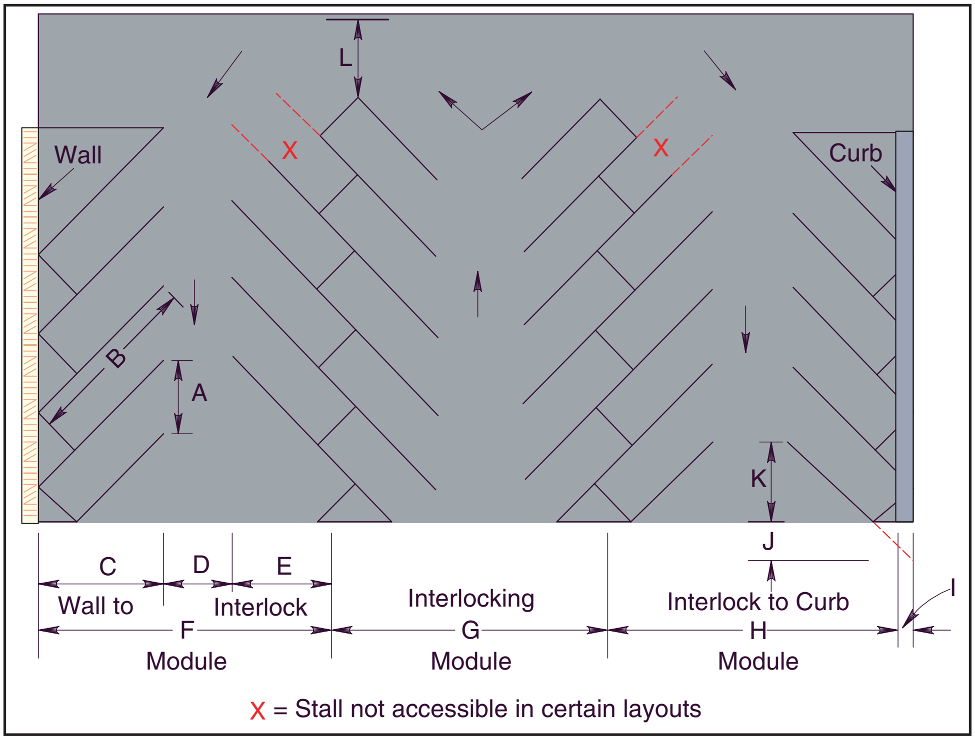
✓ Motorcycle spaces should be 4.5 feet in width and a minimum of 9 feet in length.

✓ The number and size of accessible spaces shall be provided in accordance with ABA requirements. (See section 17.2.9)

When designing for motorcycle spaces, use 90-degree parking only. There is no benefit to using angled motorcycle parking since motorcycle spaces are not as long as regular vehicle spaces, and since motorcycles can use the entire width of the access aisle to enter a parking space and therefore can use a smaller turning radius. No other features can be reduced, such as access aisles, because they still need to be accessible by emergency and maintenance vehicles.

When designing for compact car spaces, if there is enough compact car parking demand for multiple aisles, the table showing dimensions for compact cars in Exhibit 17.1 can be used for design. However, compact vehicle spaces should only be considered when full spaces are not able to be provided. Note that accessible spaces cannot be part of the compact car spaces.

Exhibit 17.1: Stall Layout Dimensions



PARKING LAYOUT DIMENSION (IN FEET) FOR 9 x 18.5 FT. STALLS AT VARIOUS ANGLES					
DIMENSION	ON DIAGRAM	ANGLE			
		45°	60°	75°	90°
STALL WIDTH, PARALLEL TO AISLE	A	12.7	10.4	9.3	9.0
STALL LENGTH OF LINE	B	27.5	23.7	20.9	18.5
STALL DEPTH TO WALL	C	19.5	20.5	20.0	18.5
AISLE WIDTH BETWEEN STALL LINES	D	12.0	16.0	23.0	26.0
STALL DEPTH, INTERLOCK	E	16.5	18.5	18.5	18.5
MODULE, WALL TO INTERLOCK	F	48.0	55.0	62.0	63.0
MODULE, INTERLOCKING	G	45.0	53.0	61.0	63.0
MODULE INTERLOCK TO CURB FACE	H	46.0	53.2	59.5	60.5
BUMPER OVERHANG (TYPICAL)	I	2.0	2.3	2.5	2.5
OFFSET	J	6.4	2.6	0.6	0.0
SETBACK	K	13.1	9.3	4.8	0.0
CROSS AISLE, ONE-WAY	-	14.0	14.0	14.0	14.0
CROSS AISLE, TWO-WAY	L	24.0	24.0	24.0	24.0

Exhibit 17.1: Stall Layout Dimensions (Continued)

PARKING LAYOUT DIMENSION (IN FEET) FOR COMPACT CARS, FOR 8 x 16 FT. STALLS AT VARIOUS ANGLES					
DIMENSION	ON DIAGRAM	ANGLE			
		45°	60°	75°	90°
STALL WIDTH, PARALLEL TO AISLE	A	11.3	9.2	8.3	8
STALL LENGTH OF LINE	B	24	20.6	18.1	16
STALL DEPTH TO WALL	C	17	17.8	17.5	16
AISLE WIDTH BETWEEN STALL LINES	D	12	16	23	26
STALL DEPTH, INTERLOCK	E	14	16	16	16
MODULE, WALL TO INTERLOCK	F	43	49.8	56.5	58
MODULE, INTERLOCKING	G	40	48	55	58
MODULE INTERLOCK TO CURB FACE	H	41	47.5	54	55.5
BUMPER OVERHANG (TYPICAL)	I	2	2.3	2.5	2.5
OFFSET	J	6.4	2.6	0.6	0
SETBACK	K	17	17.8	17.5	16
CROSS AISLE, ONE-WAY	-	14	14	14	14
CROSS AISLE, TWO-WAY	L	24	24	24	24

PARKING LAYOUT DIMENSION (IN FEET) FOR MOTORCYCLES, BASED ON 4.5 x 9 FT. PRIMARY DIMENSIONS		
DIMENSION	ON DIAGRAM	ANGLE
		90°
STALL WIDTH, PARALLEL TO AISLE	A	4.5
STALL LENGTH OF LINE	B	9
STALL DEPTH TO WALL	C	9
AISLE WIDTH BETWEEN STALL LINES	D	26
STALL DEPTH, INTERLOCK	E	9
MODULE, WALL TO INTERLOCK	F	44
MODULE, INTERLOCKING	G	44
MODULE INTERLOCK TO CURB FACE	H	44
BUMPER OVERHANG (TYPICAL)	I	0
OFFSET	J	0
SETBACK	K	9
CROSS AISLE, ONE-WAY	-	14
CROSS AISLE, TWO-WAY	L	24

17.2.6. Landscaping

The objective of parking lot landscaping is to enhance the lot, provide a buffer zone between adjacent land uses, and to subdivide large parking areas. Landscaping should never obstruct the view of motorists in a parking facility, or interfere with the parking function. Be sure to provide sufficient setbacks for all plants, so that the front or rear overhangs of parked vehicles do not damage or destroy them. Ensure that placing and maintaining shrubbery or other plants near entrances and exits does not restrict sight distance. Also consider the growth pattern of the plant, so that a small plant will not develop into a major sight restriction in the future.

17.2.7. Drainage

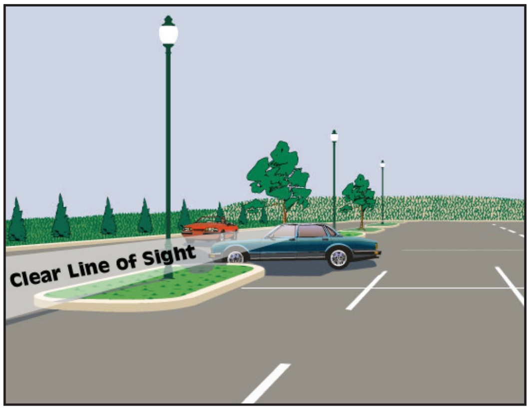
Provide adequate grading of surface lots to minimize the possibility of low or flat spots. Accumulation of standing water in a parking lot is a hazard for both vehicle and pedestrian movements, particularly in cold climates where freezing may lead to icy spots. Recommended minimum grades are 1.0 percent for asphalt surfaces and 0.5 percent for portland cement surfaces.

Proper drainage is important!

17.2.8. End Islands

Space at the end of each aisle should be kept clear of parked vehicles to allow turning motorists a clear view down the cross aisle.

Mark this area with either white paint or a raised traffic island. Islands should be designed to accommodate the turning maneuvers of vehicles in the parking lot. A passenger car requires a right-turning radius of 18 feet. Raised end islands can provide a location for signs and light fixtures.



End aisle configuration

Adequate sight distance must be provided within parking lots, particularly at the intersections of access aisles with cross aisles. Proper sight distance should be provided for the form of traffic control present, with consideration for prevailing vehicle speeds (See Chapter 4). Sight distance may be limited by parked cars. When sized correctly, the end islands can provide a buffer from parking for proper sight distance, and can provide refuges for pedestrians.

They also provide an aesthetic function by breaking up the “sea of pavement” as well as providing a place for plantings. If plantings are used, ensure that they are low height plantings so as to not limit sight distance. Periodic trimming is important to ensure that they remain at low heights.

17.2.9. Accessibility Requirements

The Architectural Barriers Act, (see https://www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-aba-standards) establishes the minimum number of required accessible parking spaces, based on the total number of spaces in the parking facility. Therefore, make certain that each parking facility provides at least the minimum number of designated accessible parking spaces as indicated in Exhibit 17.2. Parking lots for facilities should follow ABA Standards (Section F208 and 502), as this was adopted by DoD. On-street parking should follow PROWAG (R214 and R309).

Exhibit 17.2: Minimum Designated Accessible Parking Spaces

TOTAL NUMBER OF PARKING SPACES IN A PARKING LOT OR STRUCTURE	MINIMUM NUMBER OF REQUIRED ACCESSIBLE PARKING SPACES FOR PARKING LOT OR STRUCTURE
1–25	1
26–50	2
51–75	3
76–100	4
101–150	5
151–200	6
201–300	7
301–400	8
401–500	9
501–1,000	2 percent of the total
1,001 and over	20, plus 1 for each 100, or fraction thereof, over 1,000

The designated accessible parking spaces should be located to provide the most convenient access to entranceways or to the nearest curb cut. Every parking lot shall have at least one designated disabled parking space designed to accommodate a passenger van, and there shall be a minimum of one such space for every six or fraction of six required designated accessible parking spaces.

A common practice in some locales has been to paint the entire parking space blue, but this is not a recommended practice because painted surfaces may be slippery when wet. Therefore, use only the symbol illustrated in Figure 3B-22 of the *MUTCD* and detailed in the “Pavement Marking Chapter” of the *Standard Highway Signs and Marking Book (SHSM)*. Without the optional border and blue background, the standard size accessible parking space marking would measure about 24 inches wide by 28 inches high; and with the blue background and white border, it would measure about 38 inches square.

The preferred location for the symbol is near the entrance to the parking space so that drivers can see the symbol before starting to turn into the stall.

Blue lines may supplement the white parking stall markings, but only on the reserved parking space side of the white markings. If used, blue lines should be a minimum of 4 inches wide and adjacent to the white lines.

Handicapped spaces should be located immediately adjacent to the nearest building entrance; or in the case of a remote parking lot or garage, the location where pedestrians exit. Provide a 60-inch access aisle and a ramp. Display the handicapped symbol on a signpost at the head of the stall.

Accessible parking spaces in parking lots or structures shall be designed in accordance with the ABA Standard (Section 502), as follows:

1. Car parking spaces shall be a minimum width of 8 feet. Van parking spaces, except as noted in No. 3 below, shall be a minimum of 11 feet wide.
2. A minimum 5-foot wide access aisle shall be adjacent to one of the sides of each parking space, except it shall be on the passenger side of van parking spaces if using angled parking spaces.
3. As an alternate to Nos. 1 and 2, van parking spaces may be 8 feet wide if the access aisle is at least 8 feet wide; thereby reducing the total width requirements if two van parking spaces share a common access aisle (i.e., 24 feet instead of 27 feet).
4. If angled parking is used, the minimum dimensions shall be measured at a right angle across the widths.
5. Access aisles shall not overlap a vehicular travelway.
6. Access aisles shall be marked to discourage unauthorized use, where the preferred method is 6-inch white diagonal crosshatching.

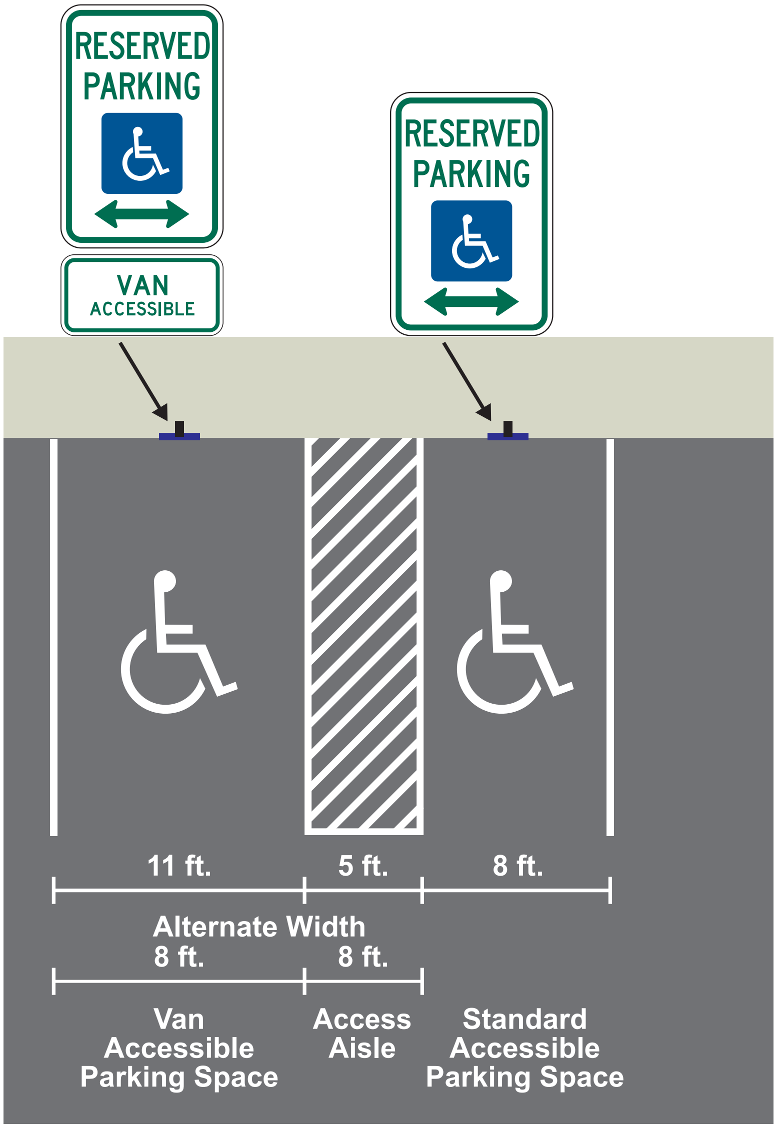
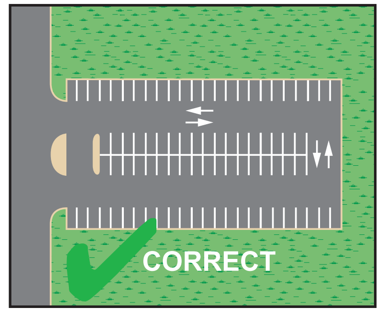
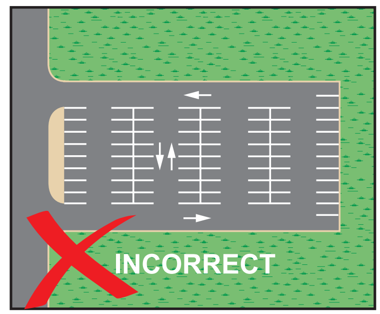
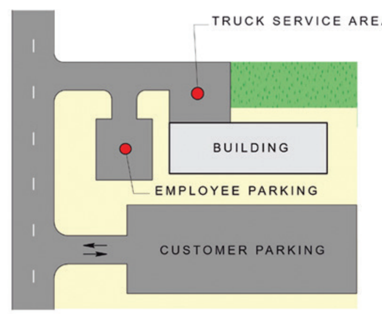


Exhibit 17.3 shows additional design considerations relating to off-street parking facilities.

Exhibit 17.3: Additional Off-Street Parking Design Considerations

<table>
<tr><th colspan="2">AISLES</th><td rowspan="2">


</td></tr>
<tr><td colspan="2">Whenever possible, provide aisles parallel to the long side of the lot with cross aisles every 30 spaces in large parking areas. This layout results in a 20 percent increase in lot capacity compared to aisles oriented parallel to the short side of the lot.</td></tr>
<tr><th colspan="2">EMPLOYEE PARKING</th><td rowspan="2">

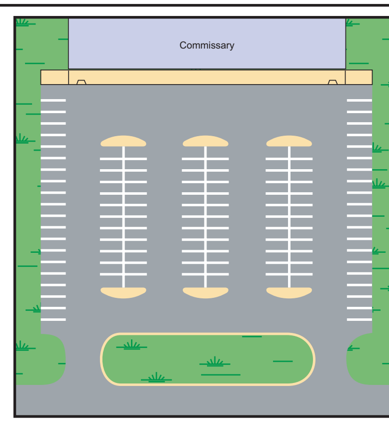
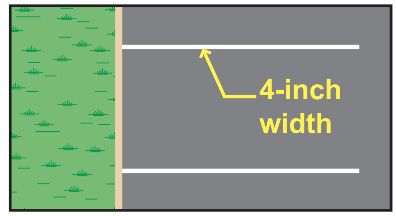
SEPARATE PARKING AREAS</td></tr>
<tr><td colspan="2">The employee parking lot for a facility should be separate from the main parking lot. Providing a separate lot helps to avoid a mixture of all-day parking with short-term customer parking.</td></tr>
<tr><th>ENTRANCES AND EXITS</th><th>ROWS</th><td rowspan="2">
</td></tr>
<tr><td>Design entrances and exits to serve as a continuation of traffic aisles. Avoid sharp turns whenever possible. Another good practice is to prohibit stalls so close to the entry/exit point that parking maneuvers would obstruct traffic flow.</td><td>Parking rows should be perpendicular to buildings for the safety and convenience of pedestrians.</td></tr>
</table>

Exhibit 17.3: Additional Off-Street Parking Design Considerations (Continued)

PAVEMENT MARKINGS Parking space markings shall be white in color and a minimum of 4 inches wide. Military installations are encouraged to use retroreflective markings for all parking space markings although it may be unnecessary in parking lots with overhead lighting.	
WHEELSTOPS Wheelstops are often used along the site boundaries of uncurbed lots, where large landscaped areas extend beyond the edge of pavement. Wheelstops in the interior of a parking lot have a few disadvantages: they may hinder people walking between cars; they are often a hazard when hidden from view by parked cars; they tend to trap blowing debris; and they adversely impact snow removal.	
SURFACE TREATMENT Paved parking areas are desirable for many reasons including controlling drainage, reducing mud and dust, improving walking surfaces, reducing maintenance costs, and providing a pleasing appearance. Paved parking lots should be marked to provide safe, efficient, and enforceable parking lot operations.	
MAINTENANCE For good visibility, repaint markings as needed, and replace old signs. Clean light fixtures at least annually, and replace bulbs before burnouts occur. A properly designed lot is great, but a good maintenance plan is necessary to keep it that way.	

17.3. PARKING GARAGES

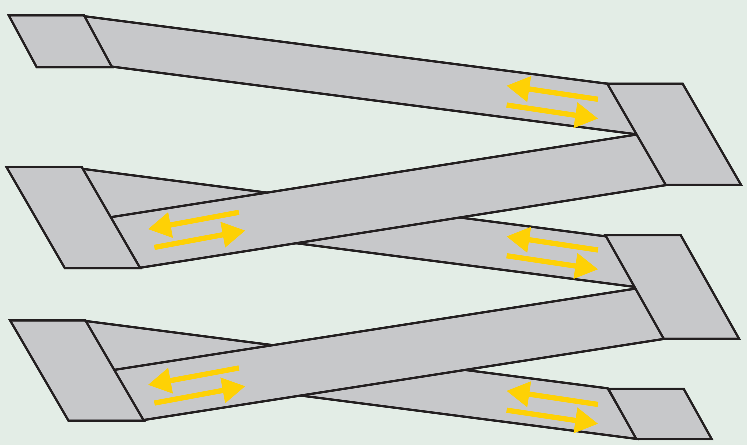
Parking garages are often used where there is a considerable demand for parking with a significantly low amount of available space. From a master planning standpoint, parking garages can provide the same amount of parking spaces while using only a fraction of land when compared to surface lots.

The primary drawback to parking garages is the cost. Parking garages often cost in excess of $15,000 per parking space. Therefore, parking garages are often not the first alternative when running out of available space for parking. When there is no space available for parking, consider possible alternatives:

- ✓ Implement a shuttle system. Parking for buildings can be located at a location farther away from the building it serves, and a shuttle can transport people to and from their buildings.
- ✓ When planning the location of a building, if there is no available space for parking, consider relocating it to a more open area where there is plenty of available land for the building and its parking area.
- ✓ Utilize demand management strategies to reduce parking demand. Encourage the use of public transportation, carpooling, or working from home.

When these alternatives are not viable, a parking garage can often be considered.

CONTINUOUS RAMP—TWO-WAY TRAFFIC



When planning a parking garage, keep entrances spaced at about 100 feet minimum to maximize the available space between the access and the adjacent street. Exits should be located on low-volume streets to reduce delay to traffic leaving the garage. The most common circulation pattern used in the United States is the continuous ramp, where sloping floors with aisles and parking spaces along both sides of the aisle provide access to the parking spaces themselves and the garage's circulation route. If stairs are the only means of pedestrians changing floors in the garage, as would typically be if there are only two to three floors, at least one stairway should be provided facing major destinations. Generally, one elevator serving a parking garage should be provided for every 250 spaces when the garage is multilevel.

Standoff distance for parking garages is not considered to be needed since they are not considered to be inhabited. Standoff distance is needed between the parking garage and inhabited buildings.

17.4. ON-STREET PARKING

About 20 percent of all crashes in built-up areas involve vehicles parked along the roadway. On-street parking is not desirable on arterial or collector roads that are designed to move high traffic volumes at moderate or high speeds. On lower speed roadways, such as residential streets, on-street parking is acceptable because it “calms” traffic and thus reduces vehicle speeds.

17.4.1. Angle Versus Parallel Parking

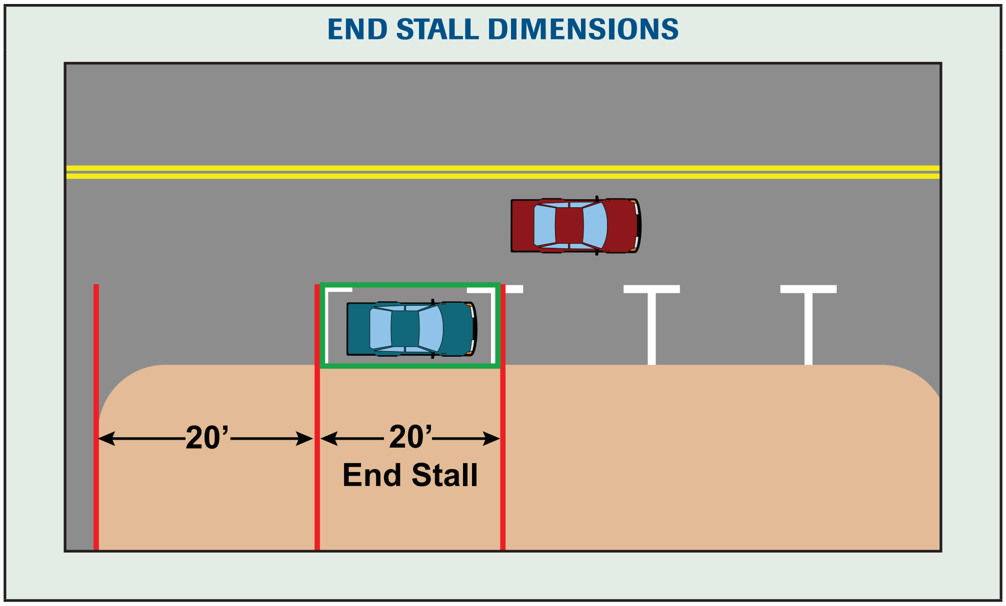
Angle on-street parking provides more parking per unit of curb length than parallel parking. However, angle parking increases the hazard of starting, stopping, and turning in moving traffic and, therefore, is discouraged. The principal hazard of angle parking is the driver’s lack of adequate visibility during backing maneuvers, especially when a large vehicle is parked upstream.

Because empty parking stalls are difficult to see with angle parking, motorists who are seeking a place to park create another hazard. They must either proceed slowly in order to find an empty stall, or stop abruptly when they come to an empty stall. Angle parking is generally unsafe and its use should be discouraged.

