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U.S. Army Transportation Command
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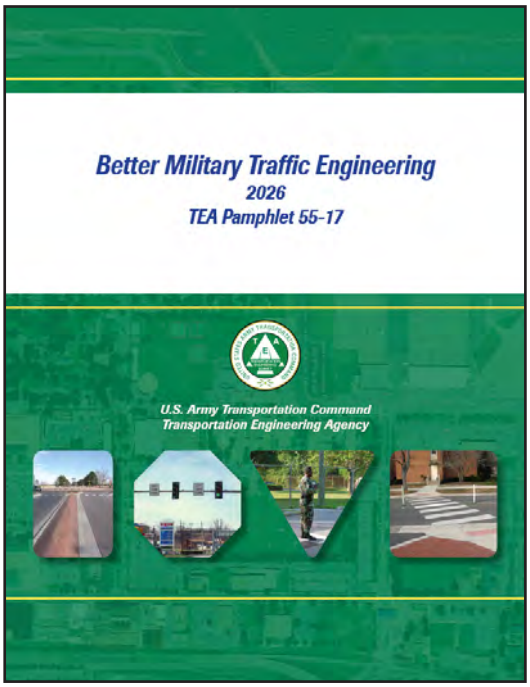
CHAPTER 1 – INTRODUCTION

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CHAPTER 1 – INTRODUCTION

1.1. FORWARD

Traffic engineering is a complex field built on the collective experience of professionals. *The Better Military Traffic Engineering* pamphlet is intended for use by individuals with responsibilities relating to traffic operations, roadway safety, and 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, with case studies and problem-solving techniques illustrating the practical application of these principles in the unique conditions found on military installations.

This pamphlet is an update to the 2016 version of *TEA Pamphlet 55-17.* As with the 2016 version of *TEA Pamphlet 55-17*, this pamphlet combines content from and supersedes *TEA Pamphlet 55-14*, dated 2011. Therefore, previous versions of *TEA Pamphlet 55-17* and all versions of *TEA Pamphlet 55-14* are voided and obsolete with the release of this document.

Many standards presented in this pamphlet are drawn from other publications, which are referenced throughout. The authors acknowledge significant contributions from the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the Federal Highway Administration (FHWA).

This document was developed using reference sources such as: 2023 *Manual on Uniform Traffic Control Devices (MUTCD)* 11th Edition, 2018 *AASHTO A Policy on Geometric Design of Highways and Streets (Green Book)*, 2025 *DoW 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 reference material. At the start of any design project, ensure that the latest versions of references are used.

This publication does not incorporate state and local guidance. Installations are recommended to familiarize themselves with state and local regulations, as there may be slight variations.

TEA's *DoW Supplement to the MUTCD* provides traffic control requirements tailored to the unique conditions found at DoW installations.

1.2. WHO IS ARTRANS?

The Transportation Engineering Agency (TEA), under the U.S. Army Transportation Command (ARTRANS), executes the Department of War's (DoW) overall transportation engineering program on behalf of the military services.

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

Achieving TEA's mission and objectives requires a strategic focus on 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 traffic engineering tools. These tools include the Better Military Traffic Engineering (BMTE) and the Access Control Point (ACP)/ Entry Control Facility (ECF) SMART Decision Evaluator. These are discussed in pamphlet Exhibit 1.1. TEA also hosts training seminars that lead 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, TEA offers several forms of training and education.

Exhibit 1.1: TEA Training and Education

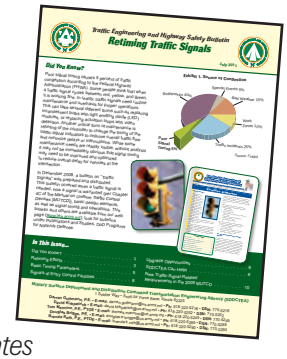
TRAINING AND EDUCATION PROGRAM	SUBJECT MATTER COVERED
TRAFFIC ENGINEERING AND HIGHWAY SAFETY BULLETINS Bulletins are published three to four times a year and address a broad range of transportation and safety topics. Bulletins are available online at: https://www.army.mil/artrans#org-tea	Bulletin topics include: ✓ *Access Management* ✓ *Pedestrian Safety* ✓ *Parking* ✓ *Traffic Calming* ✓ *Safety Audits* ✓ *Speed Limits* ✓ *Traffic Signs* ✓ *Roadside Safety* ✓ *Traffic Engineering For Better Gates* ✓ *Highway Safety Driver-Aid Treatments* ✓ *Safety Requirements of Active Vehicle Barriers* ✓ *Sign Retroreflectivity* ✓ *Intersection Traffic Control* 
PAMPHLETS TEA produces a variety of pamphlets regarding transportation issues. These materials provide specific, detailed traffic engineering guidance on key issues. Pamphlets and manuals are available online at: https://www.army.mil/artrans#org-tea	✓ *Pamphlet 55-8, Traffic Engineering Study Reference* ✓ *Pamphlet 55-15, Traffic and Safety Engineering for Better Entry Control Facilities* ✓ *Pamphlet 55-17, Better Military Traffic Engineering* 

Exhibit 1.1: TEA Training and Education (continued)

TRAINING AND EDUCATION PROGRAM	SUBJECT MATTER COVERED
TRAFFIC ENGINEERING TRAINING & TOOLS TEA's Better Military Traffic Engineering (BMTE) tool features tools and calculators that provide the military engineering community with guidance on installation traffic control and safety. The site includes instructional tutorials for personnel training and common traffic engineering calculations.	BMTE features several topic-specific tutorial sections and calculators, including: ✓ *Signs* ✓ *Signals* ✓ *ECFs* ✓ *Parking* ✓ *Roadside Safety* ✓ *Intersections* 
ENTRY CONTROL FACILITY TOOL The purpose of the ACP/ECF SMART Decision Evaluator is to help decide the best configuration for an ECF: to provide different scenarios that help determine the adequate number of ID check lanes, with the optimal number of guards in order to minimize risk, 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 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 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 as well as the background calculations used. 

1.2.2. Engineering Services

KEY POINT

TEA offers on-site crash location studies at no cost to the installations.

TEA's focus is to deliver a quality product to installations in a timely manner. Study focus areas are identified in Exhibit 1.2.



TEA offers on-site engineering studies

TEA's services include:

Safety

- ✓ Traffic safety assessment
- ✓ Fatal crash analysis
- ✓ Safety audits
- ✓ 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: Study Focus Areas

STUDY TYPE	STUDY CHARACTERISTICS
ACCESS CONTROL POINT/ENTRY CONTROL FACILITY (ACP/ECF) STUDIES	The purpose of this type of study is to assess the four priorities of an ACP or ECF consisting of: ✓ Security and Functional Requirements ✓ Safety (guards and motorists) ✓ Traffic Flow and Congestion ✓ Aesthetics
CRASH ANALYSIS	Crash analysis studies high crash or problem locations. 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 audits 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 Americans with Disabilities Act (ADA) requirements.
SPEED STUDIES	Speed studies usually involve the collection of speed data 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 traffic on streets.
SIGN MANAGEMENT STUDIES	This type of study is an inventory and inspection of installation signing to ensure that the minimum retroreflective requirements are met for nighttime driving, signs comply with *MUTCD*, and develop a GIS database for sign management.
TRAFFIC IMPACT STUDIES	Traffic impact studies typically involve identifying impacts and roadway or intersection improvement needs to mitgate the impacts resulting from development or an increase in population. The study involves estimating the number of additional trips to be generated by the proposed development or relocated development and conducting capacity analyses to assess existing and future operations.

Exhibit 1.2: 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 in the *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 layouts.
TRAFFIC SIGNAL INSPECTIONS & OPERATIONAL AUDITS	Traffic signal inspections include an inspection of traffic signal equipment (including mast arms, signal heads, controllers, 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.

CHAPTER 2 – WHY TRAFFIC ENGINEERING?

2.1. CONGESTION MITIGATION 2-3
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Basewide planning involves evaluating the overall transportation-related needs, including pedestrians and bicyclists, of an installation while considering future changes to population and land use. Frequently, changes to population and land use occur on bases without adequate consideration of transportation needs. If long-term transportation requirements are not addressed, traffic problems will develop as missions expand and more vehicles are added to an already overburdened system. Development should occur hand-in-hand with increases to roadway network capacity to ensure that transportation infrastructure keeps pace with operational growth.

In the civilian world, private developers are often required to provide additional roadway capacity when a development is built in order to accommodate the traffic that the project will generate. Developers must perform improvements to the external roadway network so that the amount of delay per motorist does not worsen. Depending on the size of the development, improvements may be required far offsite, sometimes at intersections a mile or more away.

In contrast, military installations frequently construct facilities that generate significant traffic without making corresponding roadway improvements. Development may consist only of the building itself and a parking lot, leaving surrounding roadways over capacity once the facility opens. ECFs can also become overburdened if the new development draws additional traffic through them.

To avoid these issues, it is critical that all appropriate personnel are involved during the planning stage, including:

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

Master planners should review projects for opportunities to upgrade roadways when construction occurs. For example, if a project is located along a corridor with long-term plans to widen the roadway, the project could incorporate widening in its immediate area. On a smaller scale, if basewide sidewalk upgrades are planned, a project could include sidewalk improvements adjacent to the new facility.

Traffic engineers should ensure that projects incorporate improvements to handle additional traffic, such as:

- ✓ 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.

In alignment with UFC 2-100-01, area development planning (ADP) emphasizes the integration of land use and transportation infrastructure. ADPs require planners to evaluate roadway connectivity, multimodal access, and circulation patterns to ensure that new facilities are effectively tied into the broader

installation network. This approach supports mission readiness by minimizing congestion and ensuring that transportation systems evolve alongside land use changes. Linking ADPs with transportation planning ensures that growth on the installation does not outpace roadway capacity and that facilities are developed to sustain long-term operational efficiency.

It is essential that traffic impacts be considered whenever new development is added to an installation. Reviewers should evaluate projects holistically, thinking through roadway capacity, multimodal connections, and impacts to mission-critical facilities, as discussed in Exhibit 2.1.

Exhibit 2.1: 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 turn lanes exiting the development needed?
✓ Traffic signal retiming and upgrades	• Are nearby traffic signals going to experience 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 or roundabouts more effective for traffic control?
✓ Additional turn lanes at nearby intersections	• Will intersections away from the development get additional turning traffic which will require turn lanes? • Will existing turn lane storage length need to be added?
✓ Additional roadways to link development to roadway networks	• Are multiple driveways needed to alleviate traffic to and from the development? • If an existing driveway is already in place, can a second access point be built on a nearby roadway to distribute traffic and provide access to multiple routes?
✓ Impacts to ECFs	• Are there ECFs that are currently under capacity? • Are all ECFs nearby adequately-sized to accommodate development-generated traffic? • Are processing techniques appropriate for long-term conditions?

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 or intersection capacity. The resulting effects are delays, increased travel time, increased costs, driver frustration, and unsafe driving practices.

There are four components of congestion:

Duration - The length of time during which congestion affects the travel system.

Extent - Refers to the scope of a congestion event, specifically measuring its geographic reach and the number of system users it impacts.

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 2.2, congestion is the result of several root causes, often interacting with one another.



Congested Conditions

Exhibit 2.2: Causes of Congestion

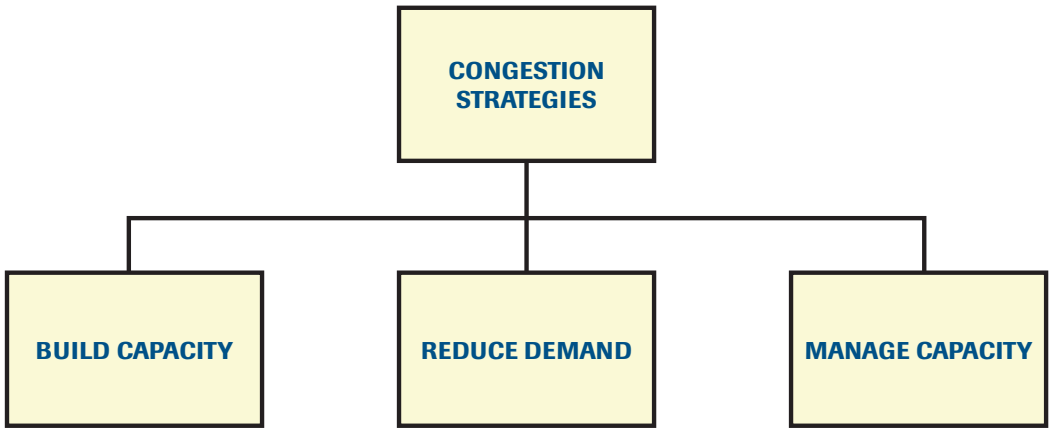
CAUSES OF CONGESTION	COMMON EXISTING CONDITIONS	COMMON FUTURE CONDITIONS WITHOUT IMPROVEMENTS
Physical Bottlenecks ("Capacity") – Capacity is the maximum amount of traffic capable of being handled by a given highway section. Capacity is determined by a number of factors: the number and width of lanes 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.
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

Exhibit 2.2: Causes of Congestion (continued)

CAUSES OF CONGESTION	COMMON EXISTING CONDITIONS	COMMON FUTURE CONDITIONS WITHOUT 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.

2.2. 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.

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 2.3 provides example performance measures for evaluating various transportation system components.

Exhibit 2.3: Example Performance Measures

PERFORMANCE	PERFORMANCE MEASURE	OBJECTIVE
SAFETY	✓ Total crashes ✓ Fatalities ✓ Injury crashes ✓ Bike/ped crashes	✓ Reduce crash severity ✓ 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 analysis 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. AREAS OF NEED

Accommodating overall areas of need is critical for acceptable traffic operations on base. 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 ECF?

- ✓ 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 construct a loop road around the cantonment's busiest areas, diverting traffic to the periphery to create pedestrian-friendly centers?
- ✓ Is development located such that access points will not impact nearby intersections?

CHAPTER 3 – TRAFFIC ENGINEERING STUDIES

3.1. PROBLEM IDENTIFICATION 3-1

3.2. TRAFFIC DATA COLLECTION. 3-3

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CHAPTER 3 – TRAFFIC ENGINEERING STUDIES

The initial step in transportation planning is the systematic identification of traffic problems within the area under evaluation. A "traffic problem" is characterized as any condition that disrupts the safe and efficient movement of traffic.

When identifying traffic problems, it is essential to account for their relative nature, as traffic challenges differ significantly across various regions. For instance, a five-minute delay in New York City may be perceived as insignificant, whereas the same delay in a rural or remote area could be highly aggravating to motorists. Thus, traffic issues must always be evaluated in the context of the specific location under analysis.

3.1. PROBLEM IDENTIFICATION



Traffic engineering studies serve as the foundation for developing solutions to traffic problems.

On a one-mile segment of free-flowing roadway with a 30-mph speed limit, the introduction of three 30-second stoppages increases total vehicular operating costs by approximately 90 percent. While quantifying the value of a motorist's time is more complex, studies indicate that motorists often prioritize time savings over fuel efficiency when making travel decisions.

Traffic-related problems on roadway networks primarily arise from two sources: congestion and crashes. Congestion leads to inefficiencies, consuming motorists' time and financial resources, while crashes result in property damage, injuries, and fatalities, imposing significant societal and economic costs.

Congestion

Motorists primarily oppose traffic congestion due to time loss and increased vehicle operating costs, the latter of which can be quantified with reasonable accuracy.

Crashes

Traffic crashes represent the most severe consequence of traffic-related issues, with significant impacts on safety. Nationally, in 2024, there were 39,254 traffic related fatalities. Of these, 11,288 fatalities were the result of speeding; 11,904 fatalities were alcohol-related; and 7,080 were pedestrians. These statistics highlight opportunities to enhance roadway systems and reduce crash rates.

On military installations, safety and operational deficiencies can be identified through crash data analysis, capacity studies, and field observations.

The crash analysis process involves systematic data collection, identification of high-frequency crash locations, data evaluation, and the formulation of remedial measures. Insights from crash histories inform and guide the implementation of countermeasures such as traffic control devices, enhanced law enforcement, driver education, and safety-focused engineering measures.

Crash reports should be systematically compiled and maintained, typically within installation security or safety offices, to support ongoing safety management efforts.

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

Engaging a variety of stakeholders offers significant advantages when analyzing crashes. Military police responsible for crash investigations possess detailed knowledge of specific incidents and are familiar with problematic locations across the base. Installation safety staff can highlight safety issues present at crash sites. Department of Public Works (DPW) personnel can share information about recent and upcoming engineering projects, as well as any limitations that may affect potential improvements. Additionally, external experts can contribute valuable perspectives by bringing fresh insights to areas of concern.

Consult TEA *Pamphlet 55-8* for guidance on identifying high crash locations and for additional details on conducting crash studies. After pinpointing high crash areas, it is essential to determine the underlying causes that make these locations prone to crashes. These factors should be carefully assessed to establish whether they are linked to design elements or traffic control measures. The following steps outline the evaluation process:

- ✓ **Gather Crash Reports**: Collect crash reports for the location being analyzed. Generally, data from the most recent two to three years is preferred, but a one-year period may be used if that is all that is available.
- ✓ **Prepare a Crash Diagram**: Create a schematic (not to scale) representation of the site to visualize crash patterns and similarities among incidents. Each incident should be plotted to indicate the direction of approach, crash type and severity, date and time, and weather conditions at the time of the crash.
- ✓ **Develop a Condition Diagram**: Produce a scale drawing of the location that details all physical features that might affect driver behavior. This should include curbs, driveways, markings, traffic control devices, and other relevant elements.
- ✓ **Collect Additional Data**: Assemble relevant information concerning traffic volumes, approach speeds, intersection delay, parking conditions, and traffic control devices.
- ✓ **Analyze Causal Factors**: Examine all collected data to identify the primary and secondary contributing factors to the crashes.

After identifying the contributing factors, a safety audit should be conducted for the intersection or roadway corridor. A safety audit is a procedural approach to evaluating roadway safety. The audit involves a focused review of the intersection or roadway corridor with attention given to the following aspects:

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

The following photos illustrate the positive impact of a safety assessment at a specific location, showing the location before and after the assessment was performed. The resulting improvements, which focused on signing and pavement marking changes, created a more logical and efficient traffic flow pattern.





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.



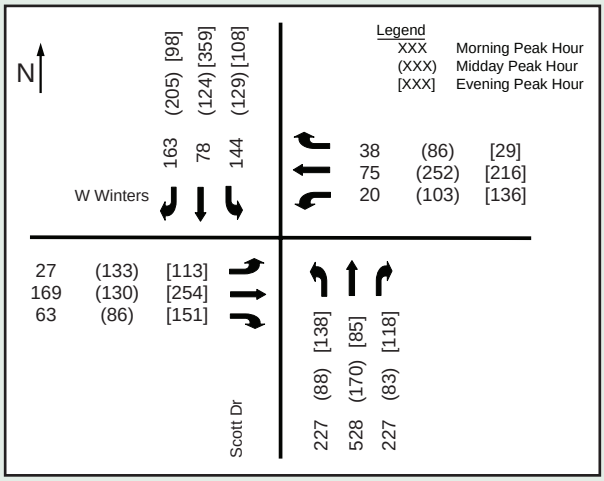
Typical turning movement counter

To understand traffic patterns at an intersection, turning movement counts (TMCs) are conducted. These counts quantify the volume and direction of all approaching vehicles—whether turning left, proceeding straight, or turning right—as they pass through the intersection, with data typically recorded in 15-minute intervals. While electronic count boards are the standard tool for this task, manual counting by personnel can be performed if equipment is unavailable. TMCs are typically conducted during the morning (0600-0900), midday (1100-1300), and afternoon (1500-1800) peak traffic periods. However, if installation-specific data has already identified more precise peak hours, the counting periods can be condensed to focus on those targeted times.

If the data was collected manually, it must be converted into a more useful format. The goal is to find the peak hour turning movement volumes for each study period. This is achieved by first summing all traffic in

15-minute increments. The peak hour is identified as the busiest 60-minute period, which consists of the four consecutive 15-minute intervals with the highest total volume. Once this peak hour is established, the specific volumes for each individual movement (left, straight, and right) are calculated for that hour. These final figures, representing the peak hour turning movements, are then typically summarized on a turning movement diagram (as shown to the left).

TYPICAL TURNING MOVEMENT COUNT SUMMARY



However, it is more common to use software to generate turning movement diagrams instead of creating them manually. As needed, these diagrams can also be adapted to include data on pedestrians, bicycles, or other classifications.

To determine a roadway's Average Daily Traffic (ADT), 24-hour count data is collected using Automatic Traffic Recorders (ATRs) like road tubes or in-lane card counters as shown below. Beyond just traffic volume, these recorders often provide critical data on vehicle speeds and classifications. This additional information has practical applications: speed data is used to validate or set speed limits, and vehicle classification data is vital for pavement engineering and analyzing truck route preferences.

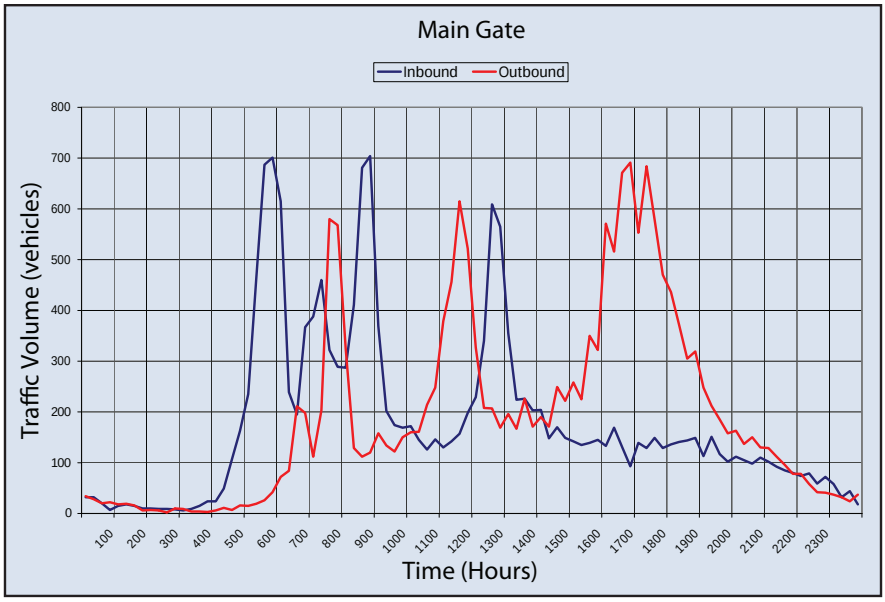


Tube-style ATR



In-lane card counter

Traffic volume profiles generated from 24-hour ATR data clearly identify peak traffic periods, as illustrated in the example profile below. This data is useful for various applications, including setting optimal hours for different traffic signal timing plans and managing ECF operating hours.



Example 24-hour traffic volume profile

For further guidance on collecting traffic data, refer to TEA *Pamphlet 55-8*.

3.3. ANALYSIS AND LEVELS OF SERVICE

Level of service (LOS) is a measure of performance based on the amount of delay through an intersection or roadway corridor. LOS calculations use peak-hour traffic volumes collected during morning, midday, and evening periods. Standard methodologies for calculating LOS are outlined in the *Highway Capacity Manual*, with software such as *Synchro* and *Highway Capacity Software (HCS)* available for analysis. Additionally, the ACP/ECF SMART Decision Evaluator is a specialized tool used to estimate the number of required ID check lanes at an ECF, helping planners ensure adequate capacity and minimize delays at base access points.

There are six LOS classifications, A through F, with A representing the best conditions and F indicating severe delays. LOS A and B are considered good, while LOS C and D are acceptable for military operations. However, LOS E and F are generally deemed unacceptable, particularly in critical areas such as base entry points, evacuation routes, and high-volume intersections near housing, schools, or command facilities. Additional detail on the LOS classifications are provided in Exhibit 3.1.

On military installations, traffic flow is influenced by unique operational and security constraints, requiring careful planning and coordination. The distinct traffic challenges found on military bases include:

- ✓ **Gate Operations & Security Checkpoints** – Entry and exit gates are critical control points. During peak hours (morning arrivals, midday activity and evening departures), gate backups can lead to extensive queuing. Delays may be exacerbated by security procedures such as ID verification, vehicle inspections, and random searches, making efficient gate management essential for maintaining a reasonable LOS.
- ✓ **School Release Traffic** – Many bases have DoW-operated schools, creating localized congestion during student drop-off and pickup periods. This often requires coordinated traffic control measures, such as staggered release times, dedicated drop-off lanes, or assigned personnel directing traffic.

- ✓ **Emergency Weather Evacuations** – Severe weather events, including hurricanes, tornadoes, or winter storms, may necessitate mass movement of personnel. Evacuation routes must be optimized for rapid departures while considering congestion at base exit points. Military installations often require emergency traffic management plans that designate primary and alternate evacuation corridors to mitigate excessive delays.
- ✓ **Deployment & Mission-Related Traffic Surges** – Bases experience surges in traffic during deployment cycles, training rotations, or special operations. Convoy movements, oversized military vehicles, and mission-critical transport operations may alter typical traffic patterns, impacting LOS at key intersections and along primary base corridors.
- ✓ **Restricted Roadways & Controlled Access Areas** – Military bases frequently have roads restricted to authorized personnel, PT or mission-specific vehicle types. LOS calculations must factor in designated priority lanes, restricted access zones, and convoy staging areas, which can affect throughput and overall network performance.

When designing new intersections or improving existing ones on a military base, planning for LOS C or better is preferred, though LOS D may be acceptable in certain constrained areas. At conventional intersections, poor LOS can often be improved by adding turn lanes, optimizing gate access control, or adjusting signal phasing and timing. Additionally, corridors governed by gate operations may require queueing analyses to minimize excessive backups during peak entry periods. If a roadway corridor experiences ongoing LOS deficiencies, additional through lanes or alternate access routes may be needed to achieve acceptable conditions.

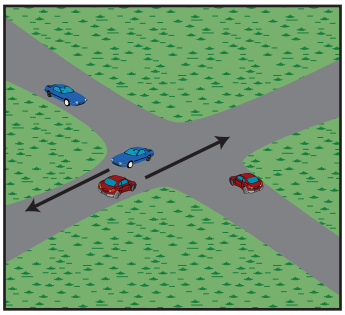
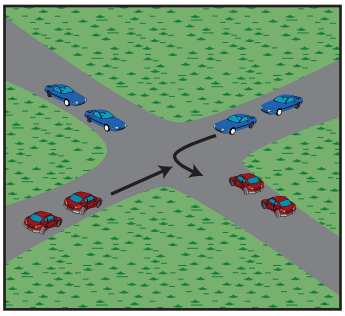
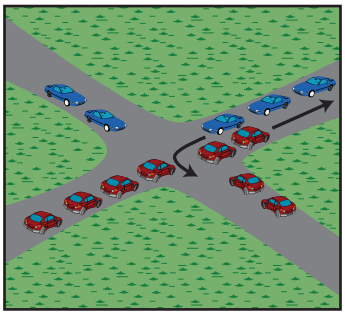
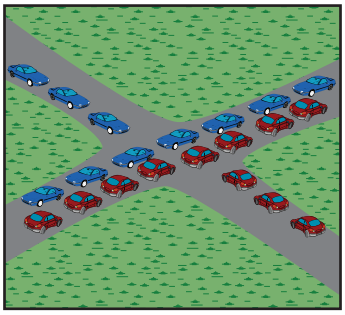


Example of Gate Backup



Example of Restricted Roadway

Exhibit 3.1: Level of Service Definitions

LOS	INTERSECTIONS		
	SIGNALIZED		UNSIGNALIZED
A	✓ 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		✓ Average delays less than 10.0 spv ✓ Little or no delay to minor street traffic
B	✓ Average delay in range of 10.1-20.0 spv ✓ More vehicles stop than LOS A		✓ Average delay in range of 10.1-15.0 spv ✓ Short traffic delays to minor street traffic
C	✓ Average delay in range of 20.1-35.0 spv ✓ Number of vehicles stopping is significant ✓ Cycle failures may begin to appear		✓ Average delay in range of 15.1-25.0 spv ✓ Average traffic delays to minor street traffic
D	✓ Average delay in range of 35.1-55.0 spv ✓ Congestion more noticeable ✓ Many vehicles stop ✓ Cycle failures noticeable		✓ Average delay in range of 25.1-35.0 spv ✓ Long traffic delays to minor street traffic
E	✓ Average delay in range of 55.1-80.0 spv ✓ Cycle failures frequent		✓ Average delay in range of 35.1-50.0 spv ✓ Very long delays to minor street traffic
F	✓ Average delay in excess of 80.0 spv ✓ Delay unacceptable to most drivers ✓ Many cycle failures		✓ Average delay in excess of 50.0 spv ✓ Extreme delays with queuing ✓ Congestion affects other intersections ✓ Warrants improvement to intersection

3.4. APPLICATION

Traffic volume data, when combined with other types of data, is fundamental to making informed decisions about traffic improvements. Key applications for this data include:

- ✓ **Justifying Traffic Signals**: Assessing whether to install or remove a traffic signal by comparing volume data against established warrants.
- ✓ **Optimizing Signal Operations**: Determining the most effective timing and phasing for traffic signals.
- ✓ **Placing Traffic Control Signs**: Establishing the need for traffic control signs based on *MUTCD* requirements.
- ✓ **Analyzing Safety**: Evaluating crash data to understand the relationship between turning movements, congestion, and crash frequency.
- ✓ **Assessing Lighting Needs**: Comparing day and night traffic volumes with corresponding crash rates to determine if street lighting is needed.
- ✓ **Classifying Roadways**: Aiding in the development of a street hierarchy (e.g., arterial, collector, and local streets).
- ✓ **Planning Improvements**: Evaluating the need for enhancements to intersections or entire roadway corridors.
- ✓ **Forecasting Growth**: Identifying long-term trends in vehicle usage and for traffic volumes in general.
- ✓ **Prioritizing Projects**: Assisting in the establishment of priorities for construction and maintenance.
- ✓ **Managing Pavement Markings**: Guiding the placement of road markings and determining repainting frequency for traffic-worn lines.
- ✓ **Analyzing Development Impacts**: Assessing parking demands and evaluating the impact of new traffic-generating developments on the surrounding road network.

CHAPTER 4 – GEOMETRIC DESIGN BASICS

4.1. ROADWAY FEATURES 4-1

4.2. CROSS SECTIONS 4-5

4.3. TURNING MOVEMENTS 4-9

4.4. INTERSECTION DESIGN CONSIDERATIONS. 4-9

4.5. SIGHT DISTANCE 4-18

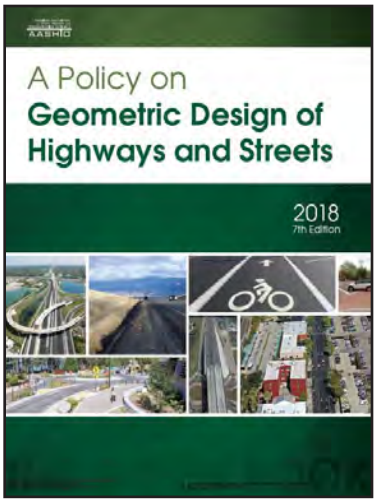
4.6. HORIZONTAL ALIGNMENTS. 4-20

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4.8. OUTSIDE CONTINENTAL UNITED STATES (OCONUS) CONSIDERATIONS 4-22

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* includes 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 exceed 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 provides 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. 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



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



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

The design team must determine which 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. AASHTO classifies design vehicles based on their physical dimensions and typical operational characteristics. Passenger vehicles include compact cars, sedans, SUVs, minivans, and pickup trucks, while Single-Unit Trucks (SUs), represent heavier vehicles with all axles on a single frame, such as local delivery trucks or dump trucks. An SU-30, for example, has a 30-foot wheelbase. Wheelbase, or WB, design vehicles represent tractor-trailer combinations and the number following WB indicates the wheelbase length in feet from the front steering axle to the center of the rear trailer axles. WB-40 is a common smaller semi and WB-67 is the national standard for large interstate trucks with 53-foot trailers.

Military vehicles, like commercial trucks, play a significant role in roadway design considerations. While both vehicle types share similarities in size and operational needs, military vehicles often have specialized functions that impact their maneuverability and roadway accommodation. Unlike commercial trucks, military vehicles may have unique axle configurations, reinforced structures, and off-road capabilities that influence their turning radius and lane requirements.

Typically, a WB-67 design vehicle is used in areas that accommodate trucks, including military installations where large transport vehicles are common. Military vehicles can generally fit within a WB-62 or WB-67 design framework, ensuring they can navigate standard roadway infrastructure. 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. However, military-specific vehicles used on installations may have additional considerations due to unique sizes or operational requirements. For example, an overwidth vehicle could use the outbound lanes at an ECF if the inbound lane is too narrow, provided certain operational techniques are used, such as closing the gate to normal traffic or at least stopping traffic in the conflicting direction. Unless overwidth, the majority of military vehicles will be able to use a facility designed for a WB-67 truck. Therefore, it is not considered necessary to use a military vehicle as a specified design vehicle.

Vehicle turning templates, as outlined in the AASHTO *Green Book*, provide guidance for evaluating turning paths. Many states also have turning templates that can be used for design. Larger design vehicles require larger turning radii and turning templates help assess vehicle movement through curves, intersection geometrics, and stop line placement.

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.

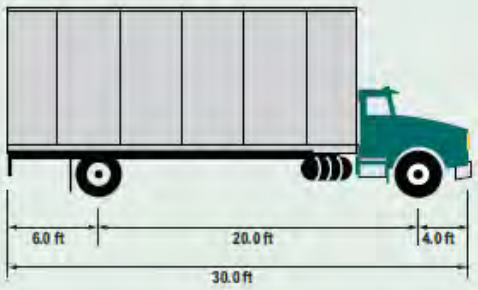
Encroachment into the adjacent lane may result in a sideswipe crash. Generally, encroachment can be

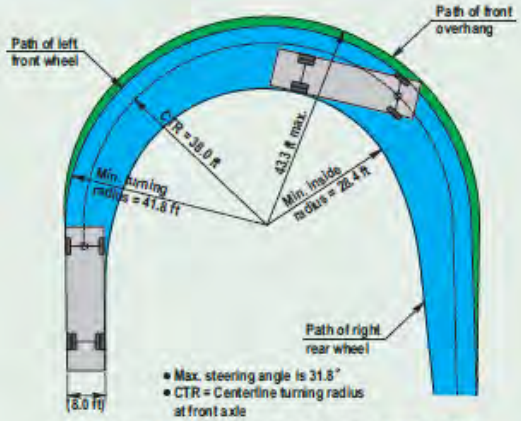
minimized by widening the lane. Recommended lane widths for sharper curves are summarized in the AASHTO *Green Book*, Table 3-26b. For example, with curve radii less than 200 feet and larger design vehicles, the lane width may exceed 20 feet.

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

DESIGN VEHICLE EXAMPLES FROM AASHTO *GREEN BOOK*

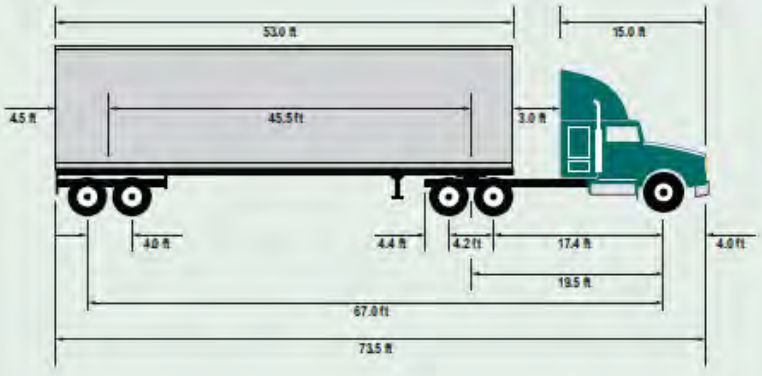
SINGLE-UNIT TRUCK (SU-30)

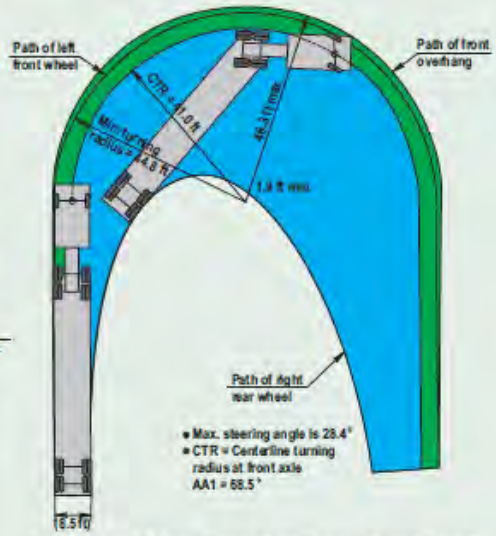




AASHTO Exhibit 2-2 Minimum Turning Path for Single-Unit Truck (SU-30) Design Vehicle from AASHTO Green Book

INTERSTATE SEMITRAILER (WB-67)



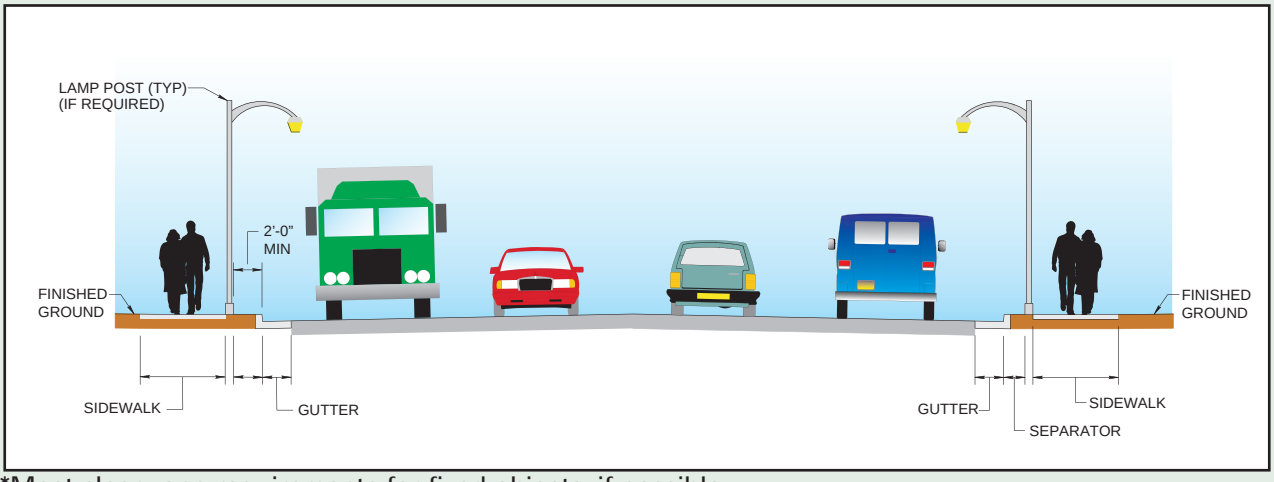


AASHTO Exhibit 2-15 Minimum Turning Path for Interstate Semitrailer (WB-67) Design Vehicle from AASHTO Green Book

4.2. CROSS SECTIONS

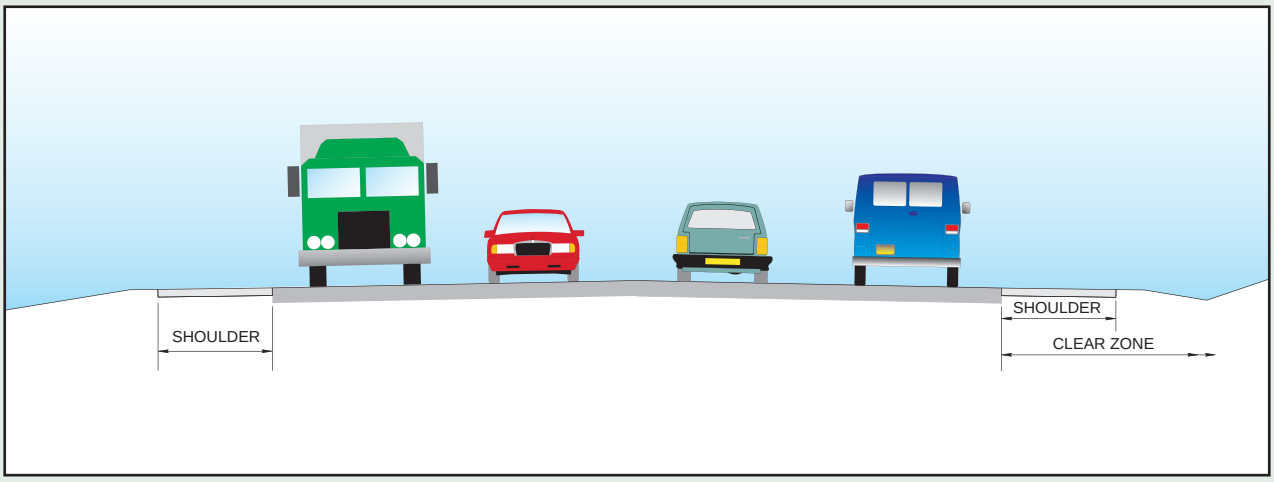
The cross section of a roadway and associated features is the width available for use by vehicles, pedestrians, drainage, and other roadway features. The preferred width of a travel lane is 12 feet. When necessary, the minimum lane width can be reduced to 10 feet, and the maximum width can be 16 feet. 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 a shoulder.

ROADWAY TYPICAL SECTION (URBAN)



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

ROADWAY TYPICAL SECTION (RURAL)

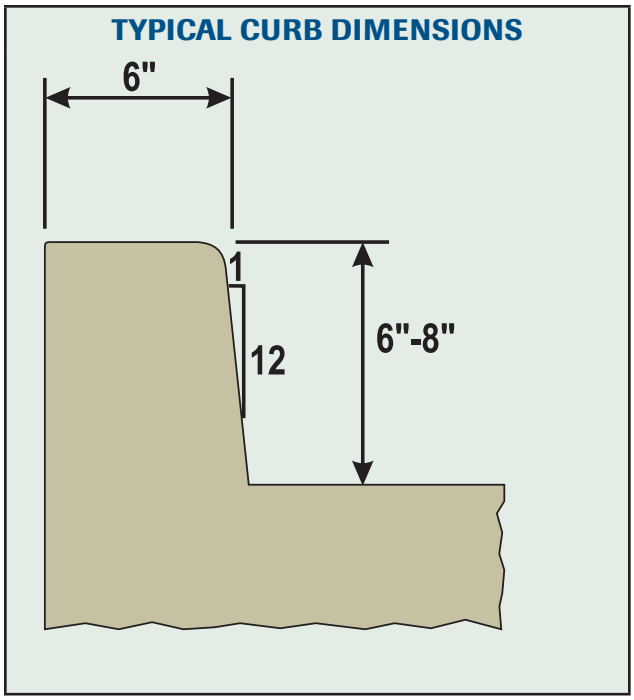


4.2.1. Curb and Gutter

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. Designers should also verify applicable state or local DOT design criteria. Curb and gutter types, dimensions, and construction standards can vary by jurisdiction.



4.2.2. Shoulders

KEY POINT

Roadway shoulders support a variety of functions.



Roadway shoulder

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.

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.

Exhibit 4.2: Roadway Classification Shoulder Width

ROADWAY CLASSIFICATION	AVERAGE DAILY TRAFFIC <400 VEHICLES (FEET)	AVERAGE DAILY TRAFFIC 400-1,499 VEHICLES (FEET)	AVERAGE DAILY TRAFFIC 1,500-2,000 VEHICLES (FEET)	AVERAGE DAILY TRAFFIC >2,000 VEHICLES (FEET)
ARTERIALS	4	6	6	8
COLLECTORS	2	5		
LOCAL				

Source: AASHTO, *Green Book*

4.2.3. Medians



Medians separate opposing directions of traffic.

Medians separate opposing directions of traffic and can provide control for left turns. Raised median islands are often used on urban arterials. Medians typically provide green space between vertical faces 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 turning vehicles. Typically, medians should not be less than 4 feet wide.

4.2.4. Bicycle Accommodations

Bicycles should be accommodated to the greatest extent possible in roadway design on military installations, including access through ECFs where feasible. In general, there are four major types of bicycle accommodations:

✓ **Shared Roadway, No Bicycle Designation**: Most bicycle travel occurs on streets and highways without designated bike lanes. Within this category, there are two subcategories:

- The roadway is fully adequate for efficient bicycle travel, requiring no additional signing or pavement markings.
- The roadway is unsafe for bicycle travel and bicycle use should not be encouraged.

For military bases, gate approaches often fall into the second subcategory due to high congestion, security screening, and limited shoulder space. Where bicycles must pass through an ECF, designated lanes or separate queuing areas may be required to ensure safe and efficient movement while avoiding conflicts with vehicular traffic. At the ID check lanes, conflicts with vehicular traffic are often unavoidable as bikes are often required to use the vehicular lanes.

- ✓ **Signed, Shared Roadway:** These routes are designated by bike route signs, with the owning agency determining suitability for shared bicycle use. The route is maintained with consideration for bicyclists, and signage informs motorists that bicycles may be present. On military installations, signed bike routes may be used to guide cyclists toward safer base access points, along roads with adequate shoulders, and avoiding high-security gate areas with restricted entry.
- ✓ **Bike Lane**: Bike lanes are established with appropriate pavement markings and signing along roadways where there is significant bicycle demand. On military installations, designated bike lanes may be provided outside ECF access points but typically do not extend through security checkpoints due to cross section width and security constraints. In cases where bike access through an ECF is required, a separate bike lane or shared-use path should be incorporated into the roadway cross section to prevent bicycles from entering mixed vehicle lanes at entry gates.
- ✓ **Shared Use Path**: When bicycle traffic is frequent, shared paths should be provided where roadways or ECF approaches are inadequate for bike travel. Shared paths may be developed parallel to primary base roadways, connecting housing areas, training facilities, and office complexes. Where gate access is required, designated bicycle waiting areas or secondary access routes should be considered to avoid conflicts with motor vehicles during peak entry periods.

Military installations often require specific bicycle policies for base access. Where sidewalks exist, bicycles should not use them unless designated for shared pedestrian and bicycle use. Instead, bike lanes or shared-use paths should be prioritized to ensure safe and efficient movement for cyclists while maintaining base security and operational flow.



Bike Lane Example

4.3. TURNING MOVEMENTS



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

The selection of a design vehicle is a key control that must be established early in the design process. 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



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 the 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. Pamphlet Chapter 6 discusses intersection traffic control.

4.4.1. Intersection Types

Intersections are classified based on the number of intersecting legs, typically as three-legged (T-intersections), four-legged (cross intersections), or multi-legged intersections. However, intersections can vary significantly in size, shape, and channelization, influenced by surrounding roadway features and user demands.

In addition to traditional roadway-to-roadway intersections, intersections may also involve pedestrian and rail crossings, requiring additional design considerations:

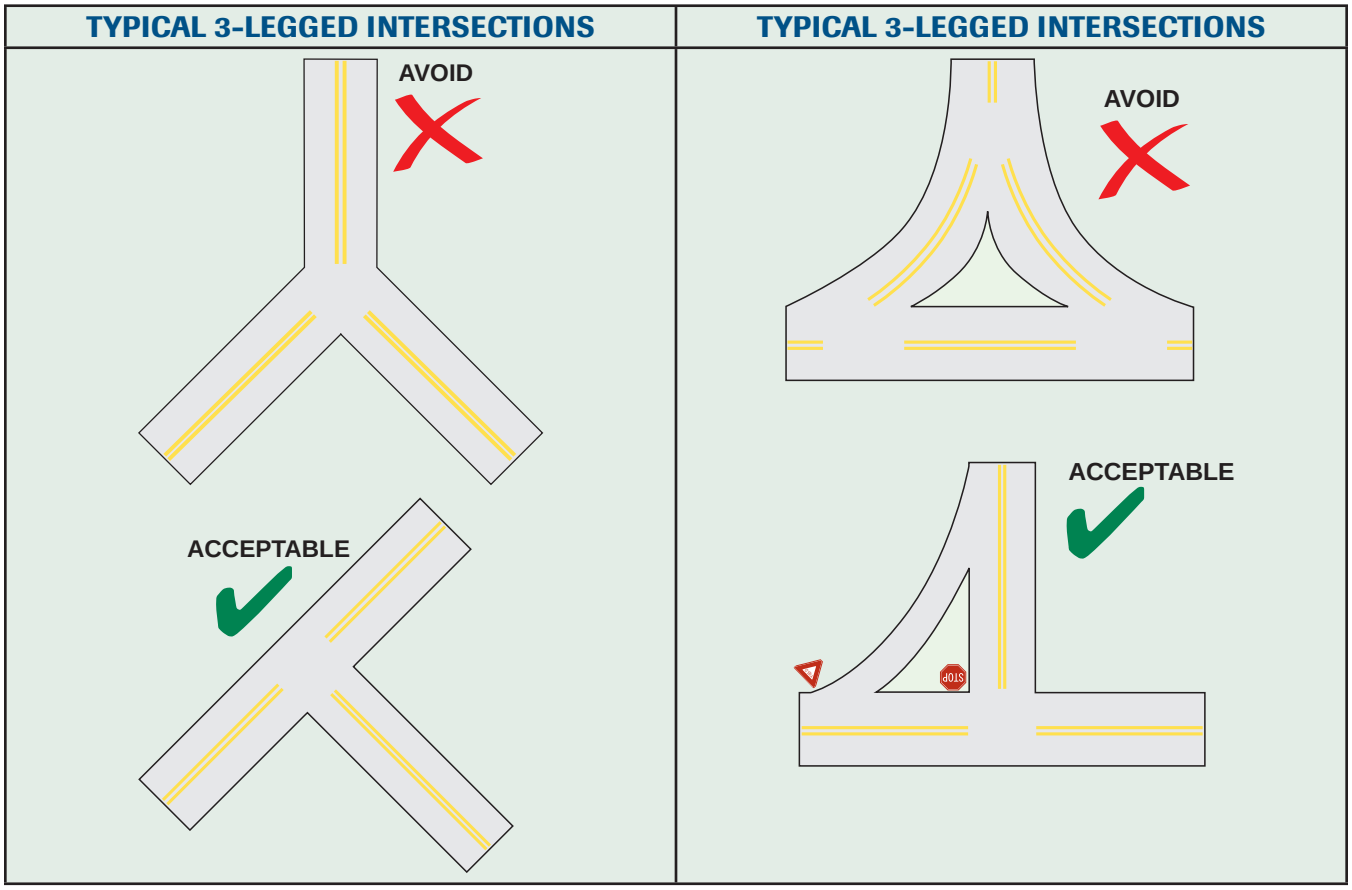
- ✓ Roadway-to-sidewalk intersections – Areas where pedestrian facilities intersect vehicular traffic, often requiring crosswalks, pedestrian signals, and accessibility measures.
- ✓ Roadway-to-rail intersections (at-grade crossings) – Locations where a road crosses railroad tracks at grade, necessitating warning signals, crossing gates, and sight distance accommodations.
- ✓ Multi-modal intersections – Complex intersections where bicycles, transit vehicles, and military or specialized transport must be accommodated alongside general traffic.

Once the intersection type is established, a final geometric design can be selected by applying the design controls and elements discussed later in this chapter.

Three-Legged

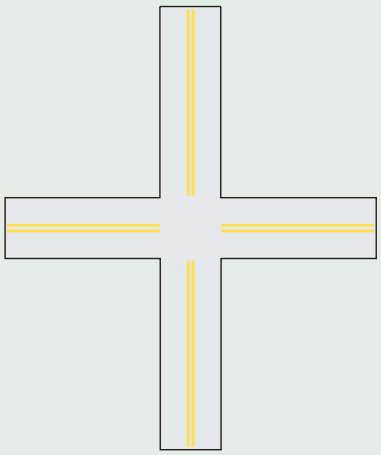
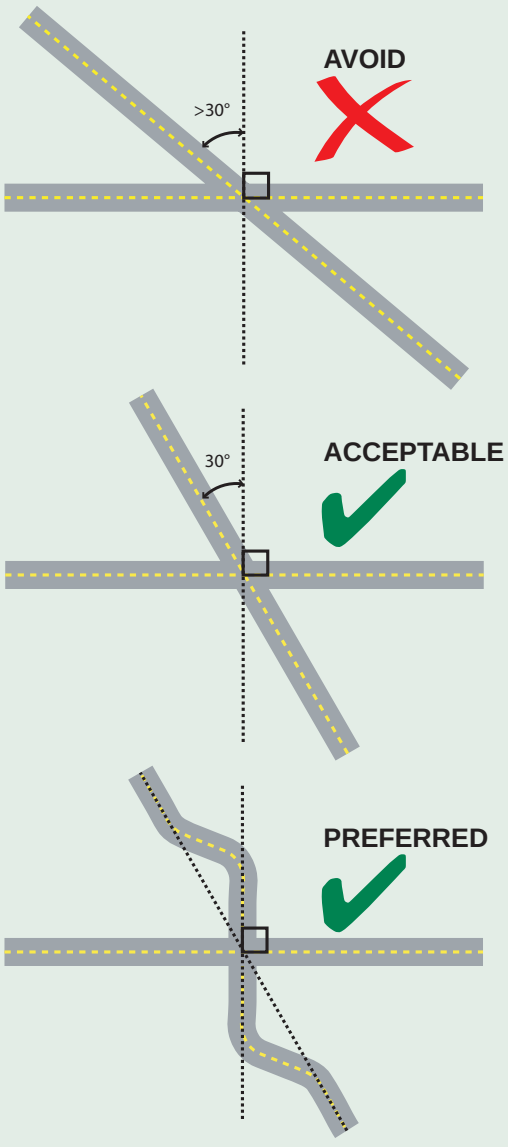
Generally, this design is used to terminate one roadway. The intersection may be flared or designed with turning roadways where turning movements are hazardous or where traffic volumes warrant their use. A Y-type design is undesirable and generally results in safety and operational problems.

An undesirable configuration of a three-legged intersection is one with two bidirectional segments off 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

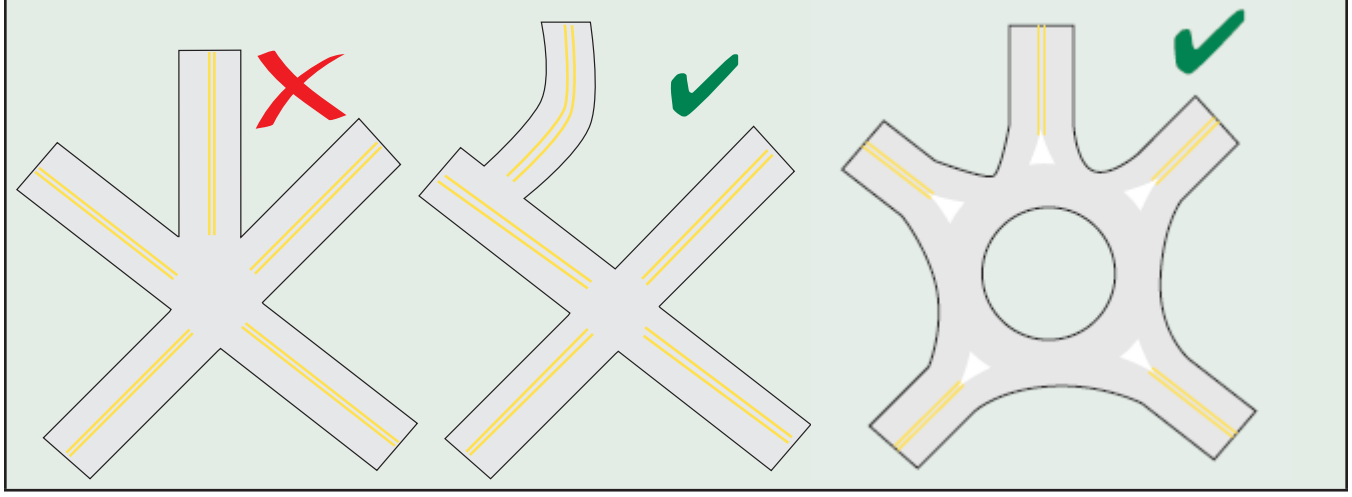
A four-legged intersection is formed where two roads meet. It allows for direct crossing movements. The four-legged intersection has many variations, which are based on operating conditions. The right-angle intersection is safest and easiest for drivers to traverse. When crossroads are not perpendicular, 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 below. 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.

TYPICAL MULTI-LEGGED INTERSECTION



Roundabouts

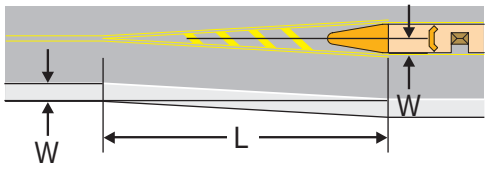
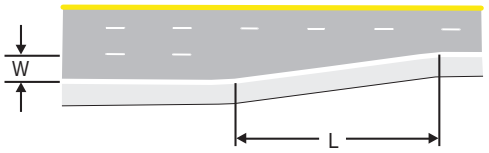
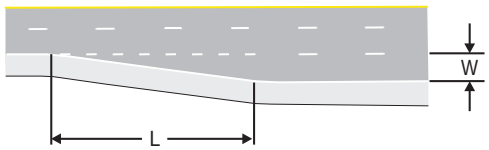
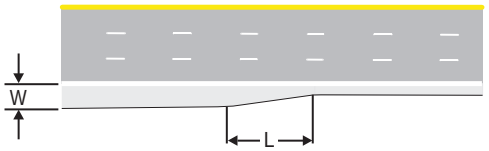
Roundabouts are another type of intersection, where traffic flows through a circular roadway. Traffic yields on entry to the circular roadway. Roundabouts are further discussed in pamphlet Chapter 10.

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: $WS^2/60$ ✓ 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 3-38 AND 3-39		✓ Speeds less than 45 mph: $L=WS^2/60$ ✓ Speeds of 45 mph or more: L=WS
LANE ADDED *SOURCE:* AASHTO *GREEN BOOK* PAGE 3-148		✓ Speeds less than 45 mph: $L=WS^2/90$ ✓ Speeds of 45 mph or more: L=(2/3)WS Minimum L = 100 feet in urban areas Minimum L - 200 feet in rural areas
SHOULDER-TO-CURB TRANSITION *SOURCE:* TEA		✓ All speeds: L=10W (10:1 ratio) recommended
W = Width of Lateral Shift (feet); S = Design Speed (mph); = Length of Taper (feet)		

Source: MUTCD and AASHTO *Green Book*

Intersection Locations

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

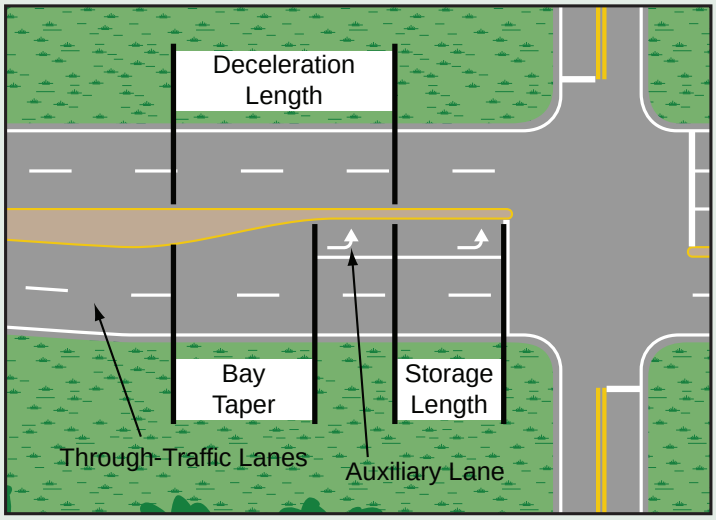
On high-speed roadways, it may be desirable to design turn lanes based on deceleration requirements rather than storage needs. This allows vehicles to gradually reduce their speed, thereby reducing the potential for rear-end collisions. Minimum deceleration lengths for lanes with an accompanying stop 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 is 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 *Green Book (pg 9-123)*

Exhibit 4.4: Desirable Full Deceleration Lengths

SPEED (MPH)	DISTANCE (FEET)
20	70
30	150
40	265
50	415
60	600
70	815

Note: These values only apply for design when raised median islands are used. Source: AASHTO *Green Book,* Chapter 9 Table 9-20

4.4.3. Islands and Channelization



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*

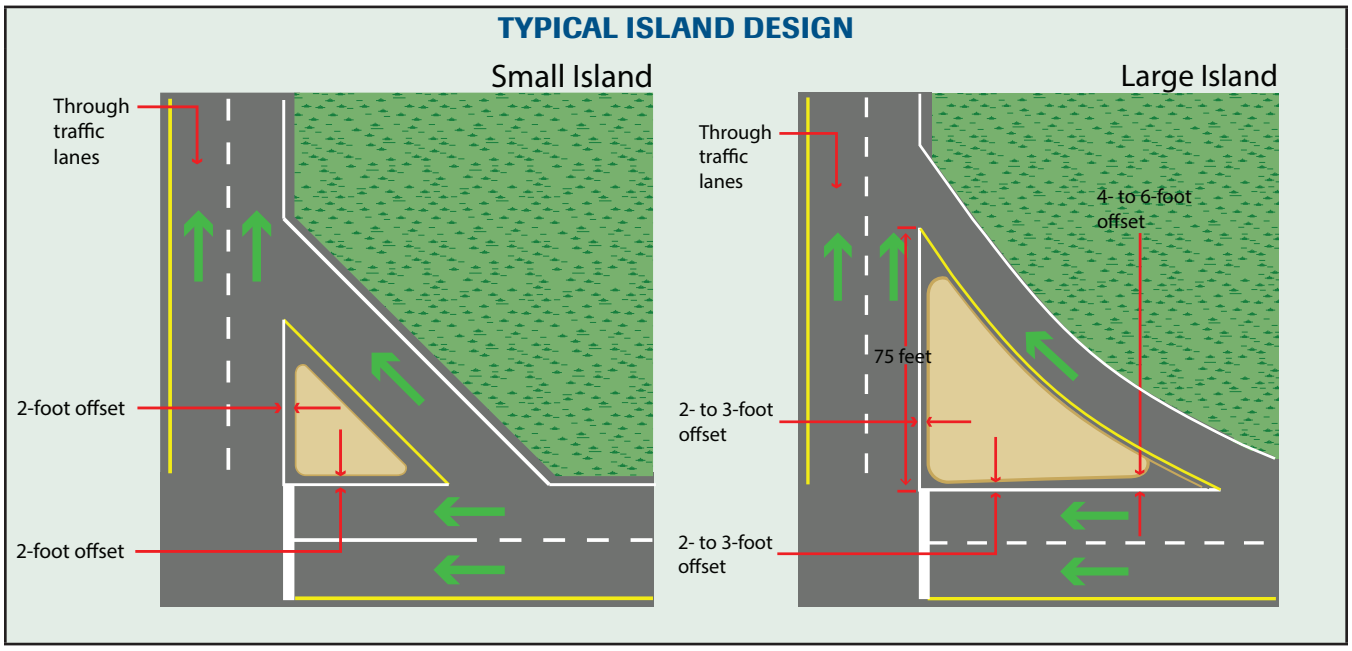
Raised islands should not be in the natural path of vehicles and should be clearly visible. Major through-traffic flow should be favored and not restricted. Avoid small islands that a vehicle could easily drive over. Islands should not be less than 75 square feet. If islands must be small, provide adequate 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 75 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.

Typical small and large island designs are shown in the figure below.



It is very important to properly sign raised channelization islands. Commonly used signs include: Divided Highway (W6-1 or W6-2) warning sign, KEEP RIGHT (R4-7), and LEFT LANE MUST TURN LEFT (R3-7).

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. 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 4.6 shows passing sight distance requirements for different speeds.

Exhibit 4.6: 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 pamphlet Chapter 8 - MARKINGS for additional information regarding passing sign distance and the marking of No Passing Zones.

4.5.2. Stopping Sight Distance



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.

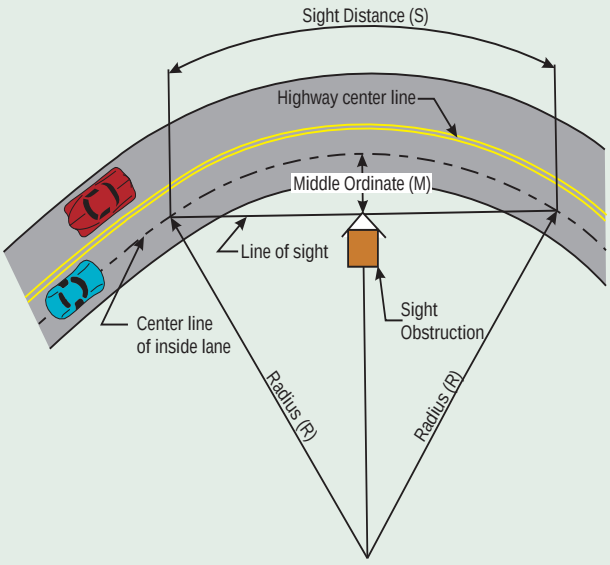
Providing appropriate stopping sight distance (SSD) addresses the need for the driver to be able to identify and react to an obstruction in the roadway ahead. This distance is based on the posted speed and the profile grade of the roadway. Calculations assume a 3.5 feet driver's eye height, a 2-foot object height, 11.2 ft/s^2 vehicle deceleration rate, and a driver reaction time of 2.5 seconds. The following table in Exhibit 4.7 shows the required SSD along a section of roadway for horizontal and vertical curves.

Exhibit 4.7: Minimum Stopping Sight Distance

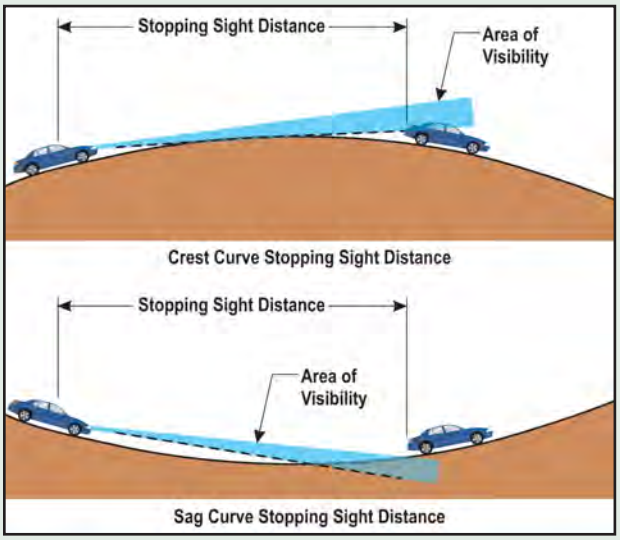
STOPPING SIGHT DISTANCES (FEET)							
SPEED (MPH)	LEVEL GRADE	DOWNGRADE			UPGRADE		
		3%	6%	9%	3%	6%	9%
25	155	158	165	175	147	143	140
30	200	205	215	227	200	184	179
35	250	257	271	287	237	229	222
40	305	315	333	354	289	278	269
45	360	378	400	427	344	331	320
50	425	446	474	507	405	388	375
55	495	520	553	593	469	450	433
60	570	598	638	686	538	515	495

Source: AASHTO, *Green Book*

UNOBSTRUCTED STOPPING SIGHT DISTANCES THROUGH CURVES



CREST AND SAG VERTICAL CURVES



4.5.3. 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.

For comprehensive guidance on intersection sight distance, including no control, stop control, and yield

control scenarios, refer to Section 6, which incorporates AASHTO *Green Book* Section 9.5 recommendations and calculation methods. Design teams can also use TEA's BMTE calculator to compute intersection sight distance values based on specific roadway and vehicle characteristics.

While Section 6 provides in-depth guidance, designers should account for sight distance needs early in the geometric layout process to ensure safe and efficient intersection operations.

4.6. HORIZONTAL ALIGNMENTS

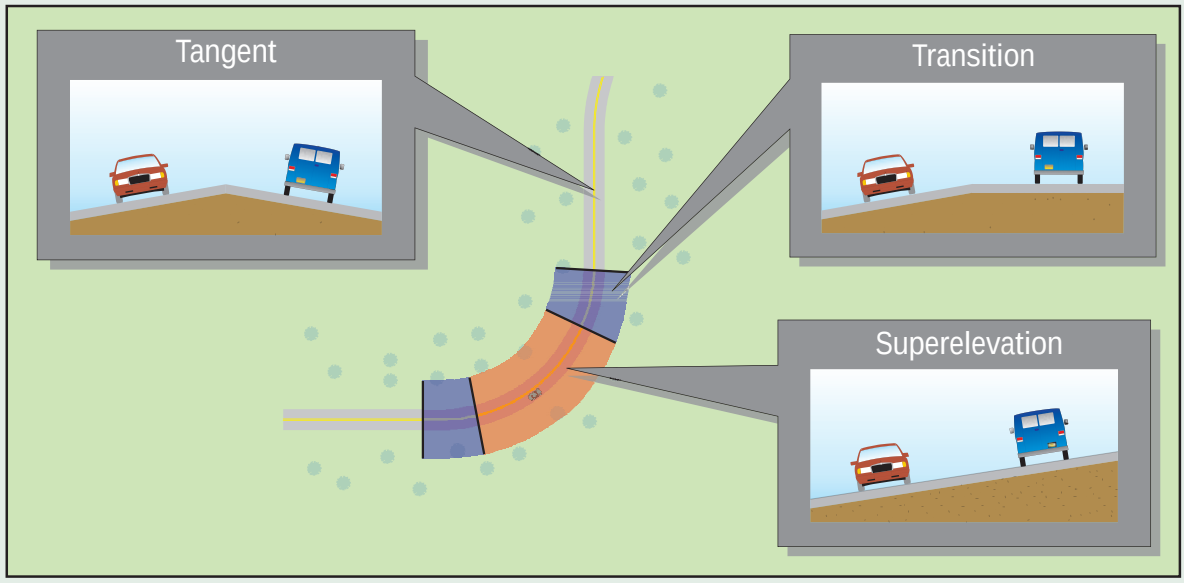
KEY POINT

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 4.8 shows required K values for varying speeds. Refer to Chapter 3.4 of the AASHTO *Green Book* for additional information.

Exhibit 4.8: 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. 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 – CIVIL SECTOR STANDARDS AND GUIDELINES

5.1. FHWA – *MUTCD* 5-1

5.2. FHWA – *STANDARD HIGHWAY SIGNS* (SHS) 5-5

5.3. AASHTO – *A POLICY ON GEOMETRIC DESIGN OF HIGHWAYS AND STREETS* 5-6

5.4. AASHTO – *ROADSIDE DESIGN GUIDE* (RDG) 5-6

5.5. ITE – *TRAFFIC ENGINEERING HANDBOOK* 5-7

5.6. TRB – *HIGHWAY CAPACITY MANUAL* (HCM) 5-7

5.7. ABA STANDARDS AND PROWAG 5-7

5.8. ANSI/IES RP-8 – *RECOMMENDED PRACTICE: LIGHTING ROADWAY AND PARKING FACILITIES* 5-8

5.9. MILITARY STANDARDS 5-8

CHAPTER 5 – CIVIL SECTOR STANDARDS AND GUIDELINES

Transportation planning and engineering on military installations must balance mission-specific requirements with the well-established practices used throughout the civil sector. To promote consistency, safety, and operational efficiency, installations should apply widely recognized civil-sector transportation standards wherever appropriate. This chapter explains the applicability of the most commonly used civil-sector guidelines—including the *MUTCD* and the FHWA *Standard Highway Signs* (SHS publication), the American Association of State Highway and Transportation Officials (AASHTO) *Green Book*, the AASHTO *Roadside Design Guide*, the Architectural Barriers Act Accessibility Standards (ABA) and Public Rights-of-Way Accessibility Guidelines (PROWAG), the Institute of Transportation Engineers (ITE) *Traffic Engineering Handbook*, the Transportation Research Board (TRB) *Highway Capacity Manual* (HCM), and *the ANSI/IES RP-8 Recommended Practice: Lighting Roadway and Parking Facilities* - and provides guidance on how these resources should be considered during planning, design, and implementation.

Unified Facilities Criteria (UFC) and United Facilities Supplement (UFS), while not civil-sector standards, are addressed separately in this chapter to clarify their role and applicability on military installations.

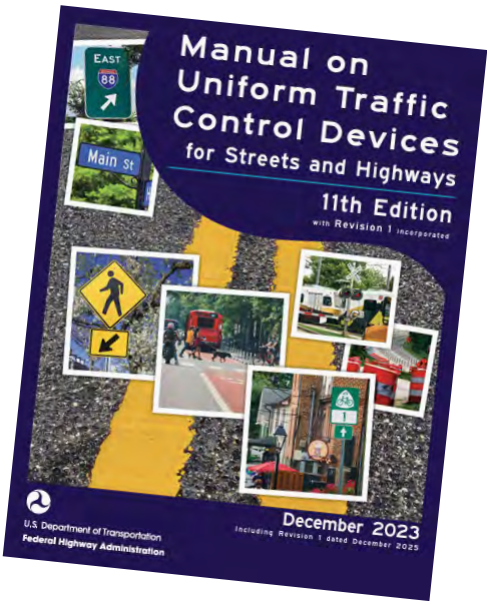
5.1. FHWA – *MUTCD*



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 at no cost at https://www.mutcd.fhwa.dot.gov.

The *MUTCD* is the national standard for all traffic control devices installed on any street, highway, or bicycle trail open to public travel. Because military installations interface with public road networks and serve a mix of drivers, *MUTCD* provides the baseline for consistent and recognizable traffic control. The manual is intended to promote efficiency by creating national uniformity in the meaning and appearance of traffic control devices; promote national consistency in the use, installation, and operation of devices; provide basic principles for traffic engineers to use in making decisions regarding the use, installation, operation, maintenance, and removal of traffic control devices; and promote safety for all road users. Criteria are provided for the following:

- ✓ Signing, including object markers and delineators
- ✓ Markings (pavement, curb, crosswalk, roundabouts, preferential lanes, rumble strips)
- ✓ Traffic signals
- ✓ Traffic control device considerations for automated vehicles
- ✓ Temporary traffic control (for work zones), including channelizing devices
- ✓ Traffic control for school areas
- ✓ Traffic control for railroad and light rail transit grade crossings
- ✓ Traffic control for bicycle facilities



As the most current version, the *MUTCD* 11th Edition is the primary resource for personnel managing roadway safety and operations.

5.1.1. *MUTCD* Applicability

Roadways Open to Public Travel

All DoW roadways that are open to public travel must comply with *MUTCD* standards. This includes installation access roads, perimeter routes, and any internal roadways. Compliance is mandatory to ensure uniformity with adjacent civil jurisdictions and to facilitate a safe and predictable traffic environment for both military and civilian drivers.

Restricted-Access Roadways

Internal roadways with full-time access restrictions to allow authorized personnel only are exempt from mandatory *MUTCD* compliance. Nevertheless, it is recommended that installations implement *MUTCD* guidelines where practical to support uniformity and minimize confusion.

5.1.2. Federal Mandates

The *MUTCD* is the national standard for all traffic control devices installed on streets and highways throughout the United States. The *MUTCD* is developed through a joint effort between the National Committee on Uniform Traffic Control Devices (NCUTCD) and the FHWA, with the Federal Highway Administrator holding the authority for its ultimate approval.

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

1. Per DoD Manual 4510.12, DoD Transportation Engineering Program, 14 June 2023

   Section 5.2:

   Installation commanders are to develop and maintain installation roadways to (1) Provide a safe driving environment for all drivers and passengers and (2) Meet Federal and State standards.

   Substantially conform to the Manual on Uniform Traffic Control Devices, the *DoW Supplement to the MUTCD* for Streets and Highways, and State DOT adopted versions of the Manual on Uniform Traffic Control Devices for all installation traffic signs, signals, markings, and other devices used to warn, regulate, or guide traffic.

   Make every effort to conform to traffic laws and regulations of the host nation when the installation is located outside the United States.

2. Per Code of Federal Regulations—32 CFR 634.4, titled “Responsibilities,” outlines the duties of various Army and Department of Defense (DoD) officials regarding the supervision of motor vehicle traffic on military installations.

   (h) Facility engineer (public works officer at Navy installations). The facility engineer, engineer officer or civil engineer at Air Force installations, in close coordination with the law enforcement officer, will ensure that traffic signs, signals, and pavement markings conform to the standards in the current Manual on Uniform Traffic Control Devices for Streets and Highways.

In accordance with Section 7-14.e of Army Regulation 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.

5.1.3. Supplementary Documents

The *DoW Supplement to the MUTCD* is a companion document to the national *MUTCD* (or state *MUTCD*, if applicable) that provides standards and guidance for traffic control requirements specifically adapted to the unique operational conditions present at military installations. Developed by TEA, it is available (at no cost) on the TEA website at https://www.army.mil/artrans#org-tea.

As a national standard, states have three options as it relates to the *MUTCD* - (1) adopt the national *MUTCD*, (2) develop and adopt their own state *MUTCD* that is in substantial conformance with the national *MUTCD*, or (3) adopt the national *MUTCD* and develop/adopt an accompanying supplement to the national *MUTCD*. The *MUTCD* website (https://mutcd.fhwa.dot.gov/resources/state_info/index.htm) provides a color-coded map of all 50 states, plus Puerto Rico and Washington D.C., that illustrates what each state has adopted. Refer to this map to determine your state's requirement.

Military installations are required to comply with both the *DoW Supplement to the MUTCD* and the *MUTCD* that is applicable to their host state. The *DoW Supplement to the MUTCD* does not replace the state *MUTCD* or its supplement; it is in addition to it. Nothing in the *DoW Supplement* will contradict the *MUTCD* as it contains traffic control devices that are only found on a military installation.

5.1.4. Purpose and Principles of Traffic Control Devices

KEY POINT

Drivers must be able to trust that a traffic control device will carry the same meaning and require the same action everywhere it is encountered.

Traffic control devices are fundamental for regulating, warning, and guiding all users on streets, highways, pedestrian facilities, bikeways, and other pathways accessible to the public. As defined in Section 1A.02 of the *MUTCD*, these devices include signs, signals, markings, and channelizing elements that use colors, shapes, symbols, words, sounds, and tactile information to communicate critical messages. These devices enhance safety and operational efficiency by facilitating the orderly movement of all road users.



The effectiveness of these devices is contingent upon their uniform design, placement, operation, and maintenance. The *MUTCD* provides a framework of mandatory Standards to ensure consistency and recommended Guidance to allow for engineering flexibility based on specific traffic and roadway conditions. Uniformity is a foundational principle, as treating similar situations consistently reduces road user perception-reaction time and fosters predictable interactions among all users. Factors such as vehicle speed are a critical input for determining the appropriate design and placement of traffic control devices.

CHAPTER 5 – CIVIL SECTOR STANDARDS AND GUIDELINES

Proper implementation of traffic control devices ensures that road users receive the information necessary to navigate streets, highways, pedestrian facilities, and bikeways safely and in compliance with the law. By following *MUTCD* principles, transportation professionals can enhance mobility, accessibility, and safety for all users.

5.1.5. *MUTCD* Terminology

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.

Section 1C.01 in the *MUTCD* defines these terms as follows:

- ✓ **Standard** – a statement of required, mandatory, or specifically prohibitive practice regarding a traffic control device. In limited, location-specific cases, the results of a documented engineering study (see Section 1D.03) might indicate a deviation from one or more requirements of a Standard provision to be appropriate. 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 Option statements.
- ✓ **Guidance** – a statement of recommended practice in typical situations, with deviations allowed if engineering judgment or engineering study (see Section 1D.03) 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 Option statements.
- ✓ **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.

5.1.6. Engineering Study and Engineering Judgment

The selection and placement of a specific traffic control device at any location should be based on the results of an engineering study or the application of sound engineering judgment.

Refer to TEA Pamphlet 55-8 for guidance on engineering studies that can be conducted as recommended.

Thus, while the *MUTCD* provides standards, guidance, and options for the design and application of traffic control devices, the document should not be considered a substitute for engineering judgment. Engineering judgment should be applied not only in the selection and implementation of traffic control devices, but also in the design and layout of the associated roadways. The final decision to install or remove any traffic control device should be made by a qualified traffic engineer.

5.1.7. Removing Unauthorized Signs and Markings

Unauthorized or non-conforming traffic control devices undermine the purpose and principles of the *MUTCD*. 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.
- ✓ Creates confusion.
- ✓ May create a safety problem.

Unauthorized or illegal devices should be removed immediately and without prior notification.

5.2. FHWA - *STANDARD HIGHWAY SIGNS* (SHS)



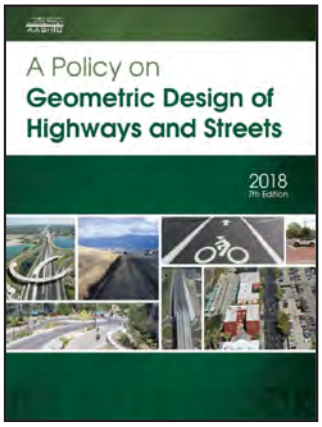
The FHWA *Standard Highway Signs* (SHS) publication is an accompanying document to the *MUTCD* that provides detailed design specifications for the signs contained within the *MUTCD*, including dimensions, letter heights, layouts, and symbol artwork. These specifications ensure that traffic signs are consistent, legible, and recognizable across all jurisdictions. Military installations should rely on the *SHS* publication to properly fabricate and implement *MUTCD*-compliant signs and to maintain uniformity with surrounding public road networks.

The current standard is the 2004 *SHS* (including its 2012 Supplement), which reflects sign designs from the 2009 *MUTCD*. This version will ultimately be superseded by the upcoming 2024 *SHS* Edition. The 2024 manual will feature design details for all 11th Edition *MUTCD* signs and pavement markings, expanded design guidelines, and symbolic traffic/lane-control signal indications. To accommodate the high volume of new signs, individual pages are being made available via phased releases on the *MUTCD* website. In addition, please note that several sign designs have been discontinued and rendered obsolete under the 11th Edition - most notably the "Share the Road" (STR) plaque, which research indicated was too vague and poorly understood by drivers.

Installations shall systematically integrate new FHWA-released sign designs as they become available and decommission any signs removed from the *MUTCD*. Timely adoption of newly released FHWA designs ensures installation traffic control devices remain current, uniform, and fully compliant with national standards. When operational requirements necessitate a non-standard traffic sign, designers should apply standard *SHS* design principles wherever practical. This practice preserves driver expectancy, maintains visual familiarity, and minimizes motorist confusion.

As an accompanying document to the *MUTCD*, the *SHS* publication is available at no cost on the FHWA-*MUTCD* website.

5.3. AASHTO - *A POLICY ON GEOMETRIC DESIGN OF HIGHWAYS AND STREETS*



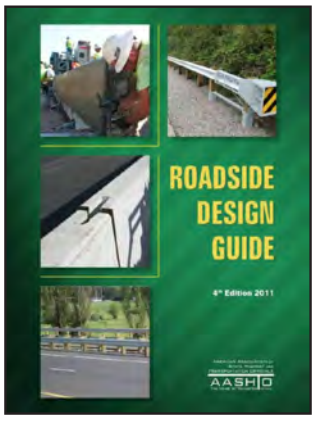
The AASHTO *Policy on Geometric Design of Highways and Streets*, (commonly called the AASHTO "*Green Book*") serves as the national standard for roadway geometric design. It defines fundamental criteria for the safe and efficient design of geometric components for transportation facilities, such as:

- ✓ Cross Section Elements
- ✓ Horizontal and Vertical Alignments
- ✓ Sight Distance Requirements
- ✓ Intersection and Interchange Basic Design Elements

The manual also addresses design vehicles and the relationship between geometric design features and traffic operations, as well as the relationship with crash frequency and severity. Adhering to these established concepts ensures that roadways are engineered to support safe, efficient, and predictable traffic operations. A more detailed discussion of these geometric design features is provided in pamphlet Chapter 4.

The 7th Edition (2018) represents the current version of the AASHTO *Green Book*. Military installations should utilize this publication as their primary civil-sector geometric design reference to ensure installation roadway networks function seamlessly with adjacent public corridors and align with motorist expectations. The AASHTO *Green Book* is particularly critical during the planning and preliminary engineering phases, where it establishes the technical baseline for evaluating design alternatives and developing roadway concepts.

5.4. AASHTO - *ROADSIDE DESIGN GUIDE* (RDG)



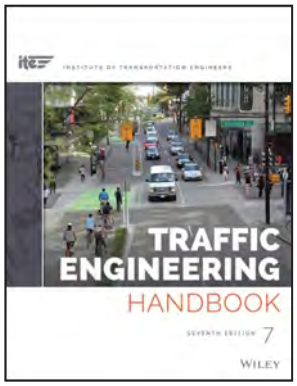
The AASHTO *RDG* provides nationally recognized criteria for engineering safer, more forgiving roadsides and implementing treatments that mitigate crash severity when vehicles depart the traveled way. The *RDG* addresses the following type of information:

- ✓ Barrier Types
- ✓ Barrier Warrants
- ✓ Barrier Placement
- ✓ Clear Zone Requirements
- ✓ Crash Attenuators
- ✓ Breakaway Supports

Because these principles fundamentally intersect with multiple facets of roadway engineering, *RDG* concepts are integrated throughout this pamphlet. Specifically, pamphlet Chapters 4, 7, 8, and 11 reference *RDG* criteria regarding clear zones, sign supports, breakaway hardware, lateral offsets, fixed objects, and urban roadside conditions to provide context-specific application guidelines.

The 4th Edition (2011) represents the current version of the *RDG*. Military installations are encouraged to utilize the *RDG* to evaluate roadside hazards and determine appropriate protective devices or geometric adjustments, ensuring installation environments align with civil-sector safety practices and driver expectancy.

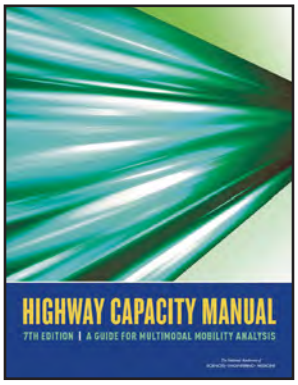
5.5. ITE - *TRAFFIC ENGINEERING HANDBOOK*



The ITE *Traffic Engineering Handbook* provides practical, industry-standard guidance for the planning, designing, and operation of multimodal transportation facilities. Aligned with widely accepted traffic engineering practices, this reference supports engineering decisions regarding intersection operations, auxiliary and turn lanes, pedestrian and bicycle accommodations, parking demand, access management spacing, and traffic-calming strategies.

On installations, the handbook is most useful for addressing operational challenges that are not fully covered by mandated standards such as the *MUTCD* or AASHTO publications.

5.6. TRB - *HIGHWAY CAPACITY MANUAL* (HCM)



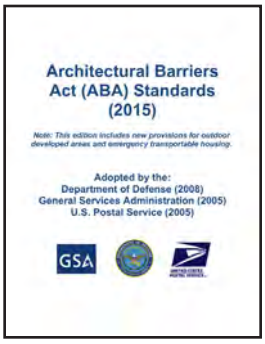
The TRB's *HCM* provides nationally accepted concepts, methodologies, and computational procedures for assessing capacity and quality (level) of service of various highway facilities and the effects of mass transit, pedestrians, and bicycles on the performance of these systems; inclusive of the following:

- ✓ Freeways
- ✓ Highways
- ✓ Roundabouts
- ✓ Intersections (Signalized and Unsignalized)

The *HCM* is the approved analysis method in the United States for assessing traffic operations.

The *HCM* is commonly used to evaluate existing and future traffic conditions, estimate delay and queuing, assess multimodal interactions, and support decisions related to roadway or intersection improvements. Since *HCM* methodologies provide the technical baseline for evaluating the operational performance of transportation networks, installation engineers can apply these procedures to systematically identify geometric shortcomings, traffic control deficiencies, or operational bottlenecks that require remediation to preserve target levels of service.

5.7. ABA STANDARDS AND PROWAG



The Architectural Barriers Act (ABA) Accessibility Standards establish requirements for accessible design in buildings, facilities, recreational areas, and off-street parking lots constructed or altered by federal agencies. The ABA Standards provide detailed criteria for accessible routes, parking, entrances, ramps, signage, and other features necessary to ensure usability by individuals with disabilities.

The Public Rights-of-Way Accessibility Guidelines (PROWAG) provide accessibility requirements for pedestrian facilities located within the road right-of-way. PROWAG addresses accessible elements within the transportation environment such as pedestrian access routes, sidewalks, crosswalks, curb ramps, detectable warning

surfaces, pedestrian signals, pedestrian push buttons, transit stops, on-street parking, and passenger loading zones. With its publication PROWAG serves as a primary source for federal accessibility standard for pedestrian facilities in the roadway environment.

Both the ABA Standards and the PROWAG provide means to meet the requirements of ABA Law and are used on military installations to ensure that pedestrian and facility designs accommodate all users. Together, they provide comprehensive accessibility guidance for both off-street facilities and pedestrian elements within the roadway environment. The standards are available at no cost through the U.S. Access Board website (https://www.access-board.gov/aba/).

5.8. ANSI/IES RP-8 – *RECOMMENDED PRACTICE: LIGHTING ROADWAY AND PARKING FACILITIES*

The ANSI/IES RP-8 (Recommended Practice number 8): Lighting Roadway and Parking Facilities standard provides nationally recognized guidance for the design and evaluation of lighting systems on roadways, intersections, roundabouts, pedestrian facilities, and parking areas. It establishes recommended lighting levels, uniformity ratios, glare control practices, and design considerations that support visibility, safety, and energy efficiency for all roadway users. RP-8-22 (2022 edition) also incorporated current lighting technologies, including LED systems, adaptive lighting strategies, and modern photometric evaluation methods. ANSI/IES RP-8-25, the 2025 edition, replaced the 2022 edition and is the current standard.

Use this guidance on military installations to ensure roadway and parking facility lighting meets modern civil-sector safety and visibility standards. These recommendations help installations design lighting systems that support nighttime driving, pedestrians, and security while remaining consistent with industry best practices.

5.9. MILITARY STANDARDS

Unlike the civil-sector standards referenced in this chapter, the UFC system provides DoW-specific planning, design, and construction requirements for military installations. These criteria supplement, not replace, national transportation standards such as the *MUTCD*, AASHTO publications, and ITE guidance. UFC documents ensure that transportation infrastructure supports installation missions, security needs, and long-term development goals while remaining compatible with broader civil-sector practices.

A UFS provides non-mandatory, supplemental information in support of UFC. As only UFC establishes enforceable criteria, UFSs are For Information Only and exist to help users understand and apply UFC requirements.

Following are relevant civil-related UFC/UFS documents:

UFC 3-120-01 Sign Standards

UFC 3-120-01 provides requirements for the selection, fabrication, installation, maintenance, and management of signs used on military installations. The document supplements traffic signing guidance contained in the *MUTCD* and establishes requirements for military-specific sign applications and facility identification signing.

UFS 2-100-01 Installation Master Planning

UFS 2-100-01 emphasizes the integration of transportation systems into area development planning. Roadways, pedestrian paths, and transit connections should be coordinated with land use to support mobility, access, and mission readiness. Transportation improvements should be considered during project siting and design to avoid future capacity shortfalls.

UFS 3-201-01 Civil Engineering

UFS 3-201-01 provides supplemental guidance for roadway geometry, drainage, site development, and other civil engineering elements commonly encountered on military installations. The document is intended to assist planners and designers in applying UFC requirements and engineering judgment during the planning and design process.

UFS 3-530-01 Interior and Exterior Lighting Systems and Controls

UFS 3-530-01 provides supplemental guidance for lighting systems and controls used on military installations. The document addresses considerations related to energy efficiency, maintainability, lighting technologies, and operational requirements that support the application of UFC criteria.

CHAPTER 6 – INTERSECTION TRAFFIC CONTROL

6.1. NO CONTROL 6-2

6.2. YIELD CONTROL 6-2

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6.6. TRAFFIC SIGNALS 6-14

6.7. RAILROAD GRADE CROSSINGS 6-16



The *MUTCD* provides guidelines and warrants for traffic control devices.

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

Determining the appropriate type of traffic control for a given intersection is a common challenge in traffic engineering. There are five fundamental types of intersection traffic control, ranging from least to most restrictive:

- ✓ No control
- ✓ Yield control
- ✓ Minor road stop control
- ✓ All-way stop control
- ✓ Traffic control signals

The core objective is to apply the least restrictive control that can effectively manage traffic, minimize delays, and provide a safe environment for all road users. Guidelines from the *MUTCD* inform this decision, primarily focusing on traffic volumes, pedestrian presence, available sight distance, and the intersection's crash record. This selection process must be conducted by a qualified traffic engineer. When additional expertise is needed, installations are encouraged to collaborate with the state transportation agency, county officials, local traffic engineering consultants, or TEA.

Engineering judgment plays a critical role in establishing intersection control and should take into account the following considerations:

- ✓ Vehicular, bicycle, and pedestrian traffic volumes on all approaches;
- ✓ Driver yielding behavior with regard to all modes of conflicting traffic;
- ✓ Number and angle of approaches;
- ✓ Approach speeds;
- ✓ Sight distance available on each approach;
- ✓ The presence of a grade crossing near the intersection; and
- ✓ Reported crash experience.

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



Stop control shall never be used for speed control.

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.

6.1. NO CONTROL

The most basic control type is to have no right-of-way traffic control devices (YIELD/STOP signs, traffic control signals) on any of the approaches to the intersection. 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.

The decision to leave an intersection without any traffic control must be supported by sound engineering judgment. This assessment should confirm that the intersection is inherently low-risk and simple in its design. Consideration for forgoing controls is appropriate when the following conditions are met:

- ✓ Clear Sight Lines: All approaches provide adequate and unobstructed sight distance.
- ✓ Simple Geometry: Each approach consists of a single lane with no separate turn lanes.
- ✓ Low Traffic Volume: The combined daily volume of all users (vehicles, bicycles, and pedestrians) is less than 1,000 units, or under 80 during the peak hour.
- ✓ No Designated Crossings: There are no marked crosswalks or bicycle lanes.
- ✓ Minor Roadways: None of the intersecting roads are classified as a through highway, main road, or other higher-order street.
- ✓ Near-Perpendicular Angle: The intersection angle is between 75 and 90 degrees.
- ✓ Low Functional Class: The intersection involves only local streets, or a local street intersecting with a collector street.

The factors listed may be considered when deciding not to use intersection control.

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

On through streets or highways, the standard right-of-way rules can be modified (or 'assigned') by installing YIELD or STOP signs to assign priority to the major road.



YIELD sign, R1-2

Per the *MUTCD*, selection of the minor road (to be controlled by YIELD or STOP signs) should be based on one or more of the following criteria:

- ✓ A roadway intersecting a designated through or numbered highway,
- ✓ A roadway with the lower functional classification,
- ✓ A roadway with the lower traffic volume,

- ✓ A roadway with the lower speed limit, and/or
- ✓ A roadway that intersects with a roadway that has a higher priority for one or more modes of travel.
- ✓ For the intersection of two roadways with relatively equal volumes, speeds, and/or other characteristics, consider the following factors in selecting the minor road:
  - Control the direction that conflicts the most with established pedestrian crossing activity or school walking routes;
  - Control the direction that has obscured vision, dips, or bumps that already require drivers to use lower operating speeds; and
  - Control the direction that has the best sight distance from a controlled position to observe conflicting traffic.