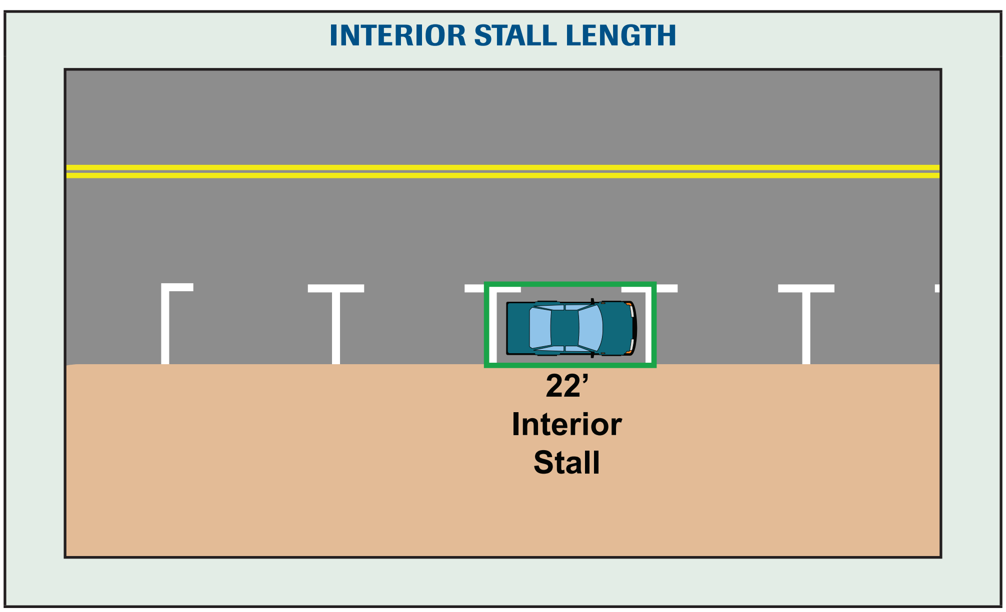
Angle parking

17.4.2. Layout of On-Street Parking Stalls

There are two types of stalls to consider when designing on-street parallel parking: the end stall and the interior stall. An end stall is used where a vehicle can be driven directly into or out of the parking space. End stalls require a length sufficient enough to accommodate a passenger car, typically 18 feet, per UFC 3-201-01, or 20 feet typical per the *MUTCD*. SDDCTEA recommends using the more stringent value of 20 feet. Maintain a minimum of 20 feet between an end stall and a curb opening or intersection, assuming there is no marked crosswalk and there is no sidewalk leading to an implied (i.e., unmarked) crosswalk.

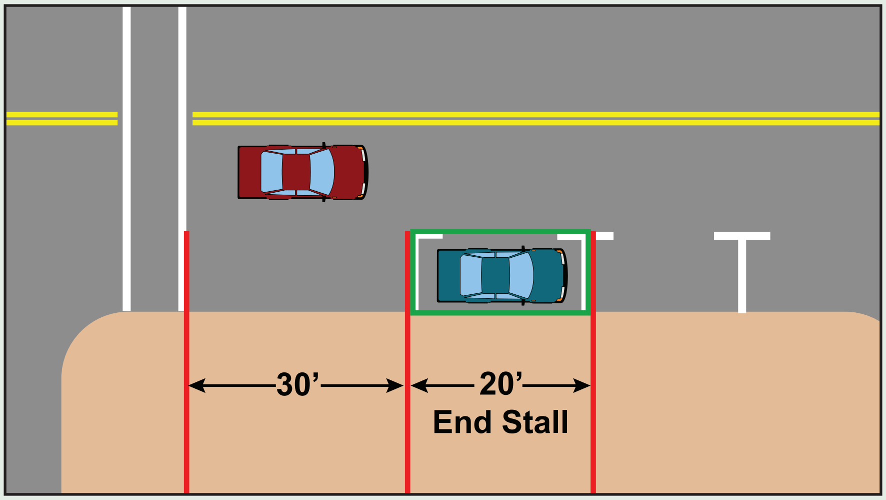


An interior stall requires room for maneuvering into and out of the parking space; therefore, a 22-foot-long stall is recommended.

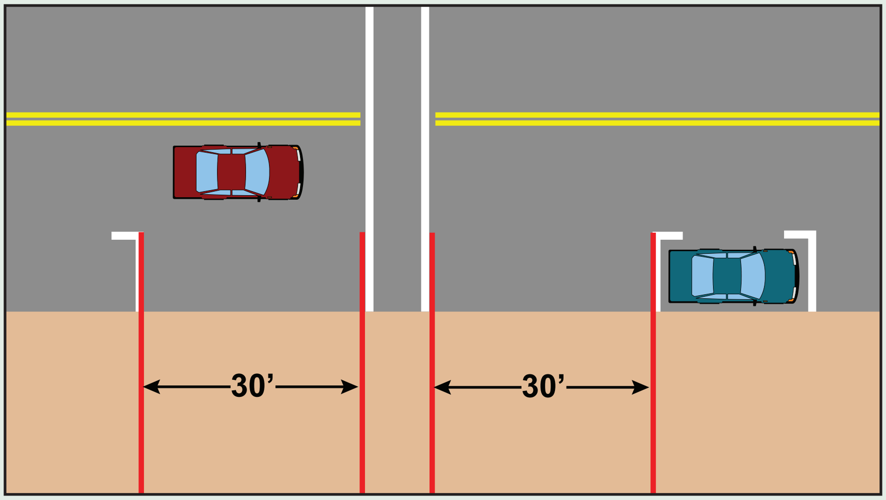


When on-street parking is located near a crosswalk, leave a buffer strip of 30 feet between the crosswalk and the parking space (on both the approaching side and the departing side of the intersection) to maximize visibility between pedestrians and motorists. This applies to crosswalks located at intersections, as well as for midblock crosswalks.

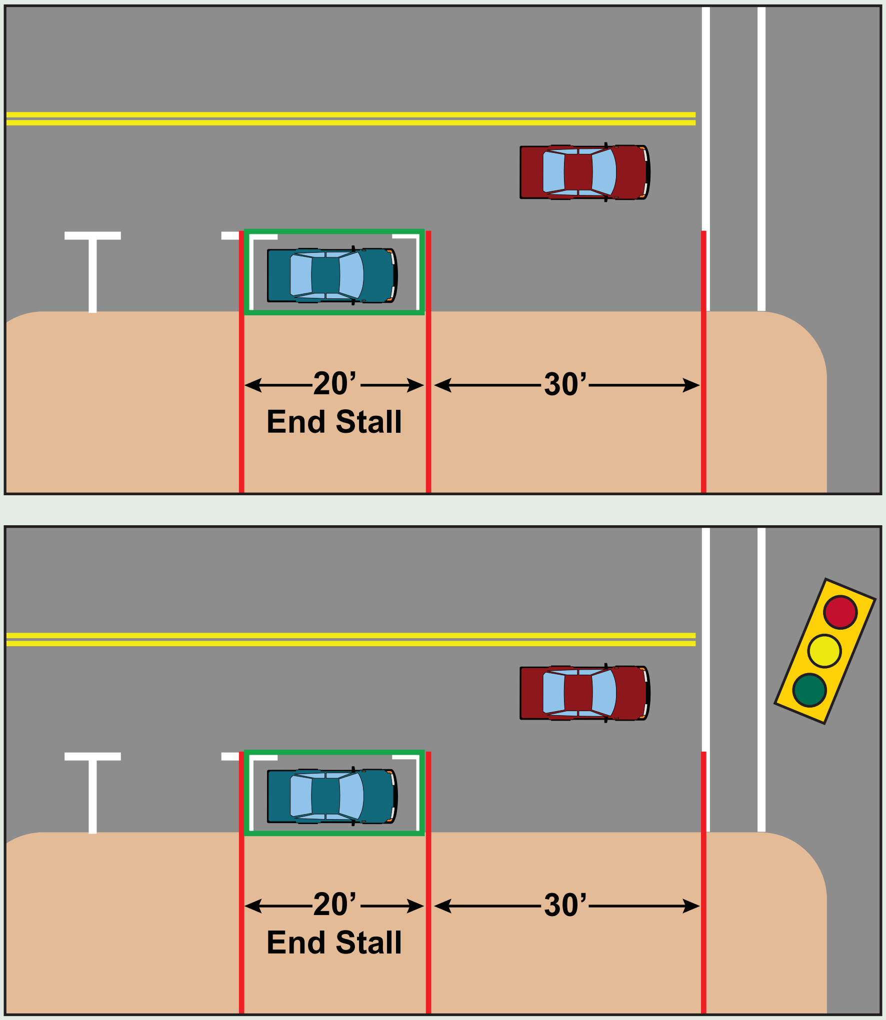
PARKING SPACE DIMENSIONS FROM CROSSWALKS



PARKING SPACE DIMENSIONS FROM MIDBLOCK CROSSWALKS



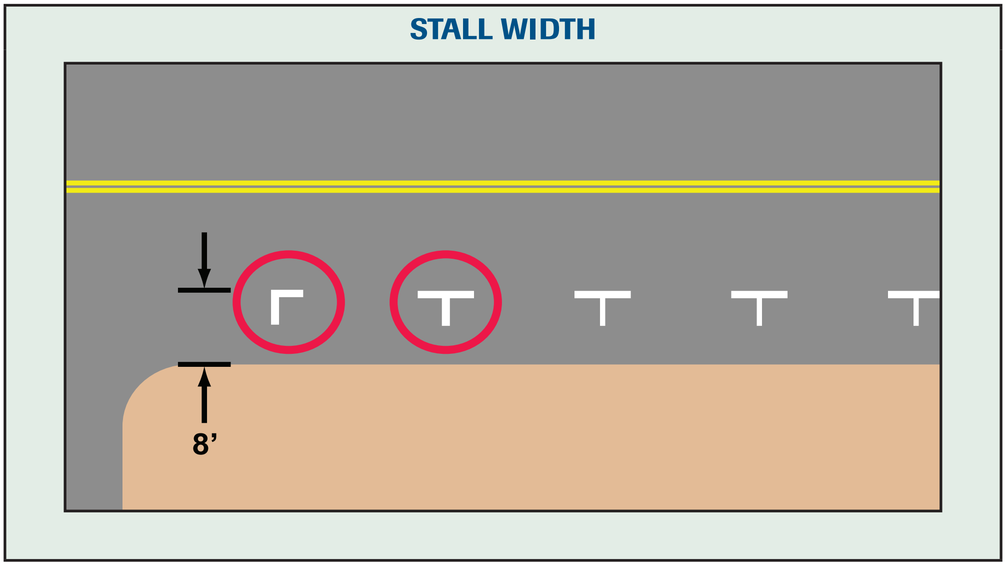
PARKING SPACE DIMENSIONS FROM CROSSWALKS



For all of the dimensions discussed in this section, note that they are minimum distances. When laying out actual distances, field-verify all parking spaces to ensure that acceptable sight distance is provided.

17.4.3. On-Street Delineation

Parallel parking stalls should be defined by white lines extending perpendicular from the curb, for a distance of 8 feet. Generally, end stall lines are L-shaped and interior stall lines are T-shaped.



17.4.4. Accessibility Requirements

Where on-street parking is provided on the block perimeter and the parking is marked or metered, accessible parking spaces complying with R309 shall be provided in accordance with Exhibit 17.4. Where parking pay stations are provided and the parking is not marked, each 20.0 ft of block perimeter where parking is permitted shall be counted as one parking space. Refer to PROWAG guidelines, R214 and R309 for additional information.

Exhibit 17.4: Minimum Designated Accessible Parking Spaces

ON-STREET ALONG THE BLOCK PERIMETER	MINIMUM NUMBER OF REQUIRED ACCESSIBLE PARKING SPACES FOR ON-STREET
1–25	1
26–50	2
51–75	3
76–100	4
101–150	5
151–200	6
201–300	4 percent of total
301–400	4 percent of total
401–500	4 percent of total
501–1,000	4 percent of total
1,001 and over	4 percent of total

17.4.5. Parking Restrictions

Control of on-street parking is accomplished through signing, markings, and enforcement. Signing and marking regulations are discussed in the *MUTCD*. Standard parking restrictions are set forth in the National Uniform Vehicle Code. Some common parking restrictions are:

- ✓ In front of a public or private driveway
- ✓ Within an intersection
- ✓ Within 15 feet of a fire hydrant
- ✓ Within 20 feet of a marked or implied crosswalk on the approach to a non-signalized intersection—SDDCTEA recommends 30 feet (Based on the SDDCTEA crosswalk guidelines, 30 feet is a requirement if the crossing is on an uncontrolled approach)
- ✓ Within 30 feet of a marked crosswalk on the approach to a signalized intersection
- ✓ Within 30 feet on the approach to any flashing beacon, STOP sign, or traffic control signal located at the side of a roadway
- ✓ Within 50 feet of the nearest rail of a railroad crossing
- ✓ On any bridge or other elevated structure on a highway.

Note that these are only common restrictions. Good engineering judgment should be applied along with local standards.

CHAPTER 18—ACCESS MANAGEMENT

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18.1. WHAT IS ACCESS MANAGEMENT?

KEY POINT

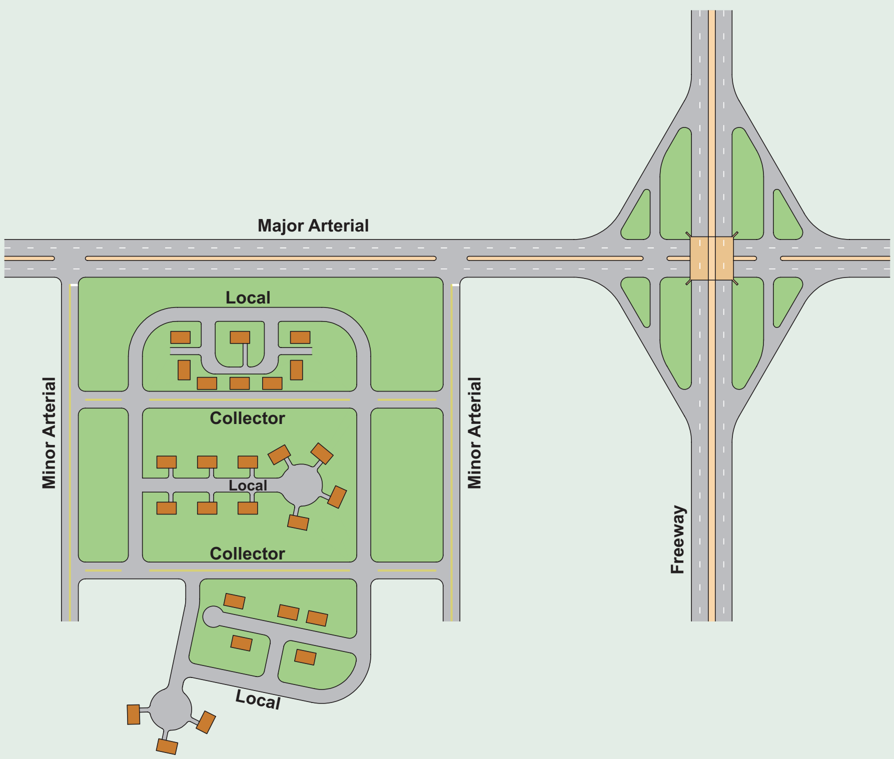
Access management provides reasonable access while minimizing impacts to traffic operations.

The *Access Management Manual*, published by the Transportation Research Board (TRB), defines access management as "…the systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway." In simple terms, it is the management of access points along a roadway such that the impact to traffic operations is minimized, while maintaining reasonable access.

By preserving the safety and efficiency of a roadway network, access management procedures balance mobility and access, which are a roadway's two primary functions. This is accomplished by carefully managing the number of conflicts that are introduced by intersecting driveways and streets.

For roadways such as freeways, access is limited to interchanges with the primary function being mobility. At the other end of the spectrum is a local street in a residential neighborhood. This roadway type functions mainly as a means of providing access to homes and serves minimally as a means of mobility. The illustration below shows a hierarchy of roadway classes, each with varying degrees of access and mobility.

HIERARCHY OF ROADWAY CLASSES



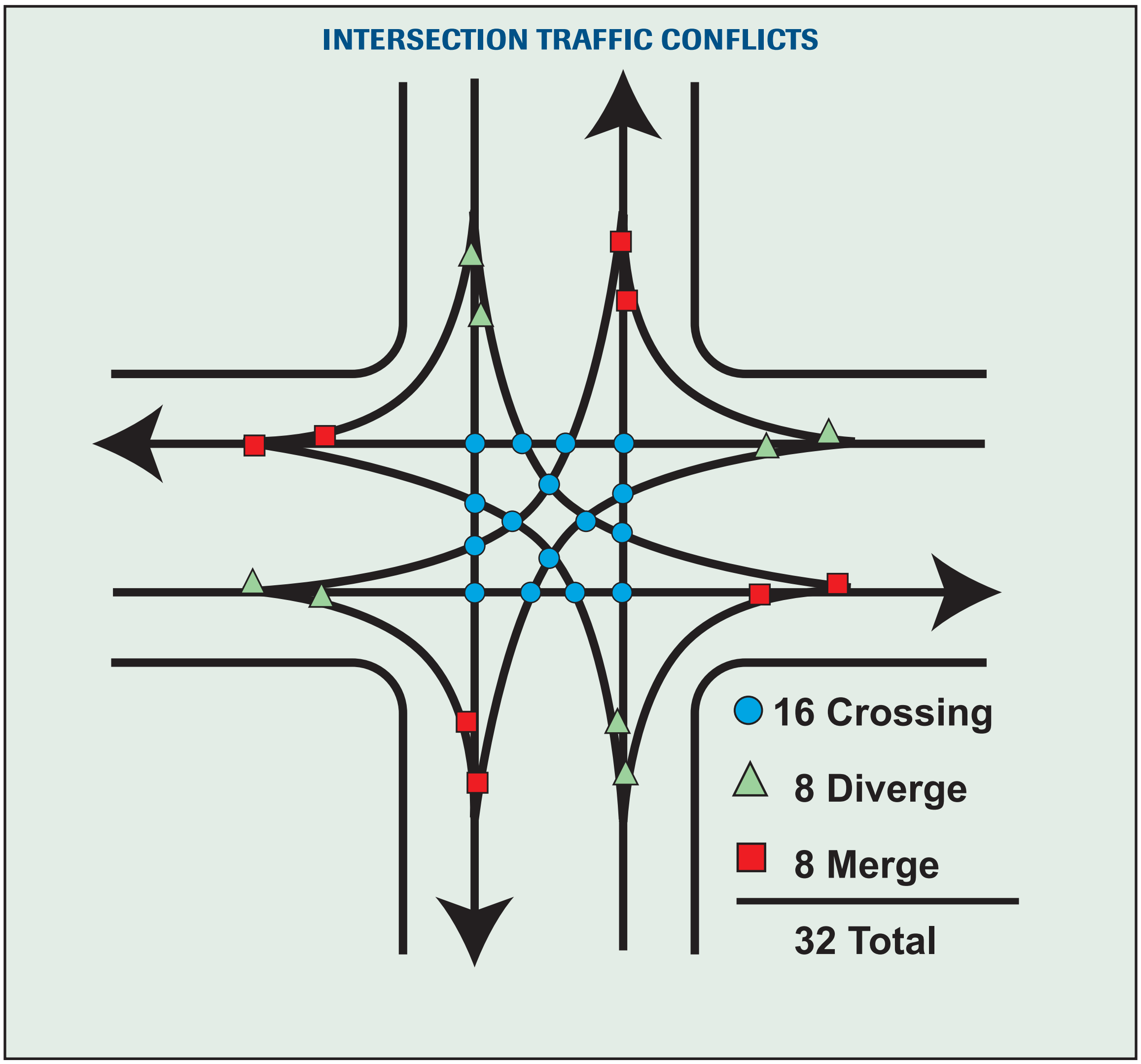
18.2. WHY IS ACCESS MANAGEMENT NEEDED?

KEY POINT

A standard four-leg intersection has 32 possible conflict points.

Without any type of access control along a roadway, access points will likely increase. Access management is important to minimize traffic conflicts along a roadway. As shown below, traffic conflicts occur when the paths of vehicles intersect.

This results when vehicles are stopping in, crossing, entering, or exiting the traffic stream. At each conflict point there exists a potential collision. As more conflict points are introduced to a segment of roadway, driving becomes more complex and motorists are more likely to make mistakes. Congestion increases and safety deteriorates. Effective access management preserves roadway capacity and reduces crashes.



18.3. PRINCIPLES OF ACCESS MANAGEMENT

KEY POINT

TRB's *Access Management Manual* identifies goals of access management.

The focus of access management is to limit and consolidate access along major roadways while ensuring that the supporting roadway network can safely and efficiently provide the necessary access. The goals of access management can be realized by adhering to the principles set forth in the *Access Management Manual*. Those principles most applicable to access management on military installations are described below:

✓ **Limit direct access onto major roadways**—Roadways serving high-traffic volumes should require a higher level of access control to protect the roadway's intended function of moving through traffic.

Access to major roadways should be restricted and instead be provided along roadways with a lower classification such as local or collector streets.

✓ **Locate signals to favor through movements**—When signalized intersections are located with long, uniform spacing, coordination between the signals ensures minimal interruption to traffic flow. If signals are located close to access that may in the future become signalized, disruption of the coordinated traffic flow will result, thereby creating congestion and greater delays. For this reason, spacing between a signal and access should be as large as possible.

✓ **Limit the number of conflict points**—More mistakes and a higher likelihood of collisions result when drivers are faced with a high conflict area, as shown below. These areas create stressful situations that require a high degree of attention. By minimizing conflicts, traffic operations improve and the potential for collisions decreases. This simplifies the driving task, resulting in a lower-stress environment for the driver.

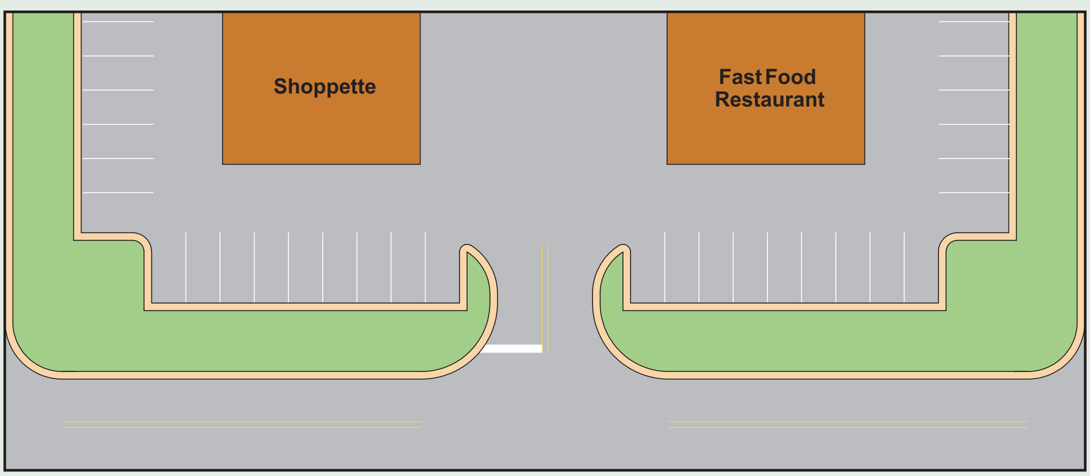
HIGH CONFLICT AREAS

Wide driveway slightly offset from opposite street results in many conflicts.

Driveways too close to a signalized intersection become blocked by stopped vehicles.

- ✓ **Separate conflict areas**—Nearby conflict areas can block movements and increase congestion. Drivers need time to react to each conflict area they are presented with. As travel speeds along a roadway increase, the necessary distance between access points increases because of driver perception-reaction time. Once drivers recognize a potential hazard, they need time to react to that hazard. For this reason, it is important to provide sufficient distance between access points.
- ✓ **Remove turning vehicles from through traffic lanes**—Turning lanes remove lower speed vehicles from the higher speed through lane. Once out of the through lane, turning vehicles can wait safely in a protected lane to complete their turn. This improves the safety and efficiency of an intersection with a street or driveway.
- ✓ **Provide a supporting street and circulation system**—During planning stages it is important to include a supporting network of local and collector streets to accommodate development such as restaurants or a an exchange/Commissary.
- ✓ **Eliminate the need for multiple driveways**—Joint property access is also key in eliminating the need for each property to have a separate driveway. As illustrated below, this connectivity allows motorists to visit adjacent properties without having to drive separately to each.
- ✓ **Preserve the functional area of intersections**—The functional area of an intersection is the area critical to safe and efficient vehicular movement. This area is where all maneuvering/lane changing takes place for drivers to complete the necessary turning movements. When access is located too close to this critical area, it can cause traffic conflicts that seriously disrupt the function of the intersection.

JOINT PROPERTY ACCESS



18.4. ACCESS MANAGEMENT STRATEGIES

When constructing new access points or upgrading existing access, it is important to consider location and spacing. These components are critical to safe and efficient roadway operation.

18.4.1. Access Location

Proper access location involves several considerations:

- ✓ Sight distance
- ✓ Following hierarchy of roadways
- ✓ Functional area of intersections

Sight Distance

Providing adequate sight distance at a driveway ensures motorists can safely enter or exit a roadway. Adequate sight distance also allows approaching drivers sufficient distance to react to entering or exiting vehicles if necessary. Section 4.5 further discusses sight distance.

Roadway Hierarchy

Avoid connecting a roadway of low functional class to one with a much higher functional class. When possible, connections should be made only between roadways with similar classification. For example, a connection between a minor and major arterial is acceptable, but connecting a local road to a major arterial should be avoided.

Functional Area of Intersections

Constructing access points in the area of an intersection where maneuvering or lane changing takes place should be avoided. This area extends at least to the end of turning lanes and to where stopped traffic typically would queue.

18.4.2. Access Spacing

Wide spacing between successive driveways is the single most important element of access management since each new access introduces numerous traffic conflicts to the roadway. These conflicts reduce travel speeds and contribute to congestion and higher crash potential. The closer these access points are, the more profound are these effects. Minimum access spacing requirements attempt to minimize these impacts.

Various sets of guidelines exist for the spacing of access points. Spacing requirements should be based on number of expected trips, speed limits, and roadway classification among other considerations. General spacing guidelines are published in TRB's *NCHRP Report 348*. Exhibit 18.1 shows unsignalized access guidelines.

Exhibit 18.1: Unsignalized Access Guidelines

OPERATING SPEED (MPH)	SPACING (FEET)
30	100-200+
45	300-500+
TYPE OF FACILITY	**SPACING (FEET)**
Major Arterials	300-500+
Minor Arterials	100-300
Collectors	100-200
Lower values apply to roadways on most military installations. Higher volumes would only apply to high-speed or median-divided roadways.	

The spacing guidelines shown above provide a range of values. The lower values apply to lower class roads or roadways with raised medians where no left turns are permitted.

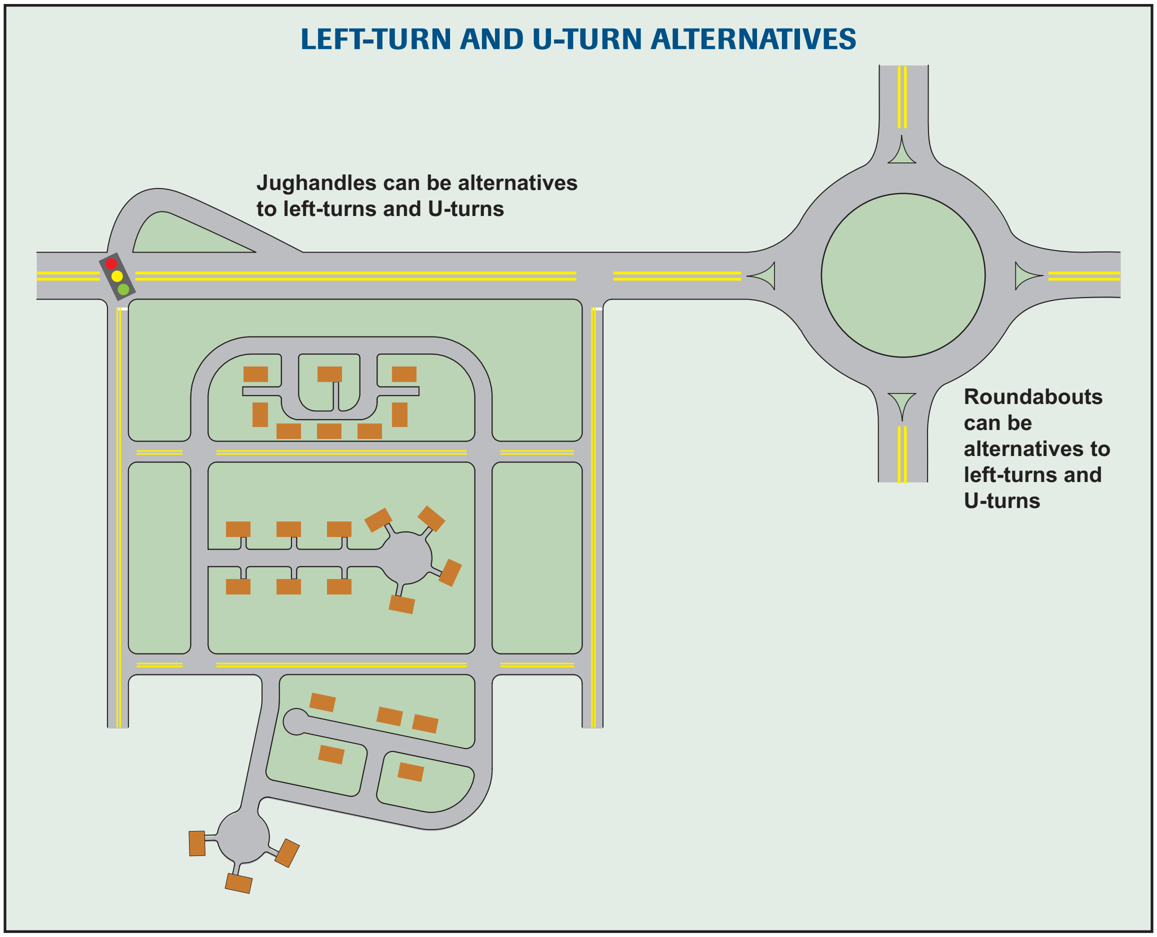
18.4.3. Additional Considerations

It is often desired to restrict some turning movements through intersections with accesses. This most often is left-turns to and/or from busier roadways with the access. The benefit of restricting left-turns generally is safety and operations related. When the volume of traffic is so high that it is extremely difficult to turn left out of the driveway, motorists may accept unsafe gaps in traffic to try to turn left. This could make the intersection more crash-prone. Motorists waiting to turn left would also cause unacceptable delays to right-turning vehicles.

When this type of restriction occurs, it may be necessary to somehow accommodate traffic that otherwise needs to make these left-turns. This may be by providing another access from the site to a side street. It could also be by providing U-turn capabilities along the major roadway. U-turn capabilities can be provided by any of the following methods:

- ✓ Provide U-turn capabilities at an adjacent traffic signal.
- ✓ Provide a jughandle at a signalized intersection.
- ✓ Provide a roundabout at an adjacent intersection to allow for U-turns without conflicting with traffic from the opposite direction.

The following figure illustrates these alternatives.


LEFT-TURN AND U-TURN ALTERNATIVES
Jughandles can be alternatives to left-turns and U-turns
Roundabouts can be alternatives to left-turns and U-turns

18.5. ACCESS DESIGN

The three basic design components of an access are:

- ✓ Corner radius
- ✓ Width
- ✓ Throat length

18.5.1. Corner Radius

Sufficient corner radius enables a vehicle to enter or exit an access without encroaching into adjacent traffic lanes. The radius should be designed for the largest type of vehicle expected to use the intersection.

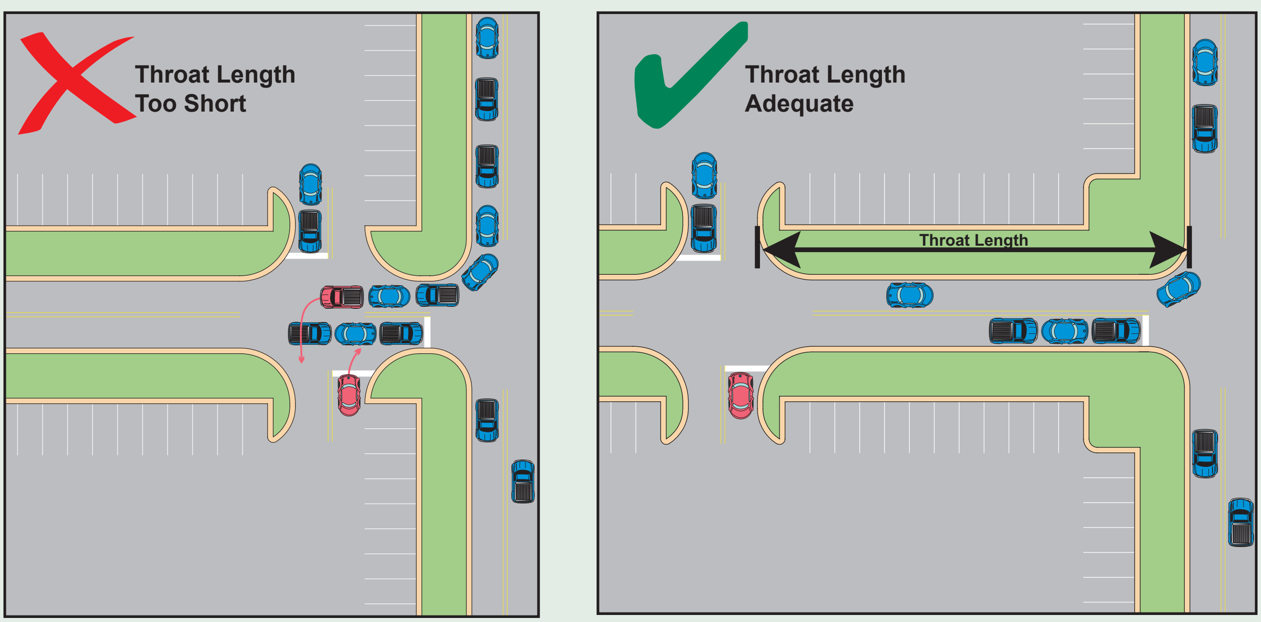
18.5.2. Width

While width must be sufficient to accommodate intended traffic movements, too large a width will result in conflicts spread over a large area. Consequently drivers will be uncertain where to position their vehicles with such a wide access. The recommended width is 12 feet for each lane. Greater widths may be necessary where truck traffic is expected.

18.5.3. Throat Length

The throat of an access is the distance between the adjacent roadway and the point internally where drivers are presented with conflicts. The throat lengths at exchange/Commissary complexes are often too short, which leaves little room for vehicles to stack when presented with an internal conflict, as shown in the illustration below. Eventually vehicles back out onto the adjacent street, which increases crash potential significantly.

DRIVEWAY THROAT LENGTH



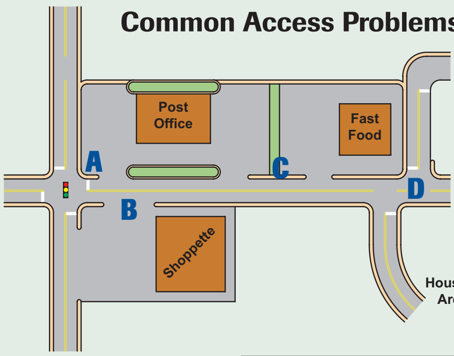
A short throat length also results in insufficient reaction time to the conflicts that a driver will be presented with upon entering the site. Exhibit 18.2 provides some general guidelines for throat lengths. Exhibit 18.3 illustrates the many problems associated with such a short throat length and provides an example of adequate throat length. The drawback to longer throat length is the impact to parking. However, ensuring safe entry into the site is more important.

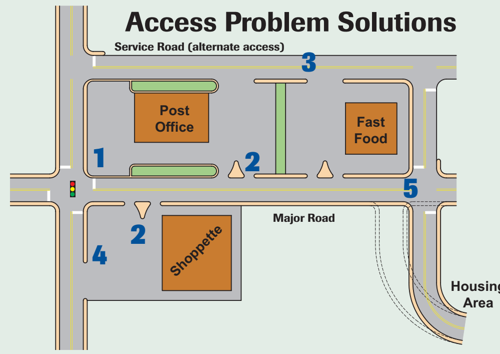
Exhibit 18.2: Throat Length Requirements

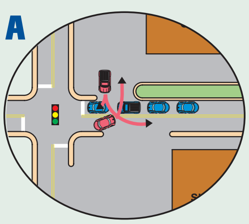
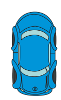
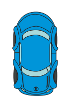
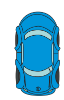
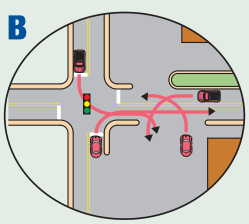
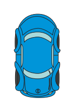
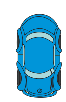
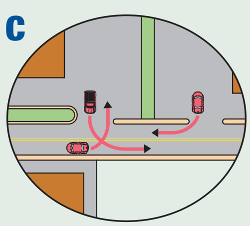
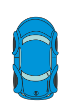
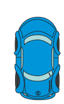
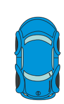
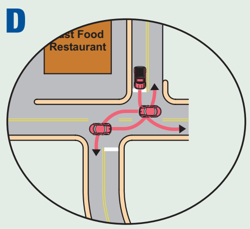
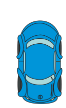
TYPE OF RETAIL ESTABLISHMENT (OR SIMILAR MILITARY FACILITY)	RECOMMENDED THROAT LENGTH	APPROXIMATE NUMBER OF CARS
Small strip mall (shoppette/video store/ fast food restaurant)	75-95 feet	5
Small shopping center or large super market (exchange/Commissary)	200 feet	11

Source: Access Management Manual

Exhibit 18.3: Access Problems and Solutions





	Access Problem Solutions / Common Access Problems	1. **Driveway closure** – Eliminating driveways when other alternative access is provided will eliminate points of conflict along the adjacent roadway.	2. **Restrict left-turn movements** – If alternate access can be provided, such as a service road, left turns can be restricted using raised concrete islands.	3. **Construct service road** – Service roads eliminate access from major roadways.	4. **Reduce width of access** – Access width reduction minimizes the length of roadway along which traffic conflicts are present.	5. **Intersection realignment** – Relocate legs of intersections, when possible, to eliminate offset.
A 	A. **Driveways too close to intersections** - When a driveway is too close to an intersection, blocking of turning movements will occur. This can have detrimental effects on the operation of the intersection.					
B 	B. **Wide, uncontrolled access along a property's frontage** - Inadequate access control, especially at the corner of an intersection, will result in a high-conflict area with frequent unpredictable, unsafe turning movements.					
C 	C. **Driveways spaced too close together** - When drivers are simultaneously exiting nearby driveways, uncertainty is involved trying to predict other nearby maneuvers. Left turns from the major street may also block multiple accesses.					
D 	D. **Intersecting roads with a slight offset** - When intersecting roads are slightly offset from one another, blocking of turning movements may result. For vehicles crossing the major roadway a slight jog results instead of a straight-line movement.					

CHAPTER 19—DEMAND MANAGEMENT

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19.1. CONGESTION

KEY POINT

Demand Management addresses congestion by reducing the number of vehicles on the road during peak periods.

The Cost of Congestion

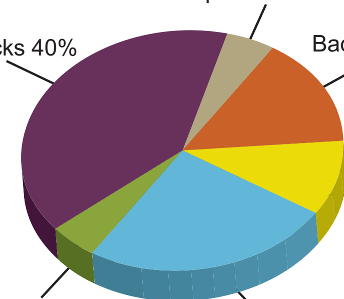
According to the 2015 Urban Mobility Scorecard, travel delays due to traffic congestion caused drivers to waste more than 3 billion gallons of fuel and kept travelers stuck in their cars for nearly 7 billion extra hours – 42 hours per rush-hour commuter. The total nationwide price tag: $160 billion, or $960 per commuter.

Source: 2015 Urban Mobility Report, Texas Transportation Institute

Congestion is not limited to cities, it also affects many rural areas, smaller communities, and military installations. Congestion takes a toll in driving time, vehicle costs, air pollution, and stress/health issues. Some of the stress is caused by the unpredictable nature of traffic, e.g., “Will I be late for that important meeting?” As a motorist, it is easier to accept consistent delays than it is to accept erratic delays.

Many roads were not designed to handle the current traffic demand. With reference to Exhibit 19.1, except for bottlenecks and poor signal timing, the other sources of congestion are usually temporary.

Exhibit 19.1: Source of Congestion



Source: FHWA

As illustrated in Exhibit 19.2, congestion can be reduced by:

1. Building additional road capacity
2. Improving the roadway efficiency
3. Reducing the number of vehicles

Option 1 is the “build option,” but experts believe that it is virtually impossible to solely build our way out of congestion. Option 2 includes eliminating bottlenecks, and adding sophisticated traffic signal and intelligent transportation systems that use technology to tweak the capacity. Studies indicate that some of these technologies have a very high return in time and fuel savings. However, the focus of this bulletin is Option 3, which is commonly called either “travel demand management” or simply “demand management.” In reality, the best approach is to use all three of these options.

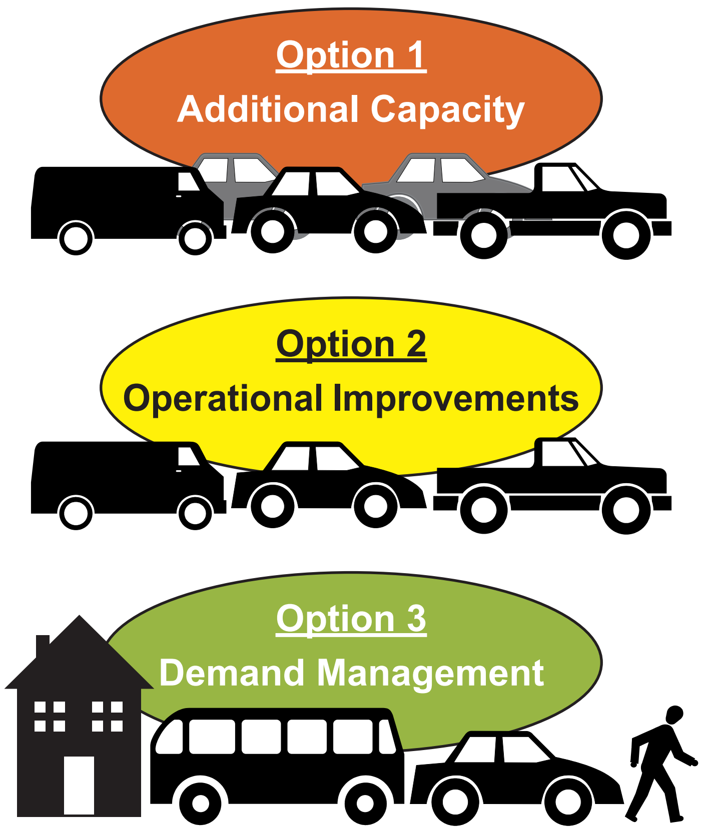
On March 19, 2015, the White House issued an executive order directing the federal government to:

- ✓ Cut energy use in federal buildings 2.5 percent every year between 2015 and 2025.
- ✓ Reduce the amount of water used in federal buildings 2 percent every year through 2025.
- ✓ Decrease greenhouse gas emissions from federal vehicles by 30 percent per mile by 2025, compared to the levels in 2014.
- ✓ Ensure federal agencies are getting 25 percent of their energy—both heat and electricity—from clean sources by 2025.
- ✓ Put more hybrid and zero-emission vehicles in the federal fleet of cars and trucks.

This executive order builds more aggressively on previous executive orders that are aimed toward cutting energy use and emission levels across the entire government.

Although the executive order is relative to an agency's energy use, the agency should be cognizant of other ways to reduce energy consumption.

Exhibit 19.2: Congestion Mitigation Options



Demand management programs attempt to address congestion at the root of the problem by reducing the number of vehicles on the road. These initiatives work to modify driver behavior by encouraging people to make fewer single-occupancy trips, travel in off-peak hours when possible, and support land-use policies that reduce the demand for vehicular travel.

Exhibit 19.3 shows six typical demand management strategies used to reduce congestion. Of the six strategies, only the first four have typical applications on military installations; therefore, the first four strategies are discussed in the remainder of this section.

As the owner of the road network and as the employer, military installations have a unique opportunity to make a difference for their employees while also eliminating some of the costs for constructing extra travel lanes and parking spaces.

The next sections identify different demand management techniques. By using these, military installations can assist their employees and other partners in making significant reductions in energy usage, travel time, and air pollution. This truly is a win-win situation for everybody.

Exhibit 19.3: Demand Management Strategies

STRATEGY	EXAMPLES
TRAVEL ALTERNATIVES	✓ Telework ✓ Flexible work hours/alternate work schedules ✓ Pedestrian/bicycle travel
HOV	✓ Carpooling ✓ Guaranteed ride home program ✓ Parking pricing and cash-out programs ✓ Instant ridesharing program
TRANSIT	✓ Enhanced bus quality and transit stops ✓ Internal shuttle service ✓ Guaranteed ride home program ✓ Subsidized fares
LAND USE	✓ "Smart Growth" policies ✓ Pedestrian/bicycle/transit connections
FREIGHT	✓ Truck-only toll lanes (TOT) ✓ Lane restrictions ✓ Delivery restrictions ✓ Availability of rail or barge
PRICING	✓ High occupancy toll lanes (HOT) ✓ Time-of-day pricing ✓ Activity center pricing

19.2. TRAVEL ALTERNATIVES

19.2.1. Telework

Telework is where employees enjoy the flexibility in work location. This is the ultimate in the reduction of travel demand since it allows workers an opportunity to work from home whenever possible. Telework is facilitated by laptop PCs, broadband Internet connections, groupware, conference calling, video-conferencing, and Voice over Internet Protocol (VOIP). Telework can also assist marginalized groups, such as caregivers, employees with disabilities, and people living in remote areas.

Telework tends to be most suitable for jobs that primarily manipulate information, such as software programming, data entry, planning, analysis, and design. In 2008 approximately 2.8 million employees worked from home most of the time, but it has been suggested that 52 million U.S. workers (about 40 percent of employees) could work from home.

Benefits of telework include:

- ✓ Enhances business across multiple time zones.
- ✓ Reduces the spread of diseases, employee turnover, and absenteeism.
- ✓ Eliminates commuting time.
- ✓ Reduces congestion, air pollution, and energy use.
- ✓ Reduces employee and employer costs.
- ✓ Eliminates the effects of weather and terror-related office and road closures.

Most employers believe that teleworkers are more productive than other employees, perhaps because teleworkers will not be part of a group talking around the water cooler or copy machine. Also, teleworkers feel blessed to be able to work from home, and there may be an underlying fear that unless they are super productive, this privilege could be taken away. Because of this indebtedness, teleworkers may be willing to further adjust their schedule to make phone calls earlier or later in the day to talk to individuals in other time zones.

Global Workplace Analytics' research (http://globalworkplaceanalytics.com) finds that:

- ✓ 50% of the US workforce holds a job that is compatible with at least partial telework and approximately 20-25% of the workforce teleworks at some frequency.
- ✓ 80% to 90% of the US workforce says they would like to telework at least part time. Two to three days a week seems to be the sweet spot that allows for a balance of concentrative work (at home) and collaborative work (at the office).
- ✓ Fortune 1000 companies around the globe are entirely revamping their space around the fact that employees are already mobile. Studies repeatedly show they are not at their desk 50-60% of the time.
- ✓ In 2014, 159,000 federal government employees reportedly telework, which represents approximately 0.1 percent of the total workforce.
- ✓ The number of federal government teleworkers has increased by 424 percent from 2005 to 2014, which significantly outpaces the overall workforce which has increased by 102 percent in the same time period.

19.2.2. Flexible and Alternate Work Schedules

Except for jobs where full teams are required at all times, installations should consider allowing employees to establish their own work schedule. In addition to smoothing out the peak-hour traffic volumes, flexible hours allow employees to be more active in family and community activities, to choose the part of the day that they work best, and to facilitate carpools, transit, and educational opportunities.

Alternate work schedules like the compressed work week can also have major implications. For example, working four 10-hour days instead of five 8-hour days reduces commuting-related travel by 20 percent. Installations should refer to OPM's Handbook on Alterative Work Schedules (see http://www.opm.gov/oca/aws/).

19.2.3. Pedestrian and Bicycle Travel

To further reduce vehicular travel and to promote healthy activities, it is highly desirable to have a good network of sidewalks, walkways, and bikeways. These facilities can be used to go to the PX, commissary, credit union, library, gym, etc., instead of jumping in the car, and they can also encourage walking or biking during the lunch hour as recreation. If employees can have a relaxing lunchtime stroll with shade trees and park benches, it is also likely that they will be more productive when they return to work after lunch.

Typical pedestrian concerns include:

- ✓ Lack of continuous walkways.
- ✓ Walkways are too narrow, have a poor walking surface, and are partially blocked by utility poles, signs, etc.
- ✓ Insufficient lighting.

To encourage employees to walk or bike to work, installations should consider a dedicated ECF when the number of pedestrians and bicyclists exceeds ten users per 15-minute interval during the morning peak hour.

19.3. HIGH OCCUPANCY VEHICLES (HOVs)

19.3.1. Carpooling

The definition of a high occupancy vehicle (HOV) generally means a vehicle having more than one person, and at the workplace this is generally referred to as carpooling. These ridesharing opportunities are an ideal way to reduce congestion and the number of required parking spaces. It also allows carpoolers an opportunity to reduce their commuting costs and save time by using HOV lanes, while at the same time provide extra time for passengers to catch up on sleep; work or reading; or just relax, unwind, and socialize. Sometimes workers know of someone in their neighborhood who works at the military installation and together they can work out their own rideshare arrangements. However, installations can encourage additional ridesharing by developing a web site for individuals to express their willingness to share a ride.

Carpooling has risks such as, what happens if a member of the carpool is required to work overtime, or if someone needs to leave work early for unanticipated personal reasons?

When these risks do materialize, the member can sometimes make a quick call and perhaps other members of the carpool can adjust their schedule or make other carpool arrangements; but this will not always work. One concept to alleviate these fears is a Guaranteed Ride Home (GRH) program.

To encourage HOVs, installations are encouraged to consider the following actions:

- ✓ Allow alternate work schedules and flex time.
- ✓ Provide an appropriate carpool-matching website.
- ✓ Develop a GRH program.
- ✓ Provide priority parking for HOV vehicles.
- ✓ Charge a daily parking fee or provide a daily cash-out payment for employees that carpool or use transit.
- ✓ Provide express lanes for HOVs through busier ECFs.

19.3.2. Guaranteed Ride Home (GRH) Program

The GRH program is where the military installation provides a guaranteed ride to accommodate stranded employees. The method of transportation could be in the form of a government vehicle, a taxi, or a rental vehicle.

Most carpoolers and transit riders consider the GRH program to be important in their decision whether to carpool or use transit, but how "emergency" is defined also affects the attractiveness of the program. Therefore, installations are encouraged to start with a very liberal program and make refinements if they believe the program is being abused. Although carpoolers like the reassurance of a GRH program, on an annual basis employers have found that a very low percentage of carpoolers will actually use the program. It is acceptable to charge a fee for the use of the vehicle.

The GRH program can also be used to assist transit riders when unexpected events come up.

19.3.3. Incentives to Encourage HOV

To encourage the use of HOVs, employees could be charged a parking fee or receive a "cash-out" for using HOV or transit. In both cases, the monetary value should theoretically equal the cost of providing parking.

19.3.4. Instant Ridesharing

In addition to maintaining an appropriate carpool-matching website, an emerging technology is instant ridesharing. Instant ridesharing is a ridesharing arrangement that enables the formation of carpools on very short notice. In instant rideshare matching systems, the employee wishing to obtain a ride sends a ride request to a ridesharing operation network or to a centralized database. The database then searches for a match with trips offered by others who have registered for the program. Instant ridesharing is also known as dynamic ridesharing, ad-hoc ridesharing, real-time ridesharing, single trip ridesharing, dynamic carpooling or casual carpooling.

HOV Lane Example

19.4. TRANSIT

Nationally, a very low percentage of all commuting is by public transportation. Some of the common reasons for not using transit, include:

- ✓ Transit connections are not convenient.
- ✓ The buses are old and uncomfortable.
- ✓ The bus stops do not have clean safe shelters.
- ✓ An emergency could happen when bus service is not available.

Installations generally cannot eliminate the first two reasons but they can help ensure that bus stops on the installation have acceptable shelters. And as noted previously, the GRH program can help more employees participate in a ridesharing program by defusing the last reason.

Employees at military installations tend to be younger and more dependent on public transportation than at most other employment centers. In fact, during basic training, recruits generally cannot have privately-owned vehicles on the installation.