When choosing a control method, the least restrictive option that ensures safety should be considered first. Therefore, if a complete stop is not necessary at all times, a YIELD sign is preferable to a STOP sign. A YIELD (R1-2) sign requires drivers to slow down and yield to conflicting traffic, coming to a full stop only when necessary to avoid interference.

Per the *MUTCD*, consider Yield control when engineering judgment indicates that all of the conditions in Exhibit 6.1 exist.

Exhibit 6.1: Justification for YIELD Control

BASE CONDITIONS (ALL SHOULD APPLY)	✓ Yield control should be considered when engineering judgment indicates:
	• Adequate intersection sight distance
	• All approaches are single lane with no separate turn lanes
	• Intersection angle is between 75° and 90°
	• Functional classification is:
	  • Two local streets, or
	  • Local street intersecting a collector

CRASH HISTORY	✓ Yield control should be considered when: • Installing Yield Control: Two or more crashes in 12 months correctable by a YIELD sign • Converting from STOP to Yield: Two or fewer crashes in the previous 12 months
TRAFFIC VOLUMES	✓ Combined entering volume is less than: • 1,800 users per day, or • 140 users during the peak hour
SPECIAL GEOMETRY / CONDITIONS	✓ Yield control may be used at: • Second intersection of a divided highway or median break • Channelized turn lanes separated by islands • Merge conditions with inadequate acceleration distance or sight distance • Right-turn-only approaches with channelized geometry

CONTEXT-BASED APPLICATIONS	✓ Yield control may be appropriate: • Where a site-specific issue can be corrected with yield control • On low-volume rural roads where adequate control is provided
STANDARD REQUIREMENTS	✓ Yield signs shall be used on roundabout approaches ✓ Yield control shall not be used on all approaches of an intersection (except roundabouts)

Source: FHWA, MUTCD

Large (corner) sight triangles are required with the use of YIELD signs. Adequate intersection sight distance (as discussed in Section 6.5) is usually the controlling factor on whether a YIELD sign can be placed in lieu of a STOP sign on low volume roadways. YIELD signs may be installed at an intersection when any one of the conditions in Exhibit 6.2 applies.

Exhibit 6.2: Applications of a YIELD sign

	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.

	On low-volume rural roads if engineering judgment indicates that a YIELD sign would provide adequate control.
	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.



Yield Ahead sign, W3-2

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. Refer to Section 7.3.1. for placement of the advance warning sign.

6.3. MINOR ROAD STOP CONTROL

6.3.1. Purpose and Applications

STOP (R1-1) signs should be used if engineering judgment indicates that a stop is always required or when additional control beyond a YIELD sign is necessary. Minor-road stop control is applied at intersections where one roadway has priority over another, requiring vehicles on the minor road to stop and yield to traffic on the major road. This control improves safety and efficiency by reducing conflicts, particularly where sight distance is limited, crash history indicates a problem, or functional classification differences exist.

Per the *MUTCD*, consider stop control on the minor-road approach or approaches when engineering judgment indicates that one or more of the conditions in Exhibit 6.3 exist.

Exhibit 6.3: Justification for Minor Road Stop Control

RESTRICTED VIEW	✓ A restricted view exists that requires road users to stop in order to adequately observe conflicting traffic on the through street or highway.
CRASH HISTORY – FOUR-LEG INTERSECTION	✓ Three or more reported crashes in a 12-month period, or six or more reported crashes in a 36-month period, susceptible to correction by installation of minor-road stop control.
CRASH HISTORY – THREE-LEG INTERSECTION	✓ Three or more reported crashes in a 12-month period, or five or more reported crashes in a 36-month period, susceptible to correction by installation of minor-road stop control.
FUNCTIONAL CLASSIFICATION DIFFERENCE	✓ The intersection is of a lower functional classification road and a higher functional classification road.
CHANGE IN CONDITIONS	✓ Conditions that previously supported installation of all-way stop control no longer exist.
LOW-VOLUME RURAL ROADS	✓ A STOP sign should be considered where the functional classification difference (noted above in table) applies, or where inadequate sight distance exists for the operating vehicle speeds.

Source: FHWA, MUTCD

After the decision has been made to install stop control, the decision regarding the appropriate street to stop should be based on engineering analysis. The STOP signs are normally placed on the minor road, and typically placed on opposing approaches for a four-leg intersection or on a single approach for a three-leg intersection. Refer to section 6.2 for selecting the minor road.

STOP signs may be installed at an intersection when any one of the conditions in Exhibit 6.4 applies.

Exhibit 6.4: Applications of a STOP Sign on the Minor Road

	For a street entering a through highway or street.
	Where restricted view or crash records indicate a need for STOP sign control.

6.3.2. Sign Layout and Placement

At most military installations, STOP signs should be 30 inches or 36 inches. In most cases, the use of a 30-inch by 30-inch sign is adequate for single-lane conventional roads. The use of a 36-inch by 36-inch sign is appropriate for multi-lane conventional roads. At locations where a stop is unexpected, an oversized 48-inch by 48-inch sign can be used.

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. Refer to Section 7.3.1 for placement of the advance warning sign.

Note that 2-WAY plaques are obsolete, and are no longer allowed to be installed with STOP signs at minor-street 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 an all-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 sign, R1-1



Stop Ahead sign, W3-1



W4-4p

6.4. ALL-WAY STOP CONTROL

KEY POINT

2-Way, 3-Way, and 4-Way plaques mounted with STOP signs are obsolete.



All-way Stop Control

All-way stop control is helpful at locations where sight distance or crash history cannot be corrected through other means. When traffic volumes on both streets are balanced and visibility, pedestrian safety, or geometric conditions warrant stopping the other legs, all-way stop control should be considered. All-way stop control is most effective when the volume of traffic on the intersecting roads is approximately equal.

Per the *MUTCD*, the decision to install all-way stop control should be based on a documented engineering study that is performed by a qualified traffic engineer. The engineering study should assess factors affecting the current operation and safety of the intersection, the opportunities to enhance these conditions, and the relevant criteria outlined in the all-way stop control warrants provided in Exhibit 6.5.

Exhibit 6.5: All-Way Stop Control Warrants

WARRANT A: CRASH EXPERIENCE	An engineering study indicates that crashes susceptible to correction by all-way stop control have occurred. Typically: ✓ Four-leg intersection: ≥5 crashes in 12 months (or ≥6 in 36 months) ✓ Three-leg intersection: ≥4 crashes in 12 months (or ≥5 in 36 months)
WARRANT B: SIGHT DISTANCE	An engineering study indicates that available sight distance on minor-road approaches is insufficient for drivers to safely enter or cross the major road. In these cases, requiring all approaches to stop can mitigate conflicts.
WARRANT C: TRANSITION TO SIGNAL CONTROL OR YIELD CONTROL AT A CIRCULAR INTERSECTION	All-way stop control may be used as a temporary or transitional measure while implementing a traffic signal or converting to yield control at a circular intersection.
WARRANT D: 8-HOUR VOLUME (VEHICLES, PEDESTRIANS, BICYCLES)	An engineering study indicates that, for any 8 hours of an average day: ✓ Combined volume on major-street approaches ≥300 units/hour, and ✓ Combined volume on minor-street approaches ≥200 units/hour (same 8 hours). ✓ If 85th percentile speed > 40 mph, thresholds may be reduced to 70%

WARRANT E: OTHER FACTORS	Additional conditions identified in an engineering study may support all-way stop control, such as: ✓ Unusual geometric conditions ✓ High pedestrian or bicycle activity ✓ School, transit, or neighborhood context ✓ Need to control conflicts or address operational concerns not captured by other warrants

Source: FHWA, MUTCD

Warrants should not replace engineering judgment. Meeting a warrant for a specific traffic control device does not, by itself, justify the installation or omission of all-way stop control. Since every intersection has distinct features that influence its operation and safety, the decision to install or not install all-way stop control should ultimately be based on the findings of an engineering study conducted for that particular location. As stated in the *MUTCD*, "The satisfaction of an all-way stop control warrant or warrants shall not in itself require the installation of all-way stop control at an unsignalized intersection."

On site roadways open to pubic travel, engineering judgment may be the basis for the decision to install all-way stop control.

All-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 plaque size is 18-inches by 6-inches for single lane and multi-lane conventional roadways, and 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.



R1-3p

6.5. INTERSECTION SIGHT DISTANCE

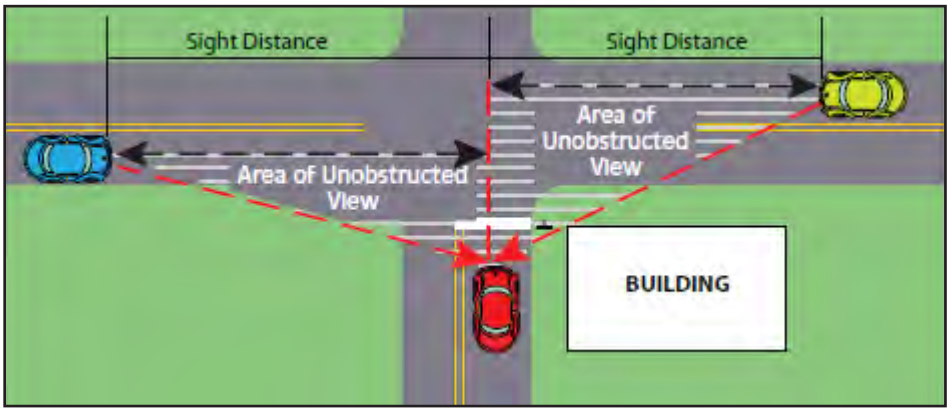
Intersection sight distance is the sight distance required by drivers to see one another (i.e., the driver at the entrance on the minor road pulling out onto the major road and the driver traveling along the major road). The sight distance requirements vary based on the type of intersection traffic control. 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. TEA's BMTE calculator can be used to compute these sight distances (See pamphlet Chapter 1).

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 6.6, 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 6.6 shows sight distance requirements for a passenger car on a flat grade turning onto a two-lane roadway. TEA'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 6.6: Stop Control Intersection Sight Distances for Two-Lane Roadways (Feet)



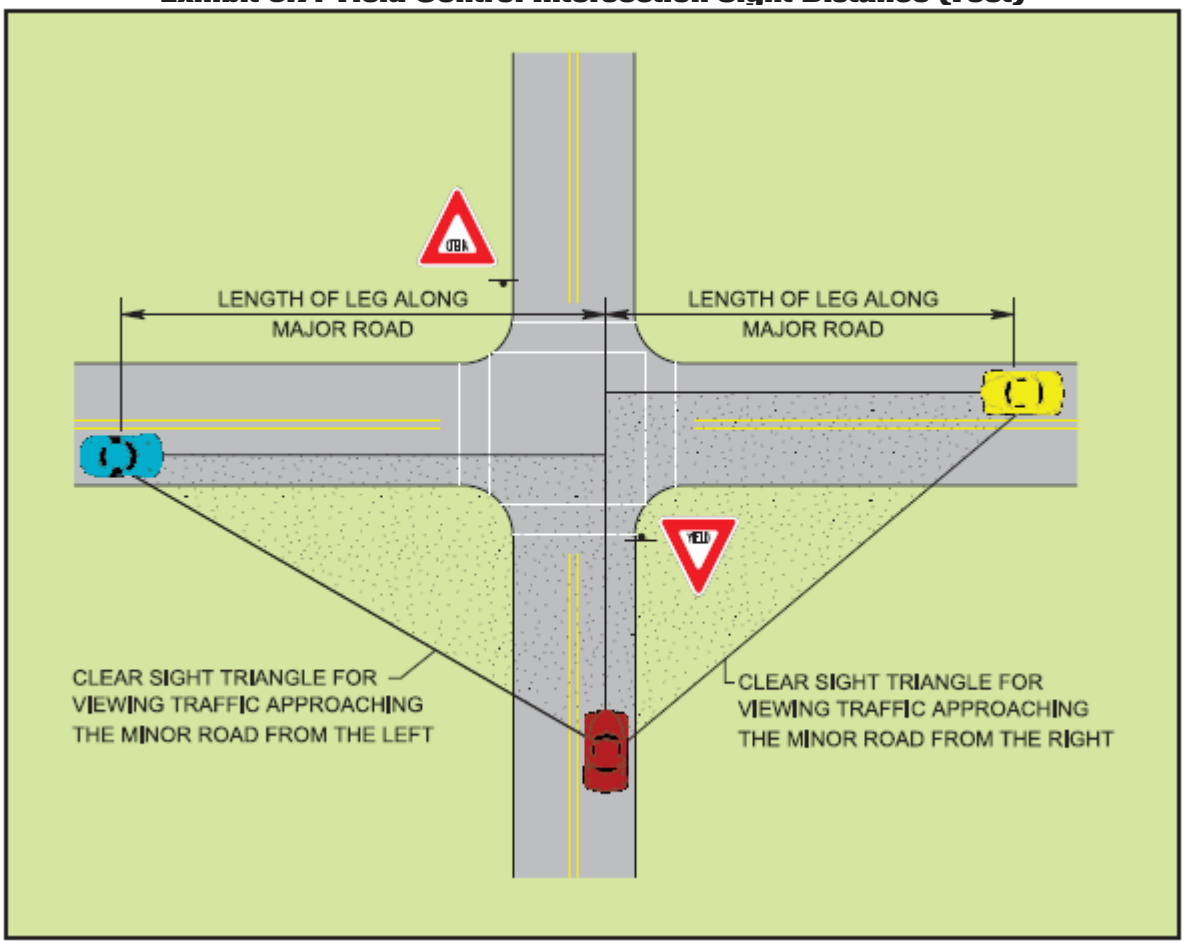
Note: The vertex (decision point) of the sight triangle on the minor road should be 14.5 ft. from the edge of the major road traveled way.

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 9–7 and 9–9

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 6.7 shows yield control sight distance for passenger vehicles crossing or turning onto a two-lane roadway, with level grades and no skew. TEA's BMTE calculator can be used to determine the recommended sight distances for other variables in this type of control.

Exhibit 6.7: Yield Control Intersection Sight Distance (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 9-53. The length of leg for left turns is equal to 82 ft. plus the lane width of the major road.*

CROSSING FROM MINOR ROAD				
MAJOR ROAD DESIGN SPEED (MPH)	**LENGTH OF LEG ALONG MAJOR ROAD (FT) MINOR-ROAD DESIGN SPEED (MPH)**			**LENGTH OF SIGHT TRIANGLE LEG ALONG MINOR ROAD (FT)**
	20-50	**55**	**60**	
25	240	250	255	130
30	290	300	305	160
35	335	345	360	195
40	385	395	410	235
45	430	445	460	275
50	480	495	510	320
55	530	545	560	370
60	575	595	610	420

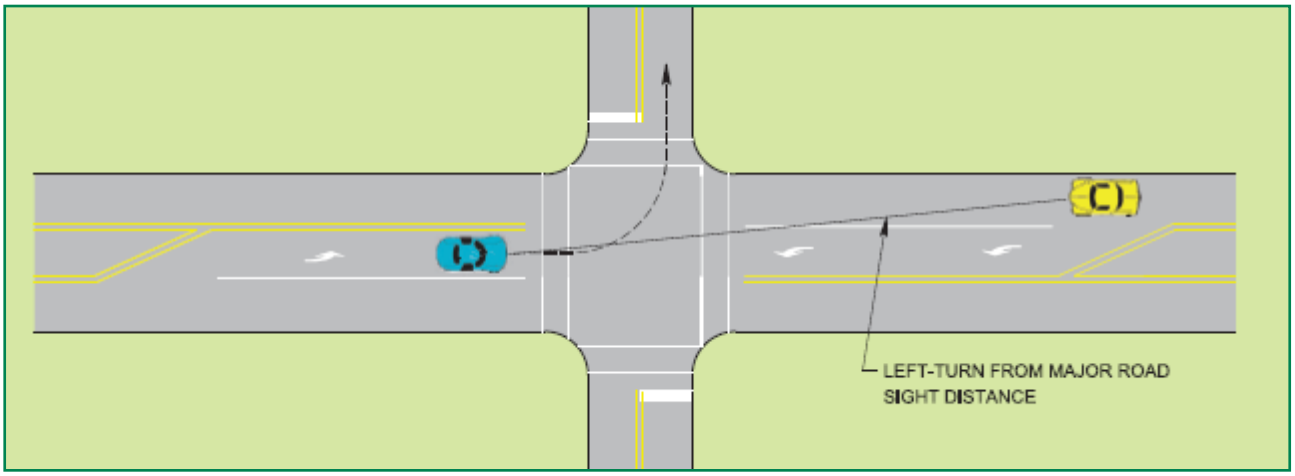
Source: AASHTO, Green Book, Tables 9-12, 9-13, and 9-15

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.

LEFT-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 6.8 shows the distance requirements for a passenger car crossing one lane of traffic. TEA's BMTE calculator can be used to determine the recommended sight distances for other variables in this type of control.

Exhibit 6.8: 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 9-17

6.6. TRAFFIC SIGNALS



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

Traffic signals assign the right-of-way between conflicting traffic flows at intersections. They are necessary when STOP sign control is insufficient to manage traffic effectively and can also provide improved accommodation for pedestrian crossings.

However, traffic signals that are unwarranted, poorly designed, incorrectly timed, or inadequately maintained may result in:

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

The installation of traffic signals should be determined through an engineering study that evaluates roadway, traffic, and other relevant conditions. Before signals are installed, at least one of the nine *MUTCD* signal warrants must be satisfied; however, meeting one or more warrants does not automatically justify installation. In fact, many state DOTs require that at least two warrants be met prior to installing traffic signals.

The nine *MUTCD* traffic signal warrants are based on vehicular volume, pedestrian activity, and crash experience. Exhibit 6.9 provides a brief overview of these warrants for reference, but it does not offer comprehensive guidance. For complete details, consult Chapter 4C of the *MUTCD.* Evaluation of warrants should be conducted by a qualified traffic engineer. If you believe an intersection may need signalization and would like assistance with the analysis, contact TEA or your state DOT (for external intersections) for a thorough evaluation.

Exhibit 6.9: 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 an engineering study determines that the pedestrian and vehicular volumes satisfy the criteria shown in *MUTCD* Figures 4C-5 through 4C-8, and there are insufficient gaps in the traffic stream of adequate length to permit pedestrians to cross the major street safely and conveniently.
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.
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

6.7. RAILROAD GRADE CROSSINGS

While not a traditional intersection, a railroad grade crossing is where a roadway and a railroad track intersect. At these crossings, trains always have the right of way, and various warning systems are used to alert vehicular traffic. These systems are classified as either Active or Passive Grade Crossings. Active Grade Crossings feature flashing lights and may include gates, whereas Passive Grade Crossings lack flashing lights or gates but must have appropriate signs and pavement markings.

Traffic control devices, signage, and pavement markings at railroad grade crossings must comply with the standards outlined in *MUTCD* Part 8, which provides requirements for both passive and active traffic control systems.

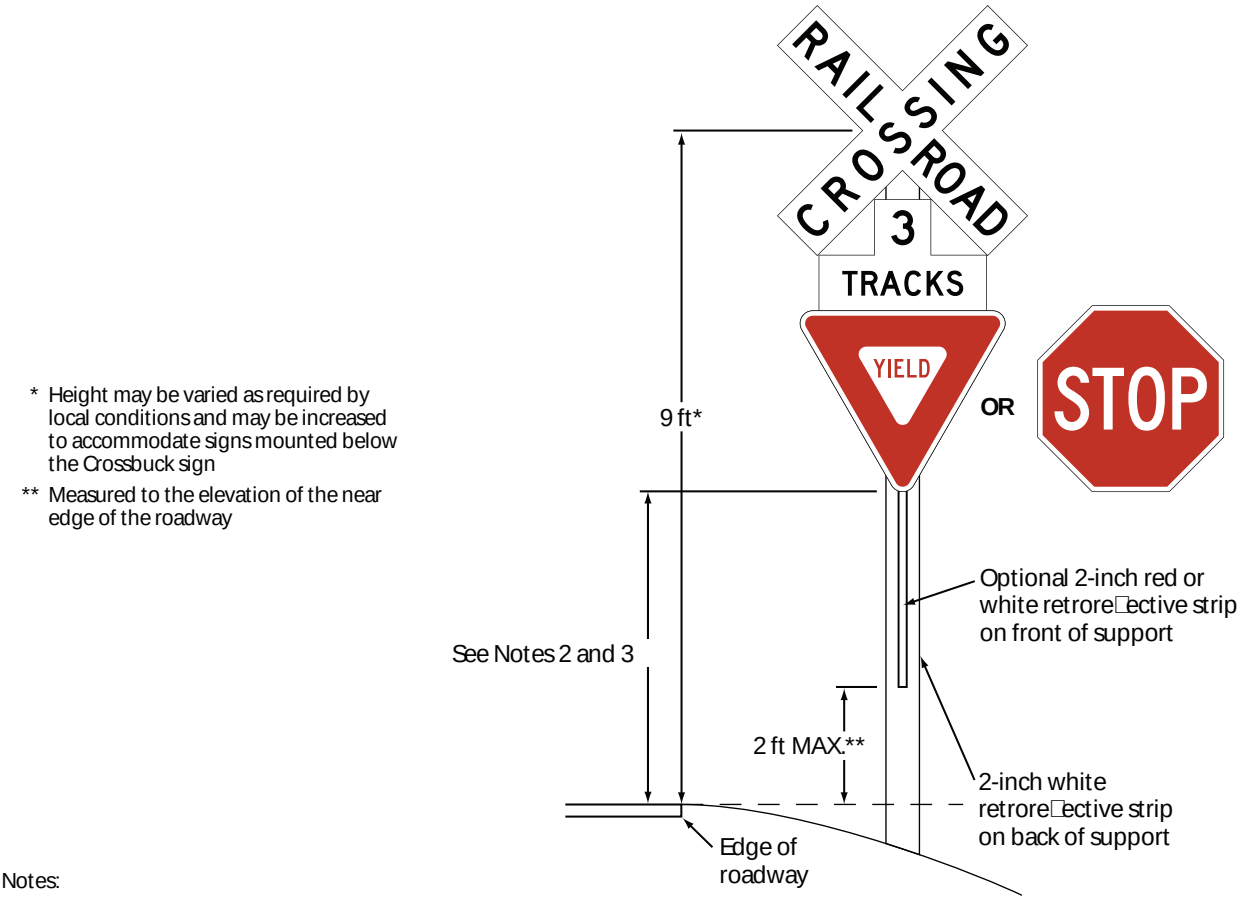
Passive traffic control systems use only signs and pavement markings to identify the grade crossing and alert drivers to slow down, yield, or stop as necessary. Active traffic control systems notify road users of an approaching or present train at the crossing. These may include four-quadrant gates, automatic gates, flashing light signals, traffic control signals, actuated blank-out and variable message signs, and other active devices.

6.7.1. Typical Signage for Passive Traffic Control Systems

Per the *MUTCD* Section 8B, at passive grade crossings, the 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. A YIELD sign shall be the default traffic control device for Crossbuck Assemblies on all highway approaches to passive grade crossings unless an engineering study performed by the regulatory agency or highway authority having jurisdiction over the roadway approach determines that a STOP sign is appropriate.

Exhibit 6.10 illustrates a Crossbuck Assembly with a YIELD or STOP sign on the Crossbuck Sign Support. Alternatively, Exhibit 6.11 illustrates a Crossbuck Assembly with a YIELD or STOP sign on a Separate Sign Support.

Exhibit 6.10: Crossbuck Assembly with a YIELD or STOP Sign on the Crossbuck Sign Support



* Height may be varied as required by local conditions and may be increased to accommodate signs mounted below the Crossbuck sign

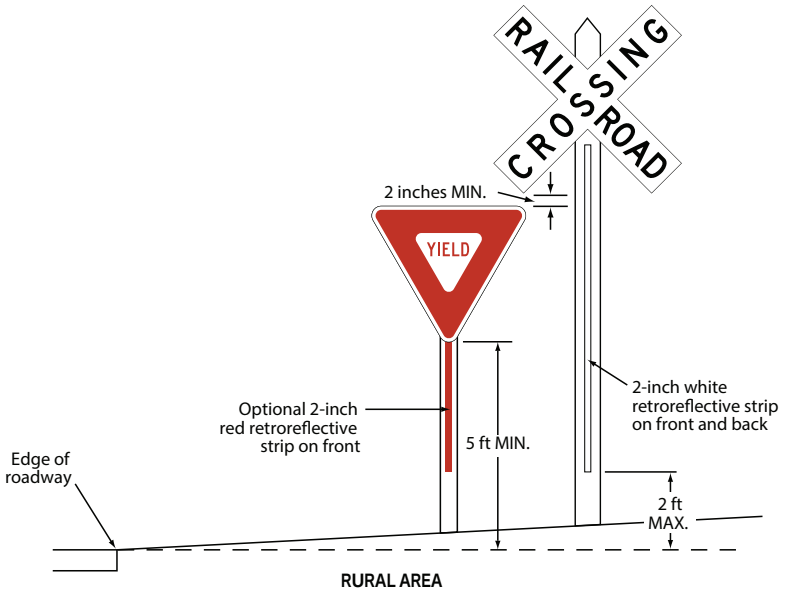
** Measured to the elevation of the near edge of the roadway

Notes:

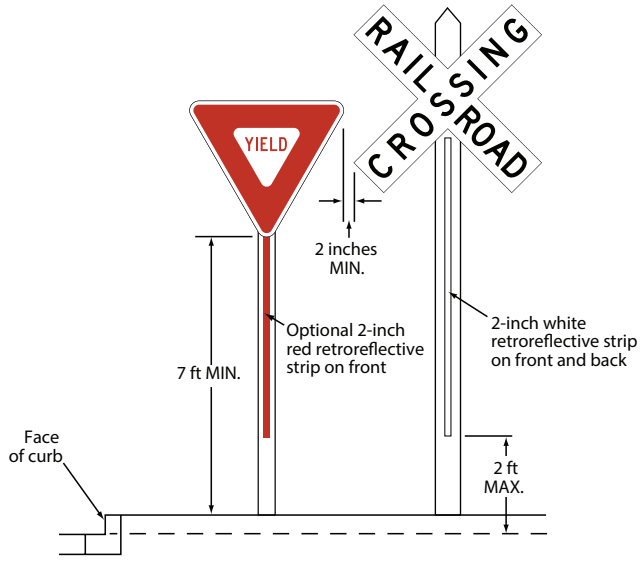
1. YIELD or STOP signs are used only at passive crossings. A STOP sign is used only if an engineering study determines that it is appropriate for that particular approach.
2. Mounting height shall be at least 4 feet for installations of YIELD or STOP signs on existing Crossbuck sign supports.
3. Mounting height shall be at least 5 feet for new installations in rural areas and at least 7 feet for new installations in areas where parking or pedestrian movements are likely to occur.

Source: MUTCD Figure 8B-2

Exhibit 6.11: Crossbuck Assembly with a YIELD or STOP Sign on a Separate Sign Support (Sheet 1 of 2)



RURAL AREA



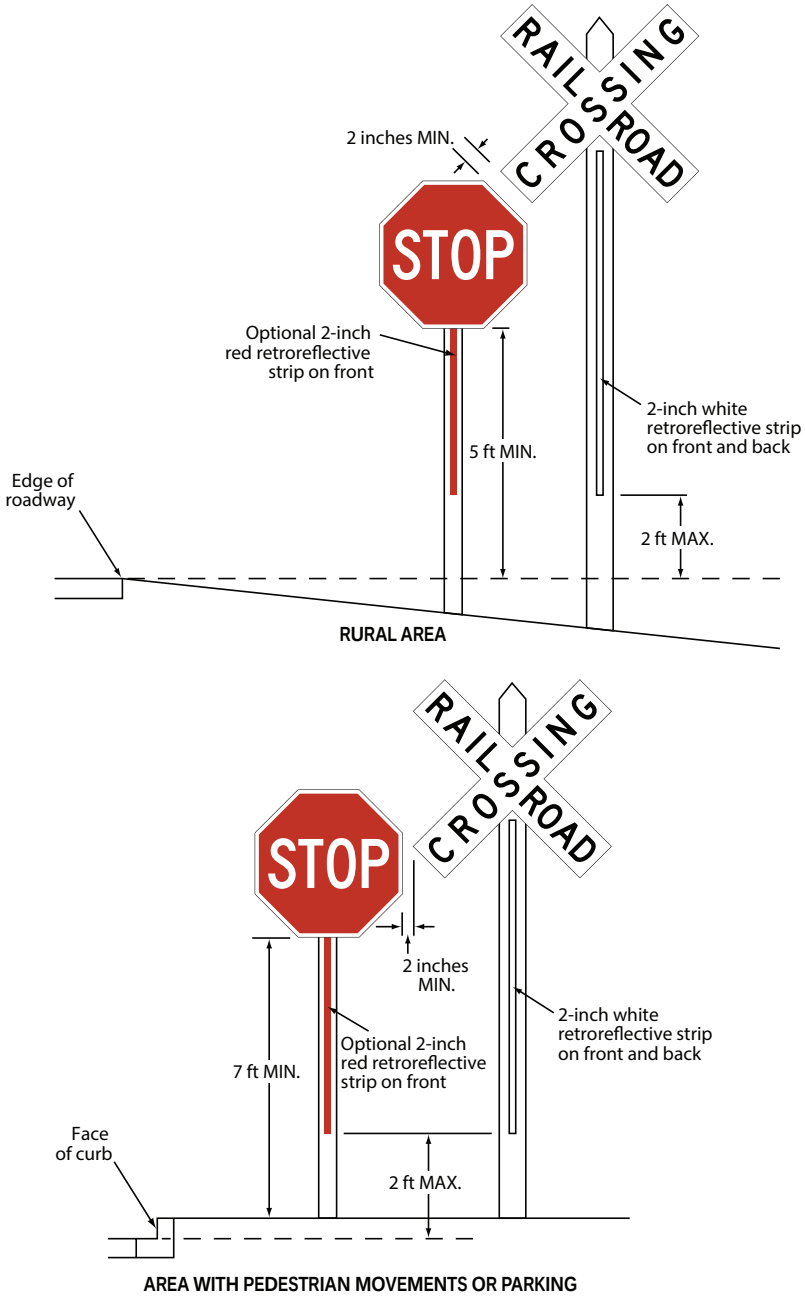
AREA WITH PEDESTRIAN MOVEMENTS OR PARKING

Notes:

1. YIELD signs are used only at passive crossings.
2. Place the face of the signs in the same plane and place the YIELD sign closer to the traveled way. Provide a 2-inch minimum separation between the edge of the Crossbuck sign and the edge of the YIELD sign.

Source: MUTCD Figure 8B-3 (1 of 2)

Exhibit 6.11 Continued: Crossbuck Assembly with a YIELD or STOP Sign on a Separate Sign Support (Sheet 2 of 2)



Notes:

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

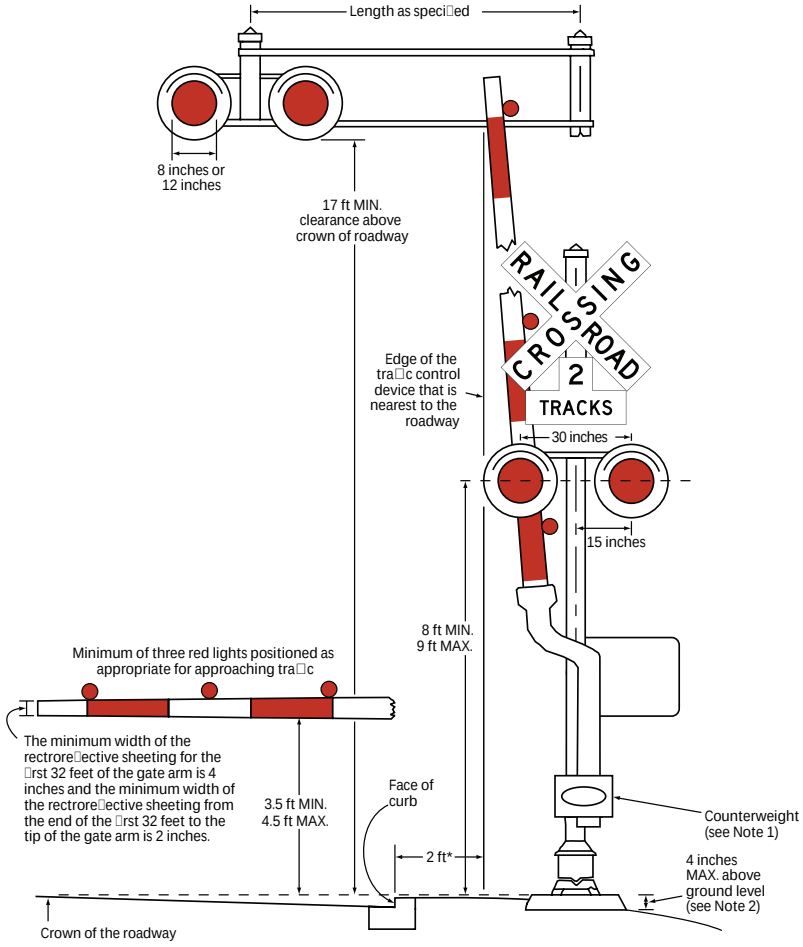
Source: MUTCD Figure 8B-3 (2 of 2)

6.7.2. 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 6.12, post-mounted and overhead flashing-light signals may be used separately or in combination with each other as determined by the Diagnostic Team (based on egineering study). Flashing-light signals may be used without automatic gate assemblies; however, where automatic gates are provided, they are used in conjunction with flashing-light signals.

Exhibit 6.12: 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 Section 8D.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 8D-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 Exhibit 6.15, 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 8- 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 Exhibit 6.14, 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.

6.7.3. Warning Signs and Pavement Markings at Grade Crossings

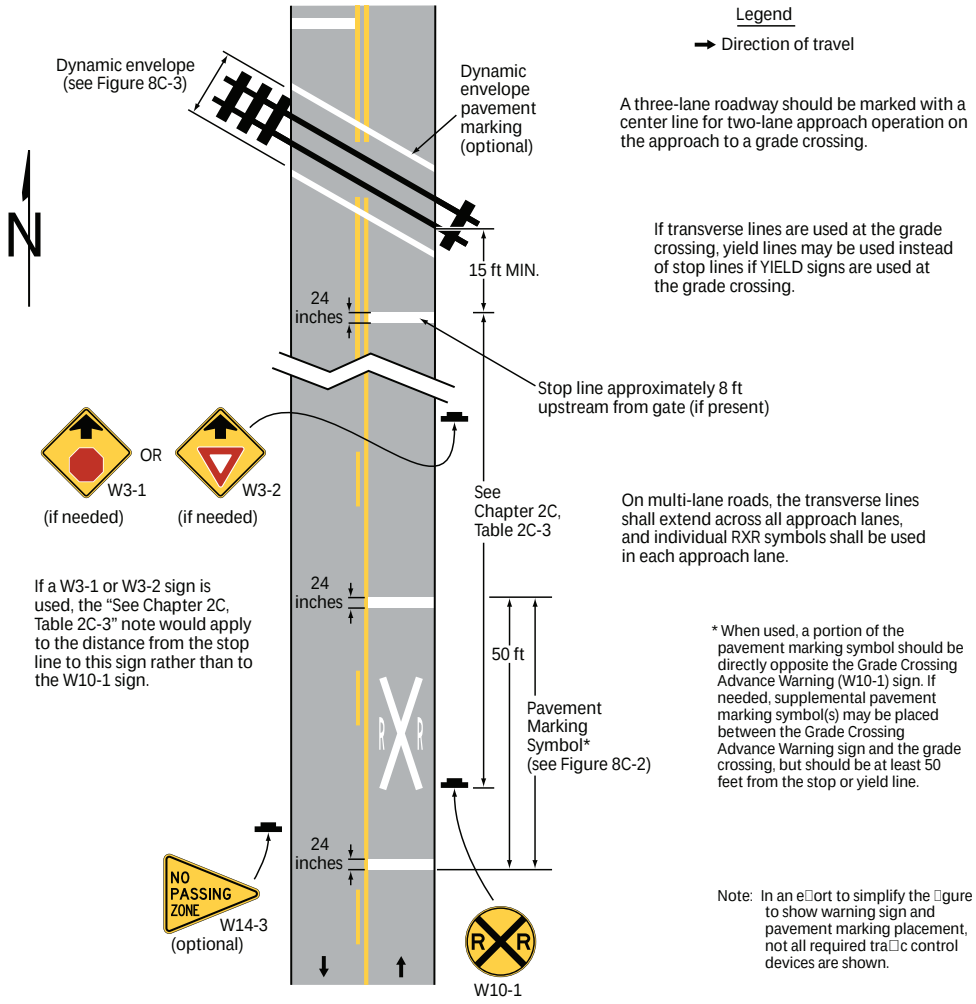
All grade crossing pavement markings shall be retroreflectorized white excluding centerline pavement markings. On paved roadways, pavement markings in advance of a grade crossing shall consist of an X, the letters RR, a no-passing zone marking, and certain transverse lines (see Exhibit 6.13). Identical 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.



W3-1 W3-2

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



Source: MUTCD Figure 8C-1

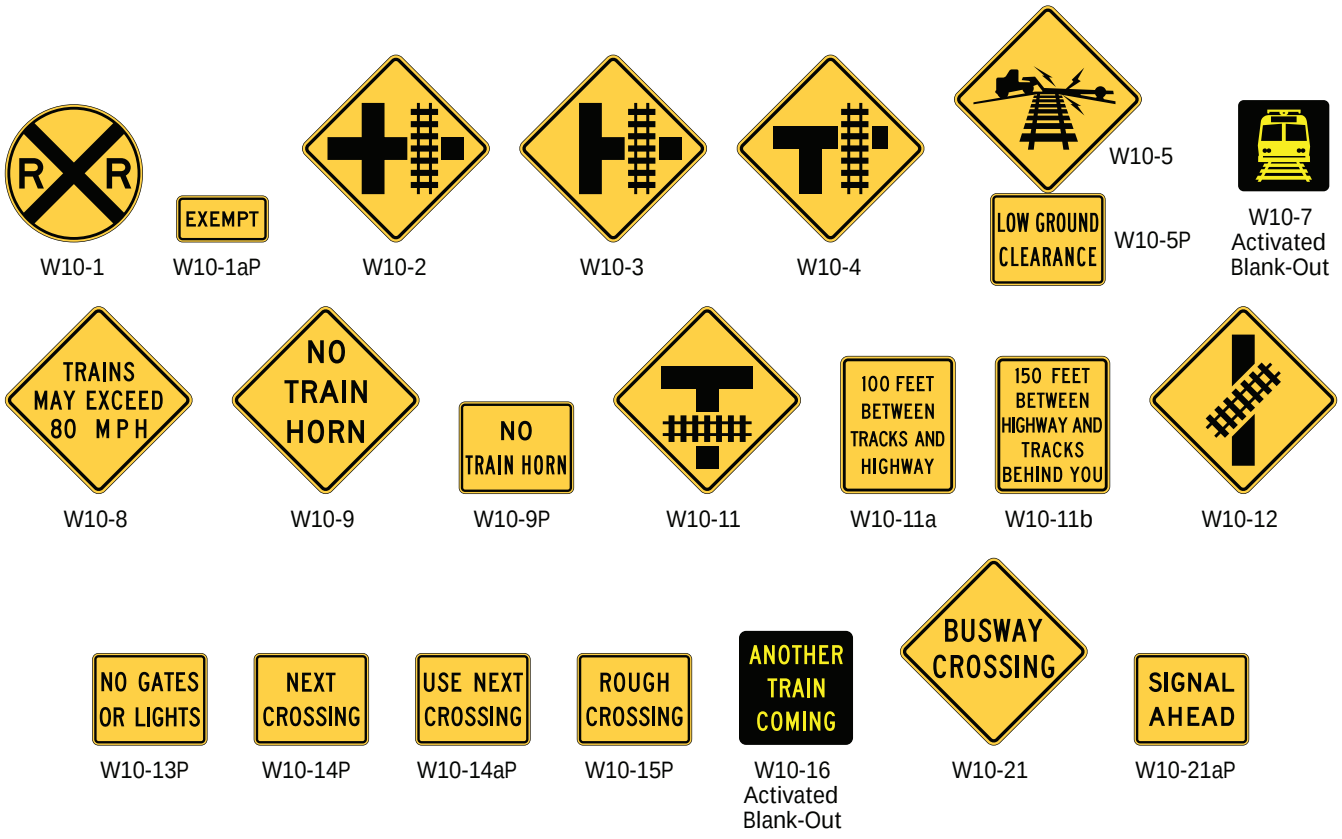
A Highway-Rail Grade Crossing Advance Warning (W10-1) sign, the first sign shown in Exhibit 6.13, shall be used on each highway in advance of every highway-rail grade crossing, except in the following circumstances:

✓ On an approach to a grade crossing from an 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 6.14: 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.

Source: MUTCD Figure 8B-4

A Yield Ahead (W3-2) or Stop Ahead (W3-1) Advance Warning sign shall also be installed when a YIELD or STOP sign is used at a passive grade crossing and conditions warrant advance notice to drivers. These advance warning signs should be placed so that drivers have adequate time to recognize and respond to the upcoming control. When a Yield Ahead or Stop Ahead sign is installed on the approach to the crossing, the W10-1 sign shall be placed upstream of it, with spacing that provides clear, sequential information to the driver.

CHAPTER 7 – SIGNS

7.1. GENERAL. 7-1

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7.1. GENERAL

A prevalent issue observed on military installations is the excessive deployment of regulatory and warning signage. There is a misconception that extra signs "can't do any harm." In reality, superfluous signage contributes to visual clutter and diminishes the conspicuity and effectiveness of critical traffic control devices.

Additional recurring deficiencies include:

- ✓ Fabrication and installation of non-standard, improvised signs, often featuring undersized legends and lacking retroreflective sheeting.
- ✓ Mounting signs at non-compliant heights.
- ✓ Positioning signs in excessively close proximity to other signs, or too close to curves, turns, or intersections.
- ✓ Installing totem pole or ladder-type signs with too many destinations.
- ✓ Using improper colors, (e.g., brown and white signs).
- ✓ Allowing obsolete (non-retroreflective or non-legible) signs to remain in place.

The authoritative reference for the design, placement, and application of traffic signs is Part 2 of the *MUTCD*. The *MUTCD*'s primary objective is to enhance roadway safety and minimize driver confusion by standardizing traffic control devices.

The FHWA actively sponsors research initiatives aimed at improving sign quality and recognition, and collaborates internationally to promote global uniformity in traffic control standards. This exchange of research and best practices regarding sign shapes, colors, symbols, and design parameters is particularly significant given the presence of international visitors on military installations.

Traffic signs represent the most ubiquitous and recognizable category of traffic control devices, with over half of the *MUTCD* dedicated to their specification and application. Despite the comprehensive guidance provided, the persistent deployment of unofficial, non-compliant signage—often fabricated with incorrect colors and shapes—continues to be a widespread issue on military installations.

For signage to achieve the intended authoritative presence, it must be legible, highly visible, and accurately positioned. Moreover, the conveyed messages, such as speed limits, should be realistic, meticulously maintained, and appropriately calibrated to the actual roadway conditions. Additional criteria for ensuring sign efficacy and proper command presence are illustrated in Exhibit 7.1.

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 FHWA's *Standard Highway Signs* (SHS) publication
BE VISIBLE	✓ Space signs at intervals of at least 150 feet from other signs ✓ Orient signs to face approaching traffic ✓ Clear obstructions and roadside features such as vegetation and utility poles ✓ Require Type III 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 when there are three or more travel 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 Classifications

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 and cultural interest signs have a brown background.

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

Exhibit 7.3: Primary Sign Colors

EXAMPLE 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 2023 *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 Zone Signs	6F, 6G, 6H, 6I
School Signs	7B
Railroad and Light Rail Transit Grade Crossing Signs	8B
Bicycle Signs	9B, 9C, 9D

7.1.2. Excessive Use of Signs



A common misconception is that additional signs are harmless. In fact, unnecessary signs contribute to visual clutter and reduce the effectiveness of essential traffic signs.

Signs shall be installed only when justified by factual evidence and field studies. The unnecessary placement of signs introduces additional fixed objects, increasing the risk of collisions and contributing to visual clutter, which may distract drivers and compromise safety. Therefore, the excessive use of signs should be avoided.

Typically, signs are not required to reiterate standard rules of the road or general vehicle operation provisions (e.g., "Slower Traffic Keep Right," "Pass Only on the Left"). Signs are essential in situations where there is non-compliance with general traffic rules, where atypical regulations are in effect at specific locations or times, or where hazardous conditions are not readily apparent.

When signs are warranted, a conservative approach should be adopted. Overuse of regulatory and warning signs diminishes their effectiveness and may lead to disregard by road users.

Guide signs serve to inform drivers about highway routes, street names, destinations, distances, available services, and points of interest. Military installations are encouraged to frequently display street name and destination signs to assist unfamiliar drivers in navigating the area.

The placement of signs must be appropriate and justified; improper or unnecessary signs are as problematic as substandard or obsolete signs. Signs installed for temporary or uncommon circumstances should be removed or covered promptly once those conditions no longer exist. Highway signs must not be used for advertising or purposes unrelated to traffic control.

In some cases, the issue is not the presence of unnecessary signs, but rather an excessive concentration of signs at a single location, which can impede readability and comprehension.



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 crossbuck 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 essential for the proper deployment of traffic control devices; e.g., a traffic engineering study may determine that signs are unwarranted at certain locations.

7.1.3. Inappropriate Use of Signs



A sign should only be installed when it serves a legitimate traffic control purpose. Non-standard, unjustified, or improperly used signs can reduce the effectiveness of traffic control devices and contribute to driver confusion.

Not all signs found on military installations are traffic control devices. Examples include security, administrative, and informational signs such as NO DRONE ZONE, NO TOBACCO USE, NO FIREARMS, NO MARIJUANA USE, and similar messages. These signs are not traffic control devices and are not governed by the *MUTCD*.

Some signs are frequently requested but generally are not recommended because they are not based on recognized traffic engineering principles or have not been shown to improve safety. Common examples include CHILDREN PLAYING, SLOW CHILDREN AT PLAY, and similar signs. Such signs can create unrealistic expectations regarding activities occurring within the roadway and may detract from traffic control devices intended to regulate driver behavior.

Signs should not be installed unless justified by engineering judgment, engineering study, established policy, or a demonstrated traffic control need. Obsolete, misleading, improperly placed, non-standard signs, or signs used for purposes other than traffic control (advertising) should be removed when identified.

When non-traffic control signs are used, care should be taken to avoid creating sign clutter or obstructing the visibility of regulatory, warning, or guide signs. Traffic control devices should remain the most prominent signs within the roadway environment.

7.1.4. Standard Signs

KEY POINT

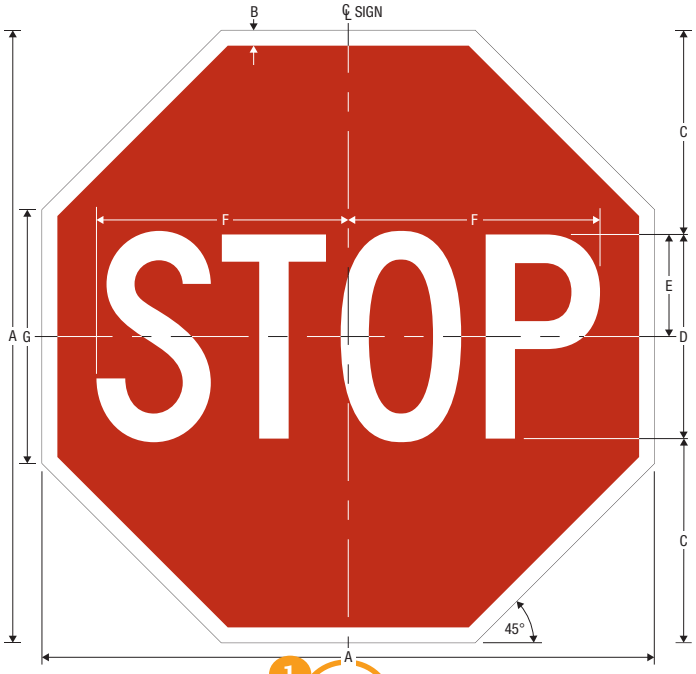
Consistent sign face design enhances recognition and legibility, which helps reduce driver frustration and supports overall safety.



Non-standard, homemade signs are not only unenforceable but also violate legal requirements. Consequently, when signage is required that is not specified in the *MUTCD* or the state's catalog of approved signs, it is imperative to consult TEA for proper design assistance. Consistent and uniform sign designs facilitate rapid recognition and comprehension by motorists, thereby enhancing roadway safety and operational efficiency. The *MUTCD* provides the foundational framework for sign design and deployment, while the *Standard Highway Signs* (SHS) publication offers detailed drawings of the standard (*MUTCD*) signs and the standard alphabets spacing charts for sign fabrication.

The current version of the *SHS* publication is the 2004 edition, supplemented by the 2012 Supplement which incorporates new and revised signs from the 2009 *MUTCD*. Both documents are required for all signs included in the *MUTCD*. These publications remain the most up-to-date resources and continue to supplement the 2009 *MUTCD*. The FHWA is actively developing a new edition of the *SHS* publication to correspond with the 11th Edition *MUTCD* (2023), with incremental updates anticipated as sections are finalized. Upon release, the updated *SHS* publication will serve as the official companion to the 11th Edition *MUTCD*. Exhibit 7.5 illustrates a typical page from the *SHS* publication, annotated with additional notes.

Exhibit 7.5: STOP Sign Design Details from the *SHS* Publication



1 R1-1
STOP

4 * Reduce Spacing 40%.

2

A	B	C	D	E	F	G
18	0.375	6	6 C*	3	7.401	7.456
30	0.75	10	10 C*	5	12.335	12.426
36	0.875	12	12 C*	6	14.802	14.912
48	1.25	16	16 C*	8	19.736	19.882

3 C

5

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

6

NOTES:

1. R1-1 is the *MUTCD* "sign designation" for a 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. The "C" denotes that this is the standard sign size for use on conventional highways. The smaller sizes are for low-volume roads and bicycle facilities.
4. This note applies to dimension D, and it means that the spacing between the letters is reduced by this percentage. (See the asterisk within column D in the table.)
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

At first glance, sign names in this pamphlet may look awkward because some are in 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 for sign names 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 Designations

The *MUTCD* and the *SHS* publication use a unique sign designation for each standard traffic sign. The first letter in the sign designation conforms 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 *SHS* publication; however, like other highway agencies, military installations also need some unique signs in order to satisfy specific needs. Since these unique signs are not addressed in the *SHS* publication, TEA has developed a standard TEA sign for each of the most common signs unique to military installations. **The sign design details for these signs are included in Appendix A of this pamphlet.**

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

- ✓ sign designation
- ✓ sign size, color, and shape
- ✓ size and series of legend
- ✓ sign face layout details

Drawings for the standard signs in Appendix A also include a brief description of the sign application. For more detailed information regarding sign application, refer to the *DoW Supplement to the MUTCD*.

7.1.5. 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.

The official fonts used for traffic signs in the US are known as the FHWA Series, or "Highway Gothic." These alphabets are categorized into six different series, arranged in order of increasing stroke width (boldness): Series B, C, D, E, E-Modified (EM), and F.



- ✓ Series B, C, D: These are the most common series used for conventional road signs. Series D is predominantly used for legends on guide signs for conventional roadways, as well as for regulatory and warning signs. In situations where sign width is constrained, such as with No Parking signs, a narrower font series (Series B or C) may be employed to accommodate limited lateral space.

✓ Series E, F: These are wider and are typically used for large signs on freeways and expressways where high-speed legibility is critical. Guide signs installed on expressways and freeways typically utilize Series E-Modified (EM) to enhance legibility at higher speeds and greater viewing distances.

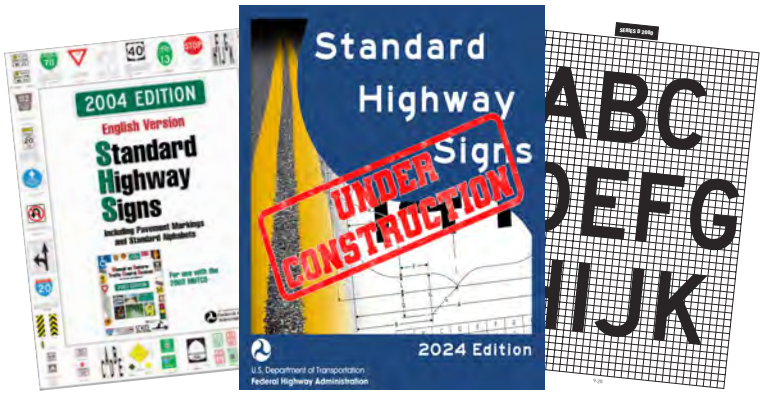
Clearview is an alternative typeface to the FHWA Standard Alphabets, designed to improve legibility on highway guide signs. In 2004, the FHWA issued interim approval (IA-5) for the use of Clearview on positive-contrast legends (light letters on dark backgrounds) for guide signs. However, in 2016, FHWA rescinded this interim approval. The FHWA reversed its 2016 decision and reinstated interim approval for Clearview in year 2023. This means agencies may again use Clearview for positive-contrast guide sign legends (e.g., white letters on green backgrounds), provided they follow the approval process and conditions set by the FHWA. Negative-contrast signs (dark letters on light backgrounds, such as regulatory or warning signs) must still use the FHWA Standard Alphabets.

Agencies must request and receive interim approval from the FHWA before using Clearview on new signs. Some states have received approval and adopted Clearview, while others continue to use only the FHWA Standard Alphabets. As state and local policies may vary, always check your state DOT's current policy for local requirements. Military installations located in states that have previously received approval to use the Clearview font, are not required to again request FHWA approval.

KEY POINT

Clearview font is again permitted under FHWA Interim Approval IA-5 for positive-contrast guide signs, subject to FHWA approval requirements and applicable agency policies. Regulatory, warning, and other negative-contrast signs must continue to use the FHWA Standard Alphabets.

Clearview font is specifically designed for use in text on traffic signs, such as words, numbers, and route markers. It is not intended for use in symbols like arrows, pictograms, or other graphical elements. Symbols—including arrows—on traffic signs are typically standardized and are not rendered in a font like Clearview; instead, they are standardized graphic designs created according to federal and state standards.



The *SHS* publication provides detailed graphics and spacing specifications for the FHWA standard alphabets utilized in traffic sign fabrication, specifically the Highway Gothic typeface. Spacing charts for Series B 2000, C 2000, D 2000, E 2000, E(M) 2000, and F 2000 are included in the *SHS* publication, as well as Appendix C of this pamphlet. The "spacing charts" are part of a comprehensive system designed to ensure that text

on traffic signs is legible from a distance and at speed. In the US, the primary standard for this is the *SHS* publication.

However, unlike the Standard Alphabets, the official spacing charts for Clearview (a licensed typeface that is proprietary) are not published by the FHWA in the *SHS* publication. Instead, they are provided by the designers and licensing agents of Clearview. Though the spacing charts are likely published in state Traffic Manuals that have approval to use Clearview, the spacing charts for Clearview 1-W, 2-W, 3-W, 4-W, 5-W, 5-WR, and 6-W have also been included in Appendix C.

The spacing charts 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 the dimensions given always apply to 4-inch high uppercase 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 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, https://mutcd.fhwa.dot.gov/knowledge/hwy_sign_calculator/index.cfm.

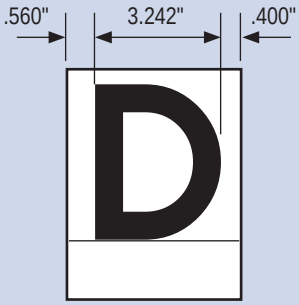
Exhibit 7.6: Alphabet Spacing Charts

STANDARD ALPHABETS SPACING CHARTS **Series EM 2000**

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
	0.560	2.962	

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		



Note:
The dimensions came from the measurements for the "D" character outlined in green.

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.

7.1.6. Design Guidelines for Custom Traffic Signs

In addition to the standard *MUTCD* signs included in the *SHS* publication and the TEA signs in Appendix A (and the *DoW Supplement to the MUTCD*), there are times when a custom sign is necessary for specific purposes or unique locations. Military installations may develop special word legend signs in situations where engineering judgment determines roadway conditions make it necessary to provide road users with additional regulatory, warning, or guidance information, such as when road users need to be notified of special regulations or warned about a situation that might not be readily apparent. Unlike colors that have not been assigned or symbols that have not been approved for signs by FHWA (in the *MUTCD*), new word legend signs may be used without the need for experimentation by FHWA. Consequently, dedicated guidance has been developed to support these requirements.

Regulatory and Warning Signs

When circumstances exist that require road users to receive regulatory or warning information beyond what is provided by the standard signs in the *MUTCD* and *DoW Supplement to the MUTCD*, adhere to the guidelines below when designing the non-standard signage.

Guidelines for Designing Non-Standard 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 *MUTCD* Section 1D.08 and Table 1D-1, as well as the *DoW Supplement to the MUTCD*. Do not use abbreviations listed in Table 1D-3 of the *MUTCD* because of their potential to be misinterpreted by road users.
3. Use the appropriate letter width and spacing between individual letters as specified in the Standard Alphabets Spacing Charts (See Part 9 in the *SHS* publication and Appendix C in this pamphlet.)
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.

It is important that the message conveyed by the special word legend sign be clear to road users. TEA can review custom sign designs to help prevent any potential misinterpretation. Additionally, submitting unique sign designs to TEA allows for the expansion of its official sign library for use at 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, each sign requires a final layout design to establish the appropriate dimensions, spacing, and placement of legends and graphic elements. Specific approval from TEA is not required, but TEA is available for consultation.

Abbreviations for Signs and Markings

Section 1D.08 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 listed in the *MUTCD*, Exhibit 7.7 and the *DoW Supplement to the MUTCD* identify additional approved abbreviations specific on military installations. *(Note: the abbreviations were approved by FHWA as part of the DoW Supplement to the MUTCD.)* If there is a need for an abbreviation beyond these lists, the recommended procedure is to forward your suggestions to TEA for a determination of acceptable use. This process will also help TEA expand the list in Exhibit 7.7 and the *DoW Supplement to the*

MUTCD .

The FHWA has identified certain abbreviations that can be misinterpreted or distract drivers. Consequently, Table 1D-3 in the *MUTCD* lists these prohibited abbreviations.

Exhibit 7.7: Acceptable Abbreviations for Traffic Control Devices

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	United States Army Garrison	USAG
Division	DIV, Div	United States Army Reserve	USAR
Fort	FT, Ft	United States Marine Corps	USMC, US Marine Corps
Headquarters	HQ, Hq	United States Marine Corps Reserve	USMCR
Joint Base	JB	United States Navy	USN, US Navy
Marine Corps Air Station	MCAS	United States Navy Reserve	USNR
Marine Corps Base	MCB	Veteran Affairs	VA
Naval Air Station	NAS		
Naval Base	NB		
Naval Station	NS		
Naval Support Activity	NSA		

Legend

All letters on signs are required to be in uppercase letters (i.e., capital letters). The exemption to this is names of places, streets, and 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.08 of the *MUTCD*. On military installations, names that should be in mixed-case on guide signs include:

- ✓ cities
- ✓ military installations
- ✓ geographic areas within installations
- ✓ gates

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.

- ✓ 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 traffic signs use the Standard Alphabets in the *SHS* publication, which are generally called "Highway Gothic" fonts. The Clearview font is the only exception and is allowable on green guide signs if your state has received FHWA-approval. Spacing charts for both fonts are included in Appendix C. Refer to Section 7.1.5 for more details.

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 7.8.

Exhibit 7.8: 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?
"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.

7.1.7. Bilingual Messages



To assist drivers with limited knowledge of the English language, always use symbol-type signs if 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 if an approved design is available. If you believe that limited understanding is a significant problem with certain signs, contact TEA to 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.

7.1.8. Retroreflectivity and Illumination



When driving at night, clear and noticeable traffic signs and road markings are essential for improving safety and easing driver stress.

Nighttime driving presents a higher risk compared to daytime travel, which underscores the critical need for sign visibility. To address this, the *MUTCD* specifies that traffic signs must be either retroreflective or illuminated to ensure consistent shape and color recognition at all hours. Utilizing retroreflective materials is generally more cost-effective than illumination, and illuminated signs are subject to potential failure due to bulb burnout. Consequently, all traffic signs should be fabricated with retroreflective sheeting, regardless of whether they are also 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:

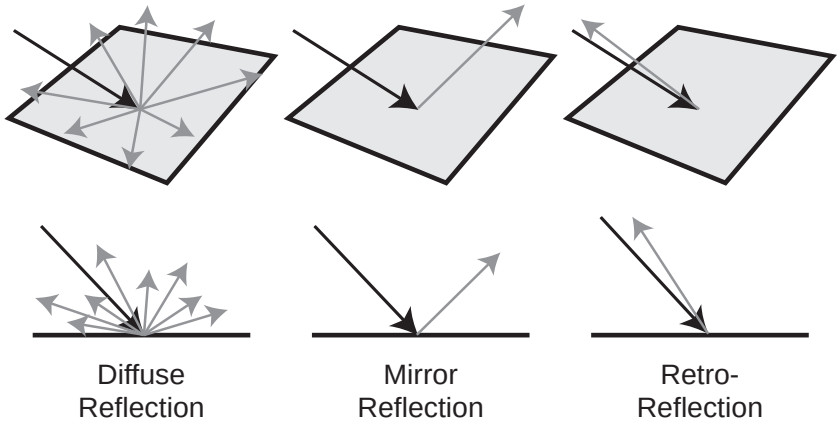
1. Older drivers have difficulty seeing at night. After age 20, drivers typically need twice as much light every 13 years in order to read. For example, compared to a 20-year old driver, a 33-year old driver needs twice as much light, a 46-year old driver needs four times as much light, a 59-year old 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?

Retroreflection is a distinct form of light reflection. Typically, most objects exhibit "diffuse reflection," where incoming light scatters in multiple directions after striking rough surfaces such as trees, fabric, or carpet, resulting in only a minor portion of the light returning toward the source. In contrast, "mirror (specular) reflection" occurs when light strikes smooth or glossy surfaces and reflects off at an equal but opposite angle; this is commonly seen on wet roads at night, where the headlights of oncoming vehicles generate significant glare. "Retroreflection," however, is characterized by a surface's ability to reflect light back toward the source, regardless of whether the surface is perpendicular to the light. The term "retroreflectivity" quantifies this capability.

The three types of reflection are illustrated in Exhibit 7.9.

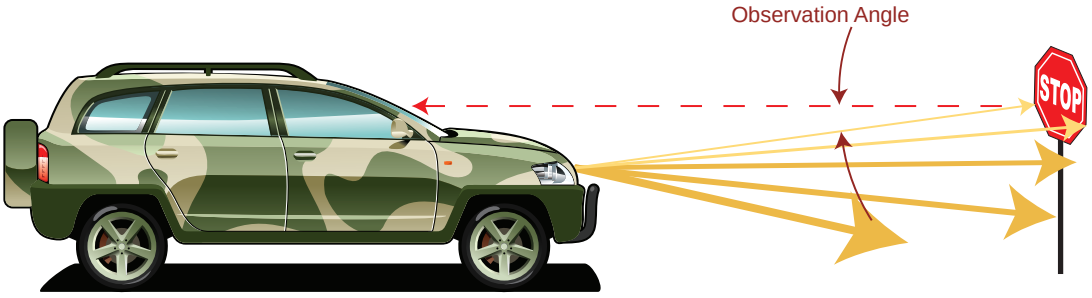
Exhibit 7.9: Types of Reflection



Retroreflective Sheeting Materials

To achieve retroreflectivity, manufacturers apply retroreflective sheeting to the sign face. This sheeting comprises either microscopic glass beads or cube-corner reflectors—commonly referred to as microprismatic material—positioned behind a smooth, translucent pigmented surface layer. Ideally, if the glass beads or cube-corner reflectors were perfectly formed, all incident light from vehicle headlights would be reflected directly back to the source. In practice, while perfect retroreflection is not attainable, drivers experience increased reflected light when their eyes are positioned closer to the light source (headlights). As shown in Exhibit 7.10, the observation angle—defined by the positions of the headlights, the sign, and the driver's eyes—affects retroreflection, with smaller angles resulting in higher retroreflective efficiency.

Exhibit 7.10: Graphic Illustration of the Observation Angle



Retroreflective materials perform optimally when the light source is nearly perpendicular to the sign face, making proper sign orientation toward oncoming traffic essential.

It is important to note that signs may appear in good condition during daylight but provide inadequate visibility at night. This issue is typically related to the type and age of the retroreflective material used. For instance, the STOP sign depicted in Exhibit 7.11 appears new during the day but lacks retroreflectivity due to the use of non-retroreflective sheeting (the sign shop also used a non-standard lettering font). These issues highlight the importance of the following practices:

- ✓ Procuring signs exclusively from reputable sign manufacturers;
- ✓ Specifying a minimum of Type III retroreflective sheeting (as required by the *DoW Supplement to the MUTCD*), and;
- ✓ Conducting nighttime inspections to verify sign visibility and performance.

Making Retroreflective Signs

Signs are made retroreflective by applying white or colored retroreflective sheeting on the sign blank. For mass-produced signs, sign messages are typically silk-screened directly onto 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. (Transparent inks allow the retroreflective properties of the white sheeting to show through, maintaining both color and reflectivity.)

One-of-a-kind signs are often made using cutout, pressure-sensitive legends (i.e., letters, symbols, numbers, and arrows). Non-black cutout legends and borders must be made from retroreflective sheeting material. (Using retroreflective sheeting for cutout legends ensures the entire sign remains retroreflective.)

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

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.

Note that military installations are able to assist drivers by making modifications to Items 5, 6, 7, and 8 only.

Exhibit 7.11: An Unacceptable, Non-retroreflective Sign



Retroreflectivity Measurement Methods

Retroreflectivity is measured using various methods, including hand-held retroreflectometers, mobile retroreflectivity measurement systems, and nighttime visual inspections.

- ✓ **Hand-held retroreflectometers** measure retroreflectivity at preset angles to simulate what drivers see. Many units also capture GPS coordinates, which can be integrated into inventory or asset management databases.
- ✓ **Mobile retroreflectivity measurement systems** allow for efficient large-scale assessments by scanning signs while in motion, eliminating the need for manual measurements.



✓ **Nighttime visual inspections**, conducted by trained personnel, provide a practical method for assessing sign visibility under real-world conditions without the need for expensive equipment and help identify signs that no longer meet minimum retroreflectivity standards.

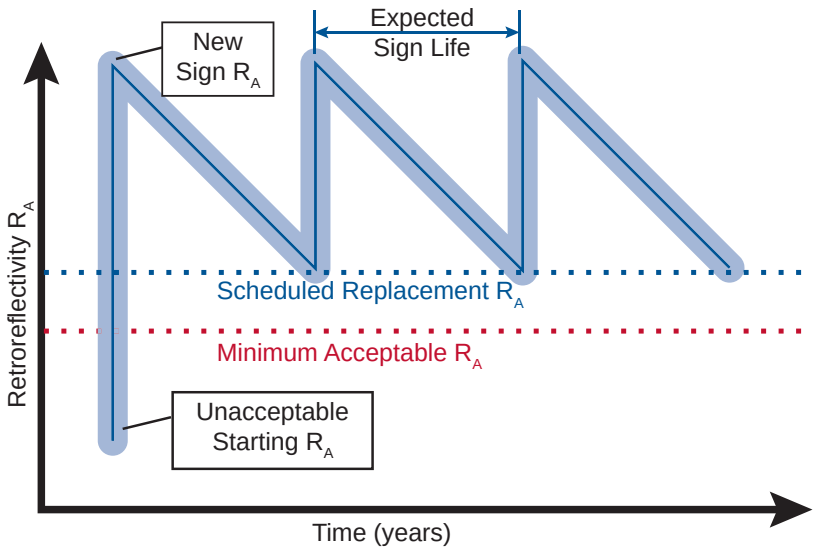
Using a portable retroreflectometer requires careful attention because signs are normally on posts. The device must either be supported by an extension pole and accurately held against the sign face, or the user must climb on a ladder. Additionally, researchers recommend taking multiple readings, as retroreflectivity can vary across different areas of a sign face.

For signs with white legend elements, such as STOP signs and guide signs, the unit must be precisely centered for accuracy. Therefore, up to six readings may be necessary, making the process both challenging and time-consuming. Signs installed overhead on mast arms or sign structures present additional measurement difficulties.

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

Therefore, it is desirable to provide a safety factor when scheduling replacement signs as illustrated in Exhibit 7.12.

Exhibit 7.12: The Decline of Retroreflectivity over Time



When is Sign Lighting Required?

Given the requirement to use high-performance retroreflective sheeting materials, which provide adequate nighttime visibility, supplemental sign lighting shall not be used unless a formal traffic engineering study documents a specific need.

7.1.9. Minimum Retroreflectivity Levels



Due to a congressional mandate, minimum retroreflectivity standards are now established for most traffic signs.

In response to safety concerns regarding nighttime visibility, Congress directed the U.S. Secretary of Transportation in 1993 to establish and include minimum retroreflectivity requirements for both signs and pavement markings in the *MUTCD*. Following extensive research, the FHWA implemented minimum retroreflectivity standards for traffic signs in 2007, which are now included as Table 2A-5 in the *MUTCD*.

These minimum values differ based on the type and color of sign sheeting, as well as the sign's size and message type. Exhibit 7.13 provides the minimum retroreflectivity levels for various sheeting types and colors.

Exhibit 7.13: Minimum Maintained Retroreflectivity Levels[1]

SIGN COLOR	BEADED SHEETING TYPE (ASTM D4956)			PRISMATIC SHEETING	ADDITIONAL CRITERIA
	I	II	III		
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
WHITE ON BLUE	W*; B ≥ 3	W*; B ≥ 5	W*; B ≥ 12	W ≥ 250; B ≥ 12	Overhead
	W*; B ≥ 3	W ≥ 120; B ≥ 7			Post-Mounted
WHITE ON BROWN	W*; Br ≥ 1	W*; Br ≥ 5	W*; Br ≥ 10	W ≥ 250; Br ≥ 10	Overhead
	W*; Br ≥ 1	W ≥ 120; G ≥ 5			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

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-5

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;
- ✓ Acknowledgment signs; and
- ✓ 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. **As identified in the *DoW Supplement to the MUTCD*, installations are required to use a minimum of Type III sheeting on traffic signs.**

FHWA has a Retroreflective Sheeting Identification Guide at https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-09/sheetguide2014_0.pdf.

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.

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 7.13. Moreover, the higher type sheeting materials (such as Type III (High-Intensity) and Type IV (High-Intensity Prismatic)) are more cost effective on an annual cost basis because they last longer. For these reasons, Type I and Type II materials are no longer acceptable.

Exhibit 7.14 illustrates a typical life cycle cost analysis using relevant costs 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 RELATIVE COST	TYPICAL SIGN LIFE (YEARS)	LIFE CYCLE RELATIVE COST
I - EG	$	7	$$
II - SEG	$$	7	$$
III - HI	$$	12	$
IV - HIP	$$$	12	$
VIII AND HIGHER (OTHER PRISMATICS)	$$$	12	$

Exhibit based on information presented in 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 sheeting 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 higher grade (better) 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.

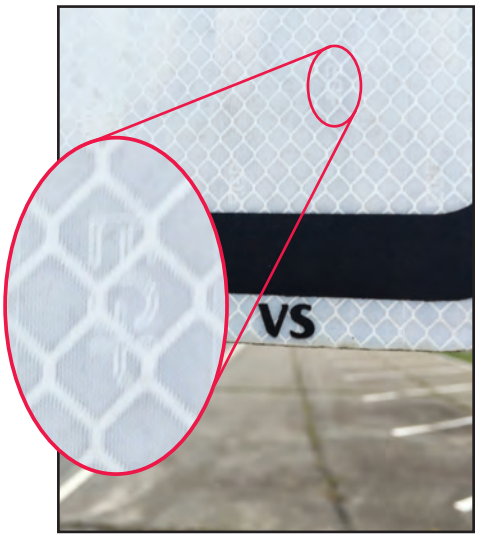
The retroreflective sheeting type for all regulatory, warning, and guide signs on military installations shall be type III or better. Higher sheeting types (IX, X) should be reserved for urban areas that are generally lighted at night. The brighter sign compliments ambient lighting. These brighter sheeting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

Some sign sheeting manufacturers have a type of Type I sheeting 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.

Chapter 4 of TEA *Pamphlet 55-8* provides guidance on managing sign programs to maintain acceptable levels of retroreflectivity.

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.



Type I EGP Sheeting Example

7.1.10. Sign Shapes, Colors, and General Design

Sign shapes and colors should always conform to those in the *MUTCD* and the *SHS* publication.

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.

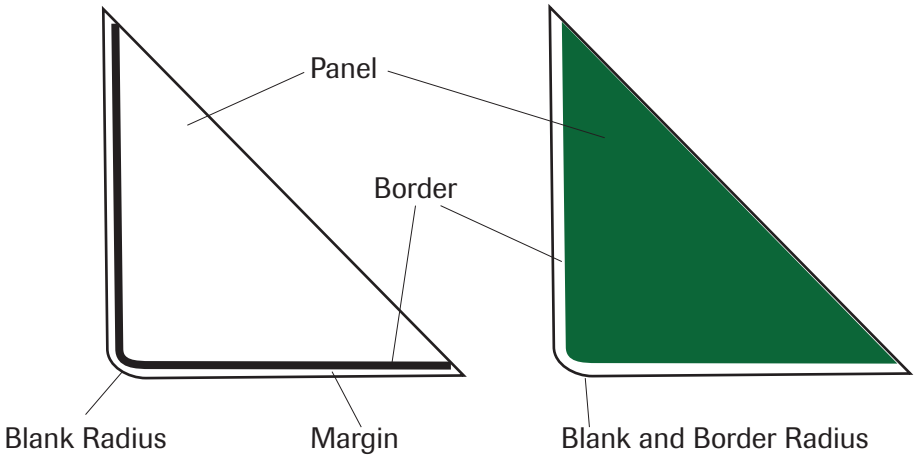
Speed greatly affects the legibility and comprehension of sign legends. Therefore, larger sign sizes are advantageous where increased legibility or emphasis is desirable.

For special circumstances such as limited highway right-of-way, parking facilities, parks, and similar applications, engineering judgment may support the use of smaller sign sizes where permitted by *MUTCD* Section 2A.07. Sign dimensions should not be reduced below the applicable *MUTCD* minimums. When sign sizes are changed, standard shapes, colors, and proportions should be retained as much 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. 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 signs with standardized shapes, such as the STOP sign, borders on signs should have rounded corners.

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



Part 7 of the *SHS* publication identifies the standard sign blanks (see section 7.1.13). 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. (For signs with a large width-to-height ratio, base the dimensions on the smaller sign dimension.)

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

*** When applicable

Sometimes engineering judgment supports the use of sign sizes smaller than the conventional dimensions, consistent with *MUTCD* Section 2A.07, due to limited highway right-of-way, restrictions on overhead sign width, or vertical clearance constraints. 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.

7.1.11. 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 *SHS* publication 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 conventional roadway system. Minimum sign size may be decreased by 6 inches in alleys that have restrictive physical conditions. Refer to the *MUTCD* and the *DoW Supplement to the MUTCD* for complete listings of sizes for all standard signs.

Exhibit 7.17: Sizes of Common Signs

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	48x18
NO PARKING (R7-SERIES)		12x18	12x18

Exhibit 7.17: Sizes of Common Signs (continued)

SIGN NAME AND NOMENCLATURE		SIZE, WIDTH X HEIGHT (INCHES)	
		SINGLE LANE	MULTI-LANE
NO TURN ON RED (R10-11, R10-11A)		24x30	24x30
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	30x30
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-1, 8B-1

7.1.12. Sign Location and Orientation

Longitudinal Placement

When multiple signs compete for a driver's attention simultaneously, there is an increased risk of confusion and unsafe maneuvers. To mitigate this, it is essential to avoid overloading drivers with unnecessary signage or placing signs too closely together.

Sign Spacing

The longitudinal spacing between consecutive signs may vary; however, on conventional roadways, a minimum spacing of approximately 200 feet is recommended. In lower-speed environments, this distance may be reduced to a minimum of 100 feet. On high-speed conventional roads, greater spacing is encouraged, though reduced spacing may be necessary in areas with a high density of signs.

Sign Placement Considerations

The placement of each sign should be determined by the sign type, the nature of its message, and the intended driver response:

- ✓ Warning signs should be installed in advance of the condition or hazard they address.
- ✓ Regulatory signs should be placed at the location where the regulation applies or at intervals along the roadway where the restriction is in effect. Regulatory signs may apply to a specific location (e.g., stop or turn prohibition) or along an entire segment (e.g., speed or weight limits). The initial regulatory sign should be as close as possible to the point where the restriction begins.
- ✓ The minimum advance placement for certain warning signs is specified in Exhibit 7.31; however, providing greater advance distance is preferable to ensure adequate driver response time.
- ✓ Guide signs should be positioned as needed to inform drivers of routes, destinations, and points of interest. When multiple signs are required at the same location, refer to Exhibit 7.18 for priority order.

Most signs can be shifted longitudinally without compromising their effectiveness. Adjustments may be made to enhance visibility, prevent sign obstruction, improve safety (e.g., by placing supports behind barriers), or optimize operational spacing between signs.

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 individual sign installations are preferred—except when one sign supplements another—grouping signs on a single post may be advantageous, particularly in urban areas with limited space. Urban sign placement often requires case-by-case evaluation.

Sign location decisions should be made with consideration for the signing needs of the entire route. If more than one sign normally belongs at the same location, relocate or eliminate the lower-priority sign. For example:

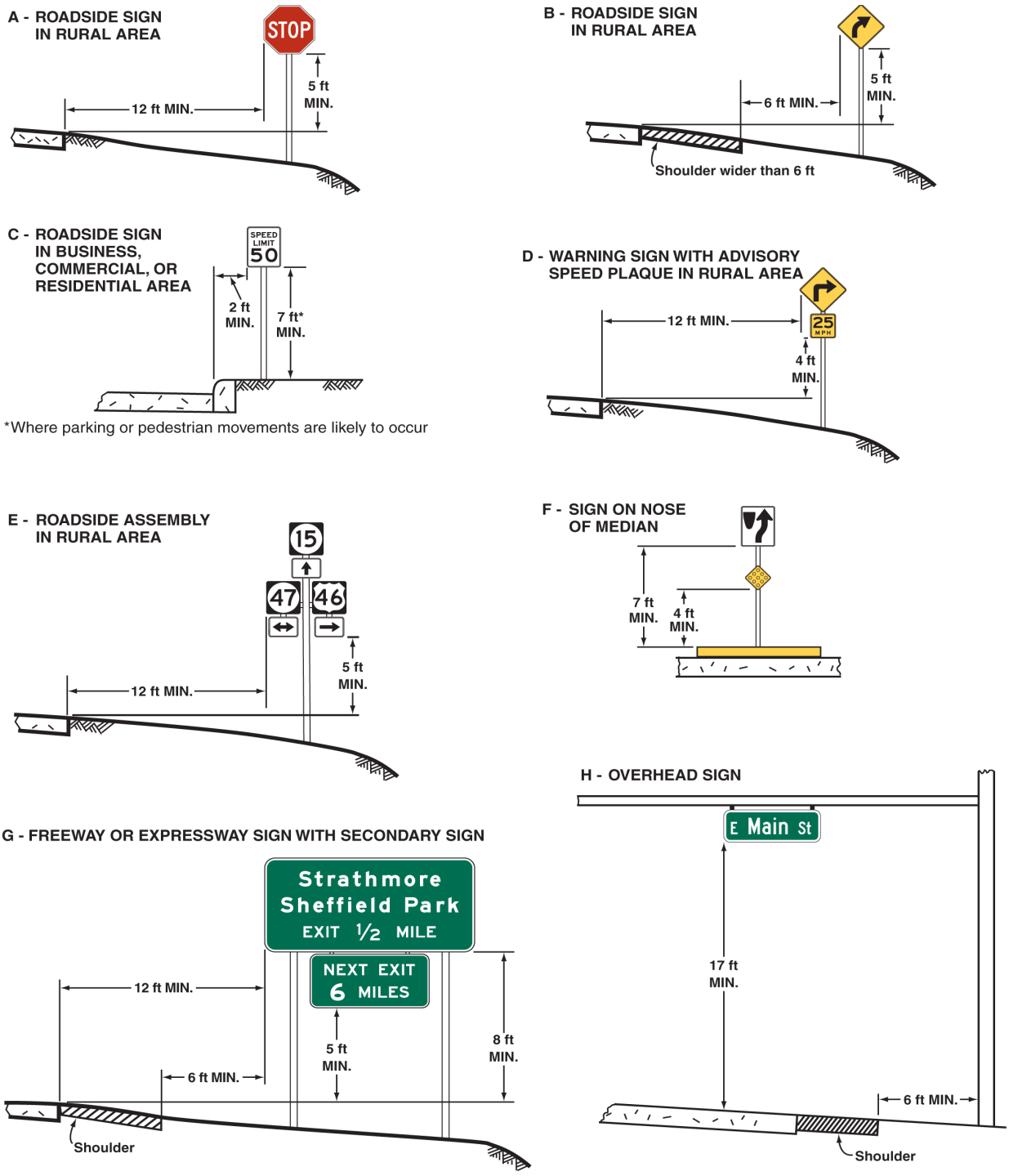
- ✓ If both a curve warning sign and a distance sign are warranted at the same location, the curve warning sign should take precedence. The distance sign may be relocated or eliminated if similar information is provided elsewhere.
- ✓ If two restrictions (such as speed limit and weight limit restrictions) both begin at a side road, the Weight Limit (R12-1) sign takes precedence and should be installed first (within 25 to 50 feet of the road's beginning) to prevent over-weight vehicle entrapment. The Speed Limit (R2-1) sign should then be placed at least 200 feet beyond the R12-1 sign.

Also, avoid installing signs at inappropriate locations, such as placing a Speed Limit (R2-1) sign immediately before an intersection, or just before, a curve with a lower advisory speed.

Lateral Placement

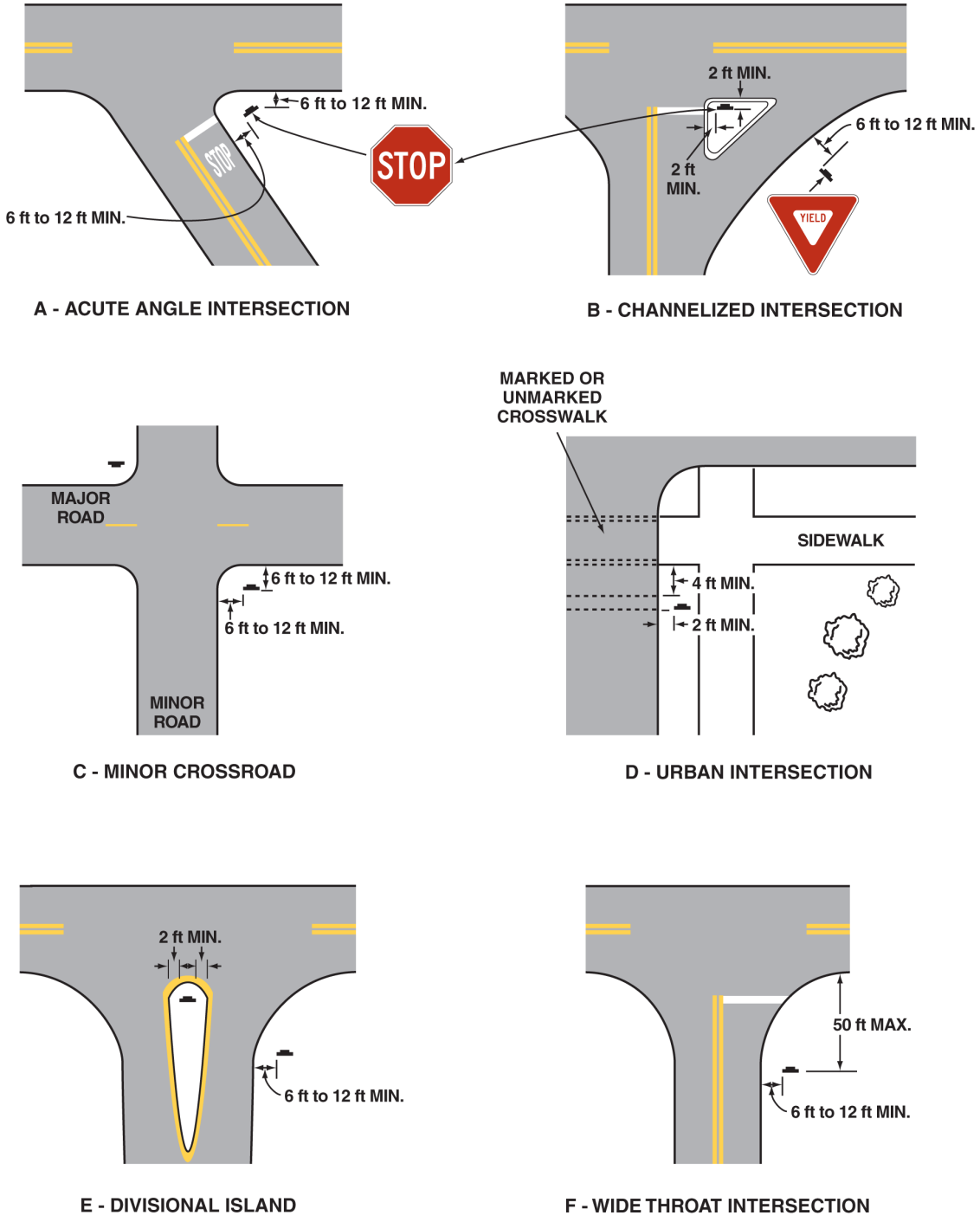
Lateral placement of signs depends on site conditions and the specific type of sign. Sign location requirements are shown in Exhibits 7.19 and 7.20, as referenced from the *MUTCD*. Signs should be positioned outside the clear zone unless they are mounted on breakaway or yielding supports. Placement should also maximize nighttime visibility, reduce exposure to mud splatter and debris, prevent signs from obscuring one another, maintain adequate sight distance for drivers stopped on minor-street approaches to major streets, and ensure that signs remain fully visible to all road users.

Exhibit 7.19: Examples of Heights and Lateral Locations of Sign Installations



Note: See MUTCD Section 2A.16 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.

Exhibit 7.20: Examples of Locations for Some Typical Signs at Intersections



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. See MUTCD Section 2A.16 for lower minimums that may be used in urban areas, or where lateral offset space is limited.

Sign Orientation

Signs should be mounted vertically and oriented at right angles to the direction of traffic they are intended to serve. If mirror reflection from the sign face reduces legibility, the sign should be rotated slightly away from the roadway to improve visibility. Signs that are placed 30 feet or more from the pavement edge should be turned toward the road. On curved alignments, the placement angle should be based on the direction of approaching traffic rather than the alignment of the roadway at the sign's location. On grades, sign faces may be tilted forward or back from the vertical position to optimize the viewing angle.

An exception to this guideline applies to parking signs, as specified in Section 7.2.11. Parking signs should be installed at an angle between 30 and 45 degrees from the edge of the roadway, so they are visible to drivers looking ahead and toward the parking side of the roadway.

For overhead installations, signs should be positioned perpendicular to the line of approaching traffic at the point where the sign first becomes legible, using a guideline of 30 feet of viewing distance per inch of letter height.

7.1.13. Sign Blanks



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.

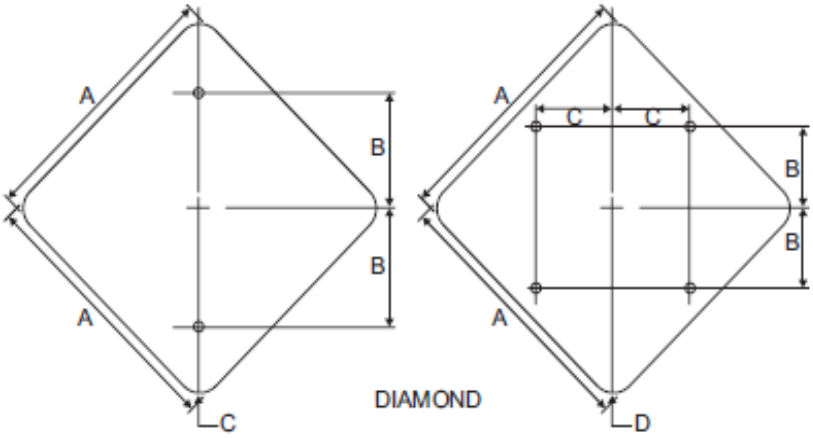
A sign blank is a flat, pre-cut piece of material that serves as the raw base (or substrate) for making a sign. It is a completely blank canvas that has been manufactured into a specific shape and size, but contains no text, graphics, or reflective sheeting yet. It is essentially the unfinished, plain panel that will later become a finished sign.

Aluminum is the most widely used material for traffic sign blanks due to its exceptional durability and weather resistance. 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 *SHS* publication includes blank standards for over 50 combinations of size, shape, and rotation of the sign blanks. The standards, as illustrated in Exhibit 7.21, include dimensions for corner radii and the locations of the mounting holes. Sign blanks are generally manufactured with rounded corners to reduce the potential for injury from exposed edges and corners. 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 *SHS* publication, 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 7.21: Example of a Sign Blank Standard



A	B	C
24	12	1.5
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”

7.1.14. Sign Supports



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 7.22 and 7.23, respectively.

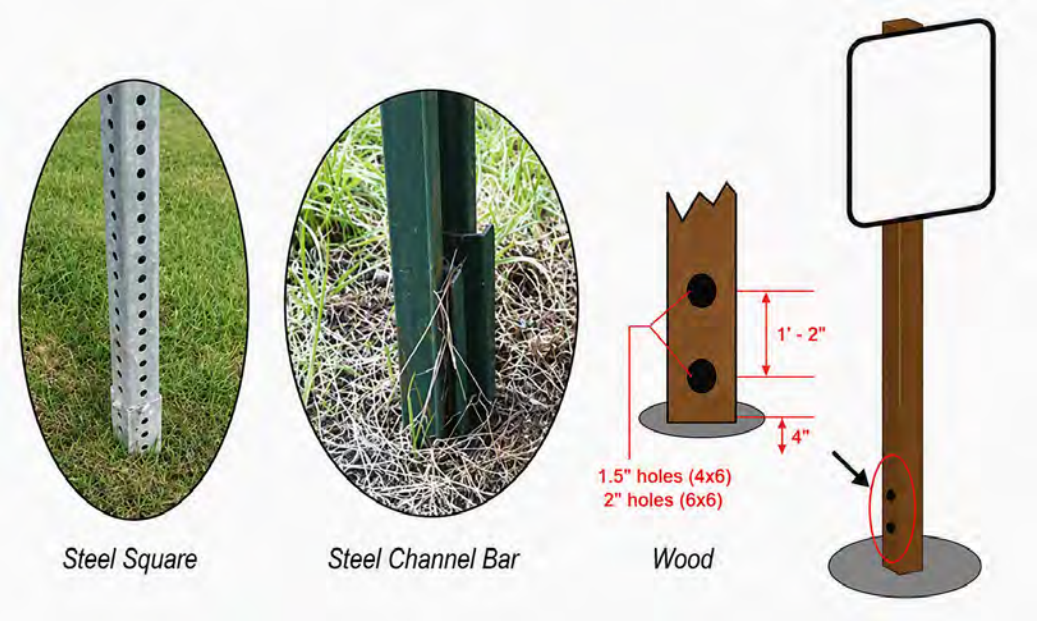
Exhibit 7.22: Common Breakaway Sign Posts

TYPE	COMMENTS*
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
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
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

* 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.

Exhibit 7.23: Small Breakaway Sign Posts



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 channels. These signs are available from some of the larger sign manufacturers, and they are constructed from extruded aluminum channels that typically are 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 may consult with TEA on the design of the sign and the sign supports.

Overhead Sign Installations

Overhead signs are generally used only with overhead traffic signals and at the following locations:

- ✓ 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 TEA for assistance. In most cases, a mast arm can be installed to support the typical signing needs, but overhead sign structures may also require shielding in the form of guardrail, barriers, attenuators, or a combination of properly placed devices.

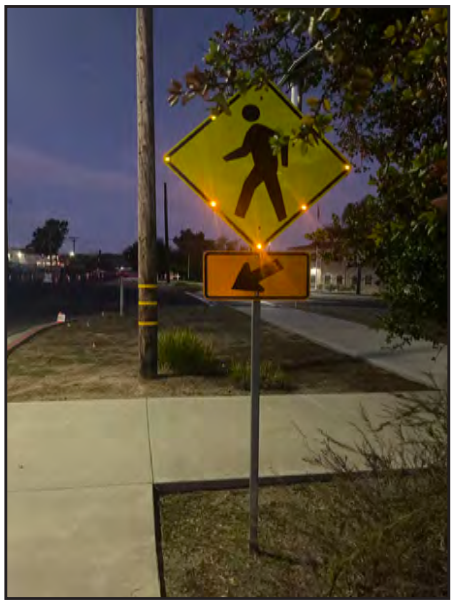
7.1.15. Enhanced Conspicuity of Standard Signs

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.11) 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 single flashing yellow light (a warning beacon) to the top of the sign, except for a STOP, DO NOT ENTER, WRONG WAY, or a Speed Limit sign. Use a red light (a stop beacon) if attaching to a STOP sign. Solar panel powered systems are frequently used. Installations should be aware, however, that the cost of running commercial power to a sign or replacing batteries can be significant.
4. Provide supplemental lighting or other active devices to enhance sign conspicuity when additional emphasis is warranted.
   a. Light-emitting diodes (LEDs) may be installed along the sign border or used to supplement a symbol or word message. LED-enhanced signs can improve sign conspicuity and driver awareness in certain applications; however, their use should be based on engineering judgment and should not replace more appropriate traffic control devices or treatments where warranted.
   b. Rectangular Rapid Flashing Beacons (RRFBs) may be used to enhance the conspicuity of pedestrian, school crossing, and trail crossing signs in accordance with the *MUTCD*.

   Note: Refer to Chapter 9 of this pamphlet for additional information regarding Warning Beacons, Stop Beacons, RRFBs, and other flashing beacon applications.
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.







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.11 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.

7.1.16. Sign Maintenance

Degraded or poorly maintained traffic control devices directly compromise driver compliance and overall regulatory effectiveness. Under most circumstances, it is cheaper to replace damaged or unreadable signs than to attempt to repair them.

Reporting of any missing, damaged or ineffective signs by personnel are critical to sustaining operational safety. Ineffective signs include those blocked by vegetation and by other signs.



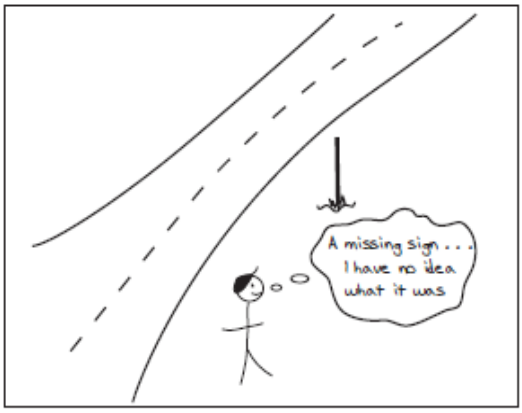
This sign should have been replaced years ago, before the red color disappeared.