There are three transit arrangements to consider:

1. External service provided on the installation with guards riding on the bus during higher force protection conditions. This is the most efficient arrangement, but security may be an issue since some passengers may not be going to or from the installation.
2. External service to a location outside the gate where there is a connection to an internal shuttle service. Although internal shuttle service is expensive, it does provide an opportunity to pick up employees who live locally and walk to the transfer location or who are dropped off from an outside carpool.
3. External service to a location outside the gate, with opportunities to walk to their employment center. Unfortunately, this arrangement only works for small installations or for those people who work in buildings near the drop-off location.

A common problem to all transit and shuttle services is the state of existing bus stops. At bus stops, shelters should be provided, particularly at stops where larger groups of riders are expected. An example of a bright and friendly bus shelter is illustrated, although a bench would be desirable. On busier roads, bus pull-offs should be provided so buses do not block the travel lane.

Some of the larger military installations have an internal shuttle service. Since these shuttle buses are frequently old and uncomfortable, there may be a benefit to upgrading the shuttle fleet with hybrid buses, buses that run on compressed natural gas (CNG), or buses that have the new clean diesel engines. These newer buses will improve passenger comfort, and be more environmentally friendly and cost effective.

Typical Bus Shelter

A Clean Cities Fact Sheet (the May 2000 issue, as published by the U.S. Department of Energy) says that CNG buses could pay for themselves in just a little more than 3 years, require less maintenance, and emit 97 percent less particulate matter and 58 percent less oxides than conventional diesel buses.

The new clean diesel-powered buses have comparable environment benefits as the hybrids but at a lower annualized cost than either hybrids or CNG buses.

If replacing buses, most installations could consider smaller shuttle buses since existing buses sometimes have trouble making tight turns. Upgrading to new smaller buses should also reduce fuel costs.

It is important to publicize any internal shuttle service, providing the specifics as to who can ride, where it goes and when.

For Arrangements 2 and 3, if a new ECF is being planned, as a minimum, a transit stop should be considered as part of an ECF design with a bus turnout pocket and a subsequent U-turn capabilities before the ID check area.

19.5. LAND USE AND SMART GROWTH

In an effort to reduce internal travel, military installations should plan for "smart growth," which refers to incorporating land-use considerations into transportation planning to minimize environmental impacts and enhance mobility. The ITE has a publication titled *Smart Growth Transportation Guidelines: An ITE Recommended Practice*. This publication provides recommendations that allow a developing community to reduce vehicular dependence by providing more mobility choices.

The following key principles should be considered for future development:

- ✓ Provide extensive street networks, including small grids with intersections spaced every 300 to 500 feet. (Larger grids require more travel for pedestrians, bicyclists, and motorists to reach their destinations.)
- ✓ Provide a well-connected system of facilities for pedestrians and bicycles to promote these types of travel.
- ✓ Mix complementary land uses to reduce trip lengths by putting more origin-destination pairs in close proximity with each other.

Perhaps the central theme is planning for integrated self-contained communities and work areas where everything is within walking distance. In addition, add transit or internal bus loop stops near the center of these "communities."

In addition to the term "smart growth," the term "walkable communities" is also used to indicate how friendly an area is to walking. While the actual evaluation requires the consideration of many subjective factors, the goal is to encourage citizens to rely less on their cars and to choose walking more often as a form of everyday transportation. Well-designed, compact communities where people can walk to school and work, to stores, parks, and restaurants significantly reduce the need to drive.

Obviously, there are many economic, health and environmental benefits of building and sustaining a community that supports walking as a primary mode of transportation.

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CHAPTER 20—CONVOYS

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KEY POINT

Field Manual 55-65 has additional information on Convoy deployment operations.

Convoys are an extremely critical method of deployment on land. Convoy operations generally are comprised of larger and heavier vehicles which tend to travel slower than the regular traffic stream. Due to this, their operations on public roadways must be given special consideration. Army Field Manual (FM) 55-65 Strategic Deployment describes procedures to follow when operating convoys. The intent of this section is to expand on some of the information contained in FM 55-65, particularly with respect to convoy operation, and considerations relating to the mix of convoy traffic with public traffic on public roadways.

20.1. CONVOY BASICS

Typically, as a convoy travels, the slowest vehicle is used to set the speed of the convoy. This vehicle is referred to as the pacesetter. A guide is used to ensure that the convoy travels the correct route, particularly when signing is poor. Guides do not have priority over civilian traffic, and must follow all traffic signals and other traffic control devices.

Civilian police should be used to assist in the following areas:

- ✓ Major intersections
- ✓ Entrances to and exits from expressways and main routes
- ✓ Densely populated and industrial areas
- ✓ Entrances to and exits from rest halt areas
- ✓ Intersection areas near the installation where the convoy originates.

Different municipalities may have different policies regarding police utilization. For example, some may require compensation for assistance, particularly if officers require overtime.

Communication between convoy vehicles is accomplished through several modes. Radio is the primary mode of communication, but visual communications are often used. Visual communications generally occur through the use of hand and arm signals from either vehicles or flaggers. Audible communications, such as horns or whistles, may also be used not only for convoy flagging, but also for temporary traffic control operations.

If a flagger assists in directing traffic, they should use high visibility safety apparel, similar to apparel used in work zones. This is critical to maximize their visibility by both the convoy drivers, as well as by public motorists driving near the convoy.

20.2. CONVOY VEHICLE CONSIDERATIONS

Vehicles in a convoy may generally be apparent due to their appearance. In lieu of this, the front and rear vehicles of each convoy must clearly indicate the presence of the convoy. This is accomplished by:

- ✓ Front vehicle displays a sign with the legend "CONVOY FOLLOWS." It also must use a blue flag, 12 by 18 inches, mounted on the left-front of the vehicle.
- ✓ Rear vehicle displays a sign with the legend "CONVOY AHEAD." It also must use a green flag, 12 by 18 inches, mounted on the left-rear of the vehicle.

Additionally, all vehicles should travel with their headlights on low beam.

20.3. CONVOY ROADWAY CONSIDERATIONS

The roadway itself should be considered in determining the appropriate route for a convoy. For oversize or overweight vehicles, a special hauling permit is required in order to request permission to use public roads.

Also, the number of travel lanes should be considered. If the travel speed of the convoy is considerably lower than the freeflow speed of the roadway, the convoy will delay public traffic. If this occurs on roadways with one lane per direction, consider finding pull-off areas to allow traffic to pass so as to not delay traffic unnecessarily. This would reduce the chances for a vehicle to attempt to pass the convoy by leapfrogging through the vehicles in the convoy. If a convoy travels a multilane arterial or freeway, vehicles would pass in the second lane. In general, having a large speed differential between vehicles by lane is not ideal, but the convoy uses attention-getting devices to maximize visibility by vehicles. Civilian police can also assist with controlling traffic.

20.4. FLAGGER EQUIPMENT

Flaggers are critical components of convoy operations. Flaggers directing convoys should use special equipment to supplement hand signals. This can include a STOP/SLOW paddle, a flag, or a lighted baton. Typically, flaggers use a STOP/SLOW paddle, or flag, as shown in Exhibit 20.1.

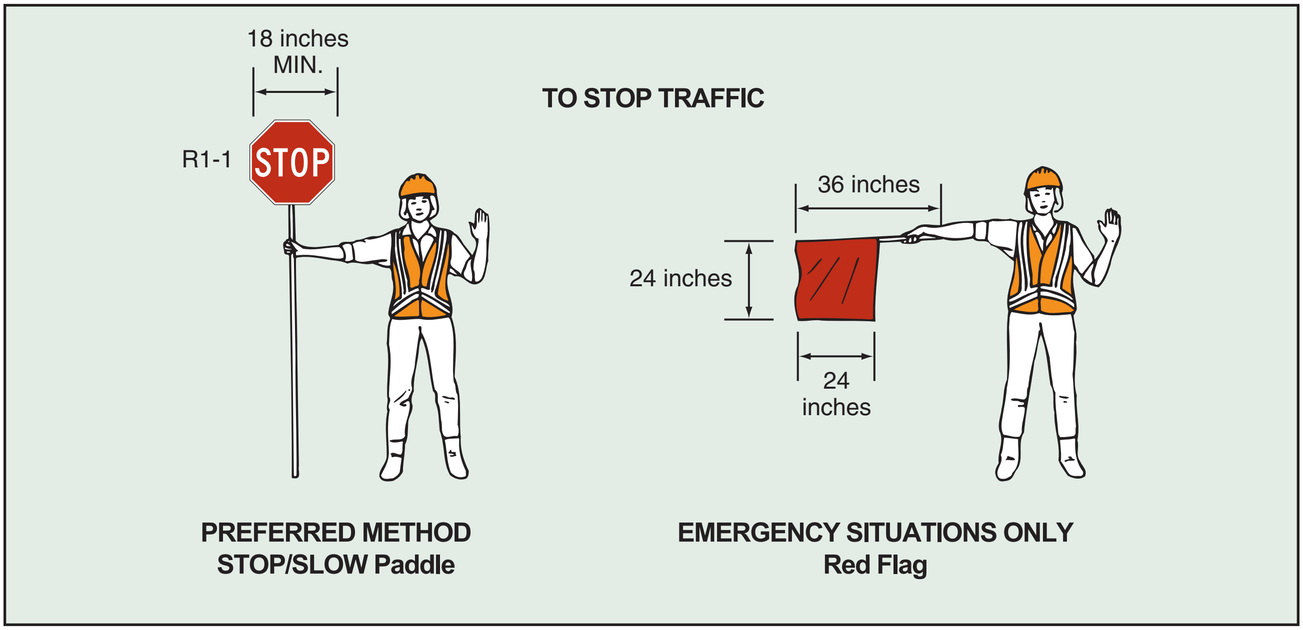
A disadvantage of the paddle is that the messages are limited to those which are contained on the paddle. If other messages are desired, such as would be the case if someone was directing the convoy to turn at a certain location, these messages would not suffice. Another disadvantage of the paddle is that it is bulky, and not as easily stored in a vehicle.

The flag offers more versatility compared to the STOP/SLOW paddle, but does not have reflectivity. Flags are made of a fluorescent orange vinyl material. This offers good visibility during daylight hours, but without retroreflectivity, it cannot be used at night. The actual flag can vary in size. Larger sizes are preferred for maximum visibility.

A lighted baton offers the advantage of nighttime visibility. Since it is not reflective, and does not have as much surface area visibility, it is not as effective during the day. For this reason, the use of a baton should be limited to nighttime.

In order to assist with audio signals, a flagger could have a whistle for use as needed.

Exhibit 20.1: Use of Hand-Signaling Devices by Flaggers



Flaggers are required to wear proper apparel, which consists of high visibility safety apparel. In most cases, proper visibility can be achieved through the use of a retroreflective vest. See Section 14.9 for additional information. Proper safety apparel is required, in part, for OSHA compliance. The lack of proper safety apparel would be a “recognized hazard” as used in OSHA’s General Duty Clause, an would therefore be an OSHA violation.

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CHAPTER 21—LIGHTING

CHAPTER 21—LIGHTING

Lighting for security purposes is very important on DoD installations, especially at ECFs, and at other sensitive locations within the installation.

There have been major advancements in lighting technology and the understanding of uniformity, contrast, glare, and the color of the light and how they affect nighttime visibility. UFC 3-530-01, entitled *Design: Interior and Exterior Lighting and Controls*, incorporates current design concepts.

Sustainability is also an important design consideration. As a result, installations should:

- ✓ Use the most effective, energy-efficient light source available.
- ✓ Avoid over-lighting, and ensure that lights are only on during the hours they are needed.
- ✓ Promote dark skies and reduce light trespass onto adjacent properties by using cutoff luminaires.
- ✓ Recycle lamps containing mercury.

Most of the exterior lighting on DoD installations is currently high-pressure sodium (HPS); however, per the UFC, installations are not to use HPS light sources for new exterior applications except where existing conditions and continuity of source types make it necessary. Although today's color-improved HPS lighting is more efficient than earlier types of lighting, pulse start metal halide (MH) lamps have become the preferred lamp on military installations because they are more efficient, require less maintenance, and provide better visibility. LED lighting is also a viable option, and provides similar benefits.

21.1. BASICS

The proper design of the lighting system will increase safety and efficiency, aid security forces, and enhance appearance. Therefore, a qualified lighting engineer should develop a lighting plan that meets lighting requirements within site constraints.

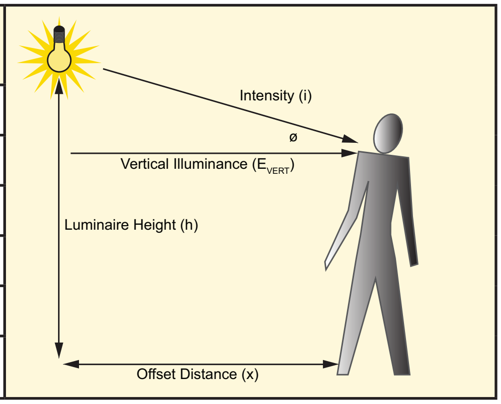
The *Roadway Lighting Design Guide* is an excellent resource for designing roadway lighting.

21.1.1. Illuminance

Illuminance is a measure of the intensity of light on a surface. A foot-candle is the U.S. customary unit of measure equal to one lumen per square foot and originally quantified as the amount of light from a typical candle burning at a distance of one foot from the surface. Exhibit 21.1 shows a range of some illumination levels.

Exhibit 21.1: Typical Illuminance Values

LIGHTING SOURCE	LEVEL OF ILLUMINANCE (FOOT-CANDLES)
Full moon	0.02
Gas station canopy	10-20
Office	20-50
Overcast day	100
NFL football stadium	300
Direct bright sunlight	10,000



Horizontal illuminance is the density of light that falls on a horizontal surface and measured at a location 6 inches above the ground. Although illuminance is typically measured on a horizontal surface, the term "vertical illuminance" is used in the ID check areas, parking lots, pedestrian areas, and perimeter lighting. Vertical illuminance is the application of light on upright objects such as people, instead of horizontal surfaces like roadways and parking lots. For security purposes, the need to illuminate people, especially their face, for identification purposes is more important than illuminating horizontal surfaces. Vertical illuminance is generally measured at a height of 5 feet above the grade.

Exhibit 21.2 shows minimum illuminance levels at select locations within DoD installations.

Exhibit 21.2: Minimum Illuminance

LOCATION	TYPICAL ILLUMINANCE (FOOT-CANDLES)	NOTES
PARKING LOTS	✓ 0.2–basic lots ✓ 0.5—enhanced security	✓ The maximum-to-minimum horizontal illuminance uniformity ratio should be not greater than 15. For parking lots, UFC gives requirements for basic lots and for enhanced security lots
PEDESTRIAN AREAS	✓ 0.5	✓ By using shorter poles with illuminance from multiple directions, adequate vertical illuminance should be provided to light individuals and their faces
PERIMETER LIGHTING	✓ 0.2–0.4 vertical illuminance	✓ See Table 6-1 in UFC 3-530-01

21.1.2. Types of Lamps

There are currently several types of lamps:

- ✓ High-pressure sodium (HPS) lamps are high intensity discharge (HID) lamps in which light is produced by radiation from sodium vapor. These currently are the most common lamp but they do not have the best efficiency, longevity, or color.
- ✓ Pulse-start metal halide (MH) lamps are the current lamp of choice for most external lighting due to their excellent color and high efficiency. These are HID lamps in which the major portion of the light is produced by radiation of metal halides and their products of dissociation, possibly in combination with metallic vapors such as mercury. However, because of a long restrike and warm-up periods, when used for security purposes they always require backup lights. (Note: Standard MH lamps are not as efficient or durable as the pulse-start types.)
- ✓ Quartz-halogen lamps are inefficient, but provide excellent color and a quick start, making them ideal for backup lighting.
- ✓ Incandescent lamps have excellent color, but poor energy efficiency.
- ✓ Fluorescent lamps have excellent color and can be of a rapid start variety.

- ✓ Light emitting diode (LED) lighting is becoming more widespread for use. LED luminaires are available to replace traditional cobrahead luminaires, or can be used on new lighting systems. LED lighting uses much less power than traditional luminaires. LED reliability is improving, however, many agencies are skeptical of LEDs because they burn out gradually. This may result in a deficient level of illumination not being noticed.

LEDs may ultimately replace other types of lighting. Some of the advantages of LEDs include:

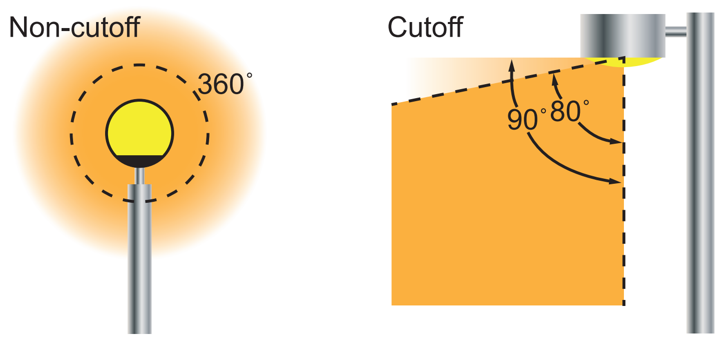
- ✓ Reduce energy consumption
- ✓ Reduce maintenance costs
- ✓ Provide more uniform illuminance
- ✓ Eliminate the need for backup lamps
- ✓ Reduce the number of insects attracted to the lights

21.1.3. Light Trespass

Light trespass is defined as any direct visibility of the source light beyond its target area. This is usually unwanted light that either illuminates adjacent properties or creates excess brightness in someone's field of vision. To help promote dark skies and minimize light trespass, whenever possible, use full cutoff luminaires as addressed in Exhibit 21.3.

Exhibit 21.3: Cutoff Classifications

CLASSIFICATION	MAXIMUM INTENSITY (% LAMP LUMENS)	
	ABOVE HORIZONTAL	80° ABOVE VERTICAL
Full Cutoff	0	10
Cutoff	2.5	10
Semi-Cutoff	5	20
Non-Cutoff	n/a	n/a



It is generally possible to classify the type of cutoff by visual observation. For example, if the lens is not visible when viewed from the side it is a full cutoff lamp, whereas a low hanging globe-like lens is a semi-cutoff lamp.

The primary issue with the full cutoff lamps is the fact that more poles and lamps may be required to provide proper illuminance. The angle of the cutoff may vary by application. For roadway lighting, a cutoff angle of 80 degrees as shown in Exhibit 21.3 may be appropriate. For other applications, such as building entrances or exits, lower cutoff angles to limit the light trespass may be more appropriate.

A canopy over an ECF will also reduce light trespass. In addition, special shields can be used to further reduce light trespass.

Exhibit 21.4 shows a significant light trespass problem.

Exhibit 21.4: A Light Trespass Problem

Photo courtesy Chuck Bueter

21.1.4. Color Rendering

The color rendering index (CRI), ranges from 1 to 100 and indicates how accurately colors are rendered by a light source. The greater the number, the better the light source is at rendering colors. “White” light produces higher CRI than “yellow” lighting. A light source with a CRI greater than 65 should always be used.

When CCTV is used as part of the traffic and security operations, it is important to provide the correct lighting to support the CCTV system. It is also important to ensure that the camera is capable of automatically adjusting the white balance.

21.1.5. Restrike and Warm-up Times

Another important design consideration is the restart or restrike time for the lamps. Restart occurs when a lamp experiences a loss of power, which could be caused by a power outage or someone accidentally turning off a light switch. Once power is restored, the time it takes for the lamp to cool down and then begin to come back on is the lamp’s “restrike time.”

After the restrike time, many lamps still take several minutes for the lights to warm up and reach their full intensity. This warm-up time is generally measured from restrike to the time the light output is 60 percent of its maximum output. Exhibit 21.5 identifies four different lamps and their restrike and warm-up times. For example, a power outage of only a few seconds may require 6 minutes for the preferred MH lamp to cool down, restart, and warm up sufficiently to produce 60 percent of its normal illuminance.

It is important to note that MH lamps should be the pulse start lamps and not the standard MH lamps. The standard MH lamp is not as efficient and does not last as long, but the biggest problem is that they have even larger restrike and warm-up times.

Exhibit 21.5: Types of Lamps

LAMP TYPE	LUMEN OUTPUT (INITIAL)	RESTRIKE TIME (MINUTES)	WARM-UP TIME TO 60% LIGHT OUTPUT (MINUTES)	LIGHT COLOR/CRI	NOTES
MH (Pulse Start)	44,000 (400W)	4	2	White/65 or greater	Preferred lamp due to high efficiency
HPS (w/color improved lamp)	37,400 (400W)	1	3	White/65 or greater	Acceptable, but has lower lumen and life expectancy than MH lamps
Quartz-Halogen	5,000 (250W)	n/a	n/a	White/97-100	Recommended backup lighting. Typical designs provide 15% of normal illuminance
LED	Up to 76,000 (up to 300W) variable by specific product	n/a	n/a	White/70 or greater	Many different size/ illumination options available

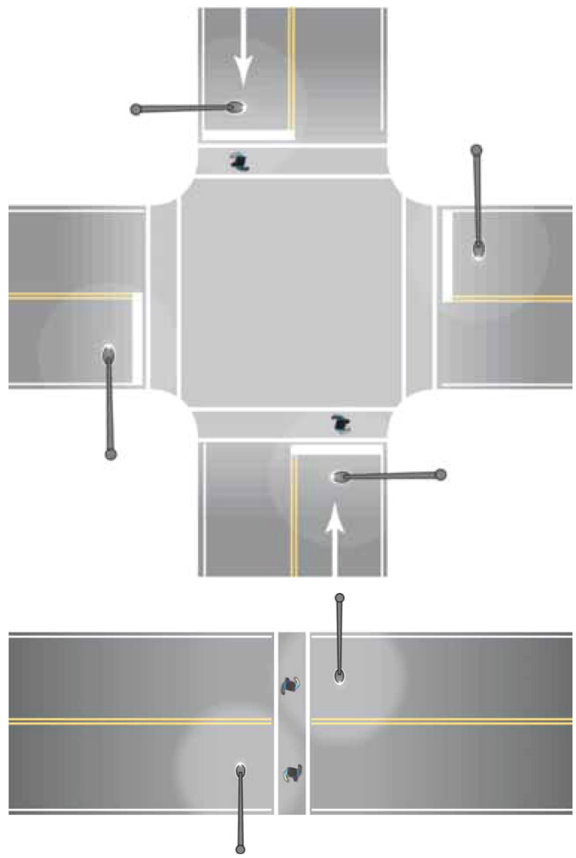
21.2. INTERSECTION AND CROSSWALK LIGHTING

Intersection lighting increases motorist and pedestrian visibility and reduces crash potential. Although no specific warrants have been established, the *MUTCD* suggests roadway lighting if a disproportionate number of crashes occur at night. Lighting should be installed at those locations where a qualified lighting engineer has determined that lighting will contribute to the efficiency, safety, and/or comfort of motorists and pedestrians. Similar lighting can also be used at midblock pedestrian crosswalks and would be especially beneficial at busier crosswalks.

Most state DOTs, as well as IESNA, have developed criteria to assist in determining lighting requirements. When designing lighting, the following factors should be considered; luminaire type, light source type, wattage, mounting height, and pole location. A qualified lighting engineer should evaluate intersection lighting.

In an effort to improve visibility of pedestrians, the preferred location of light standards for intersection and midblock crosswalks is as illustrated in Exhibit 21.6.

Exhibit 21.6: Recommended Location for Luminaires at Intersections and Midblock Crosswalks



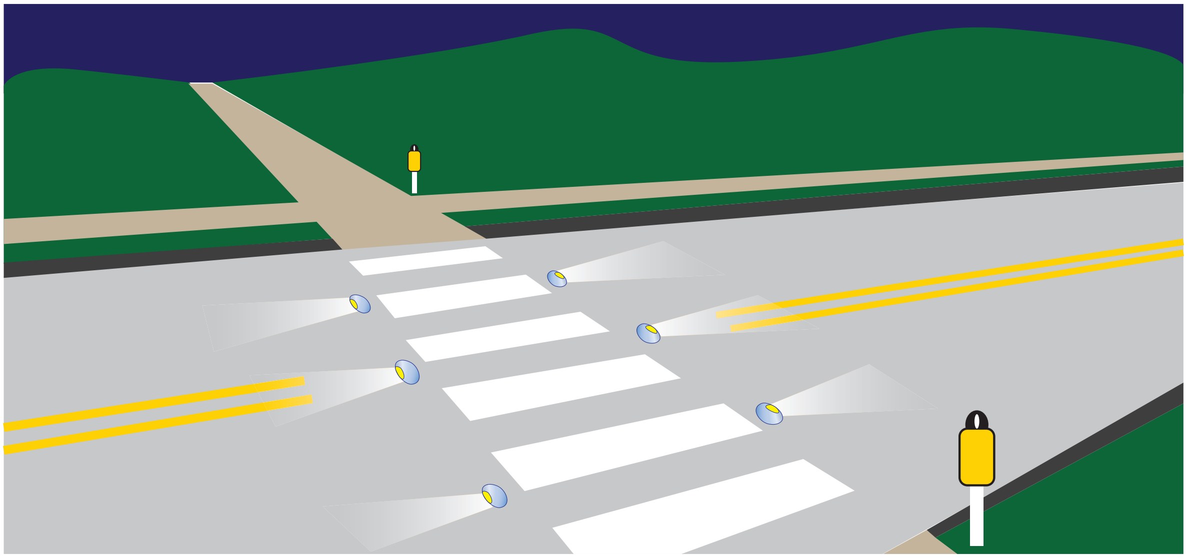
It is common to install luminaire arms for lighting on the top of traffic signal mast arms. These can be used with any type of mast arm application, to include traffic signal mast arms, mast arms for active vehicle barriers at entry control facilities, mast arms used for advance overhead lane use control sign, and mast arms used for pedestrian hybrid beacons. The luminaire should be mounted at a height of 30 feet above the road surface, with a 15 foot arm. If a mast arm exists without lighting, luminaires should not be added because it likely was not structurally designed for the loading resulting from the luminaire arm.