7.1.17. Sign Inventory

A comprehensive and actively maintained sign inventory is a fundamental component of an effective transportation infrastructure management program. Without a systematic inventory, deficient or missing signs may remain undetected for extended periods, potentially until a formal complaint is registered or a crash analysis reveals a correctable issue. A robust inventory system is therefore essential for proactive safety management.

The implementation of a computerized sign inventory system enhances the overall quality of a signing program, facilitates efficient field inspections, and has been shown to reduce sign-related crashes. Furthermore, these systems provide critical data for asset management, allowing for the forecasting of replacement needs based on the age and condition of existing signs.

The methodologies for capturing, analyzing, and managing sign inventory data have been significantly enhanced by modern technologies. The reduced cost and increased accuracy of the Global Positioning System (GPS) have made field data collection more efficient, while Geographic Information Systems (GIS) and Linear Referencing Systems (LRS) provide powerful platforms for data integration, modeling, and visualization. The current methodology allows for the capture of assets using photography and GPS, with their locations subsequently integrated via LRS to generate precise milepost/offset values.



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 (*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, retroreflectivity readings, 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).

TEA provides comprehensive Sign Management Studies for military installations. This service is designed to optimize an installation's signing program for regulatory compliance, safety, and operational efficiency. 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 TEA 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.

7.2. 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



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.

The fundamental requirement for the placement of STOP (R1-1) and YIELD (R1-2) signs at intersections is to ensure maximum visibility and conspicuity for the approaching driver. While the methodology for selecting the appropriate type of intersection control is addressed in Chapter 6, the physical location of the sign is governed by the principles of driver recognition and sight distance. STOP and YIELD signs are to be placed as close as practicable to the intersection they regulate, while ensuring adequate sight distance and readability. In accordance with the *MUTCD*, these signs should be located no more than 50 feet in advance of the edge of the intersecting roadway's pavement. While placement is not required to be contiguous with the stop or yield line, this 50-foot maximum ensures a clear association between the sign and the intersection. This placement consideration is especially important at intersections with wide throats or large corner radii.



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 *MUTCD* Section 2B.10 and Chapter 6. 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.

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.

KEY POINT

All-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.

The installation of STOP signs is to be used exclusively for assigning right-of-way at intersections and not as a traffic calming measure for speed control. Field studies have demonstrated that the deployment of unwarranted STOP signs can introduce negative driver behaviors. These behaviors include a tendency for drivers to increase their speed between signs to compensate for lost time and a greater propensity to disregard signs that are perceived as unnecessary. Therefore, placement of all-way stop control must be justified through an engineering study based on the warrants established in the *MUTCD*, particularly Section 2B.12 for all-way stop applications.



R1-1 &
R1-3P

For intersections where all-way stop control is warranted, it is mandatory that each STOP sign be supplemented with an ALL WAY (R1-3P) plaque directly below it. This ensures that drivers on all approaches are aware of the intersection's control configuration. The use of obsolete plaques, such as "2-WAY," "3-WAY," or "4-WAY," is no longer acceptable as they fail to clearly communicate to drivers whether opposing or conflicting traffic is also required to stop. If an engineering analysis determines that an existing all-way stop controlled intersection should be converted to two-way stop control, a standardized procedure must be followed to ensure a safe and effective transition. The suggested procedure is highlighted below.

Two-Step Procedure to Change All-way Stop Control to Minor Road 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).

7.2.2. 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.

For enhanced pedestrian safety at marked midblock crosswalks, many highway agencies utilize In-Street Pedestrian Crossing signs (R1-6 or R1-6a). These double-sided, portable signs are placed directly in the roadway to provide a conspicuous reminder to drivers of their obligation to yield to or stop for pedestrians. The signs are intended for use on low-speed roadways and their placement on the centerline, a lane line, or a median island near the crosswalk reduces the effective lane width, which can also contribute to lower vehicle speeds. It is prohibited to install these signs on permanent posts.

Regulatory compliance is mandatory when selecting and installing pedestrian crossing signage. The choice between the R1-6 and R1-6a sign variants must correspond to the requirements of the applicable state vehicle code. Military installations are advised to consult with their state Department of Transportation (DOT) to verify specific state requirements and to obtain a list of approved traffic control devices before proceeding with installation.

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*

As an alternative, Overhead Pedestrian Crossing (R1-9 and R1-9a) signs may be installed above the roadway at the crosswalk.

For all signs mentioned (R1-6, R1-6a, R1-9, and R1-9a), the background color may be yellow, fluorescent yellow, or fluorescent yellow-green. In addition, the "STATE LAW " text may be omitted from the sign legend depending on jurisdictional requirements.

7.2.3. Speed Limit Signs (R2-Series)

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.

Chapter 15 details the methodology for determining 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 applications. In general, Speed Limit signs should be placed at the following locations:

- ✓ At the commencement of a new speed zone
- ✓ Downstream of major intersections
- ✓ At intermediate points along extended roadway sections



R2-1

While the *MUTCD* does not specify maximum spacing requirements for Speed Limit signs, state-level vehicle codes may impose unique requirements for enforcement. In the absence of any specific state mandates, it is recommended to maintain a maximum 1-mile spacing for speed limits of 35 mph or lower, and maximum 3-mile spacing for higher speed limits. As a matter of safety, Speed Limit signs should not be placed immediately in advance of a curve or turn, an intersection, a railroad crossing, or other areas that may require a reduction in speed.

In certain situations, posted speed limits may not achieve the desired reduction in vehicle operating speeds. This ineffectiveness typically occurs when the roadway's design speed is significantly higher than the posted limit, which encourages faster travel, or when there is a perceived lack of enforcement.

To improve compliance, the following countermeasures may be considered:

- ✓ **Increased Enforcement**: Enhance the frequency and visibility of speed enforcement activities.
- ✓ **Traffic Calming Devices**: Install longitudinal speed humps engineered for the target speed limit, provided the criteria outlined in pamphlet Chapter 16 of this document are met.
- ✓ **Roadway Narrowing**: Permit on-street parking to reduce the effective width of the travel lane, which can naturally slow traffic.



R2-1 and R2-2P



R2-5iP, R2-1, R2-5P



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

When it is necessary to establish a lower speed limit for specific vehicle types, such as trucks or other heavy vehicles, the Truck Speed Limit (R2-2P) plaque shall be utilized. This plaque, displaying the restricted speed, is to be mounted below the primary speed limit sign that indicates the speed limit for general traffic. The legend on the plaque may be modified as required to designate a different vehicle class.

Advance warning of speed limit reductions greater than 10 mph should be addressed using Speed Reduction (W3-5 or W3-5a) warning signs. See Section 7.3 for additional guidance.

Boundary Speed Limit Signs

To establish a uniform speed limit across an entire installation or within designated zones (e.g., residential or industrial areas), an area-wide speed limit may be implemented. This method serves as a cost-effective alternative to the installation of individual Speed Limit (R2-1) signs on all roadways.

Implementation requires a sign assembly to be installed at the primary entrance points of the designated area. The assembly shall consist of a Speed Limit (R2-1) sign with one of the following plaques mounted above it:

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

If any roadways within the designated area have a regulatory speed limit that differs from the established area-wide speed, an UNLESS OTHERWISE POSTED (R2-5P) plaque shall be mounted below the R2-1 sign in the main sign assembly. Individual Speed Limit (R2-1) signs must then be posted on those specific roadways.

To ensure maximum visibility of these boundary speed limit assemblies, the use of the larger 30”x36” Speed Limit (R2-1) sign is highly recommended.

For multi-lane approaches, a second, redundant sign assembly shall be installed. The preferred placement for this second assembly is on the left side of the roadway, such as in a median. If this is not feasible, the second assembly shall be installed on the right side of the roadway at a minimum distance of 250 feet downstream from the first sign.

Furthermore, upon exiting an area governed by a boundary speed limit, a sign indicating the new regulatory speed limit must be installed.

When Passing Troops Speed Limit

The 10 MPH WHEN PASSING TROOPS IN FORMATION (R2-1aP-TEA) sign is designated for use on roadways where troops periodically march in formation.

This sign shall only be installed as a supplemental plaque. It must be mounted directly below the primary Speed Limit (R2-1) sign, and this requirement applies in all cases, including within areas governed by a boundary speed limit.



R2-1aP-TEA

7.2.4. Turn Prohibition Signs (R3-Series)

Turn Prohibition signs shall be installed at all intersections where specific turning movements are prohibited by regulatory authority, except where physical channelization or ONE WAY signage clearly indicates the restricted movement. 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. To maximize visibility, signs shall be placed adjacent to the corresponding travel lane or signal face. 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

7.2.5. Part-Time Restrictions

For regulatory controls that are not active twenty-four hours a day—such as turn prohibitions, special speed zones, or reversible-lane operations—the most easily understood signage is that which remains visible to motorists only when the restriction is actively in effect. To achieve this, installations should ideally deploy dynamic signage, which includes either electronic blank-out signs that remain completely dark when inactive, or changeable message signs (CMS) capable of altering all or part of the display. These dynamic systems provide immediate, unambiguous notice of current traffic rules and significantly improve driver compliance.

When funding constraints or site conditions make electronic signs impracticable, agencies may instead install supplementary plaques directly beneath a static regulatory sign. The most effective static alternative is the WHEN FLASHING (S4-4P) plaque paired with an active yellow flashing beacon, which clearly signals to drivers exactly when the regulation applies. If an active flashing beacon is also unfeasible, a static time-of-day plaque (similar to the S4-1P plaque) showing the specific hours of the restriction may be installed below the regulatory sign. When utilizing these time-of-day plaques, the restricted hours must be displayed

in civilian time rather than military time. However, planners should note that time-of-day plaques are significantly less effective than flashing or electronic options, as fast-moving motorists often lack the time to read the detailed text or may not have a reliable clock available to verify the current time.

The ROAD CLOSED FOR PT X-X AM (R11-5-TEA) sign is a military-specific example of a part-time regulatory restriction. This sign should be used where a roadway is routinely closed for physical training activities during specific hours of the day. As with time-of-day plaques, the hours of operation should be displayed using civilian time rather than military time. Where practical, the sign should be placed far enough in advance of the closure to allow motorists to select an alternate route.



R2-1 & S4-4P



R3-2 & S4-1P



R11-5-TEA

7.2.6. Road and Gate Closure Signs (R11-Series)

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.

When appropriate, the GATE CLOSED (R11-2d-TEA) sign may be used in place of the R11-2 sign. (Refer to pamphlet Chapter 8 for information on the use of this sign at gate closures.)



R11-2



R11-2d-TEA

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.

As shown on Exhibit 7.24 and discussed in *MUTCD* Section 2B.75, 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 6K.07 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 struck on an end unless the barricade has been demonstrated to be crashworthy for that application and operating speed.

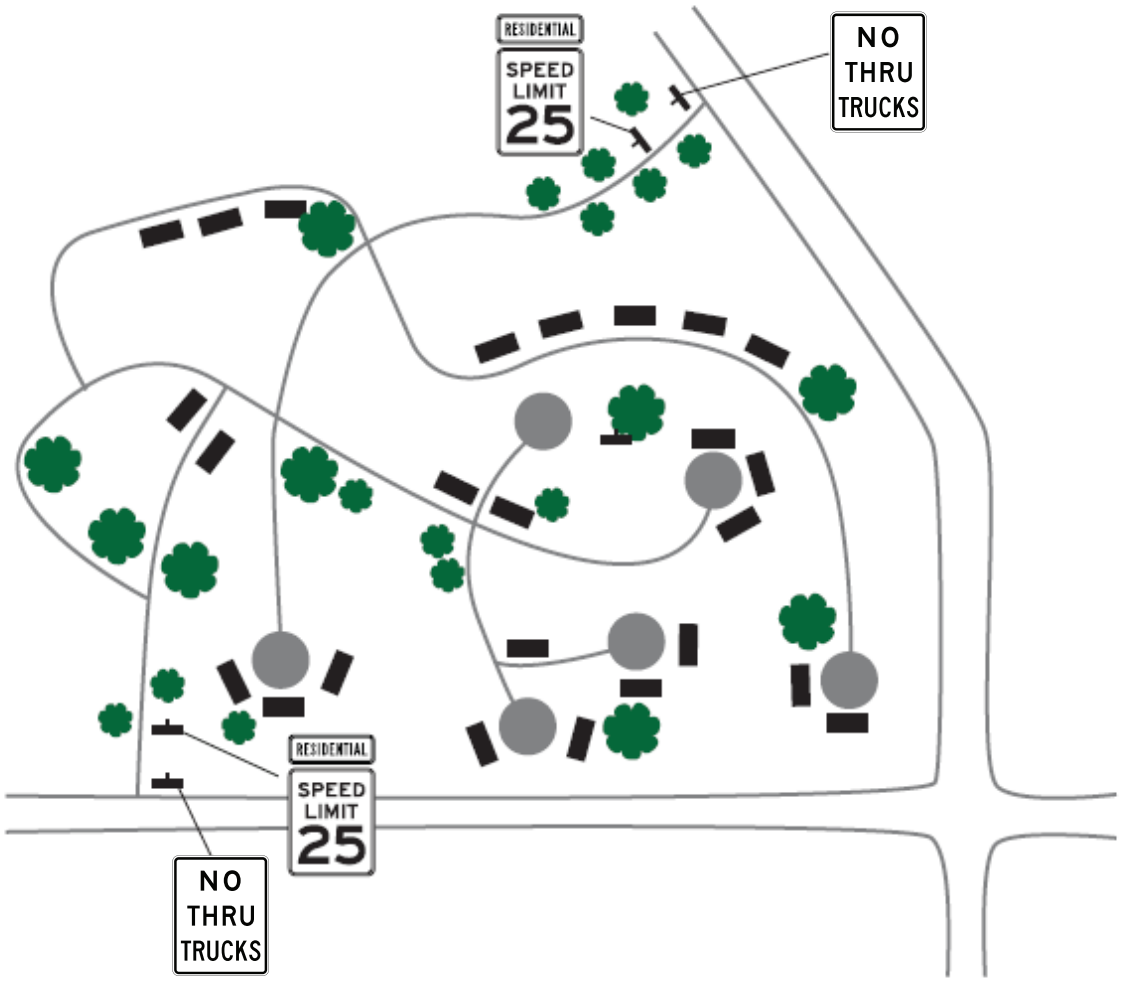
Exhibit 7.24: End-of-Roadway Barricade



7.2.7. NO THRU TRAFFIC (R5-12) Sign

The NO THRU TRAFFIC (R5-12) 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 7.25: Residential Area Signing



7.2.8. Reversible Lane Signs

Reversible-lane operations may be implemented on roadways with three or more travel lanes to accommodate peak directional traffic flows that vary by time of day. Due to the potential for driver error inherent in reversible operations, strict adherence to established traffic control standards is mandatory.

FHWA requires the use of overhead lane-use control signals when two or more lanes are reversed. These signals shall display, at a minimum, a steady RED X, a steady YELLOW X, and a steady DOWNWARD GREEN ARROW. Optional WHITE TWO-WAY or ONE-WAY LEFT TURN ARROW indications may also be used.

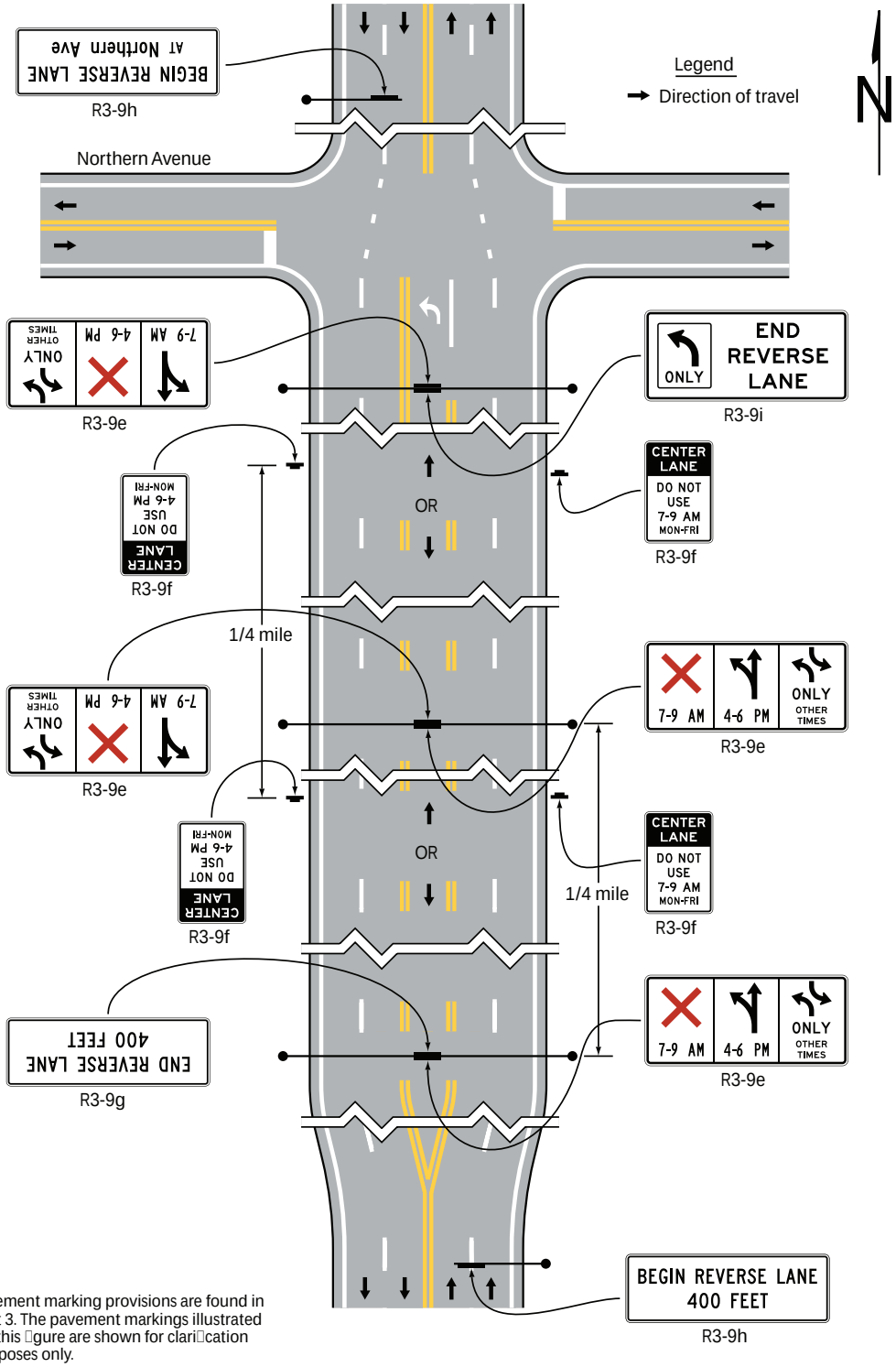
If using fiber optics or LEDs for the signals, it is possible to have a single signal section with more than one indication superimposed on top of each other, but if separate signal sections are used, they need to be arranged in the order indicated in Exhibit 7.26. However, the design and operational timing of such signal systems require the expertise of a professional engineer and are beyond the scope of this document.

For operations where only a single lane is reversed, a combination of overhead and ground-mounted signs may be used as an alternative to lane-use control signals, as detailed in Exhibit 7.27.

Exhibit 7.26: The Relative Order of Overhead Lane-Use Control Signals

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

Exhibit 7.27: Reversible Lane Control Signs



Note: Pavement marking provisions are found in Part 3. The pavement markings illustrated on this figure are shown for clarification purposes only.

Source: FHWA, MUTCD Figure 2B-7

7.2.9. 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 R7-2 sign.

Orientation

Although most traffic signs are installed approximately perpendicular to the edge of the roadway, parking-related signs with arrows erected beside a travel lane should be installed at an angle of not less than 30 degrees nor more than 45 degrees with the edge of the road, so that the signs would face drivers if drivers are looking toward the parking side of the roadway. 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.

Reserved Parking for Persons with Disabilities

Where on-street parking spaces are reserved for persons with disabilities, the Accessible Parking (R7-8) sign shall be used to designate the space and shall display the official International Symbol of Accessibility. The R7-8 sign is not required for accessible spaces within parking lots.

Signs at accessible spaces within a parking lot are governed by the ABA guidelines which specify displaying the official International Symbol of Accessibility but do not address other specifics, including color. There are no designated colors for the off-street parking signs (in parking lots) except for the many rules at installation/headquarters level. Considering, brown is an allowable color for accessible parking space signs within a parking lot.

When installed in parking lots, the sign should generally be installed at the front of the reserved parking space. If the parking space is designed to accommodate wheelchair vans, a VAN ACCESSIBLE (R7-8aP) plaque shall be installed below the R7-8 sign. To ensure the sign remains visible after a vehicle has parked, the bottom of the sign assembly may be installed as low as 5 feet above the pavement.

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



R7-2



R7-8



R7-8aP

Snow Emergency 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 Snow Emergnecy Route (R7-203) sign, but the legend on the bottom part of the sign should be modified to display the specific regulations, and include alternate type messages such as NO PARKING DURING DECLARATIONS, NO PARKING DURING EMERGENCIES, etc.



R7-203

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.

7.2.10. Traffic Signal Signs (R10-Series)

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 below.



R10-10



R10-11a



R10-12

7.2.11. Authorized Vehicles Only Signs (R5-Series)

The AUTHORIZED VEHICLES ONLY (R5-11) sign may be used to close a road to the public. When only government vehicles are permitted and all privately-owned vehicles (POVs) are forbidden, use the more specific GOVERNMENT VEHICLES ONLY (R5-11a-TEA) sign to avoid confusion.

In cases where POVs and government vehicles are allowed but tactical vehicles are not allowed, the NO TACTICAL VEHICLES (R5-11b-TEA) sign shall be used.

Install the sign at the beginning of the restricted area, placing it on the right side of the road or on both sides. The location must allow unauthorized vehicles a clear opportunity to turn and avoid the restricted zone.



R5-11



R5-11a-TEA



R5-11b-TEA

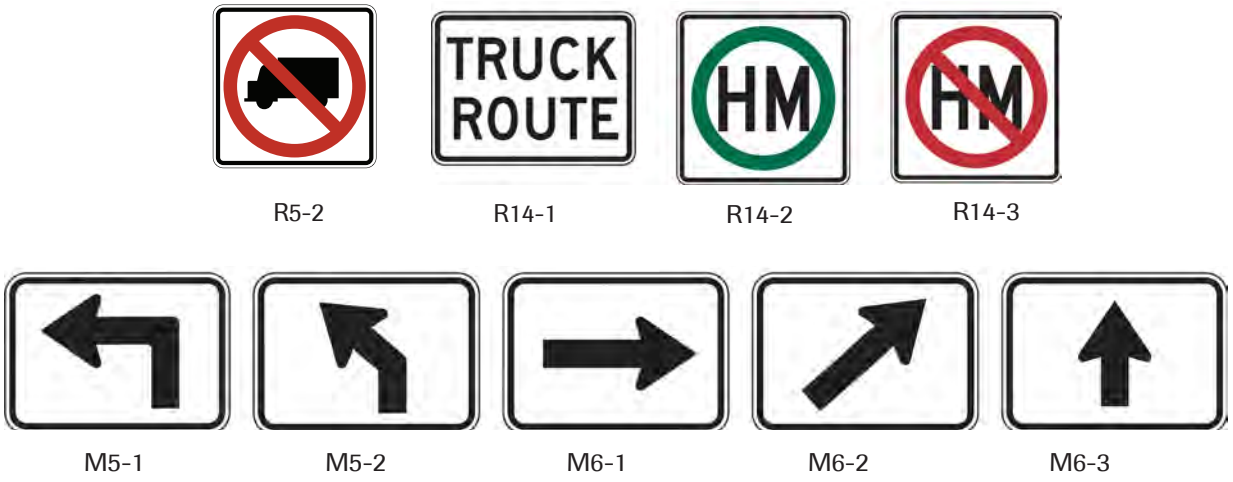
7.2.12. Truck Route Signs (R14-Series)

Military installations frequently establish designated truck and hazardous material (HAZMAT) routes to minimize population exposure to industrial traffic and hazardous cargo, such as military explosives. Standardized under the *MUTCD*, these corridors are marked using the appropriate TRUCK ROUTE (R14-1) sign or Hazardous Material Route (R14-2) sign. These signs must be installed at key locations to provide clear guidance for vehicle operators — place these markers either in advance of or immediately beyond major intersections, as well as at intermediate locations along the corridor to maintain route continuity. When a designated route changes direction, the R14-1 or R14-2 sign must be installed in advance of the intersection, paired with an appropriate directional arrow plaque (M-series as illustrated in Exhibit 7.28) positioned directly beneath the marker.

Because the establishment of a designated transport route does not automatically prohibit trucks or HAZMAT carriers from using alternative roads, installations wishing to restrict access must install explicit prohibition signage. To restrict access to a specific roadway for HAZMAT/Explosives, a Hazardous Material Prohibition (R14-3) sign must be installed at the beginning of the restricted road. To ensure operators have a physical opportunity to divert to an alternate route, the R14-3 sign should be placed within 25 to 50 feet after the intersection, positioned to be fully visible to approaching drivers before they commit to turning onto the prohibited roadway. To prohibit general truck traffic, use the No Trucks (R5-2) sign.

Typical signs and plaques used for truck routes are illustrated in Exhibit 7.28 below.

Exhibit 7.28: Truck Signs



R5-2 R14-1 R14-2 R14-3

M5-1 M5-2 M6-1 M6-2 M6-3

7.2.13. 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. The loading should be identified per UFC 3-310-08 and is beyond the scope of this document.

Once a bridge has been classified, 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 7.29 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 7.29: Sample Bridge Classification Signs



Single Lane MLC sign



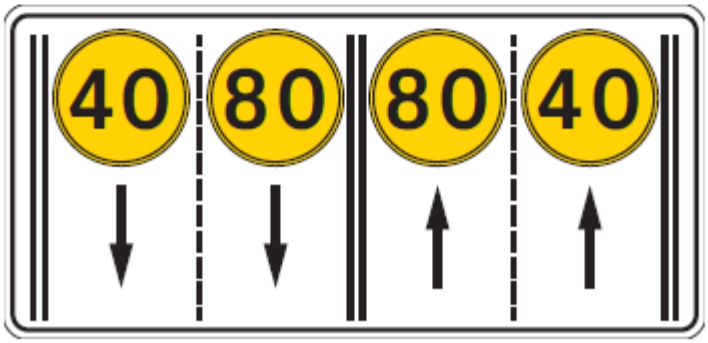
Bidirectional MLC sign



Single Lane, Dual Classification MLC sign



Bidirectional, Dual Classification MLC sign



Bidirectional, Multilane MLC sign

7.2.14. Processing/Inspection Signs (R16-Series)

The placement of a STOP sign within the ID check area of an Entry Control Facility (ECF) is strongly discouraged. However, in cases were a STOP sign is used, the PROCEED ONLY WHEN DIRECTED BY GUARD (R16-18P-TEA) plaque shall be mounted below the STOP (R1-1) sign, as drivers are required to remain stopped until instructed to proceed by security personnel.

The STAY IN VEHICLE (R16-19-TEA) sign is intended for use at ECFs and inspection stations where occupants are required to remain inside the vehicle during the identification or inspection process. The sign should be installed at the inspection location where the requirement applies.

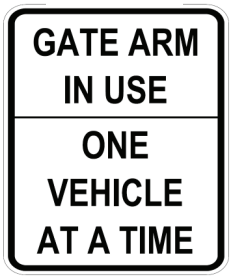
The GATE ARM IN USE – ONE VEHICLE AT A TIME (R16-20-TEA) sign is intended for use at ECFs, access gates, and other controlled entry locations equipped with gate arms. The sign should be installed in advance of the gate arm to inform drivers that only one vehicle is permitted to pass through the gate opening at a time.



R16-18P-TEA



R16-19-TEA



R16-20-TEA

7.2.15. Tire Spike Signs (R5-Series)

Tire spike signs shall be used when one-way tire spikes are in place. The signs are intended to inform motorists of their presence to prevent unintended damage.

The SEVERE TIRE DAMAGE (R5-29-TEA) sign warns motorists of the potential consequences of traveling through the tire spikes in the wrong direction. This sign shall be mounted directly below the DO NOT ENTER (R5-1) sign.

The DO NOT BACK UP – ONE-WAY TIRE SPIKES (R5-30-TEA) sign informs motorists traveling in the permitted direction that backing over the tire spikes can result in tire damage and should not be attempted.



R5-29-TEA



R5-30-TEA

7.2.16. ECF Vehicle Separation Signs (R4-Series)

The R4-31-TEA, R4-32-TEA, and R4-33-TEA signs are intended for use at ECFs and other access-controlled locations to direct specific vehicle classes to the appropriate processing lane, inspection area, or visitor center. These signs are designed to accommodate one, two, or three lines of text, respectively, and should include appropriate directional arrows.

R4-31-TEA is a single-line sign intended for directing one vehicle category (e.g., VISITORS or TRUCKS). R4-32-TEA is a two-line sign intended for directing two vehicle categories (e.g., VISITORS and TRUCKS). R4-33-TEA is a three-line sign intended for directing three vehicle categories (e.g., VISITORS, TRUCKS, and POVs). Left-turn arrows should be placed to the left of the message, while right-turn and straight-ahead arrows should be placed to the right of the message.



R4-31-TEA



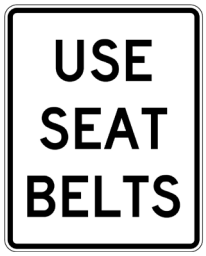
R4-32-TEA



R4-33-TEA

7.2.17. USE SEAT BELTS (R16-16-TEA) Sign

The USE SEAT BELTS (R16-16-TEA) sign, which may also feature the alternate message SEAT BELTS REQUIRED, can be used to emphasize that wearing safety belts is mandatory within the installation. For maximum effectiveness, the recommended placement for this sign is immediately following the entry gate. This location serves as a timely reminder for drivers who often remove their seat belts to present identification, encouraging compliance as they proceed onto the installation. However, it should be noted that the use of this sign is not required if the governing state law already mandates seat belt use.



R16-16-TEA

7.2.18. USE PARKING LIGHTS AT GATE (R16-17-TEA) Sign

To prevent oncoming headlight glare from blinding security personnel at ECFs, the USE PARKING LIGHTS AT GATE (R16-17-TEA) sign may be installed in advance of the checkpoint. This regulatory sign instructs approaching motorists to temporarily switch to their parking lights, ensuring guards maintain clear, unobstructed visibility of incoming vehicles and occupants as they approach the identification check stations.

By turning off their main headlights as they approach, drivers prevent their high or low beams from shining directly into the guards' eyes, allowing security personnel to clearly see the oncoming vehicle, read its license plate, and safely observe the driver.



R16-17-TEA

7.2.19. Radio Prohibition Signs (R22-Series)

When localized restrictions on the use of two-way radios and cell phones in the proximity of explosives or other sensitive areas exist, the TURN OFF 2-WAY RADIO AND CELL PHONE (R22-2-TEA) sign or the NO RADIO TRANSMISSIONS (R22-3-TEA) sign should 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.



R22-2-TEA



R22-3-TEA



R22-4-TEA

7.2.20. Cell Phone Prohibition Signs (R16-Series)

The NO HAND-HELD PHONE USE BY DRIVER (R16-15 and R16-15a) signs are intended to inform drivers that the use of a hand-held cellular phone while operating a motor vehicle is prohibited. These signs may be installed at installation entrances or other locations where a reminder of the restriction is appropriate. The signs should only be used where the prohibition is enforceable.



R16-15



R16-15a

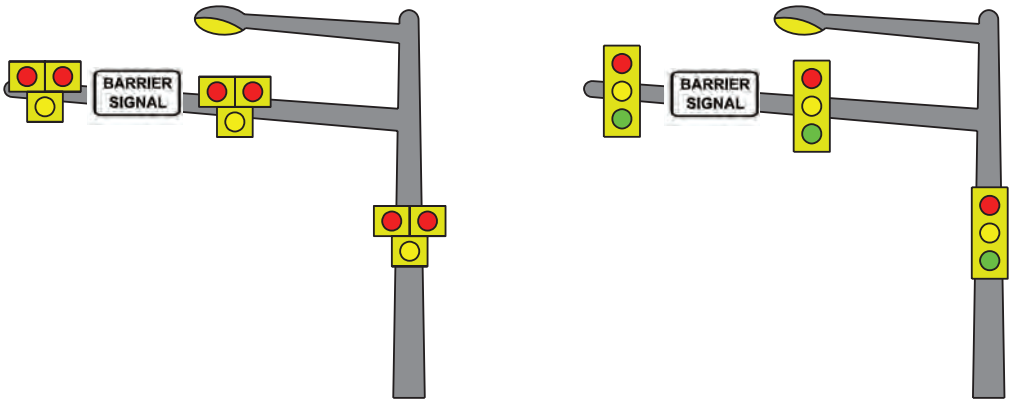
7.2.21. BARRIER SIGNAL (R10-13a-TEA) Sign

The BARRIER SIGNAL (R10-13a-TEA) sign shall be used in conjunction with traffic control signals or hybrid beacons located at active vehicle barriers (AVBs).

All roadway approaches to AVBs shall conform substantially to a TEA AVB Safety Scheme as detailed in TEA *Pamphlet 55-15*, with the latest edition of the schemes provided on the TEA website. The R10-13a-TEA sign shall be mounted adjacent to the overhead signal face when required by the TEA AVB Safety Scheme selected for use.

Exhibit 7.30 on the next page provides an illustration of the BARRIER SIGNAL sign as used with both traffic control signals and hybrid beacons. Although white legend on a red background was the previous standard, the current standard is black legend on a white background.

Exhibit 7.30: Barrier Signal Sign Use



7.3. WARNING SIGNS

Warning signs are intended to alert drivers to upcoming traffic or road conditions, and their installation should be justified by a clear need. The appropriate use of these signs on military installations is highly dependent on the environment. In low-speed, built-up areas, the use of warning signs is generally minimal and should be principally confined to alerting motorists of high-priority conditions such as an approaching checkpoint, an active vehicle barrier, or a designated pedestrian crossing. In contrast, rural or undeveloped areas may warrant a wider variety of warning signs for hazards including, but not limited to, unexpected turns and curves, STOP signs with poor visibility, pedestrian and animal crossings, low aircraft, and tank crossings. As a guiding principle, warning signs should only be installed where they will aid a large number of drivers and should not be used to denote conditions that would be readily apparent to an alert motorist.

7.3.1. Placement

The placement of warning signs must allow these 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. The advance placement distance, illustrated in Exhibit 7.31, is the distance between the warning sign and the condition or traffic control device for which the sign is being installed. Exhibit 7.31, which is derived from Table 2C-3 of the *MUTCD*, provides minimum recommended advance placement distances for warning signs.

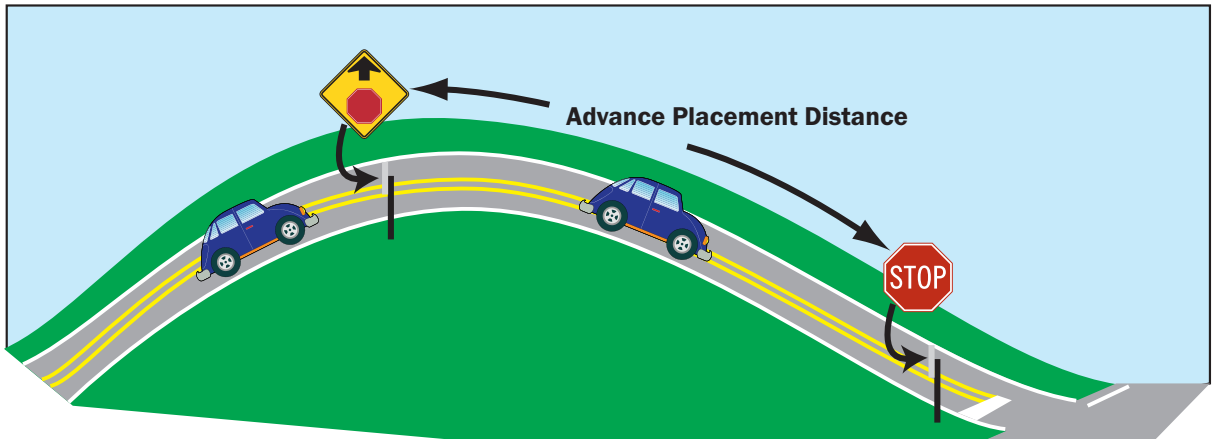
When using Exhibit 7.32, Condition A is only for those situations where motorists may have to change lanes in heavy traffic. Applicable warning signs that would be placed based upon Condition A include:

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

Condition B pertains to situations requiring motorists to decelerate to an advisory speed for an impending condition. This includes both potential stop conditions (assumed 0 mph) and locations where a driver must reduce speed to maneuver (e.g., 10-70 mph). When calculating the advance placement for Stop Ahead, Yield Ahead, Signal Ahead, and Intersection Warning signs, a 0 mph advisory speed must be used. This is because these signs precede potential stop situations where drivers may need to halt for turning or conflicting traffic,

and the placement calculation must account for the possibility of a full stop. For example, the minimum advance placement distance for a warning sign for a potential stop condition is 175 feet on a 45-mph roadway.

Exhibit 7.31: Advance Placement Distance



In cases where a warning sign precedes a turn, curve, or reverse curve, the advisory speed designated for that specific maneuver must be used to calculate the required advance placement distance. This ensures the sign is placed far enough ahead to allow drivers to safely decelerate to the advised speed before entering the curve.

Exhibit 7.32: 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	115 ft	N/A[5]						
25 mph	325 ft	155 ft	N/A[5]	N/A[5]					
30 mph	460 ft	200 ft	N/A[5]	N/A[5]					
35 mph	565 ft	250 ft	N/A[5]	N/A[5]	N/A[5]				
40 mph	670 ft	305 ft	100 ft[6]	100 ft[6]	N/A[5]				
45 mph	775 ft	360 ft	125 ft	100 ft[6]	100 ft[6]	N/A[5]			
50 mph	885 ft	425 ft	200 ft	175 ft	125 ft	100 ft[6]			
55 mph	990 ft	495 ft	275 ft	225 ft	200 ft	125 ft	N/A[5]		
60 mph	1,100 ft	570 ft	350 ft	325 ft	275 ft	200 ft	100 ft[6]		
65 mph	1,200 ft	645 ft	450 ft	400 ft	350 ft	275 ft	200 ft	100 ft[6]	
70 mph	1,250 ft	730 ft	525 ft	500 ft	450 ft	375 ft	275 ft	150 ft	
75 mph	1,350 ft	8200 ft	625 ft	600 ft	550 ft	475 ft	375 ft	250 ft	100 ft[6]

1. The distances are adjusted for a sign legibility distance of 180 feet for Condition A. The distances for Condition B (with the exception of the potential stop condition) 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 (2018 AASHTO Policy, Table 3-3, Decision Sight Distance, Avoidance Maneuver E) and adjusted for a 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 2018 AASHTO Policy, Table 3-1, Stopping Sight Distance, providing a PRT of 2.5 seconds, a deceleration rate of 11.2 feet/second^2.
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/second2, and adjusted for a 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. An alignment warning sign may be placed anywhere from the point of curvature up to 100 feet in advance of the curve. 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.

Note: Warning signs that advise road users about conditions that are not related to a specific location, such as Deer Crossing or SOFT SHOULDER, can be installed in an appropriate location, based on engineering judgment.

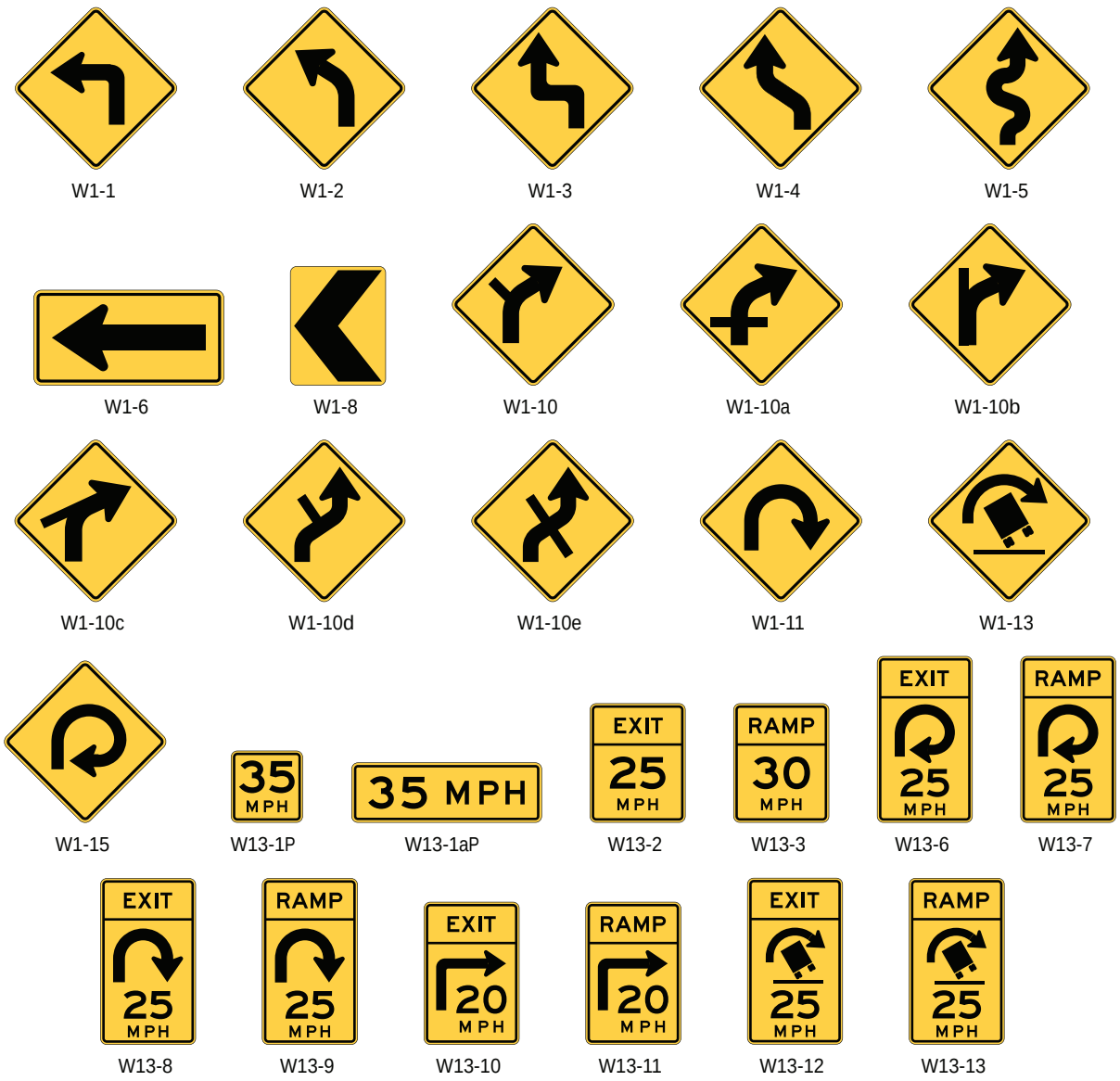
Source: FHWA, MUTCD Table 2C-3 (Speeds over 75 mph omitted from table.)

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.

Exhibit 7.33 illustrates the standard warning signs used for changes in horizontal alignment.

Exhibit 7.33: Horizontal Alignment Signs and Plaques



Note: Turn arrows and reverse turn arrows may be substituted for the curve arrows and reverse curve arrows on the W1-10 series signs where appropriate.

Source: FHWA, MUTCD Figure 2C-1

Each sign designation is unique, and it may include an "L" or an "R" suffix to indicate direction of the curve. 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. A base designation referenced without a suffix collectively encompasses both sign variants. For example, referencing the Turn (W1-1) sign implicitly includes both the W1-1L and the W1-1R signs. Note that the first five signs shown in Exhibit 7.33 have either an "L" (for left) or a "R" (for right) as the suffix at the end of the sign designation. 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 do not require specific left or right suffixes. The correct orientation for either application can be achieved by simply rotating the sign 180 degrees during mounting.

Horizontal alignment warning signs and other traffic control devices for changes in horizontal alignment should be installed in accordance with *MUTCD* Section 2C.06 and Table 2C-4. On urban streets with an AADT of 1,000 vehicles per day or less, horizontal alignment warning signs and devices may be omitted based on engineering judgment. For roadways with higher traffic volumes, the need for horizontal alignment warning signs and devices should be based on roadway type, traffic volume, and the difference between the roadway operating speed and the advisory speed through the curve.

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

> 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 used; 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.
>
> When there are two changes in alignment in opposite directions that are separated by a tangent of 600 feet or less, the Reverse Turn or Reverse Curve signs should be used instead of multiple Turn or Curve signs.

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.

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 7.34 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 7.34: Methods to Determine Spacing of Chevron Alignment Sign on Horizontal Curves

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, Table 2C-5, MUTCD

7.3.3. Intersection Warning Signs (W2-Series)

Warning signs are utilized to alert drivers to upcoming intersections and the potential hazard of merging, turning, or entering traffic. When engineering judgment indicates a critical need to inform road users in advance—particularly in the case of hidden intersections or high-volume major intersections—the installation of these signs is highly recommended. Examples of the most common W2-series warning signs are illustrated below and on the following page.

The Circular Intersection (W2-6) sign is designed for application at both traffic circles and at modern roundabouts. Although optional, the ROUNDABOUT (W16-12aP) 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:

- ✓ a YIELD sign, and
- ✓ 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 (W16-12aP) 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



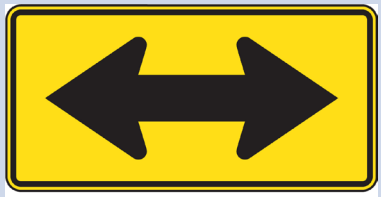
W16-12P
(optional)



W16-12aP
(optional)

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.



7.3.4. 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 7.35 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 7.35, 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 7.35: Warrants for Advance Traffic Control Warning Signs

85TH-PERCENTILE SPEED (MPH)	CONTINUOUS SIGHT DISTANCE TO THE TRAFFIC CONTROL DEVICE IS LESS THAN (FEET)	
	STOP OR YIELD SIGN*	SIGNAL FACES**
20	115	175
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 6B-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.

7.3.5. Reduced Speed Limit Ahead (W3-5 and W3-5a) Signs

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.

Advance Warning of Speed Reductions

Advance notification signs for speed reductions are not required at locations where drivers must stop or turn to enter the new speed zone, such as at the beginning of a side road.

However, in all other locations where the speed limit is reduced by more than 10 mph, advance notification is necessary. The Reduced Speed Limit Ahead (W3-5 or W3-5a) sign shall be installed to inform drivers of the upcoming change in the regulatory speed.

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 Zone Transition Signs

When the speed reduction is substantial, such as a step-down from 60 mph to 30 mph, engineers may implement transitional speed zoning to progressively lower the posted speed limit in steps, using multiple reduced speed signs and intermediate speed limits (e.g., 50 mph, 40 mph) to help drivers safely adjust to the significant speed reduction and guide them gradually into the lower speed environment. This approach helps reduce speed differential, improve compliance, and increase safety, especially where driver expectations or sight distance are limited.

7.3.6. Entry Control Facility Signs

There are several unique warning signs for use at ECFs in accordance with TEA *Pamphlet 55-15*: *Traffic and Safety Engineering for Better Entry Control Facilities*.