In the absence of mast arms, lighting is often installed on utility poles, or on exclusive light poles. All poles, including signal mast arms, light poles, or utility poles should be located outside of the clear zone, shielded by a barrier, or be breakaway (see Chapter 11). Common mistakes include locating nonbreakaway pole bases too close to the roadway, or setting the concrete foundation elevation too high such that it is a roadside hazard when struck by a vehicle, even if the pole base is breakaway. The luminaire itself should be located above the roadway itself, no farther than the edge of the roadway. For example, if the pole base is located 15 feet from the roadway, a 15-foot long luminaire arm is required to bring the luminaire back over the roadway.

For continuous roadway lighting, light poles can be installed in continuous ruins parallel to the roadway. Continuous lighting should avoid shadowing effects from too wide of spacing. The conical shape of the lighted area from one luminaire should have a slight overlap with the lighted area of the next luminaire. The exact spacing can vary depending on the height and wattage of the luminaires. A lighting design using 200 watt luminaires with a mounting height of 40 feet should use a spacing of 225 feet.

It is also permissible to use in-roadway warning lights in a line parallel to the edges of the crosswalk, either at or within 10 feet of the near edge of the crosswalk as illustrated in Exhibit 21.7. Installation of in-roadway warning lights must conform to Chapter 4N of the *MUTCD*, or the applicable state supplement to the *MUTCD*. In accordance with the *MUTCD*, in-roadway warning lights shall not be installed at crosswalks controlled by YIELD signs, STOP signs, or traffic control signals.

Exhibit 21.7: In-Roadway Warning Lights



DoD installations should be aware that these systems are expensive, and for installations with winter maintenance activities snowplowable light assemblies will be required. The lights are generally activated by a pedestrian push button and the lights flash for a sufficient period of time to allow pedestrians to either reach the far side of the roadway or another push button, for example, in a median.

21.3. PARKING LOT LIGHTING

In addition to security, lighting in parking lots also plays a critical role in maximizing visibility between motorists and pedestrians since pedestrians typically walk next to vehicle parking aisles. In large exchange and Commissary parking lots, lighting is also helpful as shoppers transfer goods from shopping carts to their vehicles.

Mounting height and spacing of luminaires should be sufficient to distribute the desired lighting intensity to the entire parking area. Pole heights range from 20 to 50 feet high or more. A normal lighting level is from 1 to 2 foot-candles, and the maximum-to-minimum uniformity ratio should be not greater than 15–20.

Locate light fixtures away from traffic aisles and parking stalls wherever possible. Light poles are ideally located in islands and protected by raised curbs. When light poles are within parking rows, locate the poles at the junctions of adjacent stalls, and install them on top of a 3-foot high concrete base to avoid accidental knockdowns. While this practice is acceptable in parking lots, high concrete bases should not be used on open roadways due to the need to provide breakaway designs in areas with higher travel speeds. Poles and fixtures should be in scale and accommodating to the setting and surrounding area, while providing adequate illuminance of the parking lot. As illustrated in Exhibit 21.8, luminaires should direct the light downward to promote dark skies.

Exhibit 21.8: Parking Lot Lighting using Full Cutoff Lamps

21.4. MISCELLANEOUS CONSIDERATIONS

Good lighting does not eliminate the need to use retroreflective traffic signs. Lighting devices should be provided in temporary traffic control areas based on engineering judgment. When nighttime work is being performed, floodlights should be used to illuminate the work area, equipment, crossings, and other areas. Except in emergency situations, flagger stations shall be illuminated at night, and provide vertical illuminance without producing disabling glare for approaching road users, flaggers, or workers.

Although solar-powered lights are not currently good for illuminance, they can be used to energize large “flashing arrow” and “dynamic message” panels used on construction projects and for special events. These solar-powered devices have large solar panels and sufficient batteries to work for many cloudy days. They also have the added benefit of operating without the noise of a generator.

Solar power is also a cost effective power source to operate flashing lights such as pedestrian-activated lights attached to pedestrian signs, or flashing lights attached to signs in remote areas that do not have readily-accessible commercial electricity.

21.5. FUTURE TECHNOLOGIES

Solar-powered lighting currently is not a viable lighting solution except as landscape lights to delineate walkways. These inexpensive lights do not adequately illuminate walking surfaces, but they are effective in defining the edges of pathways and sidewalks. Reliability of these inexpensive lights is an on-going problem.

With on-going improvements in solar collectors, batteries and energy-efficient lights, solar power will undoubtedly become a more viable option in the future.

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APPENDIX

APPENDIX A—STANDARD TEA SIGNS

Note: 'R' designates a Regulatory Sign; 'W' designates a Warning Sign

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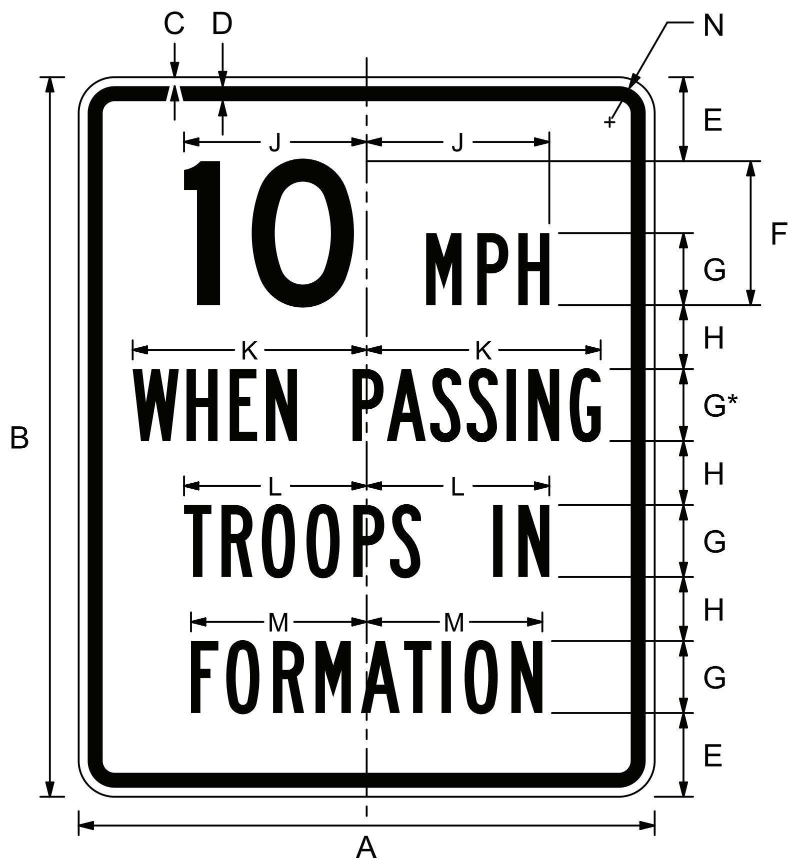
R2-1a-TEA

10 MPH WHEN PASSING TROOPS IN FORMATION

The 10 MPH WHEN PASSING TROOPS IN FORMATION (R2-1a-TEA) sign may be used along roads where troops periodically walk in formation on the roadway and the military installation has a regulation specifying the maximum speed limit in these situations. The posted speed limit should reflect whatever speed is specified in the regulation.



A	B	C	D	E	F	G	H	J	K	L	M	N
24	30	.38	.62	3.5	6D	3B	2.67	7.61	9.75	7.61	7.32	1.5

*Reduced spacing 15%

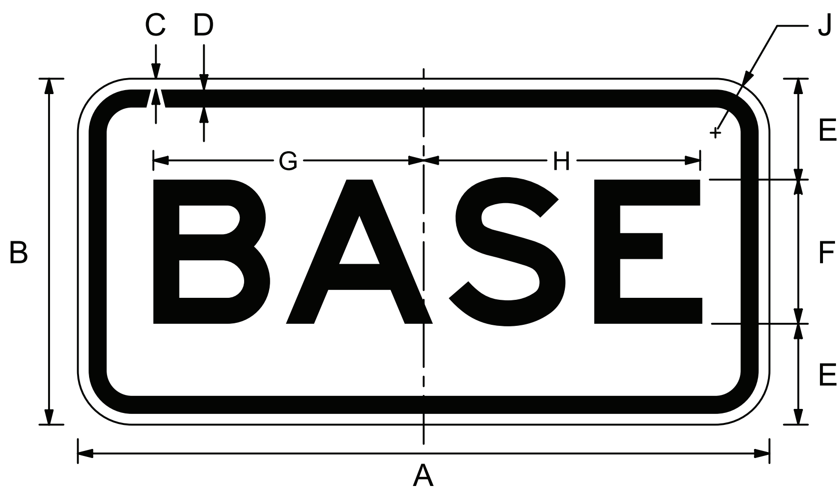
COLORS:

BORDER & LEGEND—BLACK

BACKGROUND—WHITE (RETROREFLECTIVE)

R2-5hP-TEA
BASE PLAQUE

The BASE (R2-5hP-TEA) plaque may be used above a Speed Limit (R2-1) sign at the entrance to a military installation when the boundary speed limit signing concept is used. In lieu of the word "BASE," other words such as "POST" or "BARRACKS" may be used.

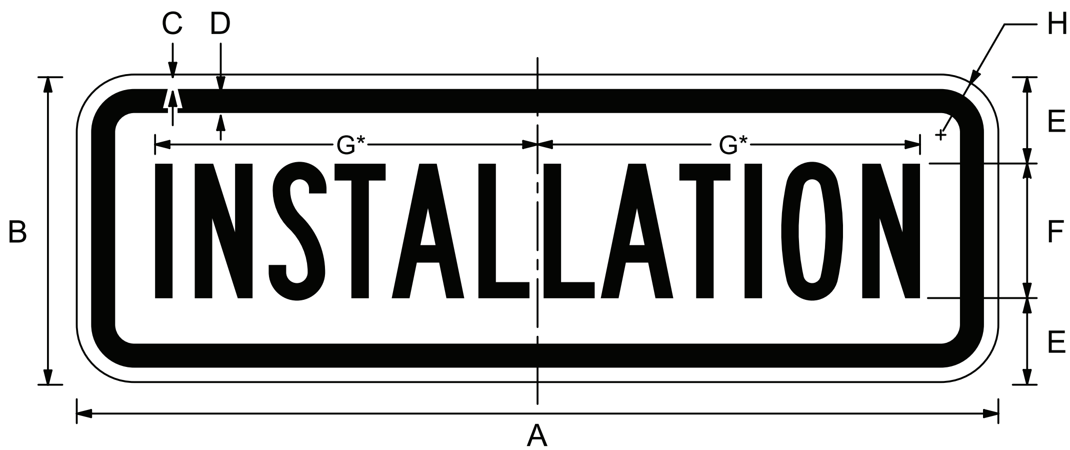


	A	B	C	D	E	F	G	H	J
C	24	12	.38	.62	3.5	5E	9.38	9.68	1.5
	36	15	.62	.88	3.5	8E	15.01	15.49	1.5

COLORS:
BORDER & LEGEND—BLACK
BACKGROUND—WHITE (RETROREFLECTIVE)

R2-5iP-TEA
INSTALLATION PLAQUE

The INSTALLATION (R2-5iP-TEA) plaque may be used above a Speed Limit (R2-1) sign at the entrance to a military installation when the boundary speed limit signing concept is used. If appropriate, use the BASE (R2-5hP-TEA) plaque in lieu of this sign due to the shorter message.



	A	B	C	D	E	F	G	H
C	24	8	.38	.62	2.25	3.5B	9.96*	1.5
	36	12	.62	.88	3.5	5B	14.3	1.5

*Reduced spacing 25%

COLORS:
BORDER & LEGEND—BLACK
BACKGROUND—WHITE (RETROREFLECTIVE)

R5-11g-TEA

GOVERNMENT VEHICLES ONLY

The GOVERNMENT VEHICLES ONLY (R5-11g-TEA) sign may be used at entrances to driveways and roadways that are only open to government vehicles as opposed to all vehicles on the installation. If the restriction starts at a location other than the beginning of the road or driveway, the preferred mounting for the R5-11g-TEA sign is on a Type III barricade that is placed close to the traveled way for added emphasis.

A	B	C	D	E	F	G	H	J	K	L	M	N
30	24	.5	.75	3.5	4C	2.5	12.70	12.94	10.32	5.44	5.68	1.5

* Reduced spacing 50%

COLORS:

BORDER & LEGEND –BLACK

BACKGROUND—WHITE (RETROREFLECTIVE)

R5-11h-TEA

NO TACTICAL VEHICLES

The NO TACTICAL VEHICLES (R5-11h-TEA) sign may be used at locations where tactical vehicles are excluded from regular use on the roadway.

A	B	C	D	E	F	G	H	K	L	M
30	24	.5	.75	3.5	4C	2.5	4.70	11	10.32	1.5

* Reduced spacing 50%

COLORS:

BORDER & LEGEND –BLACK

BACKGROUND—WHITE (RETROREFLECTIVE)

R5-29P-TEA

SEVERE TIRE DAMAGE

The SEVERE TIRE DAMAGE (R5-29P-TEA) sign may be used in the wrong-way direction of a one-way roadway that has a set of tire treadles. When used, the R5-29P-TEA sign should be mounted below a DO NOT ENTER (R5-1) sign that is installed adjacent to or in advance of the tire treadle.

A	B	C	D	E	F	G	H	J	K	L	M
30	24	.75	3.5	4E	2.5	11.34	6.30	6.18	12.29	12.53	1.5

COLORS:

BORDER & LEGEND—WHITE (RETROREFLECTIVE)
BACKGROUND—RED (RETROREFLECTIVE)

R5-29Q-TEA

DO NOT BACK UP—ONE-WAY TIRE SPIKE

The DO NOT BACK UP—ONE-WAY TIRE SPIKE (R5-29Q-TEA) sign may be used adjacent to a tire treadle to instruct drivers not to back up.

A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S
30	.5	.75	2.7	5D	2.5	1.85	.75	3C	1.65	10.08	10.48	12.18	10	7.11	12.06	1.88

COLORS:

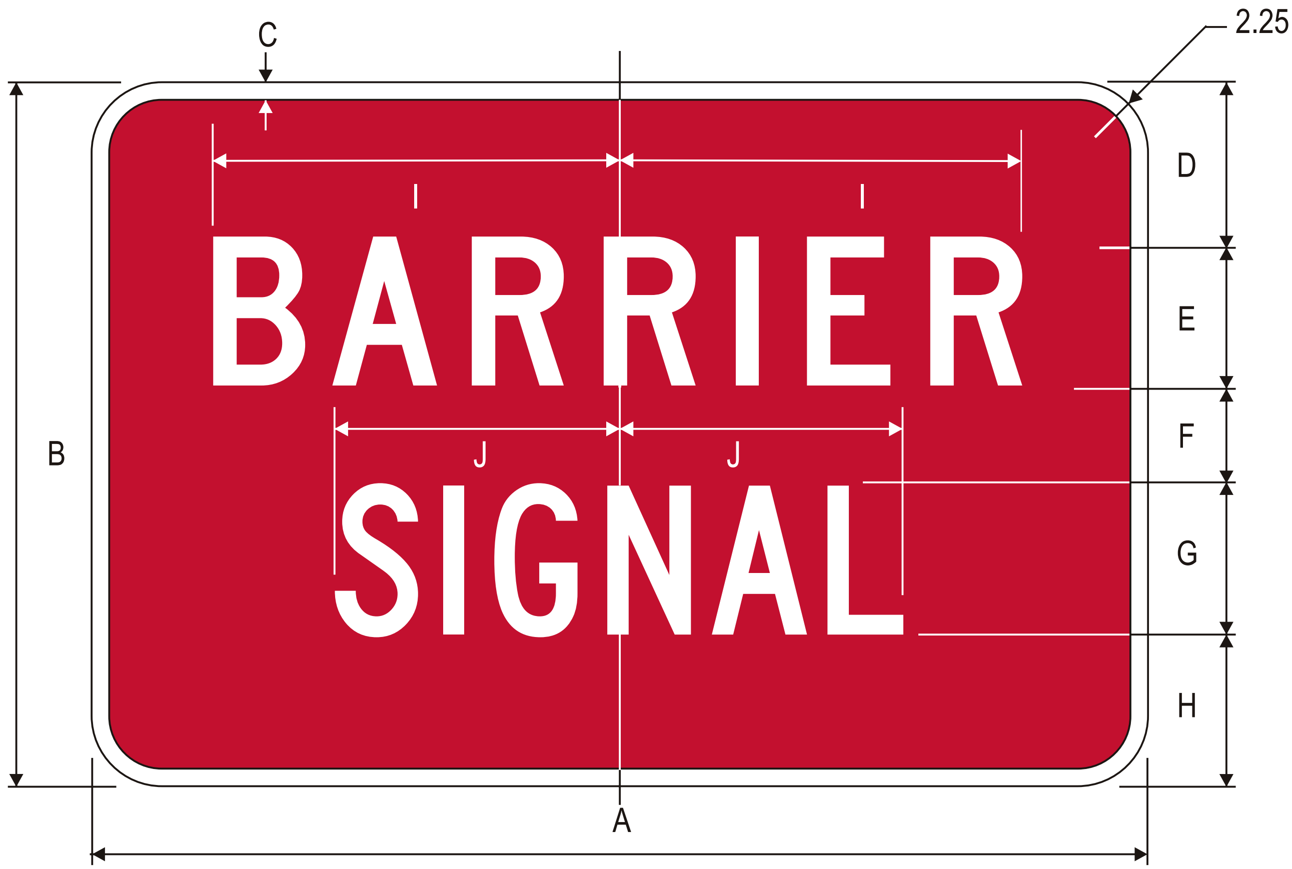
BORDER & LEGEND—BLACK

BACKGROUND—WHITE (RETROREFLECTIVE)

R10-13a-TEA

BARRIER SIGNAL

The BARRIER SIGNAL shall be used in conjunction with an active vehicle barrier signal. The sign shall be mounted overhead in between two signal heads. See SDDCTEA Pamphlet 55-15 for more information.



A	B	C	D	E	F	G	H	I	J
36	24	0.75	5.625	4.75C	3.25	4.75C	5.625	15.471	9.126

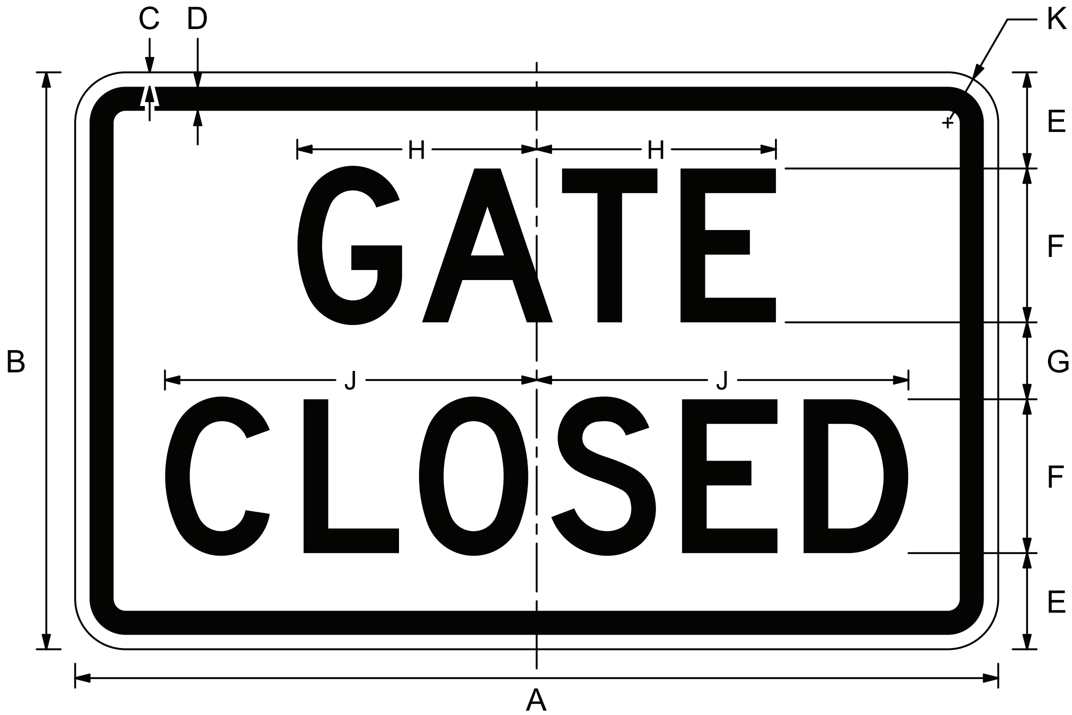
COLORS:

BORDER & LEGEND—WHITE (RETROREFLECTIVE)
BACKGROUND—RED (RETROREFLECTIVE)

R11-2g-TEA

GATE CLOSED

The GATE CLOSED (R11-2g-TEA) sign may be attached to a gate when the gate is not on a normally-used through road. When used, the R11-2g-TEA sign should be mounted at a height of 5 feet above the roadway with three horizontal barricade rails below the sign, each of which shall have vertical stripes alternately red and white at 16-inch centers when measured horizontally.



A	B	C	D	E	F	G	H	J	K
48	30	.75	1.25	5	8D	4	12.45	19.33	1.88

COLORS:
BORDER & LEGEND—BLACK
BACKGROUND—WHITE (RETROREFLECTIVE)

R11-4a-TEA
NO THRU TRAFFIC

The NO THRU TRAFFIC (R11-4a-TEA) sign may be used at the beginning of a road that goes through a congested or residential area when the road could frequently be used as a shortcut by motorists when the military installation has determined that safety can be enhanced by issuing an appropriate regulation. When used, it should be posted immediately after the intersection at the beginning of the applicable road.

A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
24	30	.38	.62	3.5	7D	3	5D	5C	5.64	8.28	7.83	10.22	9.92	1.5

*Reduced spacing 30%

COLORS:
BORDER & LEGEND—BLACK
BACKGROUND—WHITE (RETROREFLECTIVE)

R11-4b-TEA

ROAD CLOSED FOR PT

The ROAD CLOSED FOR PT (R11-4b-TEA) sign may be used to prohibit vehicular traffic during hours of physical training when the activity requires the prohibition of traffic for safety reasons. When used, the R11-4b-TEA sign should be placed at the ends of the restriction where vehicles can turn to avoid the area.

A	B	C	D	E	F	G	H	J	K	L	M	N	P
36	48	.62	.88	4.86	6D	3.35	.88	10.06	14.5	13.42	12	Var	2.25

COLORS:

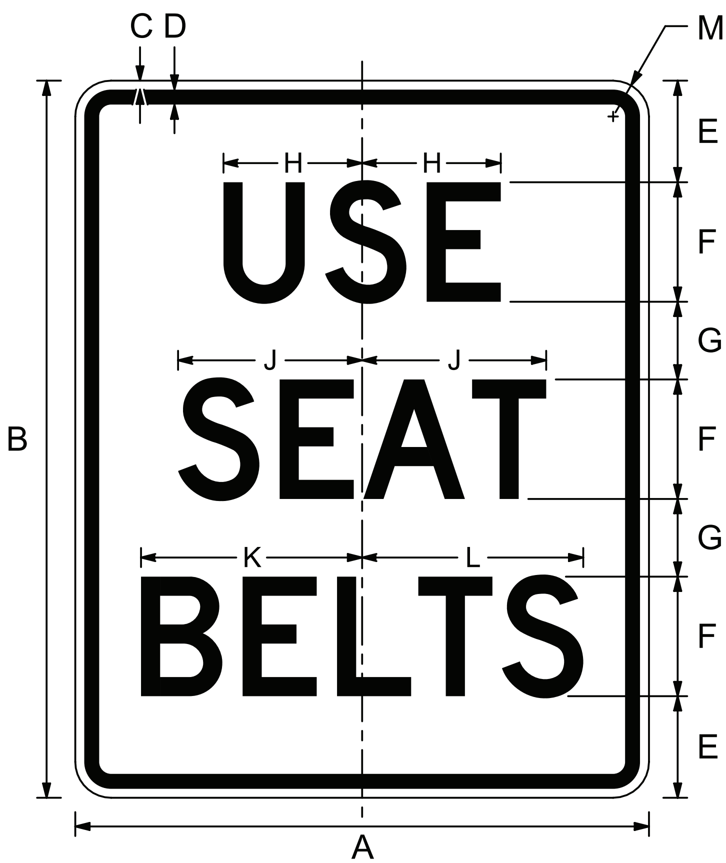
BORDER & LEGEND—BLACK

BACKGROUND—WHITE (RETROREFLECTIVE)

R16-1b-TEA

USE SEAT BELTS

The USE SEAT BELTS (R16-1b-TEA) sign may be used to remind drivers that they must wear their seat belts. This is especially applicable after an entry control facility (ECF) where occupants sometimes remove their seat belt to produce personal identification.



A	B	C	D	E	F	G	H	J	K	L	M
24	30	.38	.62	4.25	5D	3.25	5.8	7.7	9.08	9.43	1.5

COLORS:

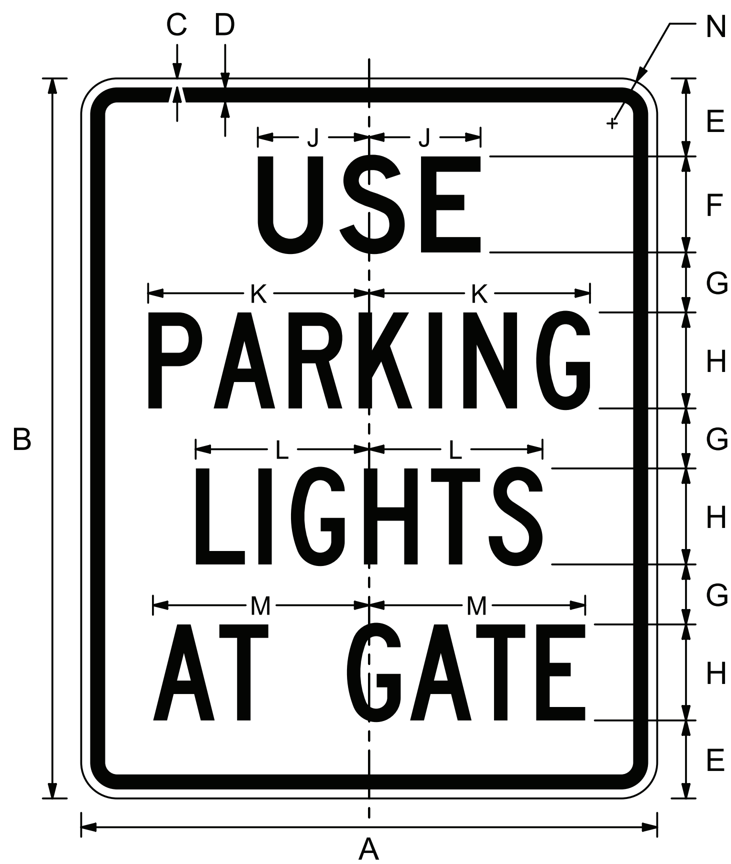
BORDER & LEGEND –BLACK

BACKGROUND—WHITE (RETROREFLECTIVE)

R16-5a-TEA

USE PARKING LIGHTS AT GATE

The USE PARKING LIGHTS AT GATE (R16-5a-TEA) sign may be used on the approach to an entry control facility (ECF) when headlights are known to create difficulties for ID checkers. When used, the sign shall be installed about 500 feet from the ECF providing overhead street lighting is provided.