Advance warning signage is mandatory within the ECF approach zone to alert all drivers of an approaching checkpoint. Every ECF shall install a primary sign assembly consisting of a CHECKPOINT (W3-10a-TEA) sign paired with either an AHEAD (W16-9P) or XX FEET (W16-2P) plaque. This assembly ensures authorized drivers have adequate time to prepare to stop, while providing errant drivers a clear opportunity to execute a turnaround before reaching the gate.

Where approach conditions dictate a need for increased emphasis—such as on high-speed routes, multi-lane facilities, or extended roadways—the CHECKPOINT XX FEET - BE PREPARED TO STOP (W3-10b-TEA) sign may be installed as a supplemental warning in addition to the primary assembly.

After the checkpoint, an additional warning sign is necessary as drivers approach the AVB. The BARRIER ACTIVATED AHEAD (W3-3a-TEA) sign, with a WHEN FLASHING (W16-13P) plaque installed below the warning sign, shall be used on all approaches to AVBs. As the sign suggests, this sign is always used with amber flashing beacons that are activated simultaneously with the activation of the AVB.

Chicanes are frequently used as a traffic calming measure and a security measure, approaching and departing 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. The Winding Road (W1-5) sign with a CHICANE placard (W1-5P-TEA) is an acceptable warning sign to alert drivers. 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 chicane). Refer to TEA *Pamphlet 55-15* for proper placement of signs and corresponding sign enhancements.



W3-10a-TEA



W3-10b-TEA



W3-3a-TEA and W16-13P



W1-5R and W1-5P-TEA

7.3.7. Pedestrian Crossing (W11-2) Sign

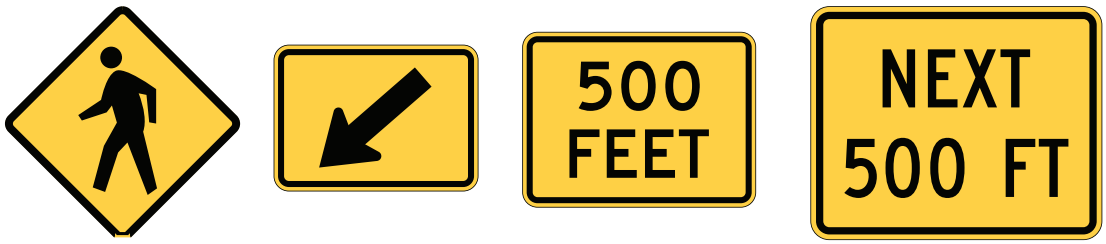
This section provides a general discussion on pedestrian signing for crosswalks. Refer to Chapter 13 for detailed guidelines on installation warrants, signing and striping of crosswalks.

Pedestrian crossing signs should be used to sign marked 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 a marked uncontrolled crossing must meet the warrants as presented in Section 13.3.

At marked uncontrolled crosswalks, the Pedestrian Crossing (W11-2) sign with a downward pointing arrow (W16-7P) plaque shall be installed at the crosswalk. Per TEA Crosswalk Warrants and Guidelines, there must be adequate sight distance prior to installation and the crosswalk shall not cross any part of an auxiliary lane and its transition.

> As outlined in Section 13.3, the installation of midblock crosswalks requires strict evaluation. Evidence indicates that marked crosswalks lacking additional enhancements can degrade pedestrian safety by fostering a false sense of security. Consequently, specific TEA warrants must be met prior to installing a crossing at a midblock location or on an uncontrolled approach. Standardized signing and marking layouts have been developed and must be applied. Refer to Chapter 13.

Refer to the TEA Crosswalk Warrants and Guidelines for signing for multiple crosswalks in close proximity, and blanket signing for existing crosswalks within housing areas.



W11-2* W16-7P W16-2P W16-4P

**A fluorescent yellow-green background color may be used for this sign or plaque.*

As a final note, pedestrian warning signs and their associated plaques are authorized to utilize fluorescent yellow-green (FYG) retroreflective sheeting as an alternative to standard yellow or fluorescent yellow material.

To maintain visual consistency and maximize driver recognition, installers must maintain color uniformity within a given area. Do not mix standard yellow and fluorescent yellow-green sign sheeting within the same vicinity or roadway corridor.

7.3.8. Military Vehicle Special Signs (W11-Series)

There is no approved symbology for this type of warning sign. No variants of these signs with symbols should be used in lieu of the text message.

The LOW AIRCRAFT (W11-26-TEA) sign may be used in advance of a runway when the sudden appearance or noise from a low-flying aircraft might startle an 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

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

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.

The HAZARDOUS CARGO CROSSING (W11-29-TEA) sign may be used to warn drivers that there may be trucks hauling hazardous materials crossing the roadway.

7.3.9. Playground (W15-1) Sign

If a designated children's playground exists near a roadway, a Playground (W15-1) sign may be installed to give driver's advance warning. When used, the sign may have a yellow or fluorescent yellow-green background. When a fluorescent yellow-green background is used, a systematic approach featuring one background color within a zone or area should be used.



W15-1

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

An Advance Street Name (W16-8P, W16-8aP) plaque may be used with any Intersection Warning sign (e.g., W2-1, W2-2, W2-3, W2-4, and W2-5) or Advance Traffic Control sign (e.g., W3-1, W3-2, and W3-3) to identify the name of the intersecting road. To improve legibility of the street name, mixed-case lettering shall be used (i.e., a combination of lower-case letters with initial upper-case letters).



W16-8P



W16-8aP

7.3.11. Gate and Road Closures

To prevent unnecessary vehicle transit and lost travel time, any ECF with restricted hours (i.e., closed on a routine basis during the workweek) located greater than one mile from a public roadway must feature advanced warning signage. 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 (W16-22P-TEA) plaque below the warning sign to indicate specific closure times. Other options include folding or removing the advance sign or using a WHEN FLASHING (W16-13P) plaque, in conjunction with amber flashing beacons. The hours should be shown in civilian times, not military times.



W20-3 &
W16-22P-TEA



W20-3g-TEA &
W16-22P-TEA

7.3.12. SPEED HUMP (W17-1) Sign



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, or loss of control for cyclists. 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 other cases, upward and downward slopes are again 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. If a series of speed humps exists in close proximity, the Advisory Speed plaque is needed only on the first SPEED HUMP sign in the series.

Refer to Chapter 16 for additional information regarding speed humps.

7.3.13. Object Markers

KEY POINT

Object markers are small warning signs but 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.

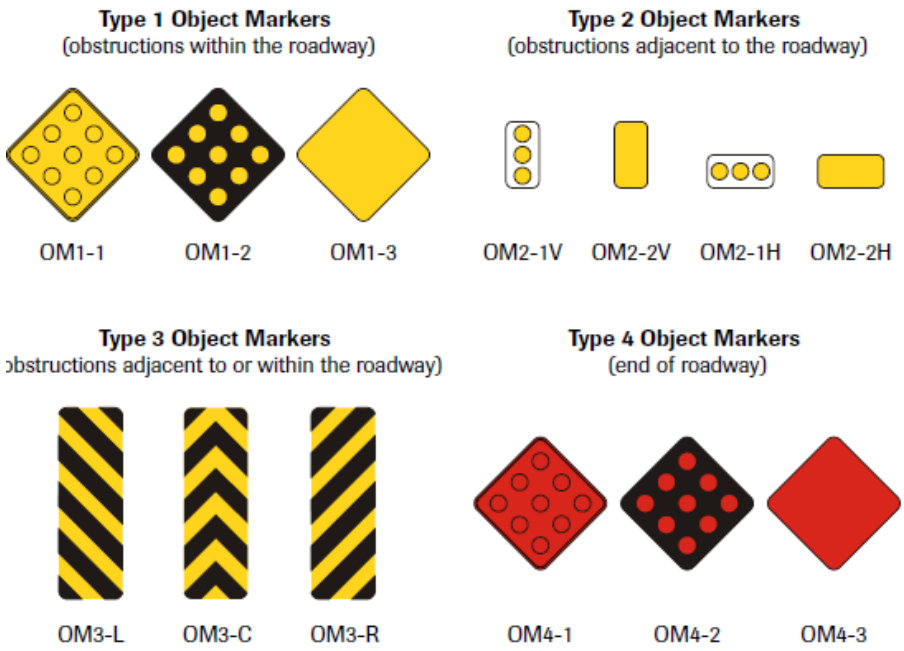
Figure 2C-17 of the *MUTCD* illustrates several types of object markers that may be used to mark roadway obstructions and other roadside hazards. The selection of the appropriate object marker should be based on the specific application, roadway geometry, and engineering judgment.

Object markers may use either retroreflective sheeting or retroreflective reflectors, as permitted by the *MUTCD*. Installations should consider visibility, maintenance requirements, durability, and life-cycle costs when selecting the most appropriate object marker for a particular location.

Exhibit 7.36 illustrates examples of commonly used object marker applications. These object markers are frequently grouped into the following four basic types:

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

Exhibit 7.36: Object Markers



Source: MUTCD Figure 2C-17

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 7.37 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.

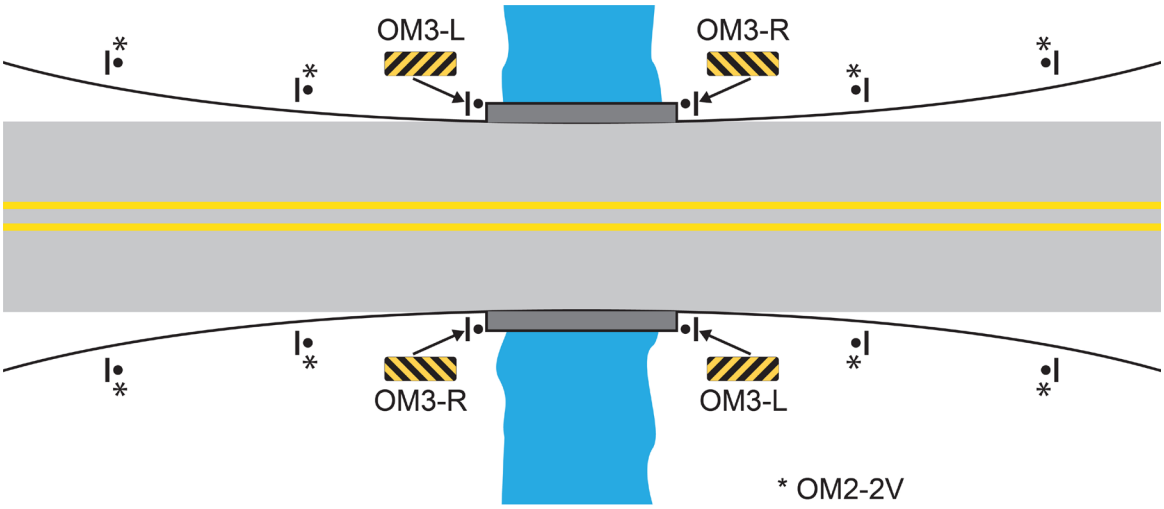
Type 2 object markers are excellent for warning of the presence of linear objects such as guard rail on the approach to bridges or the parapet on long bridges, especially when these obstructions are within 8 feet of the travel way. Wherever possible, also align these markers with the inside edge of the 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 7.37: Common Use of Object Marker



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. However, another option is to place a red-and-white Type III barricade across the end of the roadway as discussed earlier.

7.3.14. 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.



7.3.15. Advisory Speeds

KEY POINT

An advisory speed is a recommended safe speed for a specific condition.

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, since 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. Therefore, an advisory speed is only a recommendation.

The most common application of an advisory speed is with the Advisory Speed (W13-1) plaque installed below the Turn (W1-1) sign or Curve (W1-2) sign (shown below), but a W13-1 plaque may be used to supplement any warning sign to indicate the advisory speed for a condition. Another option for displaying warning speeds on Turn or Curve signs is to include it on the actual Turn or Curve sign legend (W1-1a).

If a regulatory speed limit, as displayed by black and white signs, is not appropriate at a 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.

As previously mentioned, advisory speed plaques may be used to supplement any warning sign, such as below intersection signs (such as a Cross Road [W2-1] sign 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 TEA *Pamphlet 55-15.*

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 TEA *Pamphlet 55-8* for more information on advisory speeds.



W1-1 and W13-1p

Turn sign with an Advisory Speed plaque



W1-2 and W13-1P

Curive sign with an Advisory Speed plaque



W1-1a

Combination Turn/ Advisory Speed Sign

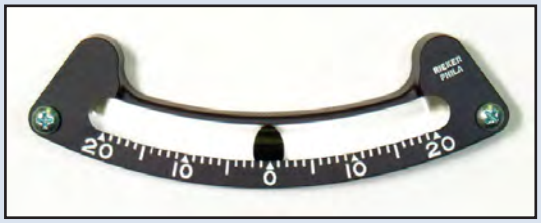


W3-10a-TEA and W13-1P

ECF Checkpoint sign with an Advisory Speed plaque

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.59). 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.

7.4. GUIDE SIGNS



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 destination. 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 *SHS* publication 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 7.38 and 7.39 provide additional details.

A maximum of three destinations should 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 7.38: 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.		

Exhibit 7.39: 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 FHWA requires the use of mixed-case lettering for all names used on guide signs.

The *MUTCD* currently defers to the *SHS* publication 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."

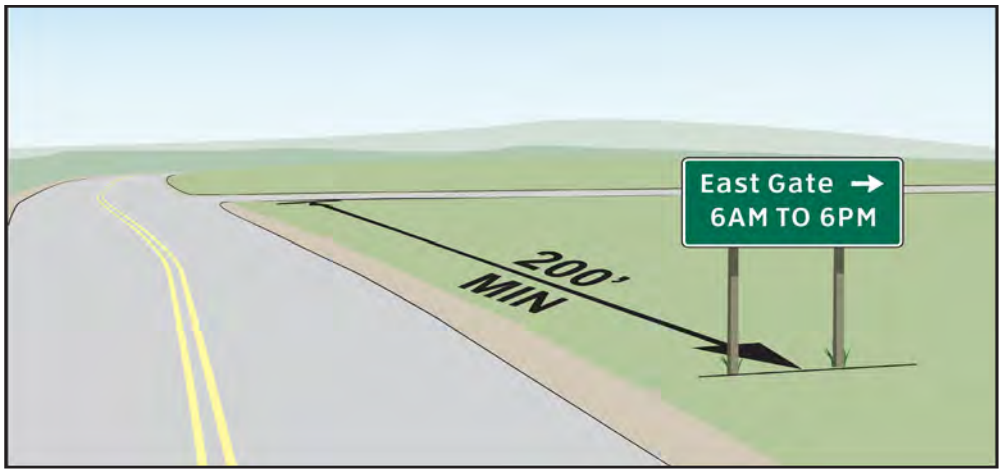
There are six different font series in Highway Gothic, Series B, C, D, E, E-Modified, and F. Within military installations, the suggested font is **Highway Gothic Series C for Street Name signs** and **Highway Gothic Series D for destination signs**. However, if signs made with these fonts would be too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

The Clearview font is newer, and uses a wider mixed-case lettering which increases visibility. Clearview is advantageous because the font is larger. Therefore, it may be considered where permitted under FHWA Interim Approval IA-5 and applicable state or local policies.The biggest disadvantage is that the wider font requires wider signs. If replacing a sign on an existing structure, verify that the loading from an increased size is adequate.

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.55, 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 8.3.7, 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



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 use mixed-case lettering. For signs with green, blue, or brown backgrounds, the legend should be white. For signs with white backgrounds, the legend should be black. Although the recommended background color is green, blue, brown, or white backgrounds are also permissible; however, it is desirable to maintain consistent colors throughout the military installation, or at least within a particular area of the installation. Letter heights should be selected in accordance with *MUTCD* Table 2D-6. In general, street name signs on conventional roads use 6-inch uppercase letters with 4.5-inch lowercase letters, while larger legends should be used on higher-speed and multi-lane roadways. Smaller legends may be appropriate on low-speed roadways. 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. If signs are mounted above a STOP or YIELD sign, it is recommended 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.



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.

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.

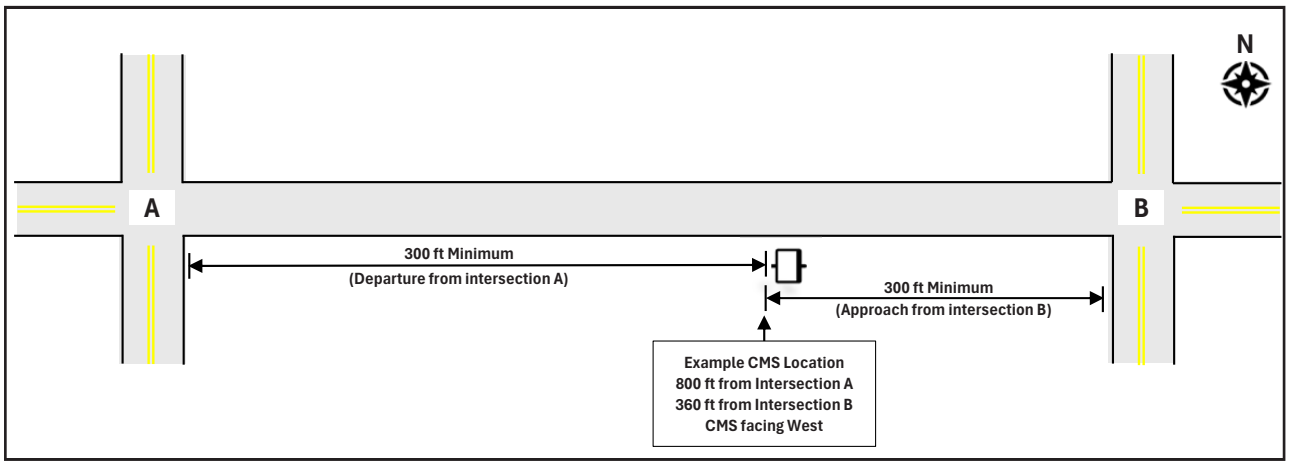
If street name signs are mounted overhead, the *MUTCD* recommends using minimum 12-inch mixed-case legends (i.e., 12-inch initial upper-case and 9-inch lower-case).

7.4.7. NON-TRAFFIC CONTROL ELECTRONIC CHANGEABLE MESSAGE SIGNS

Electronic changeable message signs (CMS) used for informational, or installation-specific messaging are not considered traffic control devices and should not be routinely installed along roadways. Where used, these signs should be limited to appropriate locations such as primary installation entrances or central community areas, and should not be placed where they could interfere with traffic control devices, restrict sight distance, or create unnecessary distraction for drivers, particularly near entry control facilities or barrier systems.

When located along or near a roadway, CMS units should be placed outside of the clear zone and positioned to minimize impacts to roadway operations. As a general guideline, CMS should not be installed within 300 feet of an intersection or within 200 feet of an active vehicle barrier, and should be set back a minimum of 16 feet from the edge of roadway to maintain adequate sight distance for vehicles and pedestrians. CMS should not be located in areas with frequent lane changing, merging, or complex traffic conditions, and the sign face should be oriented slightly away from the roadway (e.g., approximately 3 degrees) to reduce glare. These guidelines may be adjusted based on an engineering study evaluating roadway, roadside, and pedestrian safety.

Exhibit 7.40: Electronic Changeable Message Sign Placement



CHAPTER 8 – MARKINGS

8.1. GENERAL 8-1
8.2. PAVEMENT MARKINGS 8-1
8.3. DELINEATION 8-32

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 https://mutcd.fhwa.dot.gov/pdfs/11th_Edition/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



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 including centerlines, lane lines, and edge lines.
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. Marking Retroreflectivity

Importance of Retroreflective Pavement Markings

Retroreflective pavement markings play an important role in roadway safety by improving visibility, particularly at night and in adverse weather conditions. Unlike standard markings, retroreflective materials reflect light from vehicle headlights back toward drivers, ensuring clear lane guidance and reducing the risk of collisions.

Types of Retroreflective Markings

✓ Longitudinal Markings (centerlines and edge lines): Provide continuous lane guidance to prevent lane departures.

- ✓ Crosswalk Markings: Highlight pedestrian crossings, making them more visible to drivers.
- ✓ Wet-Reflective Markings: Improve marking visibility during rain, helping drivers maintain lane position in poor weather.

Safety Benefits

Maintaining adequate retroreflectivity improves road safety by:

- ✓ Reducing nighttime crashes through enhanced visibility.
- ✓ Supporting pedestrian safety by ensuring crosswalks are visible from greater distances.
- ✓ Enhancing roadway navigation in adverse conditions like rain or fog.

Maintenance and Compliance

Regular inspections and maintenance are essential to ensure markings meet minimum retroreflectivity standards. Agencies should implement monitoring programs to identify and replace faded markings to maintain optimal visibility.

Recent updates to national standards now require agencies to adopt a method for maintaining the retroreflectivity of longitudinal pavement markings. These requirements apply to roadways with speed limits of 35 mph or higher and with an ADT of 6,000 vpd or greater. This is intended to ensure markings remain visible under nighttime driving conditions.

While not all markings are subject to minimum retroreflectivity levels, agencies are encouraged to keep all pavement markings visible and effective for their intended purpose. Exceptions may apply based on roadway type, traffic volume, or environmental conditions.

To support compliance, agencies may conduct pavement marking assessments that include inventories, condition evaluations, and retroreflectivity measurements. These efforts help identify markings that need replacement and ensure consistent visibility across the roadway network. Additional information on maintaining minimum pavement marking retroreflectivity can be found in Section 3A.05 of the *MUTCD*.

8.2.2. Materials

Many different types and classes of pavement marking materials are available. Common types of pavement marking materials used in the United States, 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
- ✓ Commonly used for temporary or construction-phase markings due to quick installation and removability

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 two 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).

8.2.3. Application of Waterborne Paint



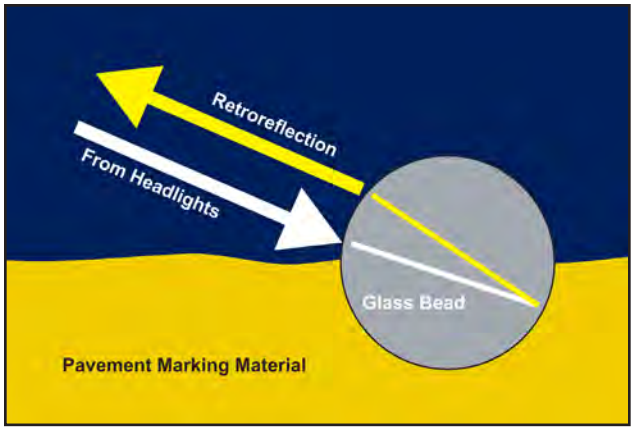
Waterborne paint with embedded glass beads is the most popular and cost-effective pavement-marking material for longitudinal lines.

Waterborne paints are generally applied at a wet thickness of at least 15 mils (0.015 inch). Therefore, 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.

8.2.4. 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.

8.2.5. 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.

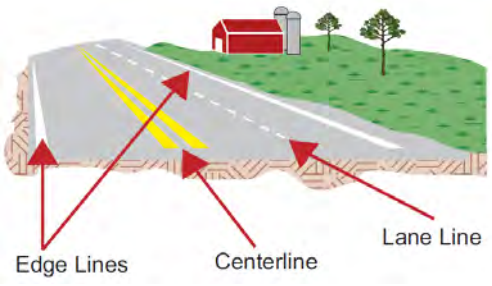
Concrete Pavements

- ✓ 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.

8.2.6. 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 8.1, these longitudinal markings include:

- ✓ Centerlines which separate opposing traffic flows.
- ✓ Edge lines that delineate the edge of the roadway.
- ✓ Lane lines which separate lanes of traffic traveling in the same direction.

Exhibit 8.1: Warrants for Pavement Markings

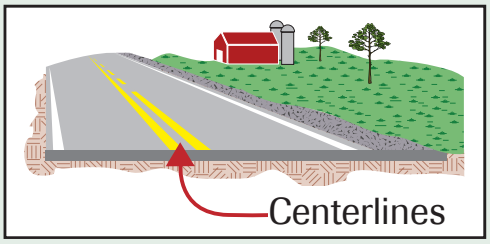
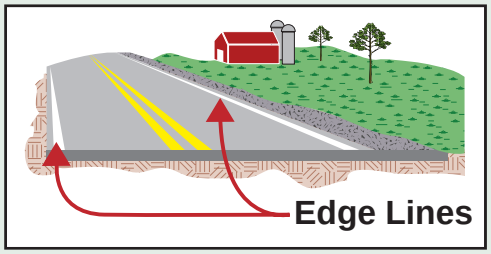
TYPE, PURPOSE, AND APPLICATION	*MUTCD* CRITERIA	BENEFITS
CENTERLINES  ✓ Provides separation of traffic traveling in opposite directions ✓ Provides delineation of separation	Standard: ✓ Mandatory for all paved urban arterials and collectors with a travel way width of 20 feet or more and an ADT of 6,000 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

Exhibit 8.1: Warrants for Pavement Markings, continued

LANE LINES ✓ Provides separation of traffic traveling in the same direction on multi-lane roadways	Standard: ✓ Mandatory for freeways and interstate highways Guidance: ✓ Should be placed on all roads with two or more travel lanes in the same direction	✓ Improves lane discipline and reduces sideswipe and lane departure 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

Exhibit 8.1 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.

The basic types of longitudinal markings are illustrated in Exhibit 8.2, and typical dimensions for pavement markings are shown 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, 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. In general, longitudinal markings should have a minimum width of 4 inches, although wider lines are helpful both day and night. Double solid yellow and white lines should typically have a 4- or 6-inch space between them. Broken yellow and white lines should have a 10-foot line and a 30-foot skip. Dotted lines should have 2-foot line and a 4-foot skip. Examples of pavement marking dimensions are shown in Exhibits 8.2 and 8.3.

Warrants for the use of pavement markings are contained in the *MUTCD*.

Exhibit 8.2: Primary Longitudinal Pavement Markings

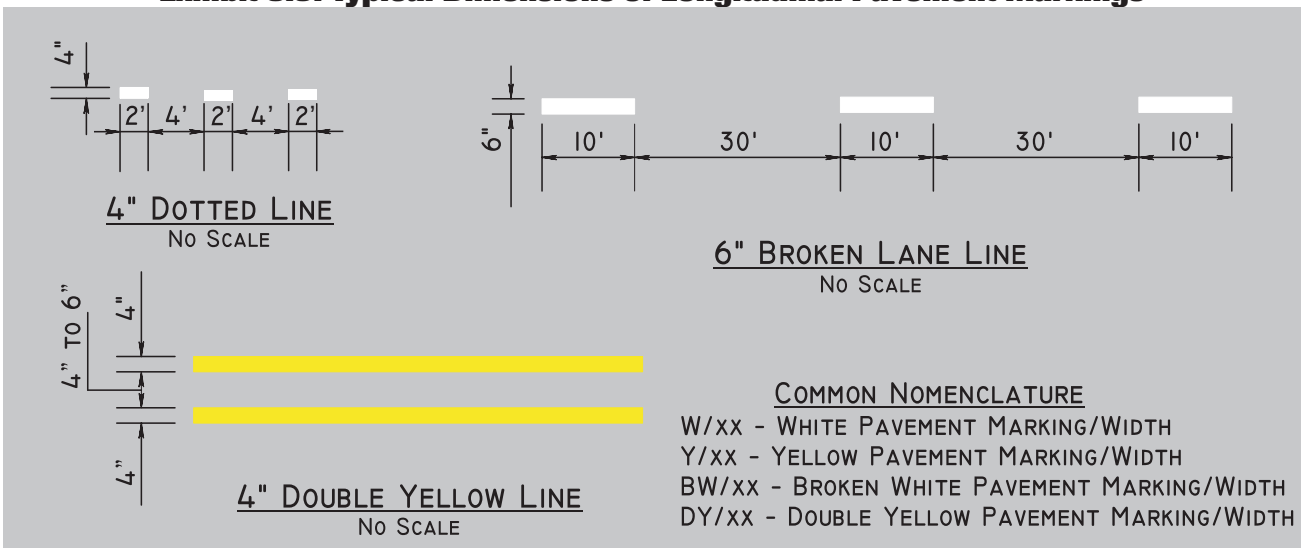
Solid Yellow Line	The solid yellow line indicates a no-passing zone applying to traffic with the solid line to its immediate left. Used alone, a single solid yellow line is only used to define the median of a freeway or divided roadway, or left edge of a one-way roadway.
Double Solid Yellow Line	A double 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 direction. Lane changing is permitted.

Exhibit 8.2: Primary Longitudinal Pavement Markings, continued

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 8.3: Typical Dimensions of Longitudinal Pavement Markings



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 8.4. 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.

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.
15. In advance of marked crosswalks where engineering judgment indicates additional restrictions on passing are necessary to improve pedestrian safety.

Exhibit 8.4: Minimum Passing Sight Distance

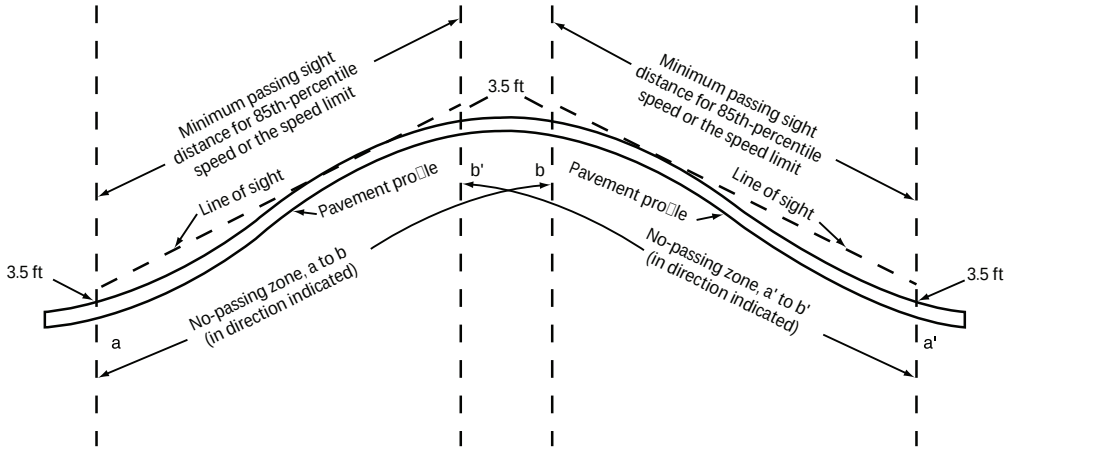
85th-Percentile or Posted or Statutory Speed Limit (mph)	Minimum Passing Sight Distance (feet)*
25	450
30	500
35	550
40	600
45	700
50	800
55	900
60	1,000
65	1,100
70	1,200
* Measure passing sight distance between two points that are 3.5 feet above the pavement.	

Source: MUTCD Table 3B-1

If establishing a no-passing zone because of Items 1 through 7, consider using an advance no-passing zone length equal to approximately 50 percent of the minimum passing sight distance shown in Exhibit 8.4.

Exhibit 8.5: Determining Limits of No-Passing Zones at Curves

A – No-passing zone at VERTICAL CURVE



a, a' Begin no-passing zone

Sight distance becomes less than minimum measured between points 3.5 feet above pavement

b, b' End no-passing zone

Sight distance again exceeds minimum

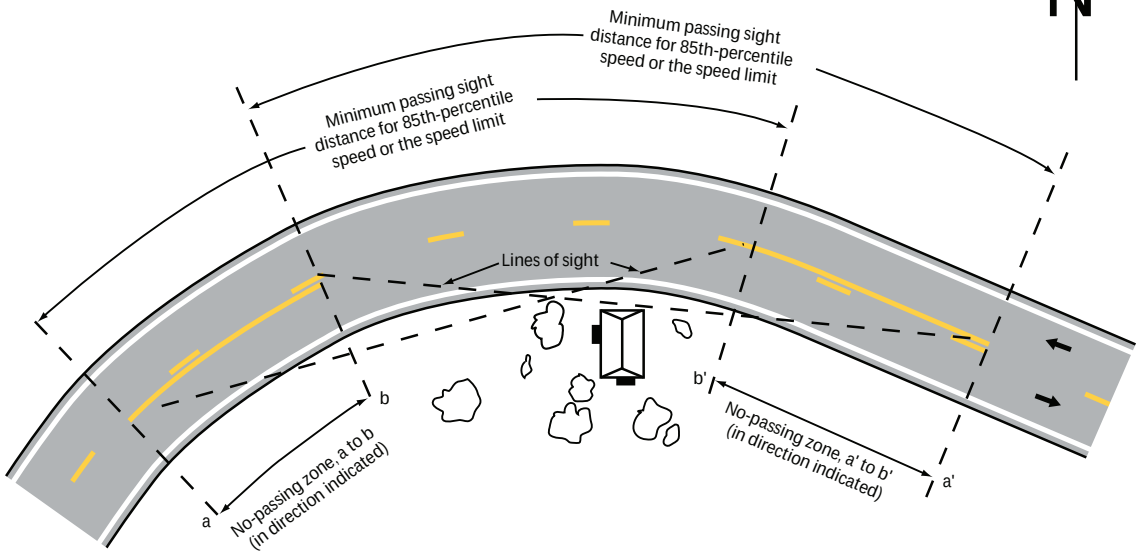
Profile View

Note: No-passing zones in opposite directions might or might not overlap, depending on alignment

Legend

→ Direction of travel

B – No-passing zone at HORIZONTAL CURVE



a, a' Begin no-passing zone

Sight distance becomes less than minimum measured between points 3.5 feet above pavement

b, b' End no-passing zone

Sight distance again exceeds minimum

Plan View

Note: No-passing zones in opposite directions might or might not overlap, depending on alignment

Source: FHWA, MUTCD

8.2.8. White Lane Line Pavement Markings and Warrants

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 white 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.

8.2.9. Longitudinal Pavement Markings at Opposing Left-Turn Lanes



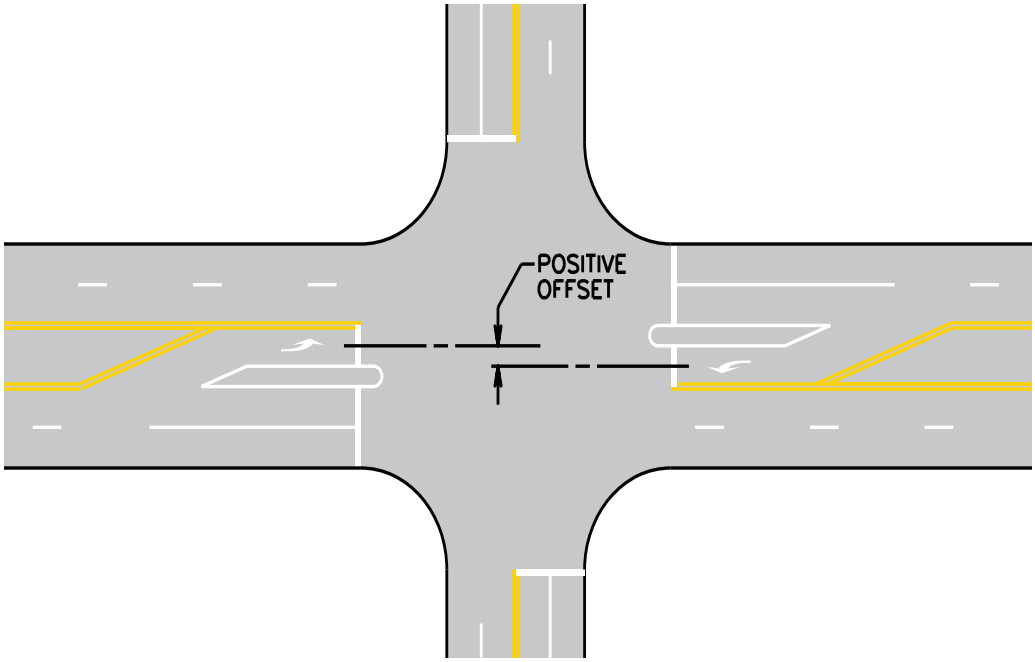
Opposing left-turn lanes can create sight distance problems for drivers if vehicles are in both turn lanes at the same time. A positive offset between the opposing turn lanes can reduce the number of crashes and this offset can frequently be accomplished by narrowing the travel lanes.

When opposing left-turn lanes exist at an unsignalized intersection or at a signalized intersection where vehicles are allowed to turn left on an unprotected left-turn signal indication (circular green or flashing yellow arrow), 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 8.6.

A study of 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 left-turn lane offsets whenever possible. According to research, the minimum desirable positive offset is 2 feet for passenger cars and 3.5 feet for truck traffic.

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, as depicted in Exhibit 8.6. Sometimes it is feasible to use reduced lane widths through the intersection to accommodate 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 width to 10.83 feet. However, any reduction in lane width should be evaluated, as narrower lanes and the presence of trucks may alter driver behavior and reduce overall intersection capacity.

Exhibit 8.6: Positive Offset at Opposing Left-Turn Lanes



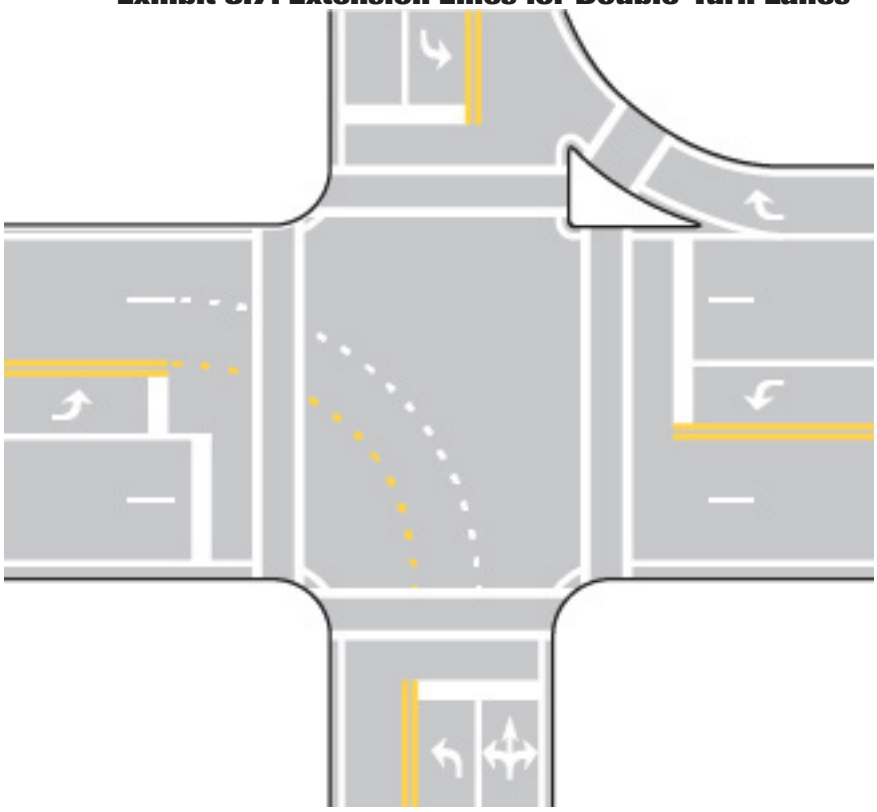
[1] *Safety Evaluation of Offset Improvements for Left-Turn Lanes (FHWA-HRT-09-035),*
http://www.fhwa.dot.gov/publications/research/safety/09035/index.cfm

8.2.10. 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 8.7, these dotted lines typically should be 2 feet long with 4 feet between the line segments. These dotted lines should be the same color and 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 8.7). Dotted extension lines may also be used where desirable to provide vehicle guidance through complex intersections, including offset intersections, skewed intersections, multi-leg intersections, closely spaced intersections, and locations where roadway alignment may not be readily apparent to drivers.

Exhibit 8.7: Extension Lines for Double-Turn Lanes

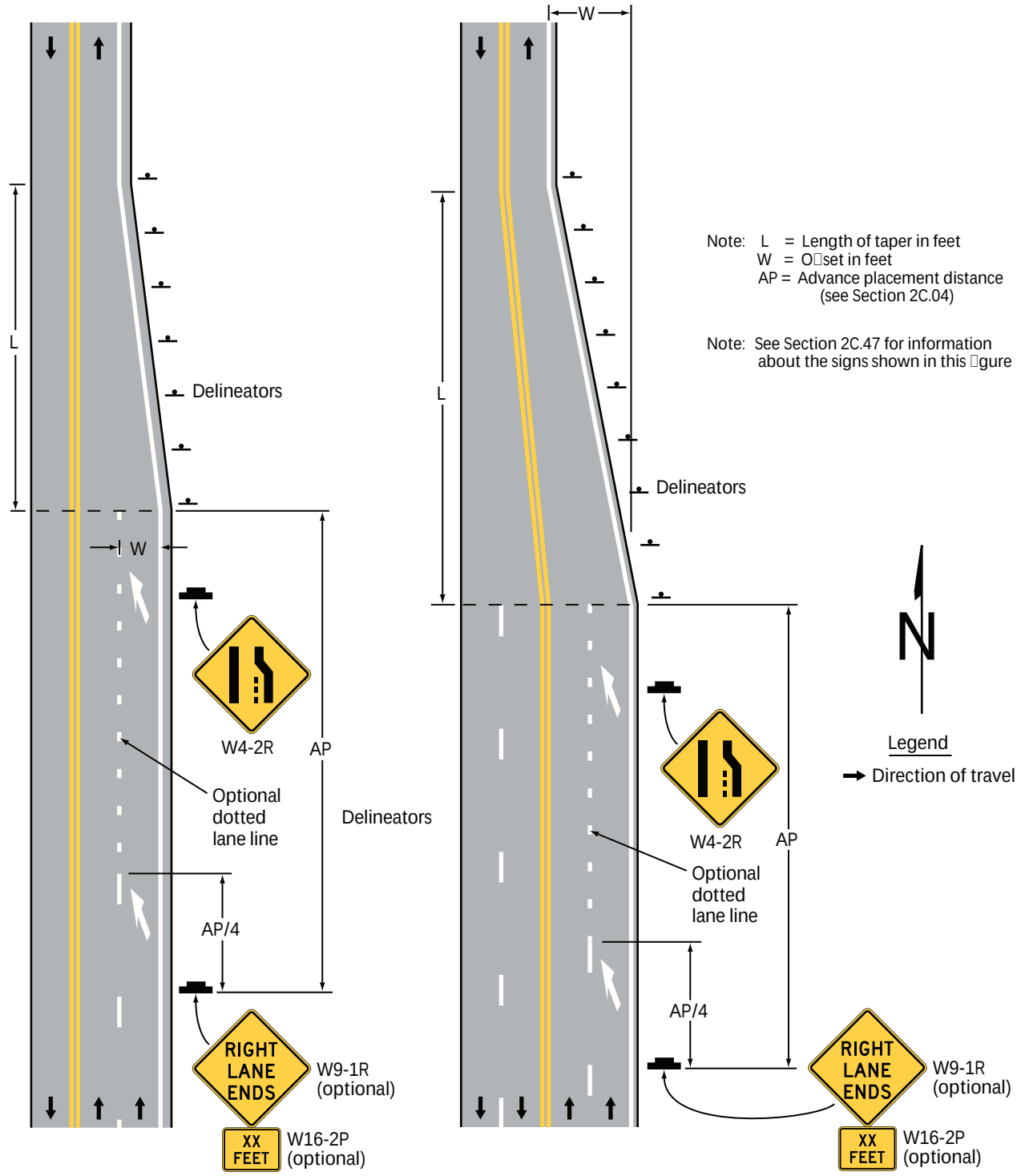


8.2.11. Lane-Reduction Transition Markings

Section 3B.12 of the *MUTCD* discusses lane reductions from where the number of through lanes is reduced, with several different scenarios identified in Figure 3B-14 of the *MUTCD*. Lane reduction transitions generally function as no-passing zones and should be marked accordingly to discourage passing maneuvers through the transition area.

Exhibit 8.8 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 "AP" is the advance warning sign distance for "Condition A" in Exhibit 7.32.

Exhibit 8.8: Typical Lane Reduction Marking



Source: FHWA, MUTCD, Figure 3B-14

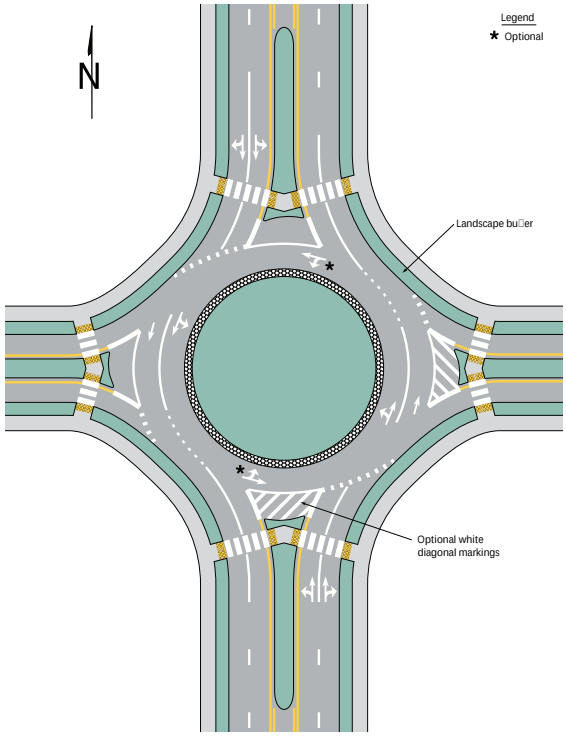
8.2.12. Markings for Circular Intersections (Roundabouts)

Even though the *MUTCD* now uses the term "circular intersections," TEA continues to recommend the use of roundabouts and applies that terminology throughout this guidance. Roundabouts provide additional capacity, safety, and many other environmental benefits, and as a result 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 3D in the *MUTCD*, which includes 8 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 8.9).

TEA can provide assistance with the design and pavement marking plan for roundabouts.

Exhibit 8.9: Example Markings for a Two-Lane Roundabout with One-Lane and Two-Lane Approaches



Source: MUTCD Figure 3D-3 (A)

8.2.13. 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
- ✓ Crosswalks
- ✓ Parking spaces

8.2.14. Stop and Yield Lines



Improper placement of stop and yield lines is problematic.

Stop and yield lines should be located between 4 and 30 feet from the near edge of the intersecting roadway and at the location where motorists are required stop or yield.

Stop Lines

The stop line is retroreflective white and should be 12 to 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) signs.

At intersections with STOP signs, there is a tendency to place these lines too far back from the edge of the intersecting roadway, often at a point where drivers cannot adequately see approaching traffic to make a safe decision to proceed. 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. When stop lines are placed excessively far back, another frequent operational issue is that drivers may stop twice, first at the marked line and then again at the STOP sign or at a position where they feel they finally have sufficient visibility.

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 35 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.