A	B	C	D	E	F	G	H	J	K	L	M	N
24	30	.38	.62	3.25	4D	2.5	4C	4.64	9.2	7.22	9.00	1.5

COLORS:

BORDER & LEGEND—BLACK
BACKGROUND—WHITE (RETROREFLECTIVE)

R22-1-TEA

NO CELL PHONE WHEN DRIVING

The NO CELL PHONE WHEN DRIVING (R22-1-TEA) sign may be used on a military installation if the officials determine that drivers are prohibited from using cell phones on military roads. When authorized, the sign may be mounted either inside or outside of each gate, with normal spacing intervals between other traffic signs.

If there is also a ban on all radio transmissions; e.g., due to the presence of explosives, use either the TURN OFF 2-WAY RADIO AND CELL PHONE (R22-2-TEA) sign or the NO RADIO TRANSMISSIONS (R22-3-TEA) sign in lieu of this sign.

A	B	C	D	E	F	G	H	J	K	L	M	N
36	.62	.88	4	6E	2.5	6D	2.5E	7.14	9.24	12.61	13.14	2.25

COLORS:

BORDER & LEGEND—BLACK
BACKGROUND—WHITE (RETROREFLECTIVE)

R22-2-TEA

TURN OFF 2-WAY RADIO AND CELL PHONE

The TURN OFF 2-WAY RADIO AND CELL PHONE (R22-2-TEA) sign may be used on a military installation if the officials determine that drivers should be prohibited from using two-way radios and cell phones due to the presence of sensitive materials. When used, the sign should be installed about 1,000 feet before the sensitive area.

A	B	C	D	E	F	G	H	J	K	L	M	N	P
42	36	.75	1.25	5	7C	4	4C	1.5	18.71	13.91	4.24	13.49	3

COLORS:

BORDER & LEGEND—BLACK

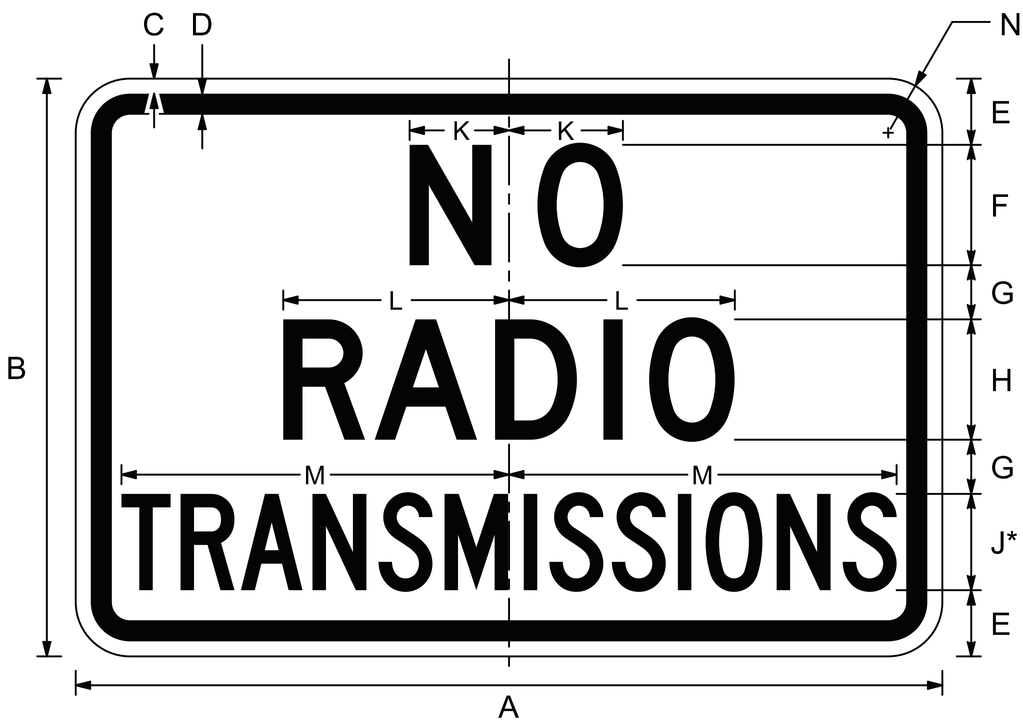
BACKGROUND—WHITE (RETROREFLECTIVE)

R22-3-TEA

NO RADIO TRANSMISSIONS

The NO RADIO TRANSMISSIONS (R22-3-TEA) sign may be used when radio transmissions would create unnecessary hazards because of the presence of things such as explosives or sensitive electronics. The restriction is designed to prohibit the use of two-way radios, walkie-talkies, and cell phones.

When the R22-3-TEA sign is used, the RADIO TRANSMISSIONS PERMITTED (R22-4-TEA) sign should also be used as appropriate.



A	B	C	D	E	F	G	H	J	K	L	M	N
36	24	.88	.62	2.75	5E	2.25	5D	4C	4.70	9.38	15.17	1.5

*Reduced spacing 50%

NOTE: The first line is now E Series and the last line has 50% reduction in spacing

COLORS:

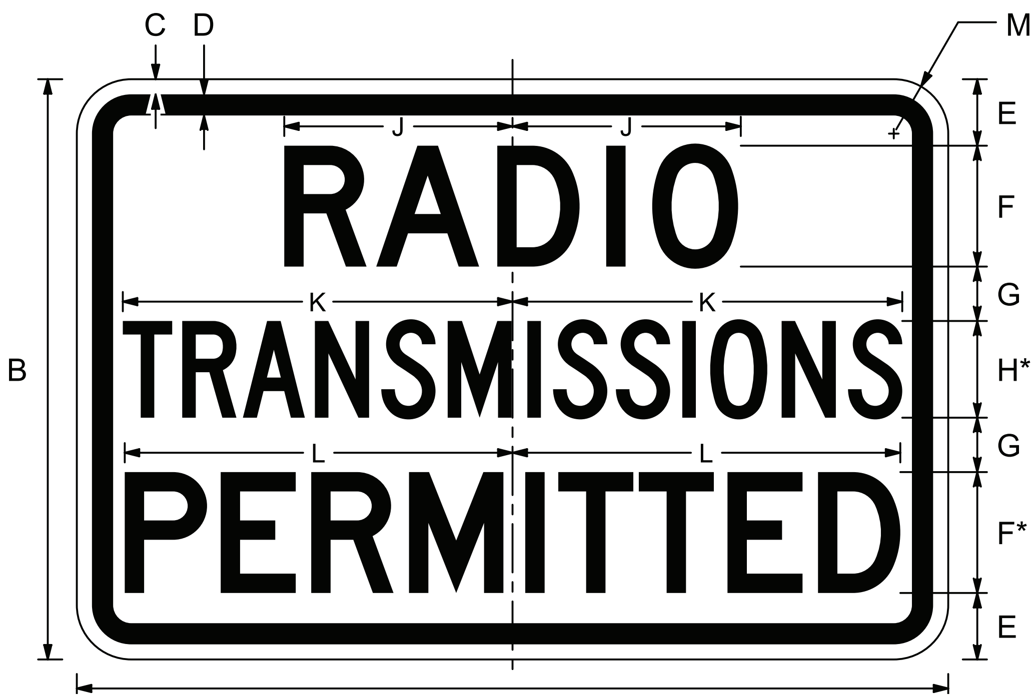
BORDER & LEGEND—BLACK

BACKGROUND—WHITE (RETROREFLECTIVE)

R22-4-TEA

RADIO TRANSMISSIONS PERMITTED

The RADIO TRANSMISSIONS PERMITTED (R22-4-TEA) sign may be used in conjunction with restrictions posted with the TURN OFF 2-WAY RADIO AND CELL PHONE (R22-2-TEA) sign or the NO RADIO TRANSMISSIONS (R22-3-TEA) sign to identify those locations where it is again safe to make radio transmissions.



A	B	C	D	E	F	G	H	J	K	L	M
36	24	.62	.88	2.75	5D	2.25	4C	9.38	15.17	15.23	1.5

*Reduced spacing 50%

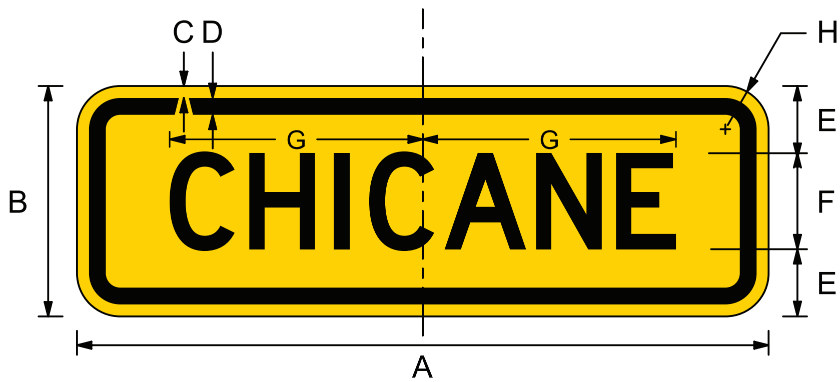
COLORS:

BORDER & LEGEND—BLACK

BACKGROUND—WHITE (RETROREFLECTIVE)

W1-5P-TEA
CHICANE

The Chicane Plaque (W1-5P-TEA) may be used below a Winding Road (W1-5) sign to warn of a chicane sometimes encountered at ECFs. See the Standard Highway Signs Manual for the design of the Winding Road sign.

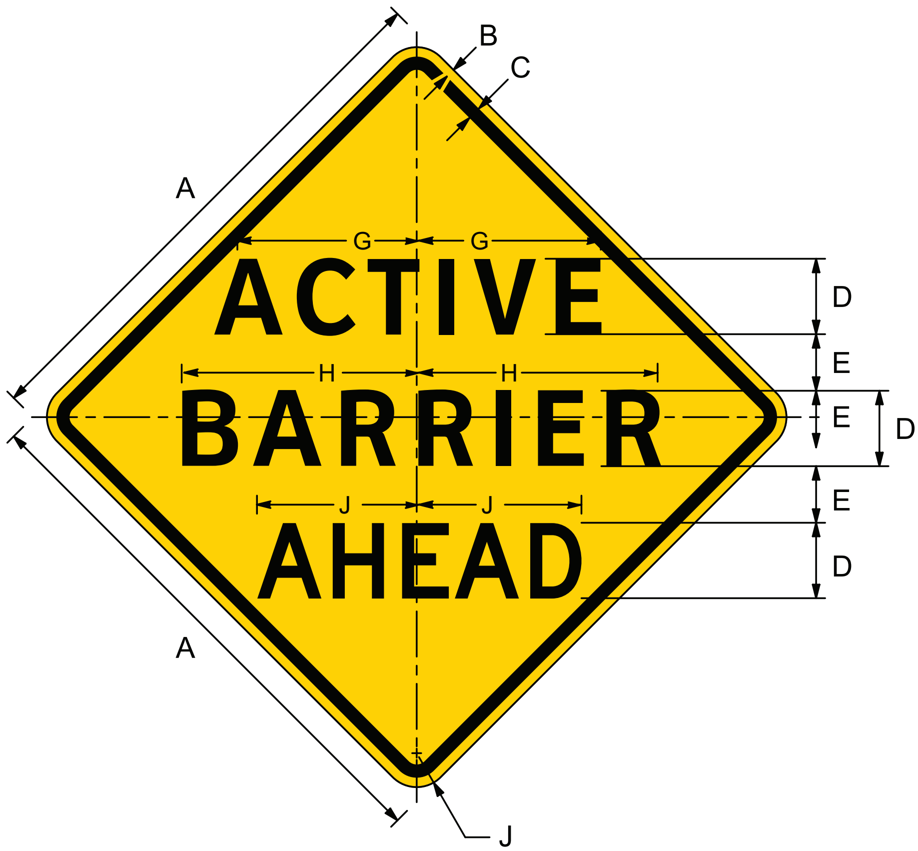


	A	B	C	D	E	F	G	H
C	24	12	.62	.88	3.5	5D	8	1.5
	30	18	.75	1.25	5.5	5D	10	1.88

COLORS:
BORDER & LEGEND—BLACK
BACKGROUND—YELLOW (RETROREFLECTIVE)

W3-3a-TEA
ACTIVE BARRIER AHEAD

The ACTIVE BARRIER AHEAD (W3-3a-TEA) sign may be used to warn drivers that they are approaching an active vehicle barrier (AVB). The W3-3a-TEA sign should normally be the first sign in a series of signs for drivers as they approach the active vehicle barrier. A Distance (W16-2P or W16-2aP) plaque may be installed below the W3-3a-TEA sign to advise drivers of the distance to the AVB.



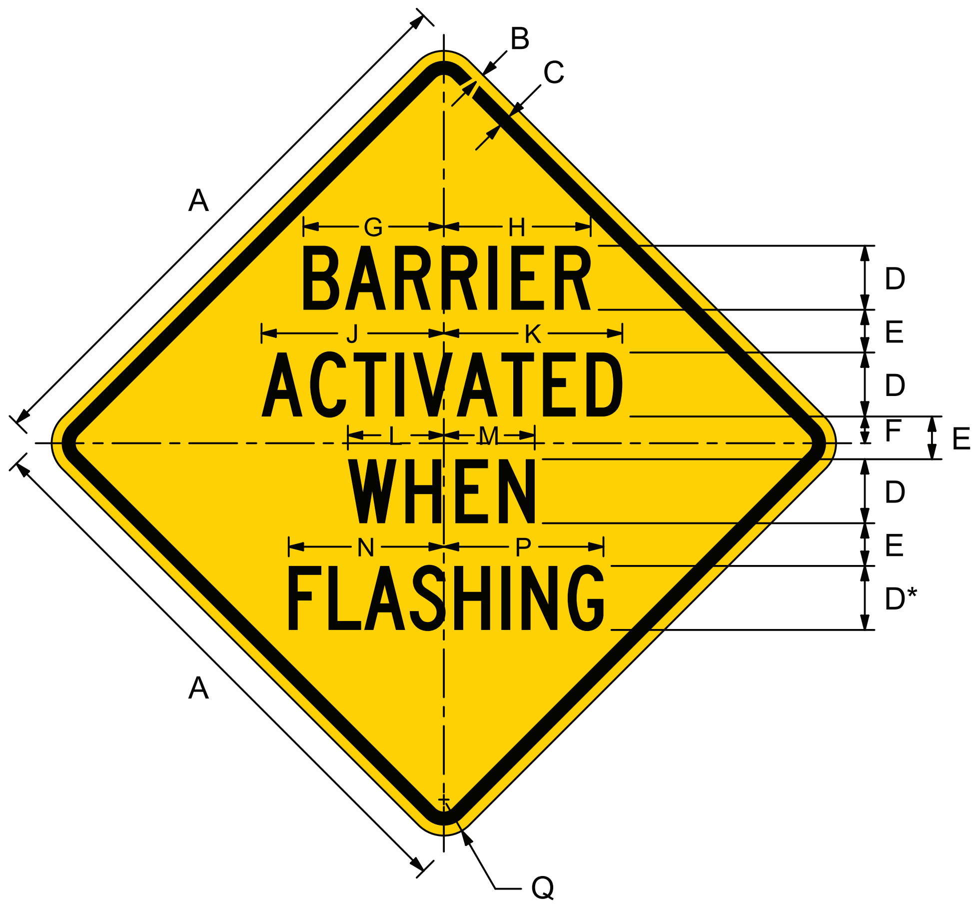
	A	B	C	D	E	F	G	H	J	K
C	36	.62	.88	4C	3.00	1.25	7.4	9.2	7.05	2.25
	48	.82	1.15	4C	4.00	1.65	9.85	12.2	9.35	3.0

COLORS:
BORDER & LEGEND—BLACK
BACKGROUND—YELLOW (RETROREFLECTIVE)

W3-3b-TEA

BARRIER ACTIVATED WHEN FLASHING

The BARRIER ACTIVATED WHEN FLASHING (W3-3b-TEA) sign may be used to warn drivers that they are approaching an active vehicle barrier (AVB) which is activated when the lights are flashing. The W3-3b-TEA sign would normally be the last sign in a series of signs for drivers as they approach the AVB, and would normally be about 100 feet in advance of the stop bar where drivers are to stop.



	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
C	36	.62	.88	4C	2.67	1.67	8.78	9.18	11.40	11.16	6.00	5.68	9.70	9.98	2.25
	48	.75	1.25	5D	3.00	2.00	13.00	13.67	17.28	16.93	8.81	8.36	14.55	14.97	3

*Reduced spacing 20%

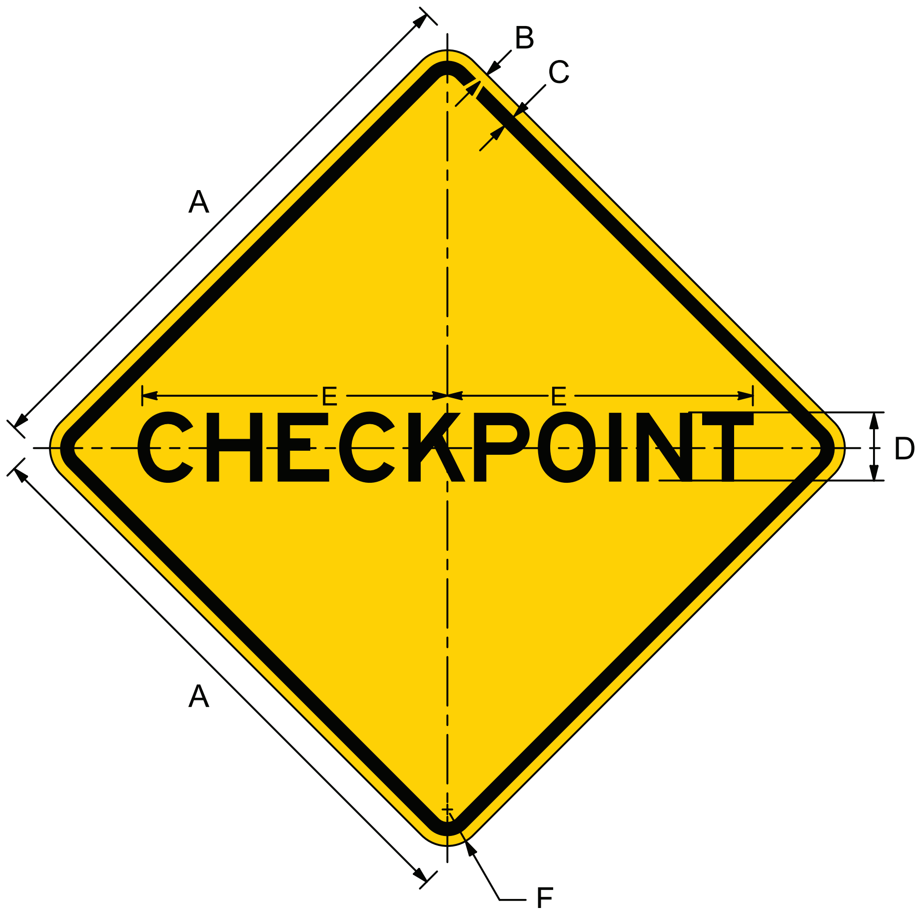
COLORS:

BORDER & LEGEND—BLACK

BACKGROUND—YELLOW (RETROREFLECTIVE)

W3-10a-TEA
CHECKPOINT

The CHECKPOINT (W3-10a-TEA) sign may be used to warn drivers that they are approaching a military checkpoint. The W3-10a-TEA sign would normally be the first sign in a series of signs for drivers as they approach the checkpoint in accordance with the signing defined in SDDCTEA's *Traffic and Safety Engineering for Better Entry Control Facilities* (Pamphlet 55-15). A Distance (W16-2P) plaque may be installed below the W3-10a-TEA sign to advise drivers of the distance to the checkpoint.



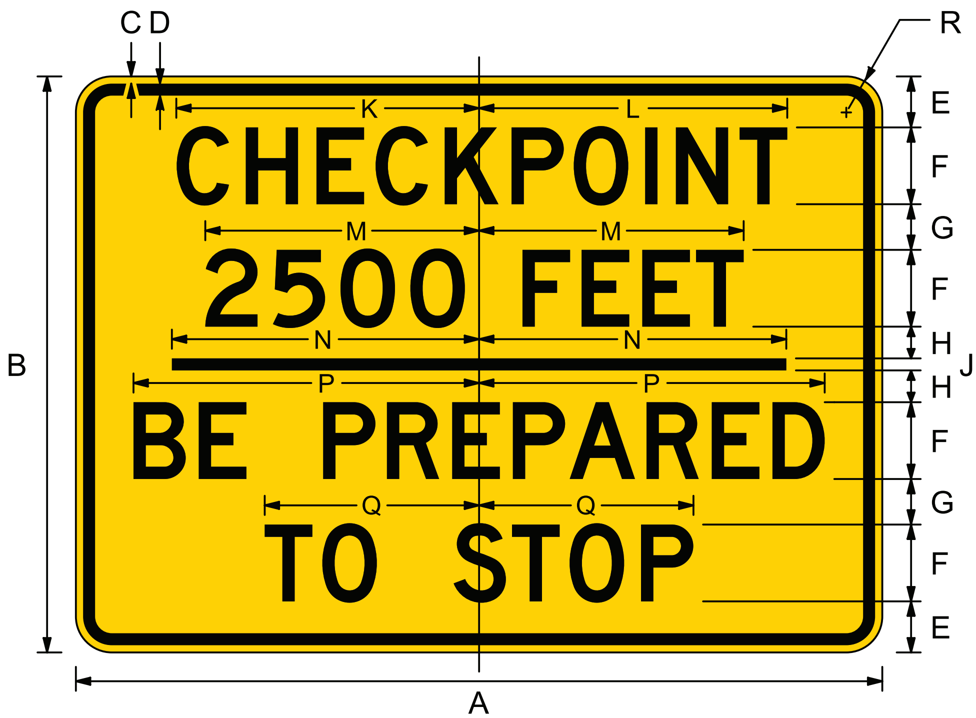
	A	B	C	D	E	F
	30	.52	.73	4C	11.2	1.85
C	36	.62	.88	4C	13.4	2.25
	48	.82	1.17	4C	17.8	3.0

COLORS:
BORDER & LEGEND—BLACK
BACKGROUND—YELLOW (RETROREFLECTIVE)

W3-10b-TEA

CHECKPOINT (___) FEET—BE PREPARED TO STOP

The CHECKPOINT (___) FEET—BE PREPARED TO STOP (W3-10b-TEA) sign may be used to warn drivers that they are approaching a military checkpoint. The W3-10b-TEA sign is intended for use only on high-speed multi-lane approach roadways when the smaller CHECK POINT (W3-10a-TEA) sign is considered to be too small. This sign would normally be the first sign in a series of signs for drivers as they approach the checkpoint in accordance with the signing defined in SDDCTEA's Traffic and Safety Engineering for Better Entry Control Facilities (Pamphlet 55-15).



A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R
84	60	.75	1.25	5.31	8D	4.75	3.31	1.25	31.54	32.10	Var.	32	35.52	22.33	3.75

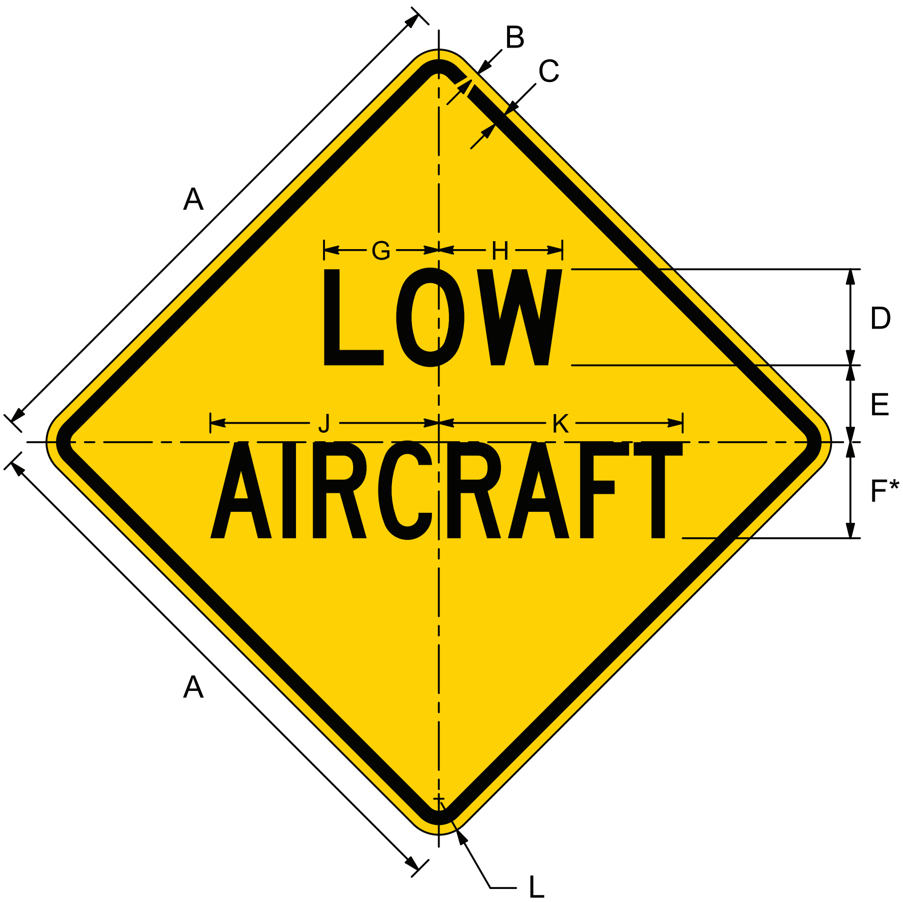
COLORS:

BORDER & LEGEND—BLACK

BACKGROUND—YELLOW (RETROREFLECTIVE)

W11-26-TEA
LOW AIRCRAFT

The LOW AIRCRAFT (W11-26-TEA) sign may be used to warn drivers that there may be low-flying aircraft, so that no one is surprised due to the sudden noise or appearance of the aircraft.