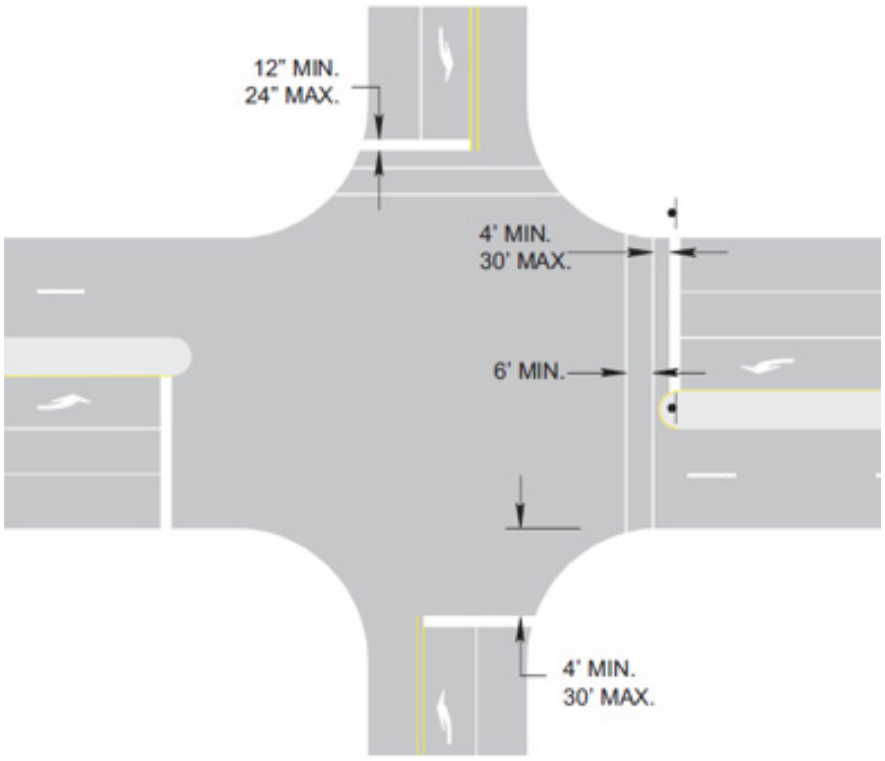
Ideally, stop lines should be set back a sufficient distance from the intersection to accommodate trucks turning into the approach roadway. At signalized intersections, the location of the lines should be adjusted to accommodate the trucks so they can clear a queue of vehicles stopped at the stop line.

Moreover, if the stop line for the left-turn 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. TEA's BMTE calculators may be used to assist with the placement of stop lines and yield lines where specific intersection characteristics are entered.

Other design details are illustrated in Exhibit 8.10.

Exhibit 8.10: Stop Line Placement

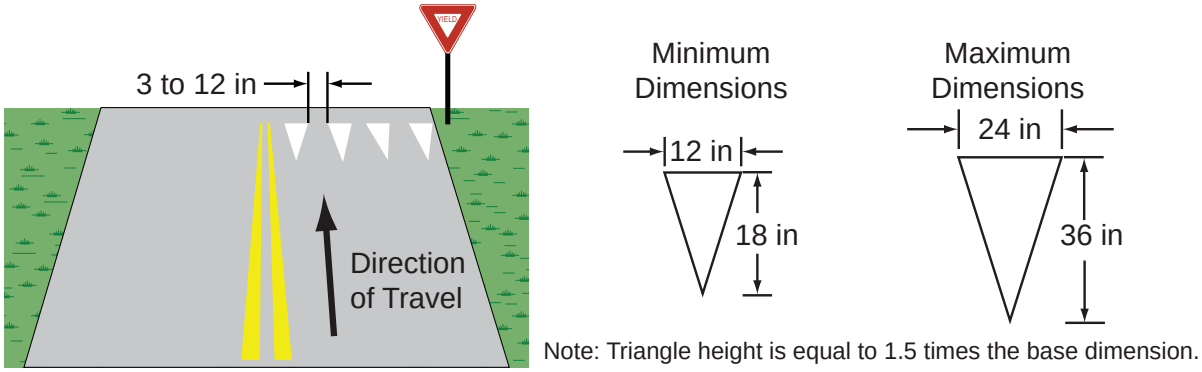


Yield Lines

Prior to the year 2000, the solid 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 point toward approaching vehicles and extend across the lane to indicate the location at which the yield is intended or required to be made. 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 8.11) or Yield Here to Pedestrians (R1-5) 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 8.11: Typical Yield Line Details



Note: Triangle height is equal to 1.5 times the base dimension.

8.2.15. 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.

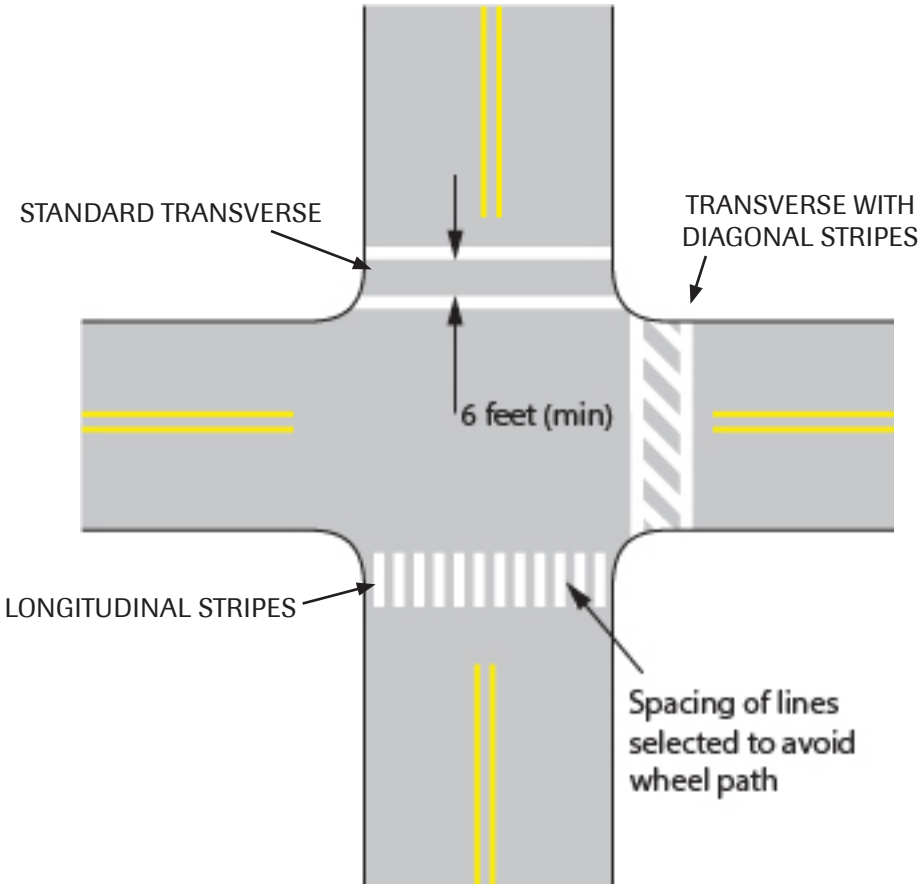
Crosswalk markings are common at intersections. Exhibit 8.12 illustrates the three types of crosswalk markings commonly used in the United States and some key design features. Although any of these three types are acceptable, it is desirable not to mix the types. The minimum effective width of a marked crosswalk is 6 feet, as measured between the inside edge of the transverse markings. At non-intersection crosswalks where the posted speed limit is 40 mph or greater, the minimum crosswalk width shall be 8 feet.

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, including those in wheelchairs and with mobility or visual impairments.



There are also decorative pavement marking materials that are commercially available to simulate brick, pavers, flagstone, etc. However, in accordance with Section 3H of the *MUTCD*, these materials are unacceptable if they are white or yellow colors designed to warn or regulate traffic, if they use any colors that fall within the chromaticity coordinates of standard traffic-control device colors as defined in Section 3H.03 (such as the greens used for bike facilities or the reds used for transit applications), 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 8.12: 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. For midblock crosswalks, high-visibility markings, warning signs, and lighting should be used to enhance pedestrian safety. Midblock crossings, and crossings on uncontrolled approaches at intersections, must meet installation warrants as developed by TEA; see pamphlet 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 pamphlet 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 8.13.

Exhibit 8.13: Skewed Crosswalk Configurations







8.2.16. 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.

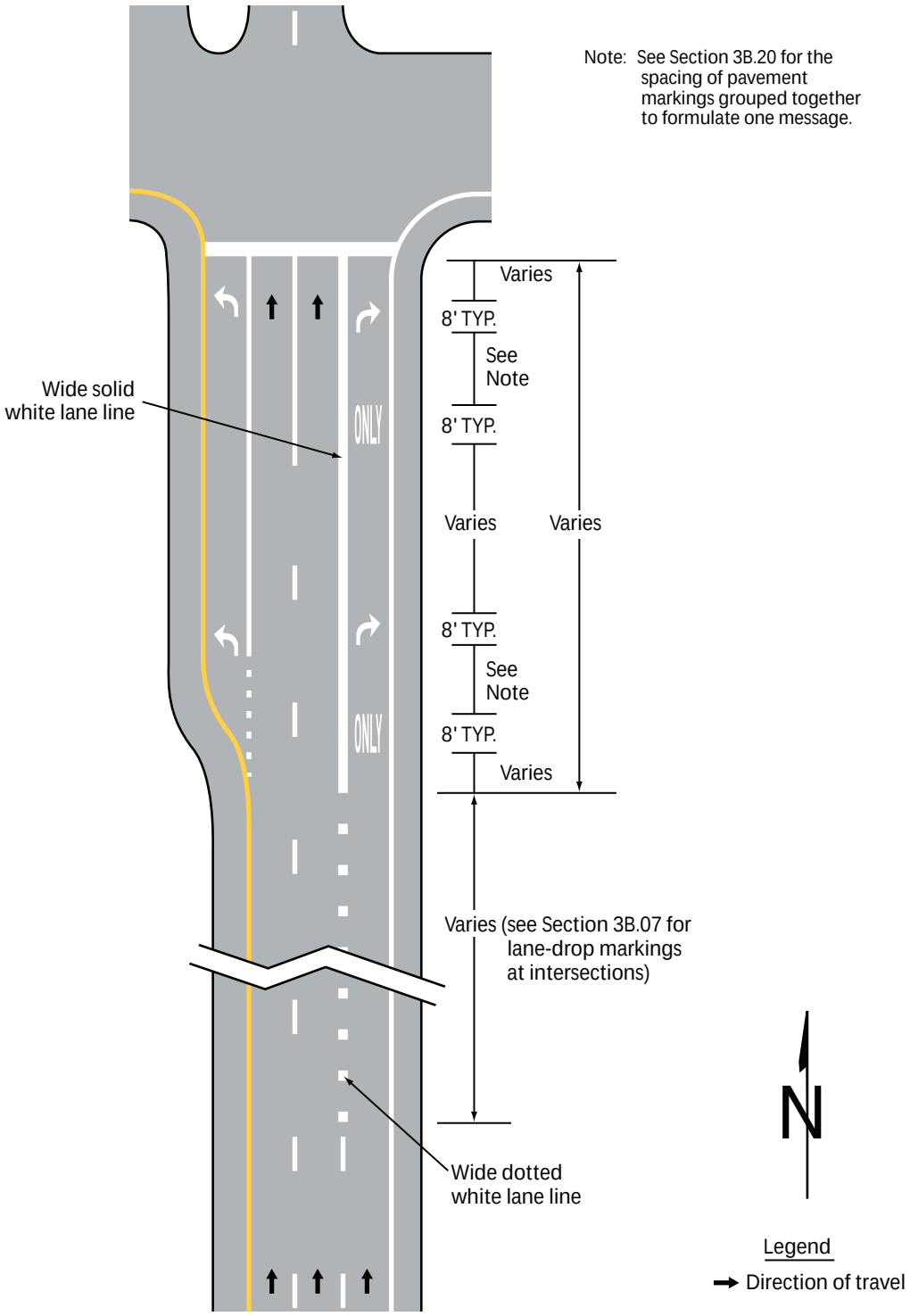
Words and symbols shall conform to Figures 3B-17 through 3B-28 in the *MUTCD*. In accordance with *MUTCD* Section 3B.21, word messages shall be a minimum of 6 feet in height on all types of roads, except "SCHOOL" is 10 feet high. A maximum of three lines of message may be used. When 2 or 3 lines of message 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 4 to 10 times the legend height (i.e., a typical spacing of 24 to 60 feet). In accordance with *MUTCD* Section 3B.20, word, symbol, and arrow markings may be proportionally reduced by up to 25 percent on roadways with operating speeds less than 25 mph. This provision may be useful on military installations where lower operating speeds are common.

Perhaps the most common of these markings is the lane-use arrow. In most cases, the lane-use arrow is used by itself, but whenever the required turn is not obvious, the word "ONLY" should be used as illustrated in Exhibit 8.14. When lane-use arrows are installed, at least 2 arrows should be used in each lane to provide adequate driver guidance.

Other common word and symbol markings include the railroad crossing symbol, and the word messages "STOP AHEAD" and "PED XING."

Exhibit 8.14: Example of Turn Arrows



Source: MUTCD, Figure 3B-12.

8.2.17. Route Identification Markings

The *MUTCD* allows for only 5 different colors of marking in *MUTCD* Section 3A.03—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 is used for that purpose. Although blue is an approved pavement marking color, the *MUTCD* does not permit its use to delineate installation or government boundary lines. TEA instead recommends using a sign at the installation boundary, such as a standard "Installation Boundary" or "Entering Government Property" sign, rather than any pavement marking.

Wayfinding guide signage as per *MUTCD* Section 2D.55, and discussed in pamphlet Section 7.8.4, 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 it 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-18 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 using a template and standard pavement marking paint. However, TEA recommends relying primarily on guide and way-finding signs for these types of routes, as signing generally provides clearer and more consistent driver guidance than pavement markings alone. A standard guide sign identifying the graduation route or destination may be used to supplement or replace pavement symbols.

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 TEA prior to use. Requests must contain full justification and rationale for deviation from criteria in the *MUTCD*.

8.2.18. Chevron and Diagonal Pavement Markings



Chevron and diagonal pavement markings are both time-consuming and expensive to install. Therefore, military installations are encouraged to take a very conservative approach in their use.

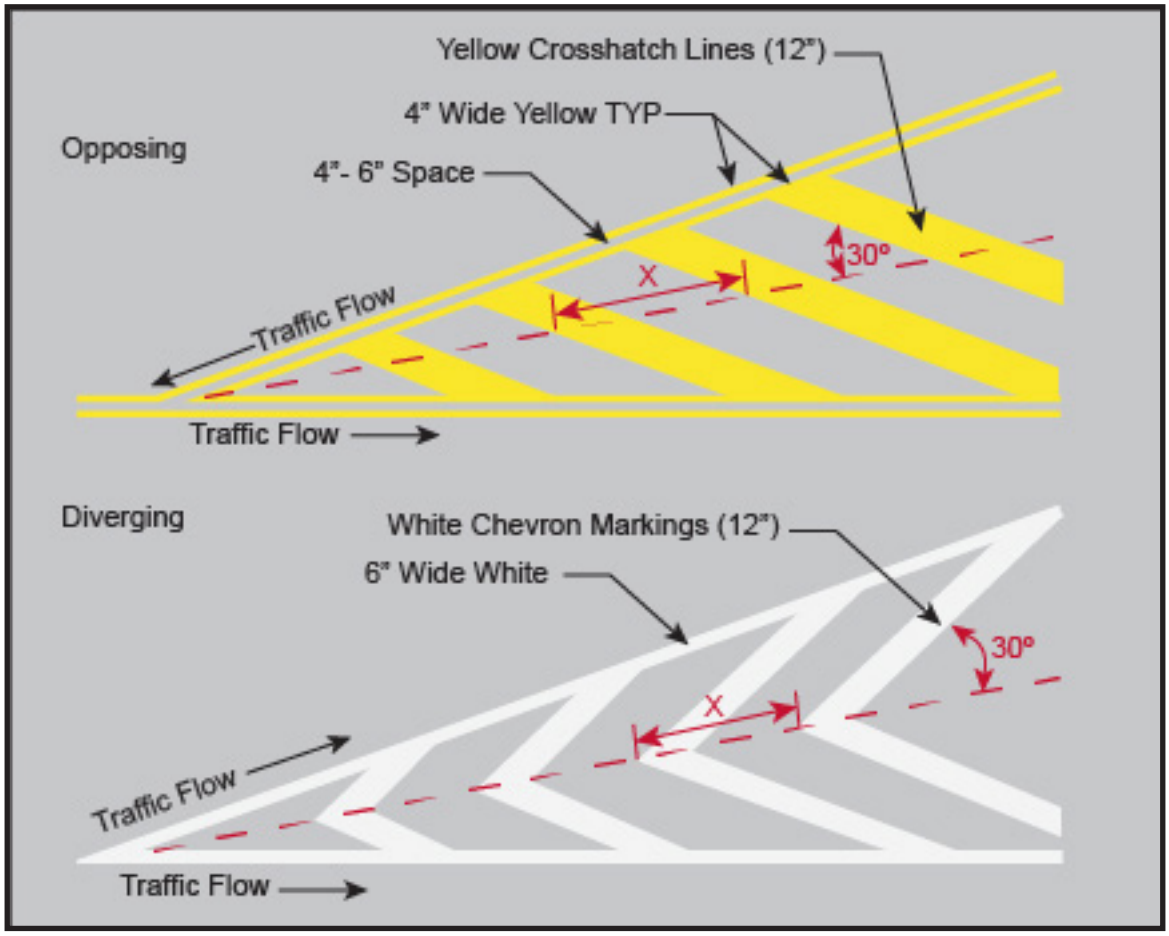
Chevron and diagonal pavement markings may be used to discourage travel on certain paved areas, such as shoulders, gore areas, buffer areas approaching and around obstructions in the roadway, within painted channelizing islands, and in buffer areas separating preferential travel lanes and other travel lanes.

When chevron and diagonal pavement 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 slanted away from traffic in the ajacent travel lane. Diagonal 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 and slant away from traffic in the adjacent travel lane. 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 chevron and diagonal pavement markings and their proper orientation are illustrated in Exhibit 8.15.

Diagonal and chevron pavement markings are generally optional in the *MUTCD*, except where white chevron markings are used within buffer areas separating preferential lanes from other travel lanes (see Chapter 3E, and Figure 3E-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 for 45+ mph roads or 8 in wide lines for roads less than 45 mph at a 30- to 45-degree angle, as illustrated in Exhibit 8.15.

Exhibit 8.15: Typical Chevron and Diagonal Pavement 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 chevron and diagonal pavement 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 direct an errant vehicle back into the proper travel path.

The following photo shows an incorrect application of diagonal pavement markings, also with corrected markings.



Wrong color and wrong angle

8.2.19. Do Not Block Intersection Markings

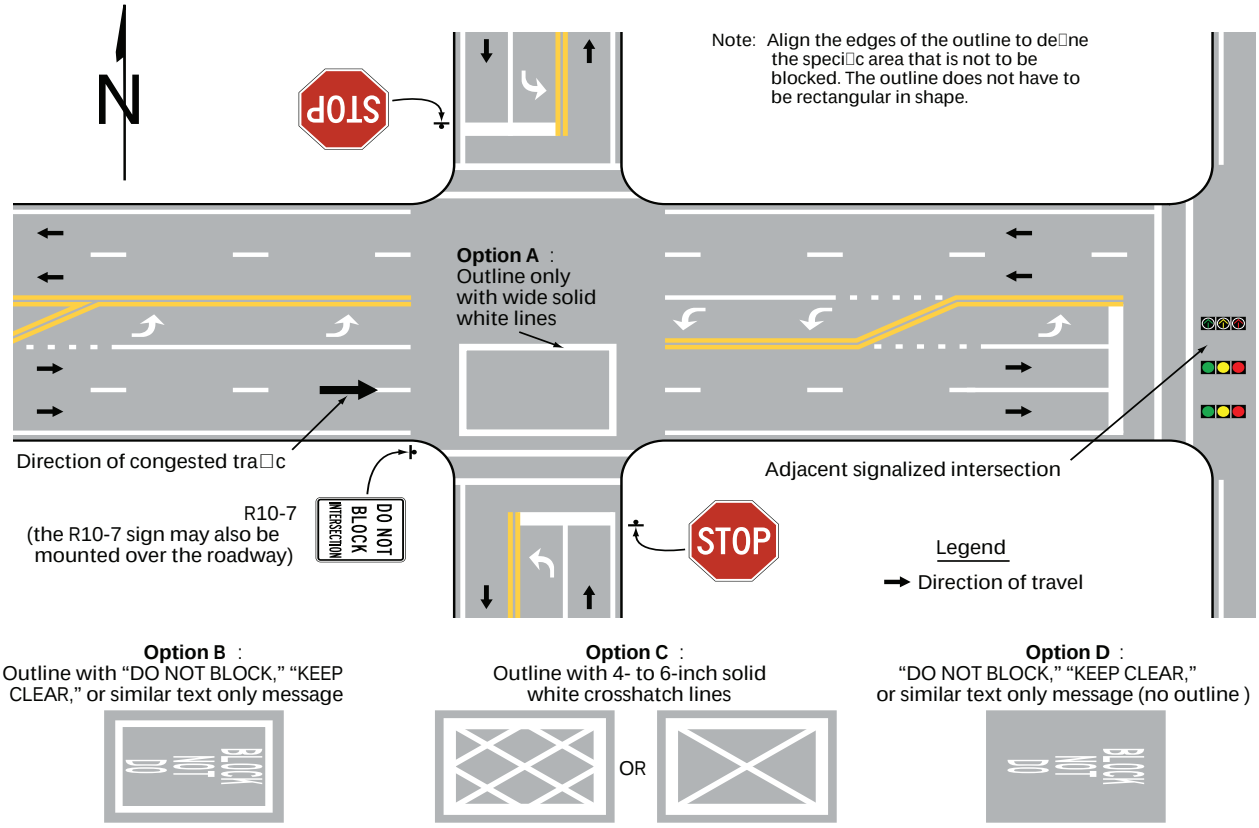
Do Not Block Intersection markings may be used to mark the edges of an intersection area that is in close proximity to a signalized intersection, railroad crossing, or other nearby traffic control that may cause vehicles to stop within the intersection and impede other traffic entering the intersection.

If used, the Do Not Block Intersection markings should consist of solid white lines that outline the area of the intersection as illustrated in Exhibit 8.16.

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 8.16: Do Not Block Intersection Markings



Source: MUTCD Figure 3B-24

8.2.20. Speed Hump and Speed Table 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 greater.

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 and speed tables should have pavement markings that comply with the *MUTCD*, specifically Sections 3B.29 and 3B.30 and Figures 3B-26, 3B-27, and 3B-28.

8.2.21. Obliteration of Pavement Markings

When traffic patterns change, old pavement markings must be removed and new ones applied in the correct locations. While grinding is a common removal method, it leaves permanent scars on the road surface that can last for the life of the pavement.



Likewise, covering old markings with black paint is an ineffective solution; the original lines eventually reappear as the paint wears away. Additionally, these black-out lines can create glare during the day and, under wet night conditions, often appear more prominent than the actual pavement markings.

High-pressure water blasting is another option for marking obliteration that overcomes the concerns associated with other techniques.

8.3. DELINEATION

While pavement markings guide drivers under both day and night conditions, roadside delineators are especially critical for enhancing nighttime visibility and providing lane guidance during adverse weather when pavement markings may be obscured.

8.3.1. Post-Mounted Delineators

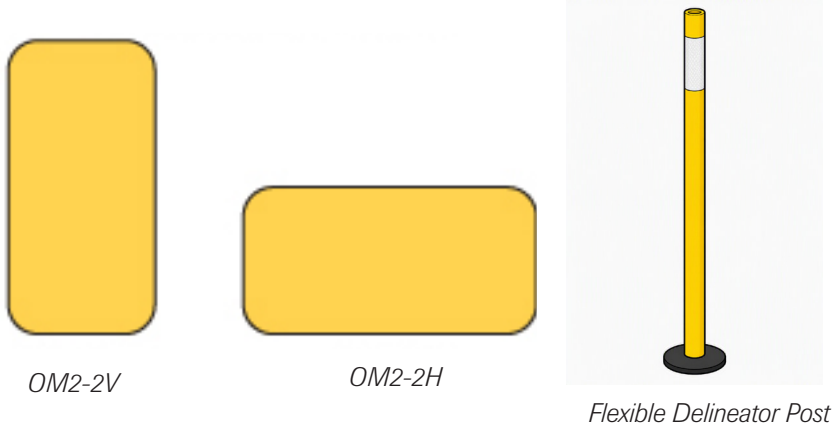
Delineators are guidance devices used to assist roadway users in following roadway alignment, particularly at night and during adverse weather conditions when pavement markings may be less visible. Delineators are commonly used along horizontal curves, interchange ramps, lane-reduction transitions, roadside barriers, guardrail installations, and other locations where supplemental guidance is beneficial. 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 8.17 illustrate one type of delineator consisting of yellow sheeting affixed to a metal or plastic substrate and then attached to a steel or wood breakaway post.
- ✓ A flexible delineator post, as seen in Exhibit 8.17, 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.

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 5 to 10 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 to supplement right-edge roadway delineation. Yellow delineators should be used on the left side of one-way roadways and in the median of divided highways, consistent with the color of adjacent centerline or left-edge pavement markings.

Exhibit 8.17: Delineators



OM2-2V *OM2-2H* *Flexible Delineator Post*

If used on mainline tangent sections of roadway, delineators should be spaced at uniform distances of 200 to about 530 feet apart. However, on curves, the spacing should be less, with the suggested spacing as indicated in Exhibit 8.18.

Exhibit 8.18: 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.

Source: MUTCD Table 3G-1

Chevron Alignment (W1-8) signs (as discussed in pamphlet Section 2.3.3) 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

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 with individual 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.

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.



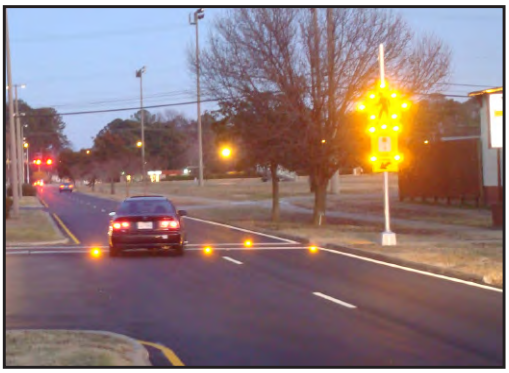
Raised pavement markers



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 RPMs may also be considered at AVBs and other access control points to improve nighttime guidance through serpentine approaches, lane shifts, and other constrained vehicle paths.



Lighted RPM Example

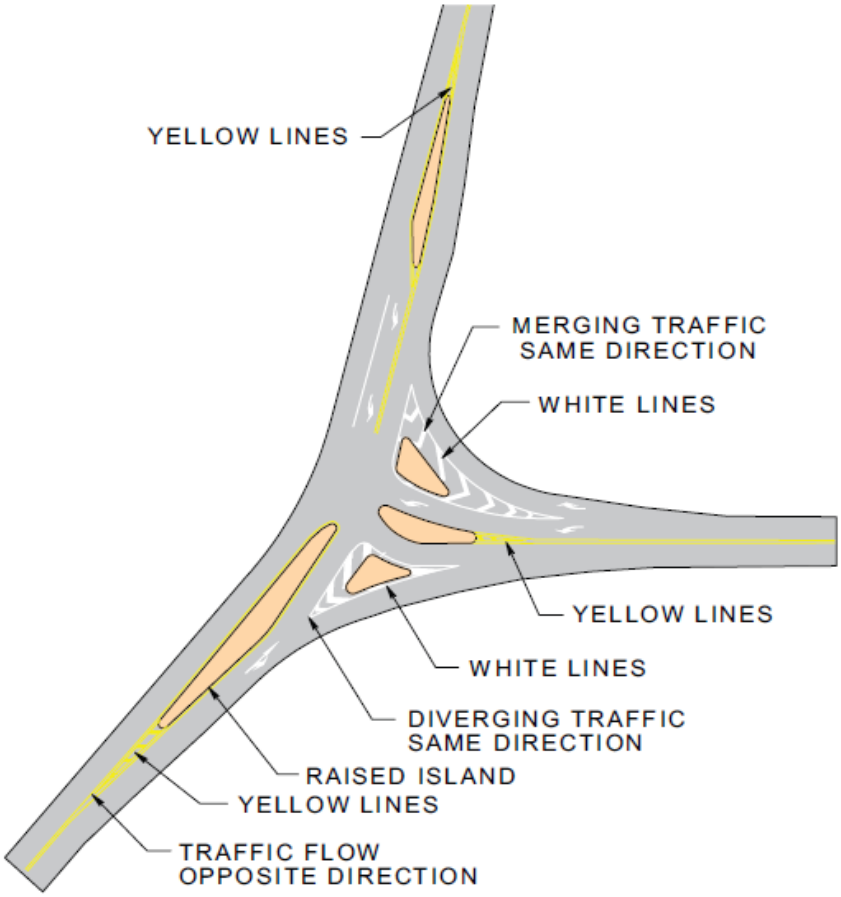
8.3.3. Islands



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 8.19 depicts an intersection with five islands. Note that the diagonal and chevron markings are optional, but if used, the 3 diagonal areas in the middle of the road would be yellow and the 2 areas with chevrons would be white.

Exhibit 8.19: An Intersection with Several Islands



8.4.4. Bollard Markings

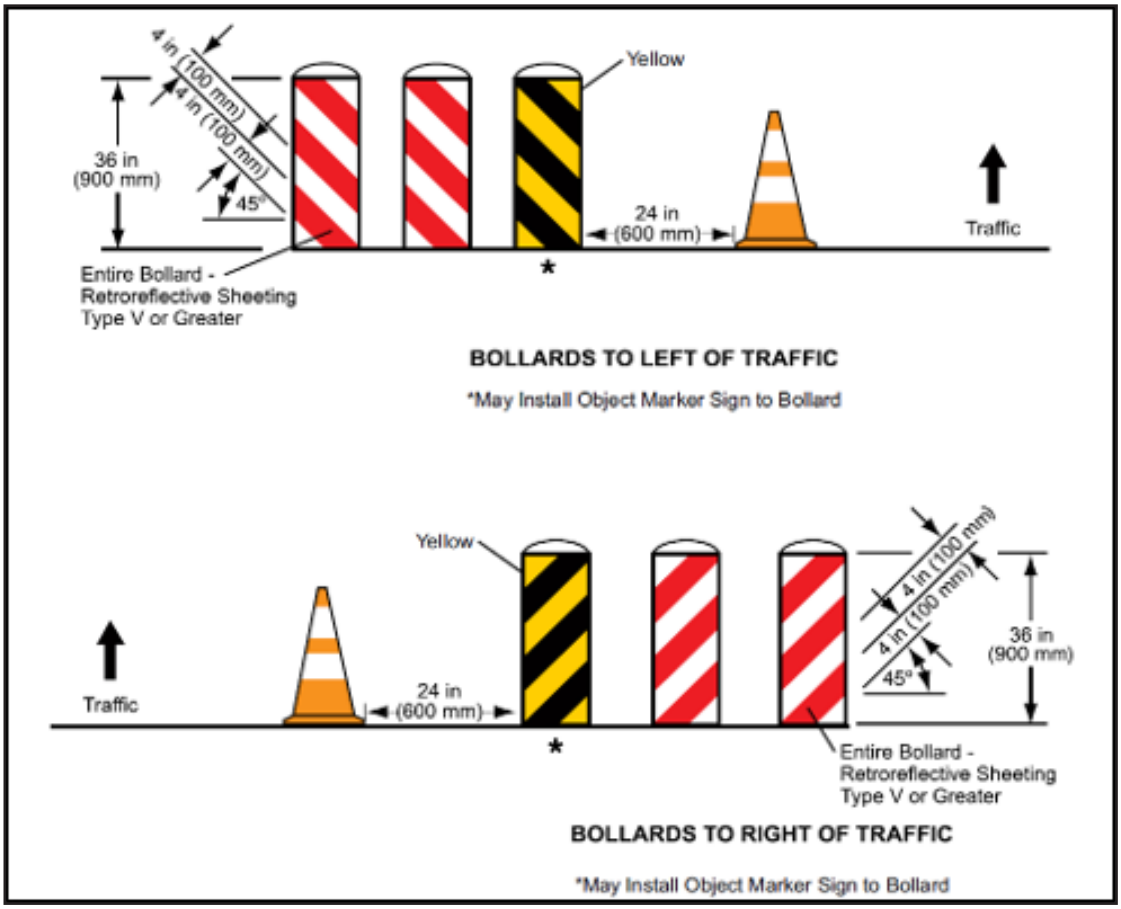
The most common in-roadway bollard system is at an ECF in order to provide security benefits by limiting vehicular speeds and movements. However, TEA does not endorse the use of these systems and encourages other design options to address security concerns.

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 of the vehicle 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 8.20 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 TEA 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 8.20: Bollard Delineation Detail



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 pamphlet 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 8.20, 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 pamphlet Section 7.3.13—Object Markers for an illustration of the chevron marking.

8.6.1. Gates



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.

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 pamphlet Section 5.8 for additional information on railroad grade crossing gates.
- ✓ **Swing 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.

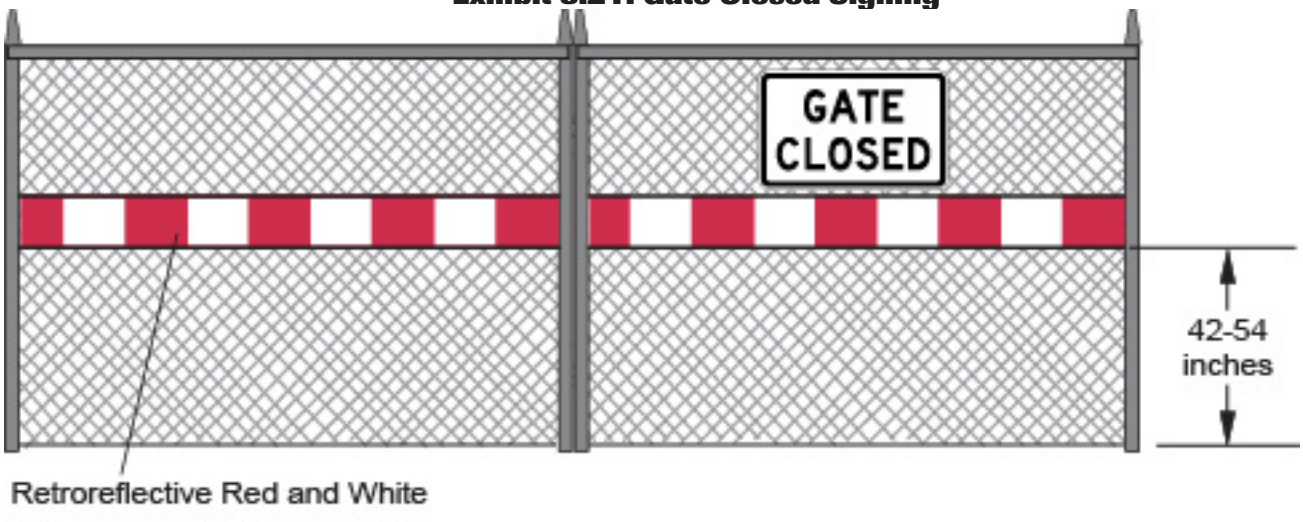
Since gates are formidable devices, it is essential that they be clearly visible, day and night. When activated, gates shall be retroreflective from both directions. The grade of sheeting shall be a minimum of a Type III material.

Safety Issues for Swing 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 swing 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 a roadway, either on a permanent or on a part-time basis, a GATE CLOSED (R11-2d-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 8D.03 of the *MUTCD*) as illustrated in Exhibit 8.21. 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 8.21: Gate Closed Signing



Section 2B.76 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 (R11-2g-TEA) signs are required, one for the inbound approach and one for the outbound approach. STOP signs are not appropriate signs for gate closures (as shown in the photo) and shall not be used in lieu of the GATE CLOSED sign. STOP signs provide the message that vehicles can proceed after having stopped.

Refer to pamphlet Sections 7.2.7 and 7.3.13 for details regarding the use of the GATE CLOSED AHEAD (W20-3g-TEA) advance warning sign.

Several safety concerns exist with the gate shown in the previous photo. Two key issues include the requirement in the *MUTCD* for a fully retroreflective horizontal rail with alternating red and white vertical stripes (see Exhibit 8.21) on both sides of each gate and the requirement in *MUTCD* Section 2B.76 that the vertical gate supports 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 which inbound lanes are open or closed. A GATE CLOSED (R10-7-TEA) sign should also be installed.

On 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 pamphlet Section 7.4.3). For gates with regular, predictable hours, a static sign may be used; for gates with variable or changing hours, an electronic changeable message sign may be appropriate.

CHAPTER 9 – TRAFFIC SIGNALS

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CHAPTER 9 – TRAFFIC SIGNALS

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.



Typical traffic signal head

As a result, there are more than 320,000 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.

- ✓ Traffic signal timing and operations are a major contributor to urban delay, but the impact varies widely by corridor and region.
- ✓ Poorly timed signals can impose significant delay and fuel costs, especially in high-volume corridors.
- ✓ About 10–12% of all fatal crashes occur at signalized intersections, according to recent FARS data.

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.

Prior to being installed, traffic signals must meet at least one of the nine traffic signal warrants presented in pamphlet Exhibit 5.4 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

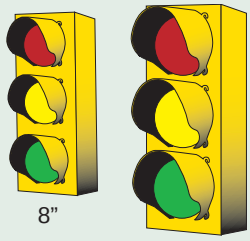
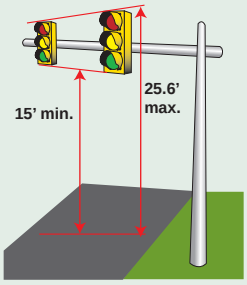
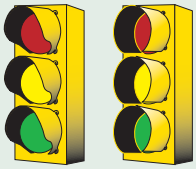
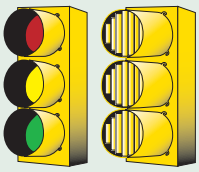
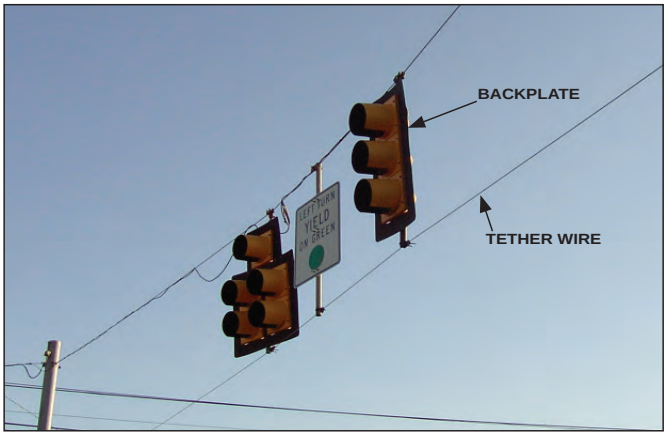
DESIGN ELEMENT	DESIGN CONSIDERATION/GUIDANCE
LENS SIZE  	✓ *MUTCD* allows 4-inch, 8-inch, and 12-inch lenses, but 12-inch indications are required for all arrows and for nearly all new circular indications. 8-inch circular lenses are allowed only in limited low-speed, low-volume cases. ✓ TEA likewise recommends 12-inch lenses in most applications, 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. ✓ For post-mounted signal faces located over a sidewalk, the bottom of the signal housing shall be at least 8 feet above the sidewalk or above the pavement grade where no sidewalk exists.
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. ✓ To increase visibility, a yellow retroreflective strip, between 1 and 3 inches wide, may be placed along the border of 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.



Signal Head Components

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 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. Signal heads may be arranged vertically or horizontally, with indications displayed in the standard red, yellow, green order as required by the *MUTCD*, and horizontal arrangements are used where vertical clearance or visibility constraints exist. Post-mounted signals are not recommended for use as the primary control of left-turn and through-traffic movements due to visibility issues.

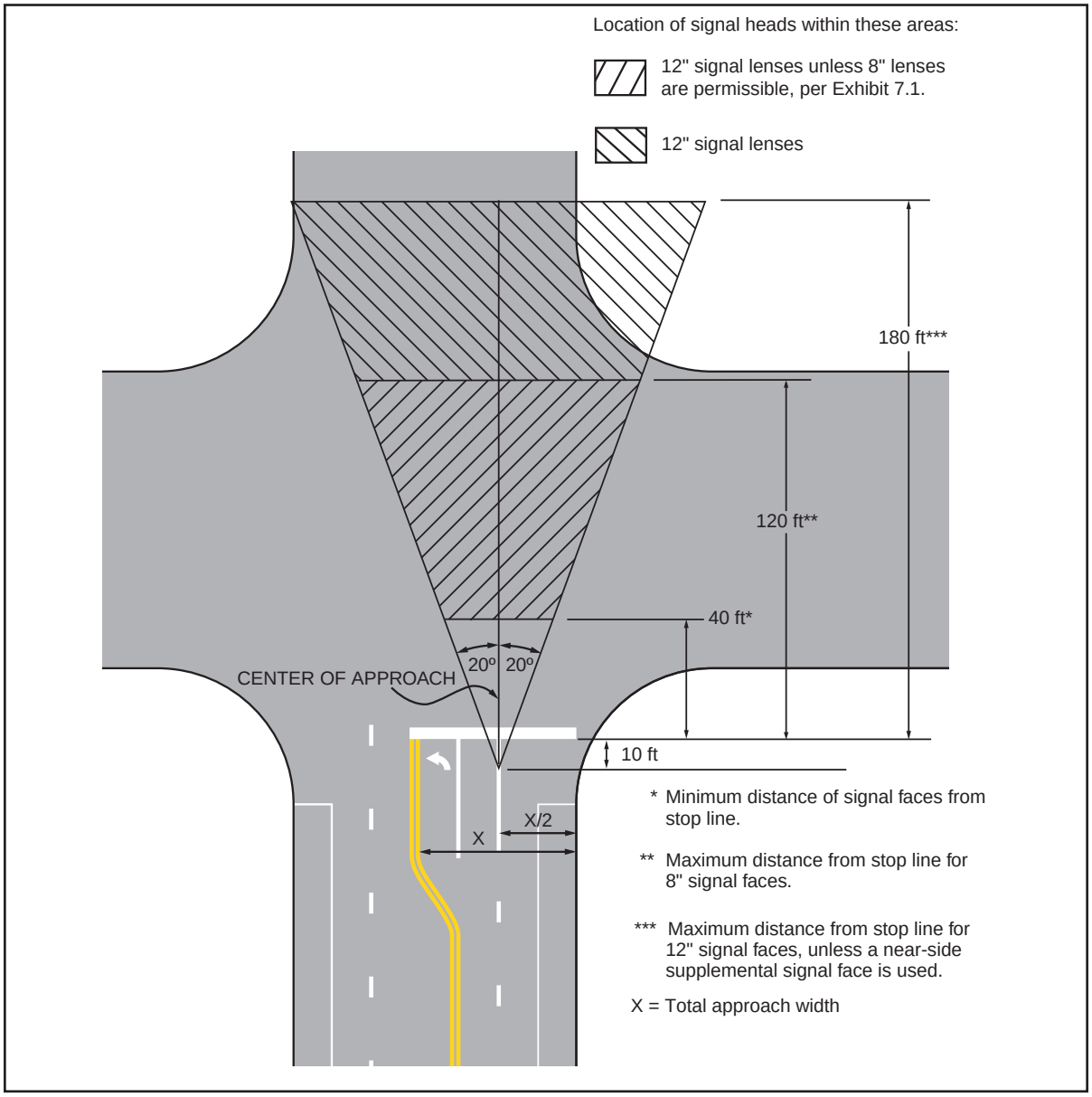
The *MUTCD* requires that at least one signal face (but preferably two) be located within a cone of 20 degrees to the left or to the right of the "center of the approach lanes extended." Signals should be located between 40 and 120 feet from the stop bar. When a 12-inch signal face is used, signals can be installed up to 180 feet from the stop bar without installation of a near-side supplemental signal face. When multiple overhead signal faces are provided for the same approach, they should be separated by at least 8 feet, measured horizontally between the centers of the signal faces. 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 in Exhibit 9.3 on page 9-5.
[3] If practical, all of the recommended number of primary through signal faces should be located overhead.

Exhibit 9.3: Horizontal Location of Signal Faces



Source: MUTCD Figure 4D-2

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 should proportional to the amount of traffic demand and the number of lanes on each intersection 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 and they must stop. Vehicles may legally enter the intersection while the yellow indication is displayed, subject to state and local traffic codes. ✓ Yellow intervals should have a duration of a minimum of 3 to a maximum duration of 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

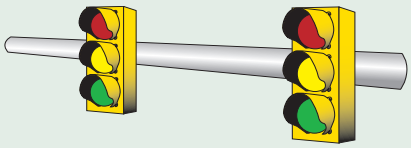
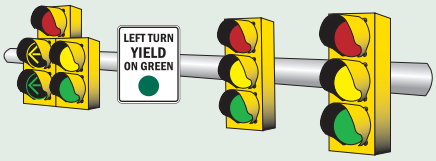
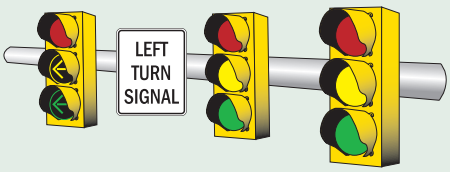
More signal phases are generally needed as traffic volumes and number of lanes increase.

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 either takes time away from existing phases or requires an increase in the overall cycle length. In both cases, the additional phase can increase delays for other movements, individual approaches, and the intersection as a whole.

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-turn 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. ✓ The Flashing Yellow Arrow (FYA) is now a widely accepted option for permissive left-turn phases and is becoming increasingly common in signal designs. Before implementation, check with your state's DOT to confirm whether this practice has been adopted.
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



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 signal timing and phasing as well as periodic evaluations.

Traffic signal operations are generally categorized into two types: pretimed and actuated. Pretimed signals are the most straightforward, utilizing a fixed amount of green time for each phase based on the time of day (i.e., AM, midday, or PM). Because these intervals are set, a green light will trigger even if no vehicles are present - such as in an empty left-turn lane. This method is most effective for areas with consistent, predictable traffic volumes. In contrast, actuated signals rely on detection - like pavement loops, video cameras, radar, or push-buttons - to allocated green time only when demand is detected. This flexibility makes actuated operations ideal for locations where traffic fluctuates throughout the day or on the minor approaches to intersections, especially during off-peak hours.

Dynamic signalization represents a more advanced operational tier, characterized by variable cycle lengths during extreme traffic conditions. This system requires full detection to function; if a phase detects continuous traffic for its entire duration, the system automatically allocates additional green time—typically in ten-second increments—to the subsequent cycle. This expansion continues as long as demand remains constant, up to a pre-defined limit. Conversely, as demand tapers off and traffic is no longer present at the end of a phase, the system progressively reduces the maximum green time to maintain efficiency. 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. Traffic signals should be evaluated periodically—typically every 2 to 3 years, or sooner when changes in land use, mission requirements, or traffic patterns occur—to ensure the system continues to operate efficiently.

Exhibit 9.7: Maximizing Traffic Signal Operations and Efficiency

STRATEGY	CONSIDERATIONS	BENEFITS
PERIODIC RETIMING 	✓ Traffic flow patterns change over time due to land use, mission changes, 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%.
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.

Exhibit 9.7: Maximizing Traffic Signal Operations and Efficiency (continued)

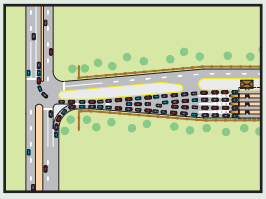
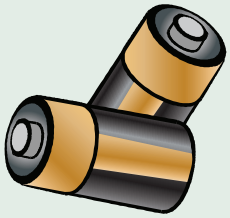
STRATEGY	CONSIDERATIONS	BENEFITS
COORDINATION 	✓ A coordinated traffic signal system consists of two or more traffic signals interconnected and timed such that platoons of traffic traveling at the design speed get green indications through successive intersections. ✓ Coordination can be achieved through 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%.
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%.
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.