	A	B	C	D	E	F	G	H	J	K	L
	24	.4	.6	5C	3.2	5C	4.78	5.14	9.50	10.15	1.5
C	30	.5	.75	5C	4	5C	5.98	6.43	11.90	12.70	1.88
C	36	.6	.9	5C	4.8	5C	7.18	7.71	14.30	15.25	2.25

*Reduced spacing 20%

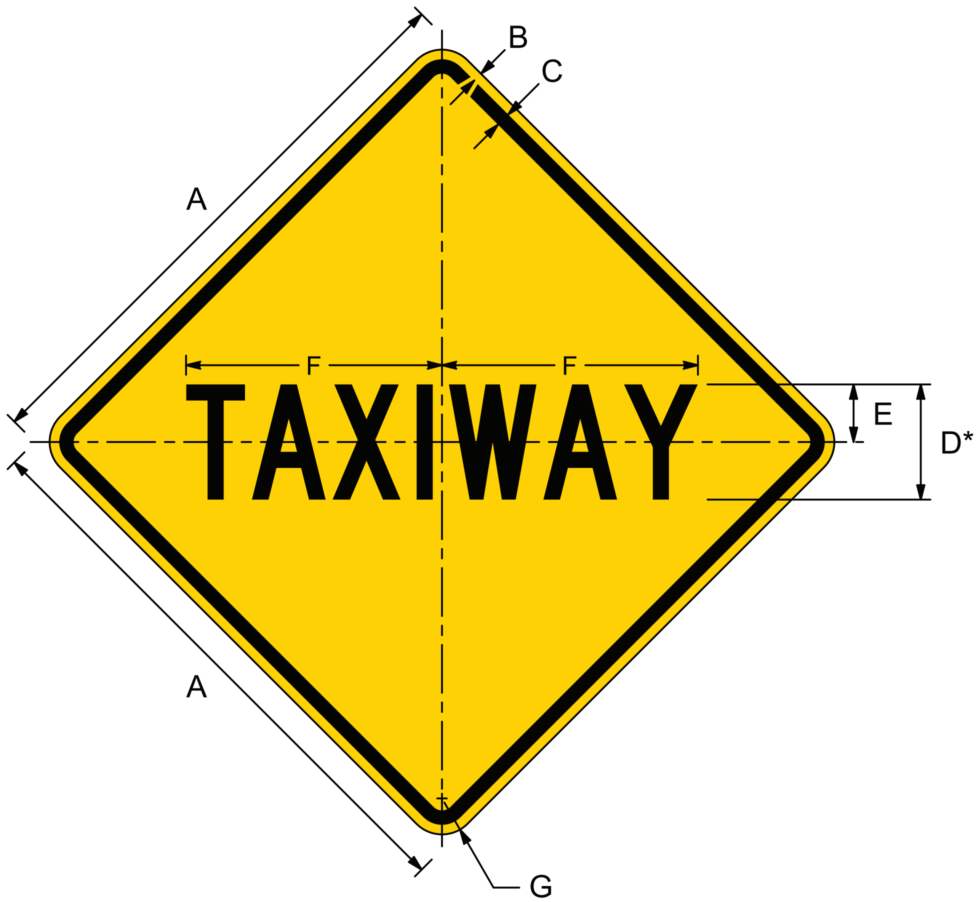
COLORS:

BORDER & LEGEND—BLACK
BACKGROUND—YELLOW (RETROREFLECTIVE)

W11-27-TEA

TAXIWAY

The TAXIWAY (W11-27-TEA) sign may be used to warn drivers that there may be aircraft crossing or running along side of the road.



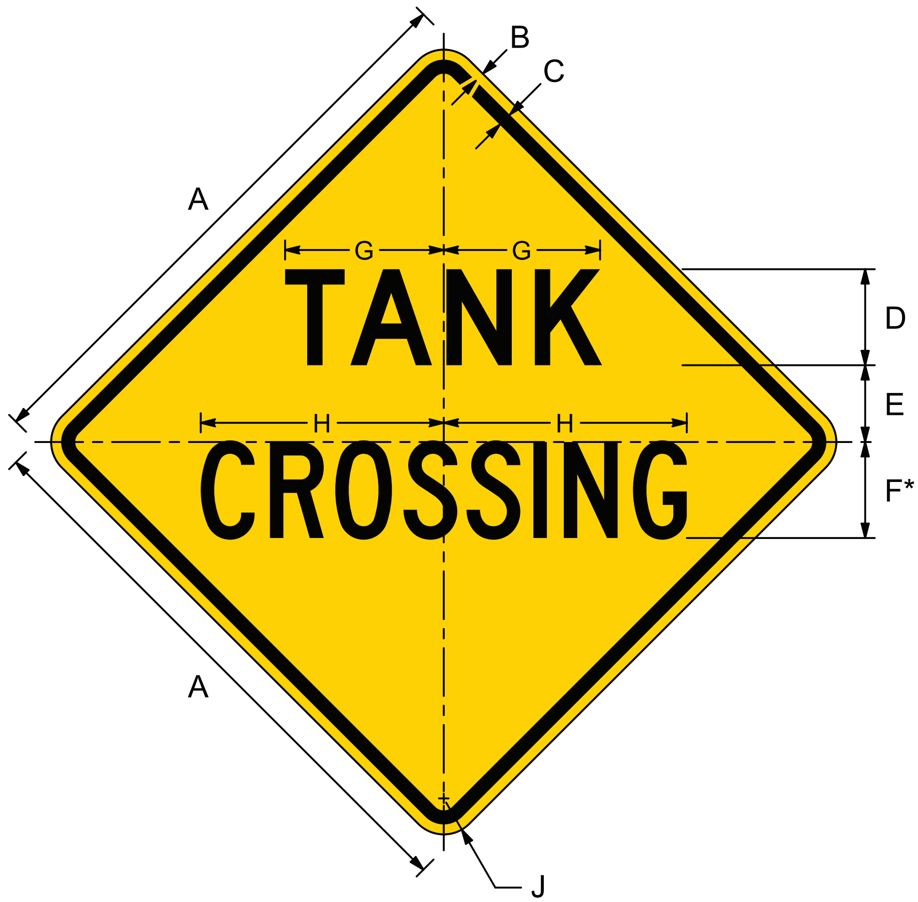
	A	B	C	D	E	F	G
	24	.4	.6	6C	2.4	10.66	1.5
C	30	.5	.75	6C	3	13.33	1.88
C	36	.6	.9	6C	3.6	16	2.25

*Reduced spacing 40%

COLORS:
BORDER & LEGEND—BLACK
BACKGROUND—YELLOW (RETROREFLECTIVE)

W11-28-TEA
TANK CROSSING

The TANK CROSSING (W11-28-TEA) sign may be used to warn drivers that there may be military tanks crossing the road, so that no one is surprised due to the sudden noise or appearance of a tank.



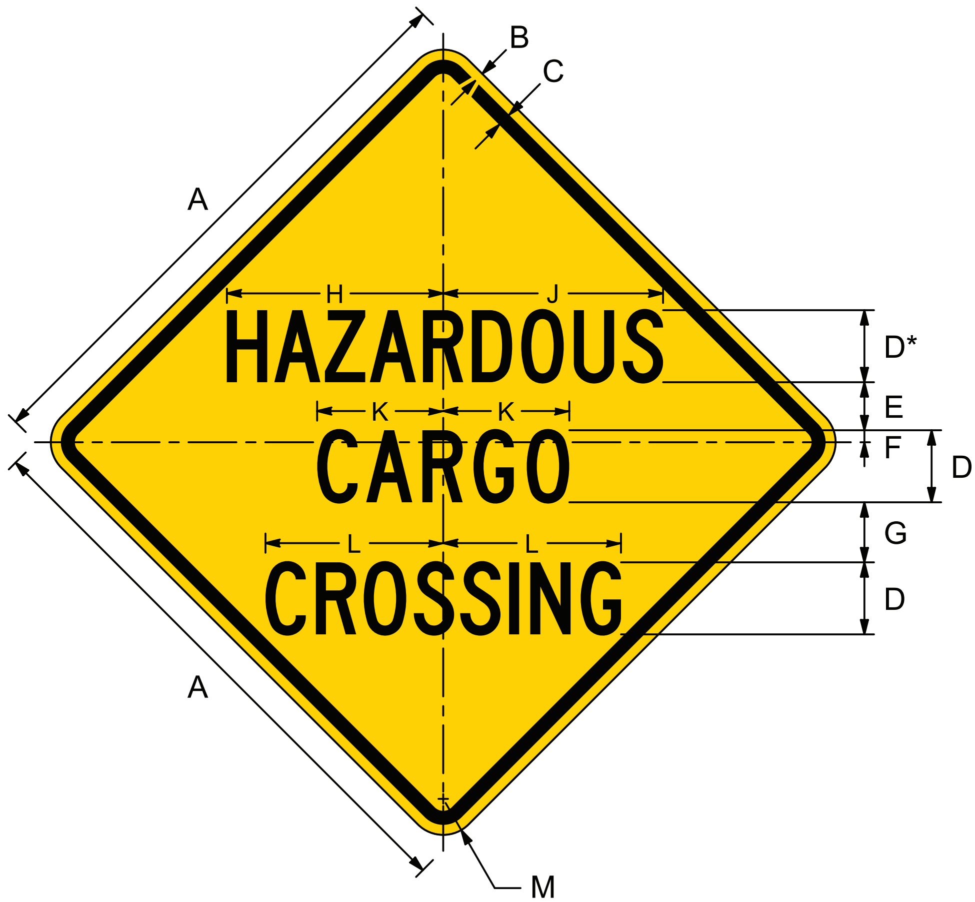
	A	B	C	D	E	F	G	H	J
	24	.4	.6	5D	3.2	5C	6.6	10.12	1.5
C	30	.5	.75	5D	4	5C	8.26	12.65	1.88
C	36	.6	.9	5D	4.8	5C	9.91	15.15	2.25

*Reduced spacing 20%

COLORS:
BORDER & LEGEND—BLACK
BACKGROUND—YELLOW (RETROREFLECTIVE)

W11-29-TEA
HAZARDOUS CARGO CROSSING

The HAZARDOUS CARGO CROSSING (W11-29-TEA) sign may be used to warn drivers that there may be trucks crossing the road with hazardous cargo. The larger size sign should be used on multi-lane roadways.



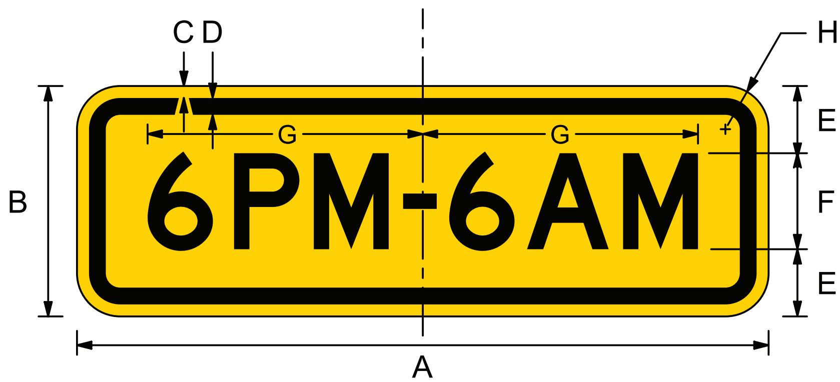
	A	B	C	D	E	F	G	H	J	K	L	M
	24	.41	.59	4.5C	2	.5	2.5	9	9.15	5.25	7.4	1.5
C	30	.52	.73	4.5C	2.5	.62	3.12	11.26	11.44	6.54	9.25	1.87
C	36	.62	.88	4.5C	3	.75	3.75	13.52	13.74	7.88	11.11	2.25

*Reduced spacing 30%

COLORS:
BORDER & LEGEND—BLACK
BACKGROUND—YELLOW (RETROREFLECTIVE)

W16-20P-TEA
APPLICABLE HOURS

The Applicable Hours (W16-20P-TEA) plaque may be used below any warning sign to identify the effective hours of the message.



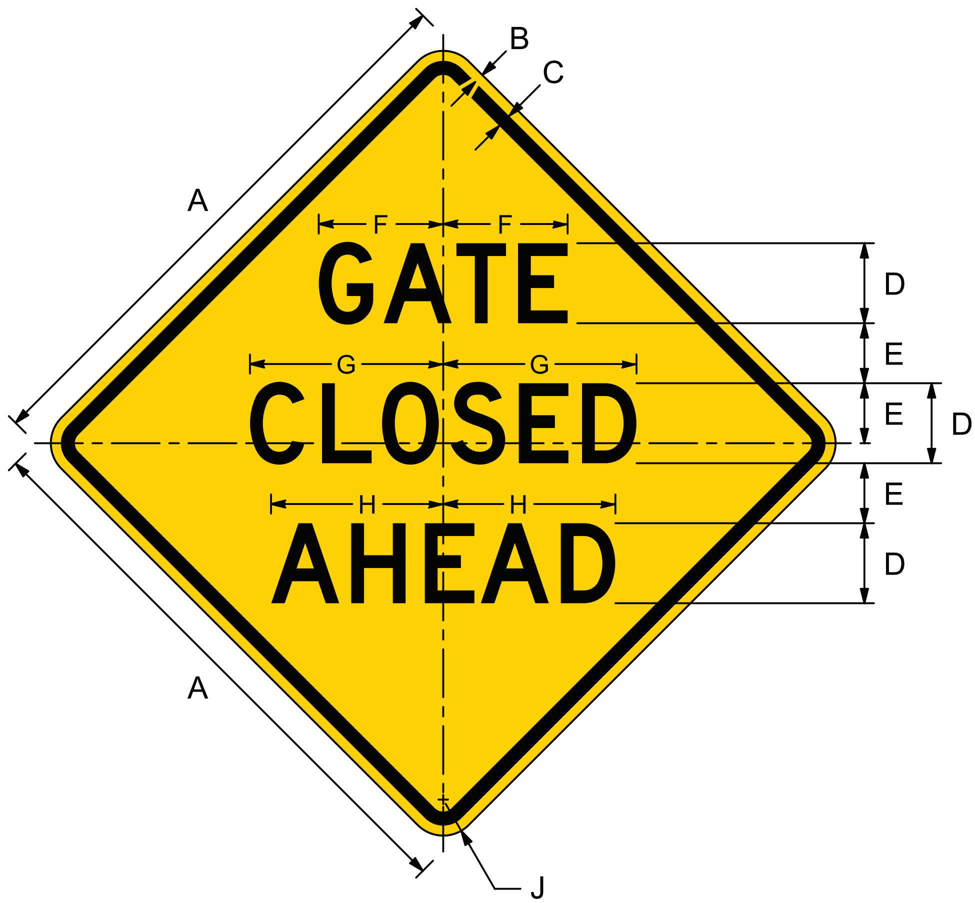
	A	B	C	D	E	F	G	H
C	36	12	.62	.88	3.5	5D	Var.	1.5
	48	18	.75	1.25	5.5	7D	Var.	1.88

COLORS:
BORDER & LEGEND—BLACK
BACKGROUND—YELLOW (RETROREFLECTIVE)

W20-3g-TEA

GATE CLOSED AHEAD

The GATE CLOSED AHEAD (W20-3g-TEA) sign may be used to warn drivers that a gate may be closed ahead. If the gate closure is a regular scheduled event, the times when the gate is closed should be included, either in place of the word AHEAD or on a SCHEDULED TIME (W20-3gP-TEA) plaque beneath the W20-3g-TEA sign. The larger size sign should be used on multi-lane roadways.



	A	B	C	D	E	F	G	H	J
	30	.51	.73	5E	3.12	6.48	10.06	8.96	1.87
C	36	.62	.88	5E	3.75	7.78	12.08	10.76	2.25
	48	.75	1.25	5E	4.75	10.89	16.92	15.06	3

COLORS:

BORDER & LEGEND—BLACK

BACKGROUND—YELLOW (RETROREFLECTIVE)

APPENDIX B—SAMPLE SIGN LAYOUTS

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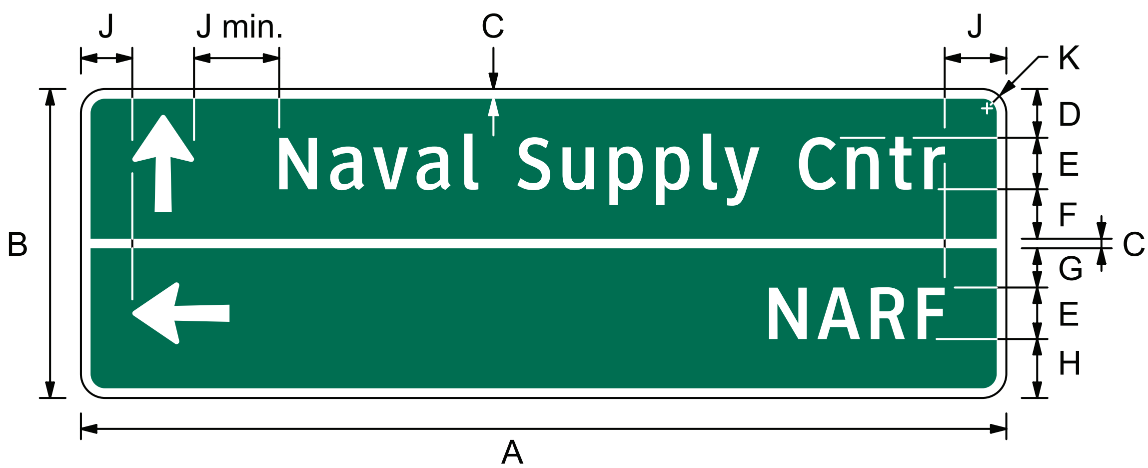
TWO-LINE DESTINATION

The Two-Line Destination sign may be used within a military installation to provide directions to two major traffic generators.

On conventional highways, the standard legend is 6 inches in height, except 4-inch legend may be used on roads with a speed limit less than 30 mph.



	A	B	C	D	E	F	G	H	J	K
	Var*	24	.75	3.79	4" 3W	3.84	3.04	4.58	4	1.88
C	Var*	30	1	4.15	6" 3W	4.35	3.15	5.35	6	1.88

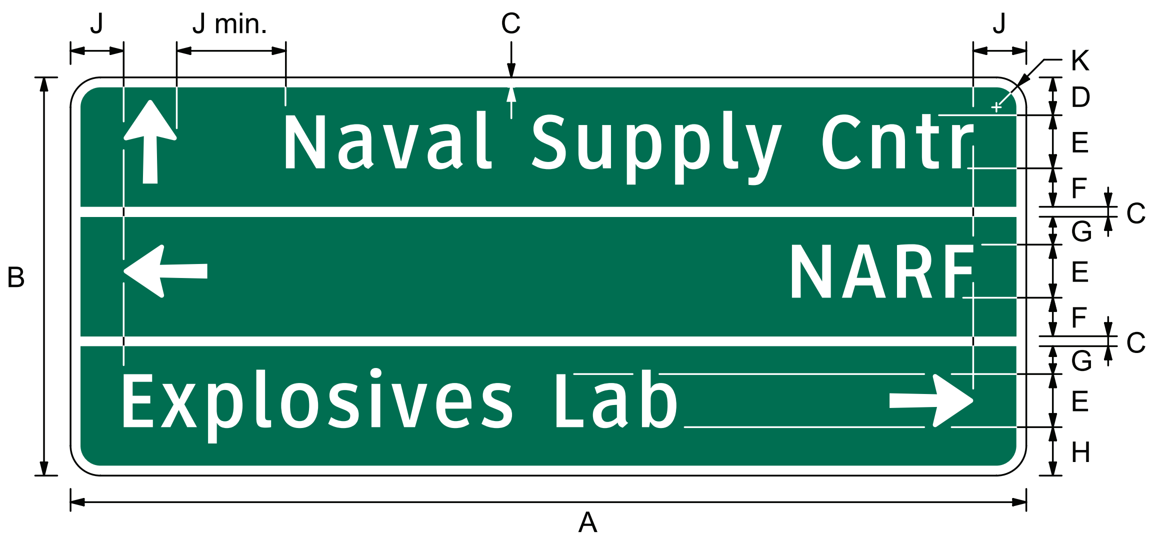
*Based on the length of the message, but rounded upward to a multiple of 6 inches

COLORS:
BORDER & LEGEND—WHITE (RETROREFLECTIVE)
BACKGROUND—GREEN (RETROREFLECTIVE)

THREE-LINE DESTINATION

The Three-Line Destination sign may be used within a military installation to provide directions to three major traffic generators.

On conventional highways, the standard legend is 6 inches in height, except 4-inch legend may be used on roads with a speed limit less than 30 mph.



	A	B	C	D	E	F	G	H	J	K
	Var*	30	.75	2.85	4" 3W	2.9	2.1	3.65	4	2.25
C	Var*	42	1	3.74	6" 3W	3.93	2.73	4.94	6	3

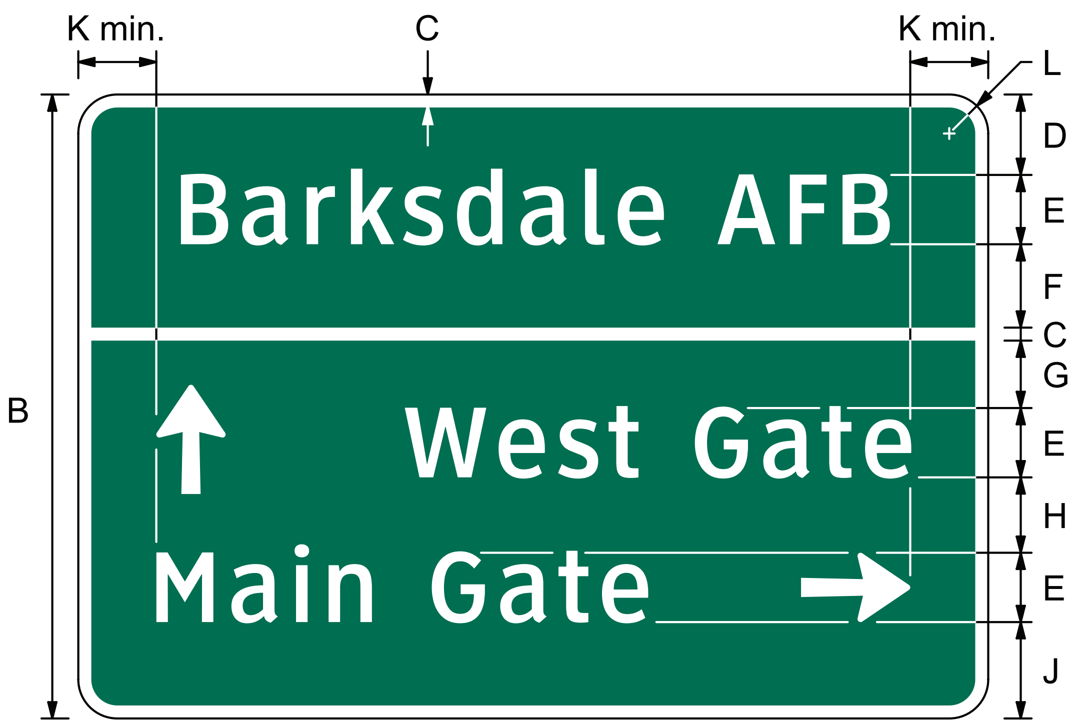
*Based on the length of the message, but rounded upward to a multiple of 6 inches

COLORS:
BORDER & LEGEND—WHITE (RETROREFLECTIVE)
BACKGROUND—GREEN (RETROREFLECTIVE)

INSTALLATION APPROACH WITH TWO GATES

The Installation Approach with Two Gates sign may be used on the approach to a military installation when directions are provided for two gates.

On conventional highways, the standard legend is 6 inches in height, except 4-inch legend may be used on roads with a speed limit less than 30 mph. Larger and bolder legends should be used on expressways and freeways.



	A	B	C	D	E	F	G	H	J	K	L
	Var*	36	.75	4.64	4" 3W	4.81	3.89	4.35	5.56	4	2.25
C	Var*	48	1	5.7	6" 3W	6.1	4.7	5.4	7.1	6	3

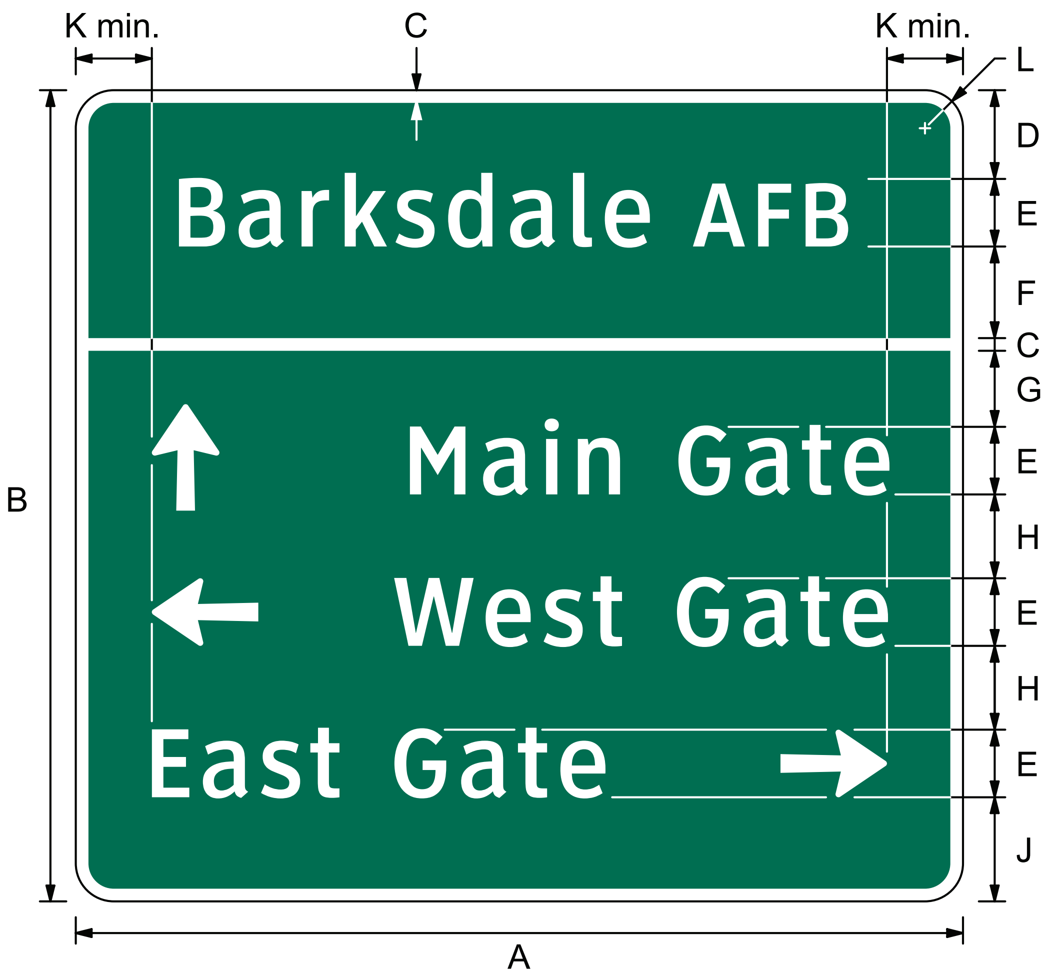
*Based on the length of the message, but rounded upward to a multiple of 6 inches

COLORS:
BORDER & LEGEND—WHITE (RETROREFLECTIVE)
BACKGROUND—GREEN (RETROREFLECTIVE)

INSTALLATION APPROACH WITH THREE GATES

The Installation Approach with Three Gates sign may be used on the approach to a military installation when directions are provided for three gates.

On conventional highways, the standard legend is 6 inches in height, except 4-inch legend may be used on roads with a speed limit less than 30 mph. Larger and bolder legends should be used on expressways and freeways.



	A	B	C	D	E	F	G	H	J	K	L
	Var*	48	.75	5.25	4" 3W	5.42	4.5	4.96	6.16	4	2.25
C	Var*	60	1	5.8	6" 3W	6.2	4.8	5.5	7.2	6	3

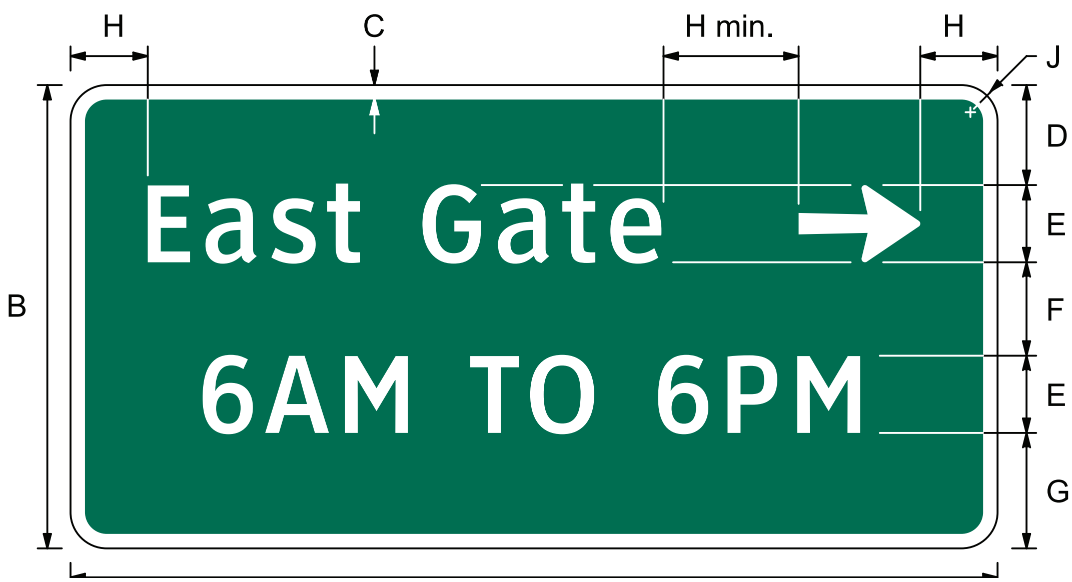
*Based on the length of the message, but rounded upward to a multiple of 6 inches

COLORS:
BORDER & LEGEND—WHITE (RETROREFLECTIVE)
BACKGROUND—GREEN (RETROREFLECTIVE)

GATE DESTINATION WITH HOURS OF OPERATION

The Gate Destination with Hours of Operation sign may be used on the approach to a military installation to provide both directions to and hours of operation of a major traffic generator.

On conventional highways, the standard legend is 6 inches in height, except 4-inch legend may be used on roads with a speed limit less than 30 mph.



	A	B	C	D	E	F	G	H	J
	Var*	24	.75	5.18	4" 3W	4.84	5.98	4	1.88
C	Var*	30	1	5.73	6" 3W	5.34	6.93	6	1.88

*Based on the length of the message, but rounded upward to a multiple of 6 inches

COLORS:
BORDER & LEGEND—WHITE (RETROREFLECTIVE)
BACKGROUND—GREEN (RETROREFLECTIVE)

SINGLE-LINE STREET NAME

The Street Name sign may be used to identify street or road names to assist unfamiliar motorists find their destination. Except for very short names, the common abbreviations Rd, St, Ave, Blvd, etc., should generally not be used unless not using them would create confusion with a nearby street name or destination.

On conventional highways, the standard legend is 6 inches in height, except: 8-inch legend should be used on multi-lane roads with a speed limit over 40 mph; 12-inch legend should be used on overhead signs; and 4-inch legend may be used on roads with a speed limit less than 30 mph. To reduce the size of the signs, the border may be eliminated.

	A	B	C	D	E	F	G
	Var*	9	.5	2	4" 2W	3	1.5
C	Var*	13.5	.5	3.05	6" 2W	4.45	1.88
	Var*	18	.75	4.05	8" 2W	5.95	2.25
	Var*	24	.75	4.6	12" 2W	7.4	2.25

If <u>Not</u> Using a Border:

	A	B	C	D	E	F	G
	Var*	8	-	1.5	4" 2W	2.5	1.5
C	Var*	12	-	2.3	6" 2W	3.7	1.88
	Var*	16	-	3.05	8" 2W	4.95	2.25
	Var*	18	-	1.6	12" 2W	4.4	2.25

*Based on the length of the message, but generally rounded upward to a multiple of 3 inches

COLORS:
BORDER & LEGEND—WHITE (RETROREFLECTIVE)
BACKGROUND—GREEN (RETROREFLECTIVE)

TWO-LINE STREET NAME

The Two-Line Street Name sign may be used to identify street or road names at an intersection where the street or road name changes. Except for very short names, the common abbreviations Rd, St, Ave, Blvd, etc., should not be used unless not using the abbreviation creates confusion with a nearby street name or destination.

On conventional highways, the standard legend is 6 inches in height, except: 8-inch legend should be used on multi-lane roads with a speed limit over 40 mph; 12-inch legend should be used on overhead signs; and 4-inch legend may be used on roads with a speed limit less than 30 mph. To reduce the size of the signs, the border may be eliminated.

	A	B	C	D	E	F	G	H
	Var*	16	.5	2	4" 2W	3	3	1.88
C	Var*	24	.5	3	6" 2W	4.55	4.45	1.88
	Var*	32	.75	4.1	8" 2W	6	5.9	2.25
	Var*	44	1	4.6	12" 2W	8	7.4	2.25

If Not Using a Border:

	A	B	C	D	E	F	G	H
	Var*	15	-	1.5	4" 2W	3	2.5	1.88
C	Var*	22	-	2.5	6" 2W	3.55	3.95	1.88
	Var*	28	-	2.55	8" 2W	5	4.45	2.25
	Var*	36	-	1.6	12" 2W	6	4.4	2.25

*Based on the length of the message, but generally rounded upward to a multiple of 3 inches

COLORS:
BORDER & LEGEND—WHITE (RETROREFLECTIVE)
BACKGROUND—GREEN (RETROREFLECTIVE)

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APPENDIX C—STANDARD ALPHABETS SPACING CHARTS

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Measurements based on 4-inch uppercase letter height.

Character	Left (in.)	Width (in.)	Right (in.)
A	0.120	2.161	0.120
B	0.440	1.721	0.200
C	0.320	1.721	0.320
D	0.440	1.721	0.320
E	0.440	1.521	0.200
F	0.440	1.521	0.120
G	0.320	1.721	0.320
H	0.440	1.721	0.440
I	0.440	0.520	0.440
J	0.120	1.761	0.440
K	0.440	1.761	0.200
L	0.440	1.521	0.120
M	0.440	1.961	0.440
N	0.440	1.721	0.440
O	0.320	1.841	0.320
P	0.440	1.721	0.120
Q	0.320	1.841	0.320
R	0.440	1.721	0.200
S	0.200	1.721	0.200
T	0.120	1.521	0.120
U	0.440	1.721	0.440
V	0.120	1.881	0.120
W	0.120	2.561	0.120
X	0.200	1.881	0.200
Y	0.120	2.161	0.120
Z	0.200	1.721	0.200
a	0.120	1.481	0.280
b	0.320	1.481	0.200
c	0.200	1.481	0.080
d	0.200	1.481	0.320
e	0.200	1.481	0.120
f	0.120	0.920	0.080
g	0.200	1.441	0.240
h	0.320	1.441	0.280
i	0.320	0.520	0.320
j	0.000	0.920	0.320
k	0.320	1.601	0.080
l	0.320	0.520	0.320
m	0.320	2.361	0.280
n	0.320	1.441	0.280

Character	Left (in.)	Width (in.)	Right (in.)
o	0.200	1.481	0.200
p	0.320	1.481	0.200
q	0.200	1.481	0.320
r	0.320	1.041	0.080
s	0.120	1.280	0.080
t	0.000	1.200	0.000
u	0.280	1.441	0.320
v	0.080	1.721	0.080
w	0.080	2.241	0.080
x	0.000	1.841	0.000
y	0.080	1.841	0.080
z	0.120	1.441	0.120
1	0.200	0.840	0.440
2	0.200	1.721	0.200
3	0.120	1.721	0.200
4	0.200	1.961	0.320
5	0.320	1.721	0.200
6	0.120	1.721	0.320
7	0.200	1.721	0.320
8	0.200	1.721	0.200
9	0.320	1.721	0.200
0	0.320	1.841	0.320
&	0.200	2.962	0.120
!	0.440	0.520	0.440
“	0.440	1.561	0.440
#	0.320	2.521	0.320
$	0.200	1.721	0.200
¢	0.320	1.761	0.320
/	0.000	3.963	0.000
*	0.320	2.081	0.320
.	0.320	0.560	0.320
,	0.320	0.600	0.320
:	0.320	0.560	0.320
(	0.320	1.200	0.200
)	0.200	1.200	0.320
-	0.120	1.240	0.120
@	0.320	4.000	0.320
=	0.120	2.241	0.120
+	0.120	2.241	0.120
?	0.200	2.081	0.200

Measurements based on 4-inch uppercase letter height.

Character	Left (in.)	Width (in.)	Right (in.)
A	0.120	2.561	0.120
B	0.440	2.241	0.240
C	0.360	2.241	0.360
D	0.440	2.241	0.360
E	0.440	2.041	0.240
F	0.440	2.041	0.120
G	0.360	2.241	0.360
H	0.440	2.241	0.440
I	0.440	0.560	0.440
J	0.120	2.041	0.440
K	0.440	2.241	0.240
L	0.440	2.041	0.120
M	0.440	2.642	0.440
N	0.440	2.241	0.440
O	0.360	2.361	0.360
P	0.440	2.241	0.360
Q	0.360	2.361	0.360
R	0.440	2.241	0.240
S	0.240	2.241	0.240
T	0.120	2.041	0.120
U	0.440	2.241	0.440
V	0.120	2.481	0.120
W	0.120	3.042	0.120
X	0.120	2.361	0.120
Y	0.120	2.561	0.120
Z	0.240	2.241	0.240
a	0.160	1.921	0.320
b	0.360	2.041	0.240
c	0.240	2.001	0.120
d	0.240	2.041	0.360
e	0.240	2.041	0.160
f	0.160	1.240	0.080
g	0.240	2.041	0.360
h	0.360	2.041	0.320
i	0.360	0.560	0.360
j	0.000	1.160	0.360
k	0.360	2.161	0.080
l	0.360	0.560	0.360
m	0.360	3.362	0.320
n	0.360	2.041	0.320

Character	Left (in.)	Width (in.)	Right (in.)
o	0.240	2.041	0.240
p	0.360	2.041	0.240
q	0.240	2.041	0.360
r	0.360	1.321	0.080
s	0.160	1.681	0.120
t	0.040	1.441	0.040
u	0.320	2.041	0.360
v	0.080	2.361	0.080
w	0.080	3.762	0.080
x	0.000	2.601	0.000
y	0.080	2.481	0.080
z	0.120	1.681	0.120
1	0.360	0.840	0.440
2	0.240	2.241	0.240
3	0.240	2.241	0.240
4	0.120	2.481	0.360
5	0.240	2.241	0.240
6	0.360	2.241	0.360
7	0.120	2.241	0.360
8	0.240	2.241	0.240
9	0.240	2.241	0.240
0	0.360	2.361	0.360
&	0.360	4.000	0.000
!	0.440	0.560	0.440
“	0.440	1.721	0.440
#	0.240	3.042	0.240
$	0.360	2.241	0.360
¢	0.240	1.961	0.120
/	0.000	4.083	0.000
*	0.320	2.081	0.320
.	0.160	0.640	0.160
,	0.160	0.640	0.160
:	0.160	0.640	0.160
(	0.360	1.200	0.160
)	0.160	1.200	0.360
-	0.120	1.401	0.120
@	0.360	4.000	0.360
=	0.120	2.601	0.120
+	0.120	2.601	0.120
?	0.240	2.441	0.240

Measurements based on 4-inch uppercase letter height.

Character	Left (in.)	Width (in.)	Right (in.)
A	0.120	3.402	0.120
B	0.480	2.723	0.200
C	0.400	2.723	0.400
D	0.480	2.723	0.400
E	0.480	2.481	0.200
F	0.480	2.481	0.120
G	0.400	2.723	0.400
H	0.480	2.723	0.480
I	0.480	0.640	0.480
J	0.120	2.561	0.480
K	0.480	2.802	0.200
L	0.480	2.481	0.120
M	0.480	3.122	0.480
N	0.480	2.723	0.480
O	0.400	2.842	0.400
P	0.480	2.723	0.120
Q	0.400	2.842	0.400
R	0.480	2.723	0.200
S	0.200	2.723	0.200
T	0.120	2.481	0.120
U	0.480	2.723	0.480
V	0.120	3.042	0.120
W	0.120	3.562	0.120
X	0.200	2.723	0.200
Y	0.120	3.442	0.120
Z	0.200	2.723	0.200
a	0.200	2.281	0.360
b	0.400	2.401	0.240
c	0.240	2.361	0.120
d	0.240	2.401	0.400
e	0.240	2.361	0.160
f	0.160	1.441	0.080
g	0.240	2.401	0.400
h	0.400	2.361	0.360
i	0.400	0.640	0.400
j	0.000	1.321	0.400
k	0.400	2.561	0.080
l	0.400	0.640	0.400
m	0.400	3.963	0.360
n	0.400	2.361	0.360

Character	Left (in.)	Width (in.)	Right (in.)
o	0.240	2.441	0.240
p	0.400	2.401	0.240
q	0.240	2.401	0.400
r	0.400	1.521	0.080
s	0.160	1.881	0.120
t	0.040	1.601	0.040
u	0.360	2.361	0.400
v	0.080	2.842	0.080
w	0.080	4.523	0.080
x	0.000	3.122	0.000
y	0.080	3.002	0.080
z	0.120	2.001	0.120
1	0.400	1.000	0.480
2	0.400	2.723	0.400
3	0.720	2.723	0.400
4	0.080	3.002	0.480
5	0.400	2.723	0.400
6	0.400	2.723	0.400
7	0.280	2.723	0.280
8	0.400	2.723	0.400
9	0.400	2.723	0.400
0	0.400	2.842	0.400
&	0.400	3.562	0.000
!	0.480	0.640	0.480
“	0.160	0.720	0.160
#	0.240	3.402	0.240
$	0.200	2.723	0.200
¢	0.400	2.441	0.280
/	0.000	4.123	0.000
*	0.320	2.161	0.320
.	0.160	0.720	0.160
,	0.160	0.720	0.160
:	0.160	0.720	0.160
(	0.400	1.321	0.160
)	0.160	1.321	0.400
-	0.120	1.401	0.120
@	0.400	4.003	0.400
=	0.480	1.921	0.480
+	0.120	2.682	0.120
?	0.280	2.601	0.280

Measurements based on 4-inch uppercase letter height.

Character	Left (in.)	Width (in.)	Right (in.)
A	0.160	4.083	0.160
B	0.520	3.242	0.280
C	0.400	3.242	0.400
D	0.520	3.242	0.400
E	0.520	3.000	0.280
F	0.520	3.000	0.160
G	0.400	3.242	0.400
H	0.520	3.242	0.520
I	0.520	0.720	0.520
J	0.160	3.042	0.520
K	0.520	3.322	0.120
L	0.520	3.000	0.160
M	0.520	3.762	0.520
N	0.520	3.242	0.520
O	0.400	3.362	0.400
P	0.520	3.242	0.160
Q	0.400	3.362	0.400
R	0.520	3.242	0.280
S	0.280	3.242	0.280
T	0.160	3.000	0.160
U	0.520	3.242	0.520
V	0.160	3.682	0.160
W	0.160	4.243	0.160
X	0.280	3.482	0.280
Y	0.160	4.083	0.160
Z	0.280	3.242	0.280
a	0.200	2.441	0.320
b	0.360	2.481	0.240
c	0.240	2.481	0.120
d	0.240	2.481	0.360
e	0.240	2.481	0.160
f	0.160	1.521	0.080
g	0.240	2.481	0.360
h	0.360	2.481	0.320
i	0.360	0.720	0.360
j	0.000	1.200	0.360
k	0.360	2.401	0.080
l	0.360	0.720	0.360
m	0.360	4.163	0.320
n	0.360	2.481	0.320

Character	Left (in.)	Width (in.)	Right (in.)
o	0.240	2.561	0.240
p	0.360	2.481	0.240
q	0.240	2.481	0.360
r	0.360	1.841	0.080
s	0.160	2.441	0.120
t	0.040	1.841	0.040
u	0.320	2.481	0.360
v	0.080	2.842	0.080
w	0.080	3.842	0.080
x	0.000	2.922	0.000
y	0.080	3.082	0.080
z	0.120	2.561	0.120
1	0.400	1.200	0.520
2	0.280	3.242	0.280
3	0.280	3.242	0.280
4	0.160	3.762	0.400
5	0.280	3.242	0.280
6	0.400	3.242	0.400
7	0.160	3.242	0.400
8	0.280	3.242	0.280
9	0.280	3.242	0.280
0	0.400	3.362	0.400
&	0.400	3.602	0.000
!	0.520	0.720	0.520
“	0.520	2.041	0.520
#	0.240	3.482	0.240
$	0.400	3.242	0.400
¢	0.400	2.922	0.280
/	0.000	4.203	0.000
*	0.320	2.201	0.320
.	0.160	0.720	0.160
,	0.160	0.720	0.160
:	0.160	0.720	0.160
(	0.400	1.321	0.160
)	0.160	1.321	0.400
-	0.120	1.401	0.120
@	0.400	4.000	0.400
=	0.120	2.601	0.120
+	0.120	2.601	0.120
?	0.280	2.682	0.280

Measurements based on 4-inch uppercase letter height.

Character	Left (in.)	Width (in.)	Right (in.)
A	0.160	4.043	0.160
B	0.560	3.242	0.320
C	0.400	3.242	0.320
D	0.560	3.242	0.400
E	0.560	2.962	0.280
F	0.560	2.962	0.280
G	0.400	3.242	0.400
H	0.560	3.242	0.560
I	0.560	0.800	0.560
J	0.160	3.042	0.560
K	0.560	3.282	0.080
L	0.560	2.962	0.080
M	0.560	3.722	0.560
N	0.560	3.242	0.560
O	0.400	3.362	0.400
P	0.560	3.242	0.160
Q	0.400	3.362	0.400
R	0.560	3.242	0.280
S	0.440	3.242	0.440
T	0.160	2.962	0.160
U	0.560	3.242	0.560
V	0.160	3.682	0.160
W	0.160	4.243	0.160
X	0.280	3.482	0.280
Y	0.160	4.043	0.160
Z	0.280	3.242	0.280
a	0.440	2.642	0.800
b	0.800	2.642	0.440
c	0.440	2.642	0.440
d	0.440	2.642	0.800
e	0.440	2.642	0.440
f	0.400	1.681	0.440
g	0.440	2.642	0.800
h	0.800	2.642	0.800
i	0.800	0.800	0.800
j	0.080	1.481	0.800
k	0.800	2.642	0.440
l	0.800	0.800	0.800
m	0.800	4.403	0.800
n	0.800	2.642	0.800

Character	Left (in.)	Width (in.)	Right (in.)
o	0.440	2.722	0.440
p	0.800	2.642	0.440
q	0.440	2.642	0.800
r	0.800	2.000	0.160
s	0.360	2.642	0.440
t	0.360	2.081	0.480
u	0.800	2.642	0.800
v	0.360	3.082	0.360
w	0.360	4.083	0.360
x	0.440	3.202	0.440
y	0.360	3.402	0.360
z	0.480	2.722	0.480
1	0.480	1.200	0.560
2	0.440	3.242	0.440
3	0.120	3.242	0.400
4	0.120	3.722	0.560
5	0.440	3.242	0.440
6	0.400	3.242	0.400
7	0.240	3.242	0.400
8	0.400	3.242	0.400
9	0.400	3.242	0.400
0	0.400	3.362	0.400
&	0.400	3.602	0.400
!	0.560	0.800	0.560
“	0.560	2.281	0.560
#	0.400	3.522	0.400
$	0.440	3.242	0.440
¢	0.400	2.682	0.280
/	0.000	4.283	0.000
*	0.320	2.241	0.320
.	0.160	0.800	0.160
,	0.160	0.800	0.160
:	0.160	0.800	0.160
(	0.400	1.521	0.160
)	0.160	1.521	0.400
-	0.120	1.401	0.120
@	0.400	4.043	0.400
=	0.120	2.601	0.120
+	0.120	2.601	0.120
?	0.280	2.762	0.280

Measurements based on 4-inch uppercase letter height.

Character	Left (in.)	Width (in.)	Right (in.)
A	0.160	4.563	0.160
B	0.560	3.762	0.400
C	0.400	3.762	0.280
D	0.560	3.762	0.400
E	0.560	3.242	0.400
F	0.560	3.242	0.400
G	0.400	3.762	0.400
H	0.560	3.762	0.560
I	0.560	0.760	0.560
J	0.160	3.322	0.560
K	0.560	3.762	0.160
L	0.560	3.442	0.160
M	0.560	4.323	0.560
N	0.560	3.762	0.560
O	0.400	4.203	0.400
P	0.560	3.762	0.400
Q	0.560	4.203	0.400
R	0.560	3.762	0.400
S	0.400	3.762	0.400
T	0.160	3.442	0.160
U	0.560	3.762	0.560
V	0.160	4.203	0.160
W	0.160	4.683	0.160
X	0.160	4.083	0.160
Y	0.160	4.563	0.160
Z	0.280	3.762	0.280
a	0.320	3.042	0.480
b	0.480	3.162	0.320
c	0.320	2.802	0.200
d	0.320	3.162	0.480
e	0.320	3.202	0.320
f	0.120	1.721	0.120
g	0.320	3.000	0.480
h	0.480	2.962	0.480
i	0.480	0.760	0.480
j	0.040	1.240	0.480
k	0.480	2.802	0.120
l	0.480	0.760	0.480
m	0.480	4.723	0.480
n	0.480	2.962	0.480

Character	Left (in.)	Width (in.)	Right (in.)
o	0.320	3.202	0.320
p	0.480	3.162	0.320
q	0.320	3.162	0.480
r	0.480	2.000	0.120
s	0.280	2.922	0.280
t	0.120	1.921	0.160
u	0.480	2.962	0.480
v	0.080	3.362	0.080
w	0.080	4.603	0.080
x	0.080	3.522	0.080
y	0.080	3.682	0.080
z	0.200	3.042	0.200
1	0.560	1.321	0.560
2	0.400	3.762	0.400
3	0.400	3.762	0.400
4	0.160	4.083	0.560
5	0.400	3.762	0.400
6	0.400	3.762	0.400
7	0.160	3.762	0.160
8	0.400	3.762	0.400
9	0.400	3.762	0.400
0	0.400	3.882	0.400
&	0.560	4.603	0.160
!	0.560	0.760	0.560
“	0.560	2.000	0.560
#	0.080	3.522	0.080
$	0.400	3.762	0.400
¢	0.320	3.000	0.200
/	0.000	4.283	0.000
*	0.280	2.241	0.280
.	0.280	0.760	0.280
,	0.280	0.760	0.280
:	0.280	0.760	0.280
(	0.400	1.361	0.120
)	0.120	1.361	0.400
-	0.160	1.401	0.160
@	0.400	4.000	0.400
=	0.160	2.601	0.160
+	0.160	2.601	0.160
?	0.400	3.362	0.400

T-U-V

W

X-Y-Z

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