Exhibit 9.7: Maximizing Traffic Signal Operations and Efficiency (continued)

STRATEGY	CONSIDERATIONS	BENEFITS
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.
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

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. Several types of hybrid beacons are commonly used, including pedestrian hybrid beacons, hybrid beacons for emergency vehicle access, hybrid beacons for AVBs, 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 an uncontrolled 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 pamphlet 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. AVB Hybrid Beacons

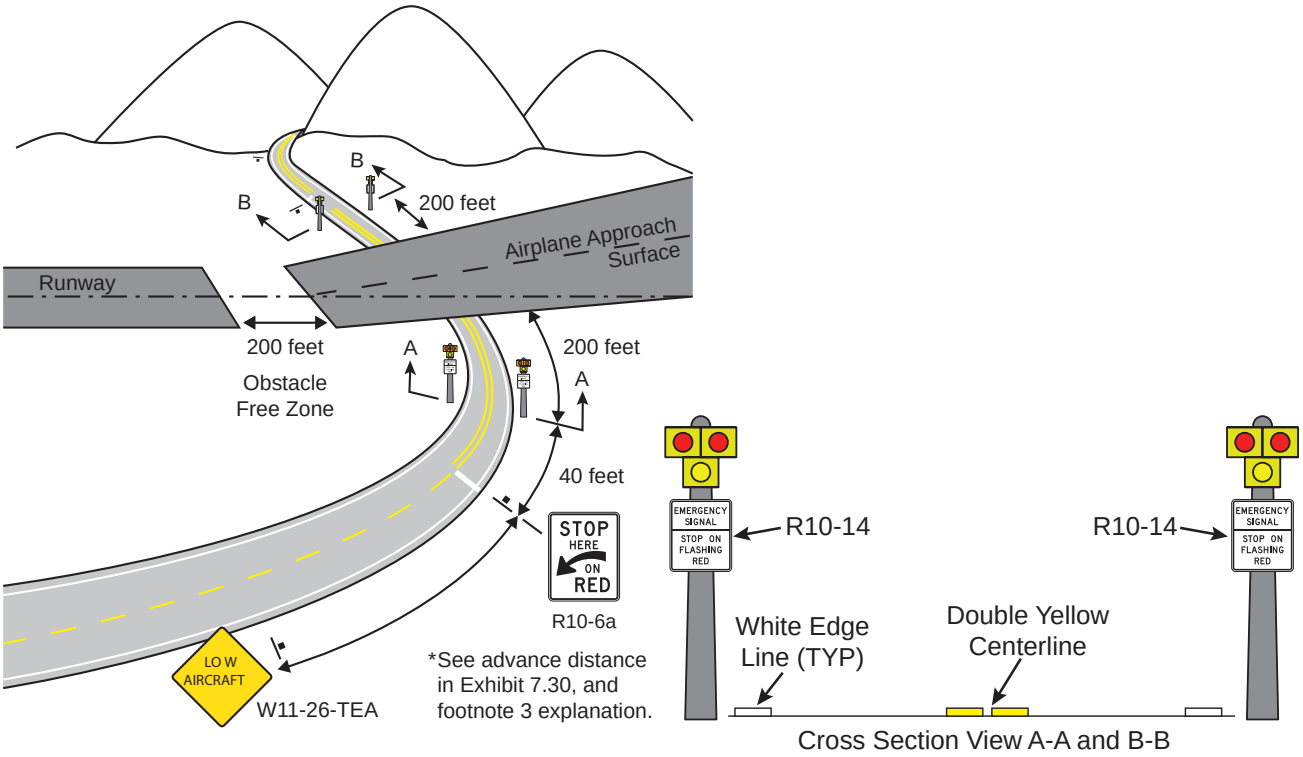
Hybrid beacons are now preferred for use at AVBs when signals are required for an AVB Safety Scheme and operate similarly to emergency-vehicle hybrid beacons. See TEA *Pamphlet 55-15* for more guidance.

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 line 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 line. A STOP HERE ON RED sign, (R-10-6a) should be located adjacent to the stop bar. See pamphlet Exhibit 7.30 for the appropriate distance for the placement of this sign. The sign should be located per footnote 3 in that exhibit, 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 pamphlet 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 or main catonement 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 of the intersection and in some cases diagonally across the intersection.	Traffic signals can be programmed with a lead pedestrian interval (LPI), which gives pedestrians a 3-4 second head start before parallel vehicle traffic receives a green light. By separating pedestrians and motorists in time, this interval allows pedestrians to establish themselves in the crosswalk before vehicles begin to turn.
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 occur. ✓ 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, signs, and signal heads.	Research suggests that LPIs significantly decrease pedestrian-vehicle conflicts and improve motorist yielding rates. For instance, a study by Van Houten et. al (2000) found that even a three-second LPI positively influenced pedestrian behavior and reduced dangerous interactions with turning vehicles.

Exhibit 9.10: Pedestrian Signal Features

FEATURE	CONSIDERATIONS
INFRASTRUCTURE 	✓ Sidewalks at intersections used by pedestrians should be at least four 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. Refer to pamphlet Chapter 13 for more details. ✓ Crosswalks should be clearly marked in accordance with the *MUTCD*.
INDICATIONS 	✓ Pedestrian signals are encouraged to provide clear guidance on when to cross. New pedestrian signal installations should utilize the white WALKING PERSON and an orange UPRAISED HAND. ✓ To improve pedestrian awareness, countdown displays should be considered to indicate the remaining time in the pedestrian change interval (flashing UPRAISED HAND). ✓ Countdown pedestrian signals are required at any location where the flashing DONT WALK interval exceeds 7 seconds. ✓ Where there is a significant amount of visually impaired pedestrians, consider using APS signals which emit audible tones when the WALK indication is active. These are an option per ADA, but required under PROWAG.
TIMING NEEDS 	✓ Calculate the duration of the flashing UPRAISED HAND (DONT WALK) by dividing the crossing width by the assumed walking speed. ✓ Utilize pedestrian walking speeds of 3.5 feet per second (fps) for normal conditions or 3 fps in areas with high child, elderly or wheelchair activity. ✓ Ensure this interval is long enough for any pedestrian who has already left the curb to safely reach the other side, generally at least 7 seconds.
PUSH BUTTONS 	✓ Signal Operation: Provide pedestrian phases where pedestrian activity is frequent or where pedestrian timing does not impact traffic operations. ✓ Utilization of Push Buttons: Use push buttons only at locations where pedestrian activity is infrequent and full-time phasing is not warranted. ✓ Hardware: Utilize large mushroom-plunger style buttons (pictured at left) for ADA accessibility. ✓ Placement: Install push buttons within 10 feet of the ADA landing area and not more than 10 inches from the sidewalk edge.

9.4. COMMON OPERATIONAL AND MAINTENANCE ISSUES



Proper maintenance is critical to a traffic signal's efficiency and safety.

Maintenance of traffic signals is a very important topic and agencies should rely on current guidance such as FHWA's *Traffic Signal Timing Manual*, Second Edition, the *Traffic Signal Operations Handbook*, recent ITE publications, and state DOT signal maintenance manuals to ensure they are following the latest best practices.

A simple, proactive 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.

TEA Can Help!

One of TEA's services is an Operational Audit for Traffic Signal Sustainability (OATSS) study. With this type of study, TEA performs the following:

- ✓ Collect traffic data at 4 to 6 signalized locations
- ✓ Identify existing signal equipment and operational deficiencies
- ✓ Conduct traffic analyses to determine delay and LOS
- ✓ 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.

Traffic signal timings should be re-evaluated every 3 to 5 years or when significant changes to traffic flow patterns occur.

Poor traffic signal maintenance leads to frequent breakdowns, which can increase the likelihood of crashes, reduce intersection efficiency, generate motorist complaints, and discredit the responsible authority.

Current industry guidance suggests that an average signalized intersection requires roughly 60 hours of maintenance annually, including approximately 70% preventive maintenance, 25% responsive maintenance, and 5% design or modification work. Despite this need, traffic signal maintenance too often becomes a secondary, non-critical 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, missing or broken backplates; 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 signal indications with LED indications
	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).
	Check pedestrian countdown.
	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.

Exhibit 9.12: Traffic Signal Maintenance Checklist (continued)

CHECK	COMPONENT
	CONTROLLER CABINET
	Check electrical connections.
	Test system with a simulated power outage.
	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.
	Place user manuals, operational and wiring diagrams under controller cabinet if missing.
	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.

Developed with information from ITE's Traffic Signal Maintenance Handbook

9.5. FLASHING BEACONS

9.5.1. Warning Beacons



A Warning Beacon (*MUTCD* Section 4S.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 sign or a regulatory sign where the use of a yellow flashing indication is permitted. Warning Beacons shall not be used with regulatory signs that convey prohibitions or mandatory requirements—such as STOP, DO NOT ENTER, WRONG WAY, or Speed Limit signs. 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 warning signs.
- ✓ As emphasis for midblock 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.
- ✓ A Warning Beacon may also be used to supplement a sign or plaque that includes WHEN FLASHING to show the regulation or condition applies only at certain times, since embedded flashing LEDs are not allowed for these signs.

9.5.2. Stop Beacons

A Stop Beacon (*MUTCD* Section 4S.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 rectangular rapid flash beacons (RRFBs) to enhance the conspicuity of various pedestrian crossing, school crossing, and trail warning signs can be found in Chapter 4L in the *MUTCD*. Refer to pamphlet Section 13.7.3. 'Additional Crosswalk Enhancements' for information on RRFBs at crosswalks.

RRFBs operate solely as a type of Warning Beacon. They remain dark until activated—either by pedestrian

pushbutton or passive detection—and then flash for a predetermined duration or until the pedestrian has cleared the crosswalk. All RRFB units associated with the same crossing shall begin their rapid-flashing indications simultaneously and shall cease flashing at the same time.

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.

9.5.4. Military and Tactical Applications

Flashing beacons may also be used in unique military contexts to enhance safety and visibility at designated crossing points or operational zones. These applications are typically temporary, mission-specific, and may include:

- ✓ At convoy crossing points on public or controlled-access roadways to alert civilian traffic to the presence of slow-moving or armored vehicles.
- ✓ At tank or heavy vehicle crossings where visibility or terrain conditions require additional driver awareness.
- ✓ Near military base perimeters or access control points where heightened alert or restricted access conditions exist.
- ✓ In support of temporary traffic control during military exercises or emergency mobilizations.

In some cases, permanent installations may be appropriate, such as AVBs or flashing beacons used in conjunction with warning signs for tank crossings or other military-specific hazards. These permanent applications should follow the same design principles and operational standards as non-military uses, such as overhead flashing intersection beacons or supplemental warning systems.

Flashing beacons used in these contexts shall be coordinated with appropriate military and transportation authorities to ensure compliance with applicable safety standards and to minimize confusion for civilian drivers. Yellow flashing indications are typically used and signify to convey caution. Red flashing indications may be employed where a full stop is clearly warranted and consistent with broader traffic control guidance.

CHAPTER 10 – ROUNDABOUTS

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CHAPTER 10 – ROUNDABOUTS

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

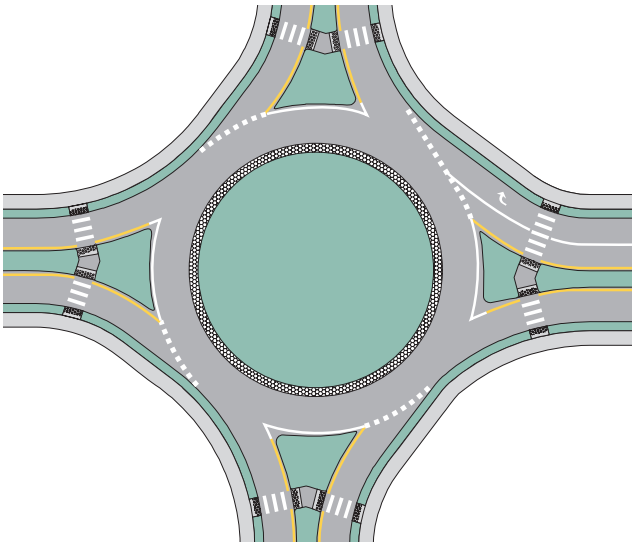
Two key characteristics of any roundabout include:

- ✓ 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.

Roundabouts are generally the safest intersection design available. They are smaller than traffic circles and are designed to reduce vehicle speeds and eliminate the need for weaving across high-speed lanes. Unlike traffic circles, roundabouts operate under a consistent set of rules and geometric principles, making them more predictable and safer for all users.

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 tend to gain public acceptance quickly. After an initial installation, local communities often request additional roundabouts, leading to clusters of installations in certain regions. In the early 2000s, there were approximately 1,000 roundabouts in the United States. As of 2023, that number has grown significantly, with estimates suggesting over 13,000 modern roundabouts now in operation nationwide. This growth reflects a broader shift in transportation policy, with many state and local agencies embracing roundabouts for their safety, operational, and environmental benefits.



When asked about roundabouts, most drivers in the United States who are unfamiliar with them initially express dislike. However, after a roundabout is constructed in their area, the majority of local drivers tend to favor them an often advocate for more to be built.

A roundabout is a circular intersection designed with yield control at entry points, allowing vehicles on the circulatory roadway to proceed while deflecting approaching vehicles counterclockwise around a central island. It is a modified traffic circle that adheres to specific geometric design criteria aimed at enhancing driver awareness, reducing traffic speeds, and improving traffic flow. Roundabouts help alleviate traffic congestion by eliminating left turns. Since each approach to the roundabout functions as an intersection with a one-way street, drivers are only affected by traffic flow from one direction, minimizing delays. Additionally, only right turns are permitted, further simplifying navigation.

The curved travel path of a roundabout naturally slows vehicles down. This design feature eliminates severe angle and head-on crashes and ensures that any collisions that do occur happen at much lower speeds, making them far less severe than those at traditional intersections.

Roundabouts can range from a 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.

Compact roundabouts, also referred to as urban compact or mini-roundabouts, are a variation of the standard roundabout designed for constrained urban environments where space is limited. These roundabouts maintain the key operational principles of larger roundabouts such as yielding upon entry and low-speed circulation but feature smaller inscribed circle diameters and tighter turning radii. They are particularly effective for traffic calming and improving safety at intersections where traditional roundabouts may not be feasible. Compact roundabouts often include a fully traversable central island and may omit raised splitter islands, depending on site constraints. Their design encourages slower vehicle speeds and can be retrofitted into existing intersections with minimal right-of-way impacts.

10.1. ROUNDABOUTS VS. TRAFFIC CIRCLES



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. Other 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



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.

In United States, 45 percent of all crashes occur at intersections. However, research shows that converting a traditional intersection to a roundabout has significantly reduced both the overall number of crashes and the likelihood of injuries. In addition, many researchers believe

Studies show that roundabouts:

- ✓ Are safe and efficient.
- ✓ Are environmentally friendly.
- ✓ Reduce travel speeds.
- ✓ Provide for landscaping and beautification.
- ✓ Are contagious.

that United States is still on the learning curve because crash rates in United States are higher than in other countries where roundabouts are more common.

As illustrated in Exhibit 10.3, single-lane roundabouts have 75% fewer conflict points than conventional intersections and eliminate crossing conflicts, reducing dangerous side-impact crashes.

Exhibit 10.2: Roundabouts vs. Other Types of Intersections

Advantages:

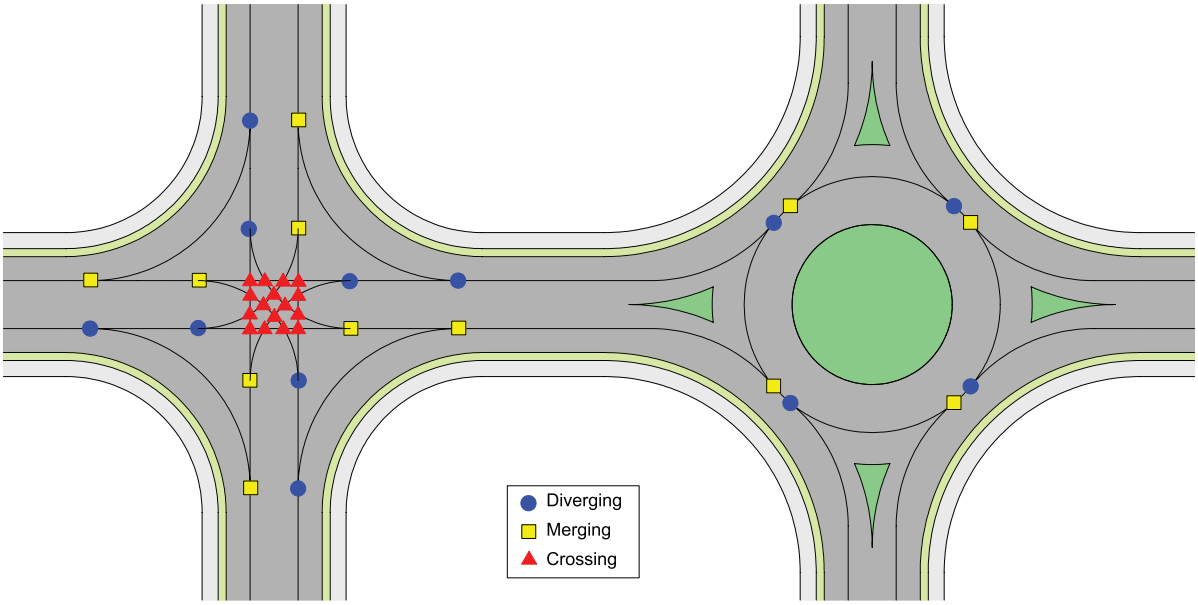
- ✓ Fewer and less serious crashes.
- ✓ Improves safety for pedestrians—the splitter island provides a refuge for pedestrians to allow a two-stage crossing, with each stage crossing a one-way roadway.
- ✓ Can be used for speed control, especially speed mitigation at ECFs.
- ✓ Improves traffic flow with fewer stops.
- ✓ Resolves issues with not obeying traffic signals.
- ✓ Reduced delays in light traffic, unlike signalized intersections.
- ✓ Accommodates U-turns, even for larger trucks.
- ✓ Continued operation during power outages.
- ✓ No overhead traffic signals to hinder over-height loads.
- ✓ Facilitates the junction of more than four roadway approaches.
- ✓ Eliminates left-turn issues.
- ✓ Easily designed to restrict exits with turn prohibitions.
- ✓ Unlike signalized intersections, storage lanes are not required.
- ✓ Simpler entry decisions benefit all drivers, especially older and novice ones.
- ✓ Improves air quality, saves energy, reduces lanes, and adds landscaping opportunities.
- ✓ Lower maintenance costs and longer service life compared to traffic signals.

Disadvantages:

- ✓ May require a larger intersection footprint.
- ✓ May require pedestrians to walk a greater distance.
- ✓ Cannot prioritize specific roadways; all approaches are treated equally.
- ✓ Unfamiliar drivers may find roundabouts confusing.
- ✓ Potentially greater construction expense compared to a signalized intersection, unless extensive widening for turning and storage lanes.
- ✓ With too many roundabouts in close proximity to each other, drivers may get disoriented.

Exhibit 10.3 compares the conflict points at a conventional four-legged intersection with those at an equivalent single-lane roundabout. A conventional intersection contains 32 conflict points, including 8 merging, 8 diverging, and 16 crossing movements. In contrast, a comparable roundabout has only 8 conflict points, consisting of 4 merging and 4 diverging movements. Not only are the total number of conflicts greatly reduced, but the remaining ones are same-direction movements, which are far less severe and carry a much lower risk of injury.

Exhibit 10.3: Comparison of Conflict Points



Pedestrian-vehicle conflict points for a roundabout are reduced by 50%, with crossings limited to one direction at a time, enhancing safety for both vehicles and pedestrians.

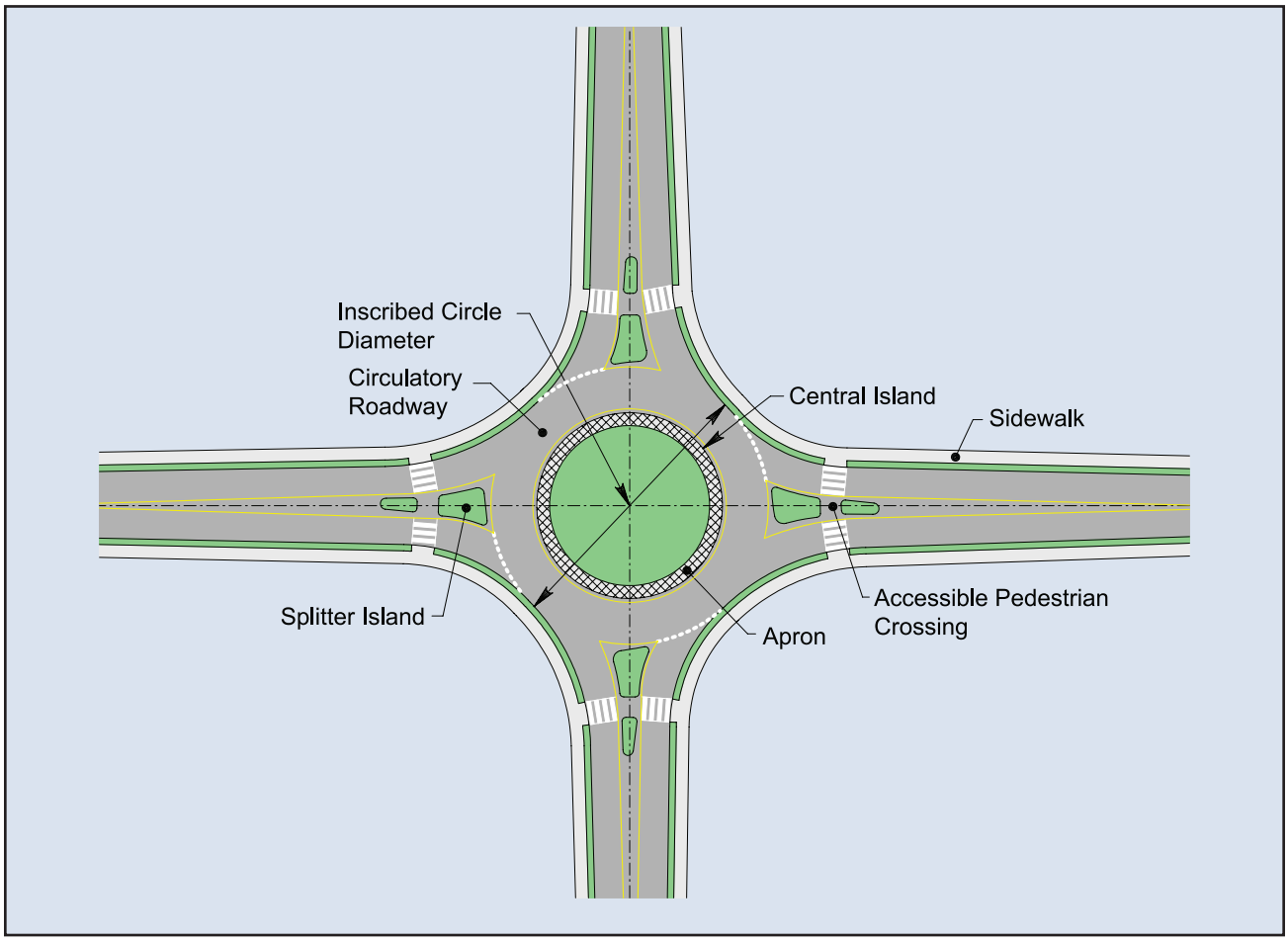
In addition to safety, efficiency is another major benefit of roundabouts. Many studies have documented reductions in delay, unnecessary stops, fuel consumption, emissions, and energy usage.

The only intersection traffic control that is approximately as safe as a roundabout is a multiway stop-controlled intersection. However, multiway stop intersections have less capacity, more delay, many negative environmental consequences due to stopped traffic and can create disrespect for STOP signs.

10.3. DESIGN CONSIDERATIONS

Roundabout design is iterative and requires a professional familiar with FHWA's *Guide for Roundabouts* (NCHRP Report 1043, 2023). See Exhibit 10.4 for key features.

Exhibit 10.4: Key Roundabout Features



Size – A roundabout's size is primarily determined by its inscribed circle diameter (ICD), which is the distance measured between the outer edges of the circulatory roadway. The circulatory roadway is the path vehicles use to travel counterclockwise around the central island. The ICD must be large enough to accommodate the intended design speed and number of lanes, increasing as either of those factors increase.

The design speed of the circulatory roadway is determined by the speed of vehicles approaching from approximately 300 to 350 feet away. The design should ensure a significant speed reduction. For example:

- ✓ For a 45 mph approach, the target design speed is 50% of that speed (22.5 mph).
- ✓ For a 25 mph approach, the target design speed is 62% of that speed (15.5 mph).

If approach speeds differ, the design must accommodate the highest speed. Additionally, design speeds at merge and exit points may be slightly higher than the main circulatory speed.

In an urban environment, the ICD typically ranges between 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.

While a single-lane roundabout can accommodate approximately 20,000 vpd, the true capacity of a roundabout is determined by its performance during peak hours. Key factors include the distribution of traffic across its approaches and the mix of turning movements. A detailed analysis of the peak hour traffic volume is required to determine if additional lanes are necessary.

Alignment – Proper alignment requires the centerline of each approach to pass through the roundabout's center, which balances speeds and makes the central island conspicuous.

The **splitter island** is a raised median on each approach designed to separate traffic, slow vehicles, and provide pedestrian refuge. Its design is critical: it must be long enough for pedestrians, curved to control speed, and aligned with the central island. The island's width must not encourage high speeds, and it must work in concert with signs and pavement markings to ensure safe navigation.

Central Island Shape – The central island is the raised area in the center of a roundabout around which traffic circulates. While typically circular, its shape can be adapted to fit specific intersection constraints. Common alternative shapes include:

- ✓ Elliptical: Used to accommodate specific approach alignments.
- ✓ Teardrop: Often implemented at intersections involving one-way streets.
- ✓ Turbo-shaped: Designed with flared sections to physically guide drivers into dedicated turn lanes.

The final shape is determined by several factors, including:

- ✓ The number and alignment of approaches.
- ✓ The number of lanes on each approach.
- ✓ The presence of exclusive turn lanes.
- ✓ The inclusion of one-way streets.

Pedestrians – Pedestrians should be accommodated outside the circulatory roadway and across the splitter island. The most common crossing is a bent crosswalk, to make the crossing as short as possible (see Exhibit 10.4). *MUTCD* recommends crosswalks at least 20 feet from the circulatory roadway; 25 feet from yield lines is recommended.

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 – Roundabouts must be designed to accommodate the largest vehicles that will use the intersection, such as buses and tractor-trailers. This is achieved with a **truck apron**:

a mountable portion of the central island designed for the off-tracking of large vehicle rear wheels. To discourage use by passenger cars, the apron should be raised slightly above the circulatory roadway and constructed with a distinct color or texture. However, it must be fully mountable and strong enough to support the weight of the largest design vehicles.

Before applying these design principles, it is helpful to look at a common example of where approach geometry, signing, and pedestrian elements can fall short. The following illustration highlights several issues that often arise when the approach to a roundabout is not designed to properly manage speed, guide drivers, or support pedestrians.

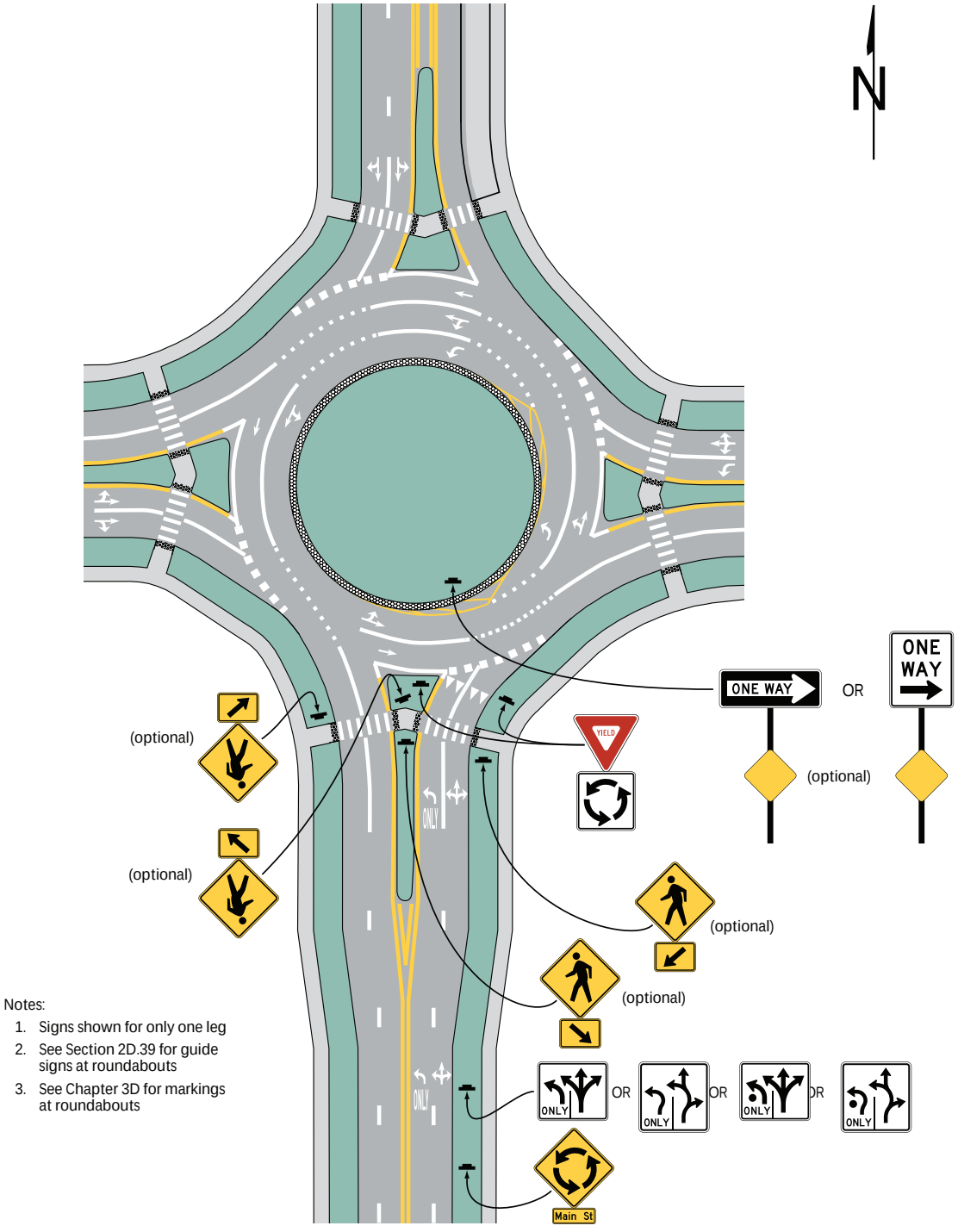
Exhibit 10.5: Deficiencies in Roundabout Approach Design

- ✓ 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 (see Exhibit 10.6).
- ✓ A One Way (R6-1 or R6-2) 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 complex than that of single-lane versions, as it requires meticulous attention to path alignment. The primary objective is to ensure that drivers who enter in the correct lane can follow a continuous path to their exit without needing to cross solid lane lines. To achieve this, lane assignments must be custom-designed based on design-hour traffic volumes, ensuring approach lanes align perfectly with circulatory and exit lanes. A key design technique to facilitate this alignment is the inclusion of a short tangent section at the entry, just after the splitter island, which helps guide vehicles into the proper circulatory lane. Exhibit 10.6 provides examples of these custom lane assignments.

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.

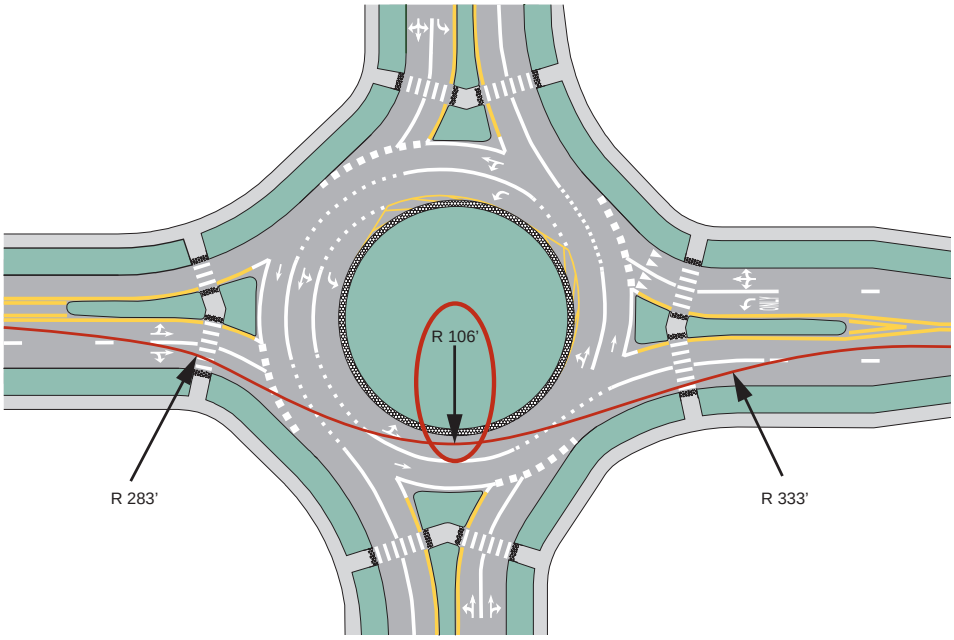
Drainage must be specially designed. Existing drainage systems usually need to be reconfigured since the roundabout extents are beyond those of a traditional intersection. If tying into existing drainage systems, inlets located at the edges of a roundabout may be shallower since they are located farther from where they would have been with the original intersection layout. It is critical that roundabouts not have areas that pond stormwater.

A key advantage of a well-designed roundabout is its traffic calming effect. This is verified through a "fastest path analysis," which ensures the roundabout's geometry forces drivers to slow to an appropriate speed, typically 25-30 mph. The analysis checks the smoothest, straightest path a vehicle can take, which may be the through-movement or a right-turn path. A successful design should create a speed differential of at least 10 mph between the approach speed and the fastest path speed.

The controlling factor in this analysis is deflection—the degree to which the geometry forces a vehicle to curve. Insufficient deflection, often caused by a central island that is too small or a circulatory roadway that is too wide, will result in undesirably high speeds.

This issue is especially critical in multi-lane roundabouts, where wide roadways can allow a vehicle's fastest path to overlap both lanes, as illustrated in Exhibit 10.7. This lane encroachment negates the roundabout's safety benefits and increases the potential for sideswipe collisions.

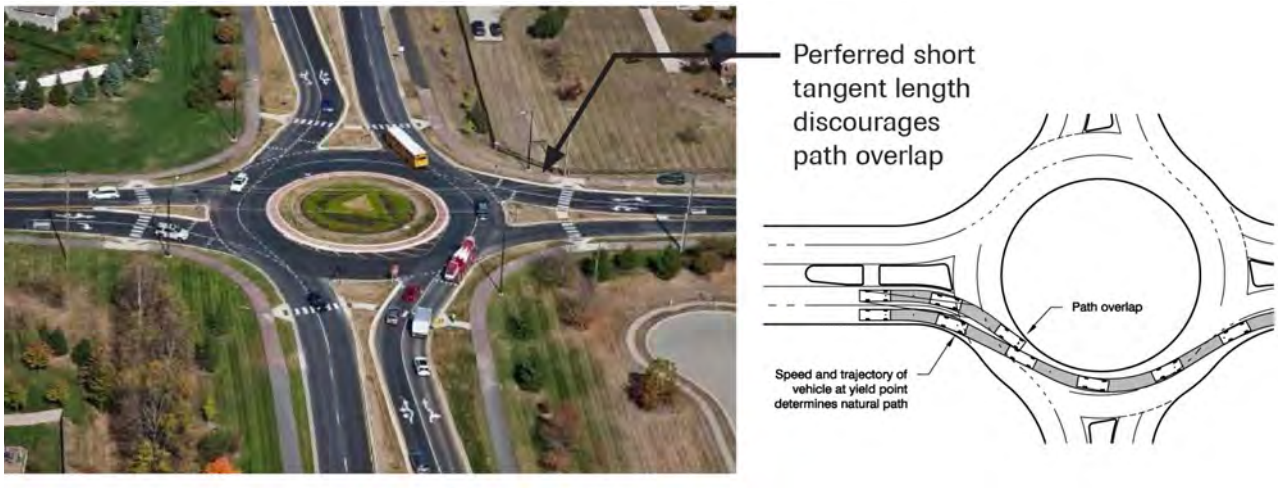
Exhibit 10.7: Fastest Path Overlap



Path overlap is a critical design flaw in multi-lane roundabouts where the geometry causes adjacent travel paths to cross, creating a high risk of sideswipe collisions. This typically occurs at the entry, where the outer lane's path leads into the inner circulatory lane. The solution is to provide a short tangent section at the entry before the yield line, which straightens the approach and properly aligns vehicles with their intended lane before they enter the roundabout. This preferred design, shown in Exhibit 10.8, is consistent with guidance in NCHRP Report 1043 [1].

Exhibit 10.8: Preferred Design to Avoid Path Overlap

Source: Hazel Dell Parkway Project, Carmel, Indiana & Exhibit 9.23, NCHRP Report 1043



Roundabout geometry must accommodate the turning path of the largest design vehicle, typically a WB-67 truck. A truck apron allows the rear wheels to off-track during through and left-turn movements. However,

the geometry for right turns must be designed with a sufficient radius so the vehicle can navigate the turn without its cab mounting the apron.

To confirm compliance, designers must provide a turning template analysis (e.g., Autoturn) for the specified design vehicle. This analysis must demonstrate that all movements can be completed as intended. For additional support, TEA offers design review services to verify proper vehicle accommodation.

CHAPTER 11 – ROADWAY SAFETY IMPROVEMENT PLAN

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Safety on public roadways is a well-regulated and thoroughly documented priority, with continuous efforts to identify and implement methods for improvement. Equally important is addressing roadway safety on military installations, where all roadways should ensure safe travel for both motorized and non-motorized traffic. Achieving this goal involves educating roadway users on safe driving practices, designing roadways to align with posted speed limits, ensuring intersections are equipped with appropriate traffic control devices and meet sight distance requirements, and maintaining safe travel conditions through work zones.

11.1. VEHICULAR CRASHES



Vehicular accidents can occur due to a variety of reasons including: inclement weather, driver distraction, road debris, animal obstruction, substandard roadway geometrics, and 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 11.1 shows mitigation techniques for several different crash types.

Exhibit 11.1: Common Crash Types

TYPE OF CRASH	COMMON CAUSES	SAFETY UPGRADES/ RECOMMENDATIONS
REAR IMPACT	✓ Not maintaining proper distance between vehicles ✓ Driving at an unsafe speed for the conditions and with nonfunctional equipment ✓ Unexpected congested conditions ✓ Brake light visibility issues	✓ Educate the public on the dangers of driving while impaired and the importance of avoiding distractions ✓ Maintaining a safe following distance and speed when traveling behind a vehicle.
SIDE IMPACT/ SIDESWIPE/ANGLE	✓ Failure to stop at a controlled intersection ✓ Loss of control of vehicle due to unsafe speed or weather conditions ✓ Driver drifting out of lane due to distraction or impairment.	✓ Check intersections for proper traffic control devices with no obstructions ✓ Educate public on maintaining safe speeds, and not being distracted or impaired while driving.

HEAD-ON COLLISION	✓ Driver encroaching into opposing traffic due to weather conditions, distraction, or impairment ✓ Driver enters a highway or one-way street from the wrong direction.	✓ Educate public on not driving while impaired and avoid distractions ✓ Increase DUI checkpoints, and ✓ Check that proper traffic control devices are utilized at highways and one-way streets.
ROLLOVER	✓ Turning too sharply at a high rate of a speed ✓ A result from a rear, side, or head-on collision.	✓ Refer to the rear, side, and head-on collision recommendations.
SINGLE CAR INCIDENT/RUNOFF	✓ Substandard roadway geometrics ✓ Driver distraction or impairment ✓ Driver avoiding obstacle (i.e. other vehicle, pedestrian, animal, or debris).	✓ Check roadway for geometric deficiencies ✓ Educate public on not driving while distracted or impaired.

11.2. CRASH RECORDS

As discussed in Section 11.1, it is important to maintain vehicular crash records in order to develop methods to increase safety on military base roadways.

11.2.1. Military Crash Records

Military installations maintain crash and safety records as part of routine reporting. While these records document the personnel, vehicles, and property involved, they typically lack the detailed crash-specific information needed for engineering analysis. Because the forms focus on accountability and damage estimates and are managed by security forces, engineering personnel often have limited access to data useful for transportation studies.

Within the Department of the Army, DA Form 3946 – Military Police Traffic Accident Report is the standard form for documenting traffic accidents investigated by military police. The Navy and Air Force use separate service-specific reporting forms.





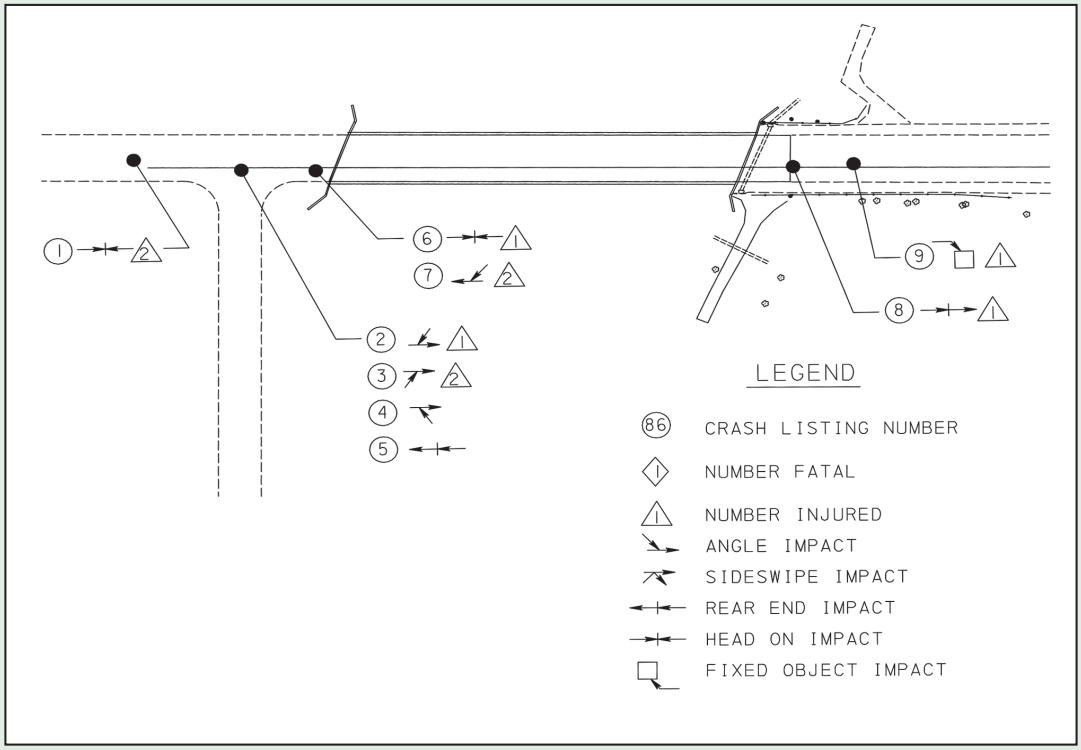
Car pulled out of parking spot and hit pole

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.

11.2.2. 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.

CRASH DIAGRAM EXAMPLE



11.3. IMPROVING ROADWAY SAFETY

The two key elements to increasing safety on military roadways are to educate roadway users on safety and implement roadway safety improvements. See TEA *Pamphlet 55-8* for information on calculating benefit-cost analysis information.

11.3.1. Roadway User Safety Considerations

Roadway safety can be enhanced through improvements to the physical features of the roadway, as outlined in Section 11.3.2 and the Roadway Safety section of this pamphlet. However, safety is also influenced by factors beyond the control of the roadway-owning agency. These factors are associated with roadway users, including drivers, vehicles, pedestrians, and bicyclists.

One of the most significant factors influencing roadway safety is the driver. Numerous aspects of highway safety depend on the actions and behaviors of road users, which can be enhanced through targeted enforcement, public education initiatives, and advancements in vehicular technology. These include:

- ✓ Maximizing seatbelt use by driver and all passengers.
- ✓ Eliminating drug and alcohol impaired driving.
- ✓ Obeying speed limits, and driving slower when road conditions demand it.
- ✓ Eliminating distracted driving, particularly cell phone use, and texting.
- ✓ Practicing safer driving techniques, such as limiting lane changing, maximize turn signal use, and obeying traffic control devices.

Exhibit 11.2: 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 distracted driving ✓ Enforce no texting or holding of phones while driving (where applicable by law) ✓ Enforce traffic violations
VEHICLE	✓ Vehicle in poor operating condition ✓ Vehicle lights not operational ✓ Vehicle's windshield wipers or tires are in need of replacement	✓ Educate on the importance of vehicle preventive maintenance ✓ Consider requiring proof of annual vehicle inspections
PEDESTRIANS/ BICYCLISTS	✓ Not wearing helmet ✓ Not wearing high visibility safety apparel ✓ Not following traffic control devices ✓ Not using sidewalks or crosswalks	✓ Educate on the importance of practicing safe bicycling ✓ Designate and enforce the use of crosswalks within high volume areas ✓ Implement appropriate traffic control devices in high pedestrian volume areas ✓ Create or designate pedestrian/bicyclist pathways to keep them off of roadways
TEMPORARY WORK ZONE	✓ Improper temporary traffic control devices ✓ Workers not wearing proper safety apparel	✓ Enforce the use of a temporary traffic control plan that is designed to current standards ✓ Enforce driver compliance to work zone traffic controls ✓ Enforce workers to practice standard safety requirements

11.3.2. Roadway Safety Improvement



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.

11.4. FHWA-RECOMMENDED IMPROVEMENTS

The FHWA has identified 25 Proven Safety Countermeasures (PSCs) that transportation agencies are strongly encouraged to implement. These strategies are effective in reducing roadway fatalities and serious injuries and are applicable across all roadway types—from rural two-lane roads to urban arterials, and from high-volume freeways to local streets.

Each countermeasure addresses one or more of FHWA's safety focus areas: intersections, roadway departures, speed management, and pedestrian/bicyclist safety. Several are crosscutting strategies that apply broadly across contexts.

Exhibit 11.3: FHWA-Recommended Crash Countermeasures

FOCUS AREA	COUNTERMEASURES	GUIDANCE HIGHLIGHTS
INTERSECTIONS	✓ Roundabouts ✓ Corridor Access Management ✓ Backplates with Retroreflective Borders ✓ Leading Pedestrian Intervals ✓ Reduced Left-Turn Conflict Intersections ✓ Signal Visibility Enhancements	✓ Roundabouts reduce severe crashes by 78–82% and overall crashes by 44–48%. ✓ Access management treatments can cut crashes by 20–50%. ✓ Retroreflective backplates lower red-light running crashes by 15–30%. ✓ Leading pedestrian intervals reduce pedestrian-vehicle crashes by up to 60%.
ROADWAY DEPARTURES	✓ Longitudinal Rumble Strips & Stripes ✓ Safety Edge ✓ Enhanced Delineation & Friction for Curves ✓ Shoulder Widening ✓ Clear Zone Improvements	✓ Shoulder rumble strips reduce run-off-road crashes by 29–50%. ✓ Centerline rumble strips cut head-on crashes by 30–50% ✓ Safety Edge reduces run-off-road crashes by up to 35% ✓ High-friction surface treatments lower wet-weather curve crashes by 50–90%.

SPEED MANAGEMENT	✓ Road Diets (Roadway Reconfiguration) ✓ Gateway Treatments ✓ Speed Feedback Signs ✓ Variable Speed Limits	✓ Road Diets reduce crashes by 19–47% and improve multimodal access. ✓ Gateway treatments calm traffic entering communities. ✓ Speed feedback signs typically reduce speeding violations by 10–20%. ✓ Variable speed limits adapt to conditions, lowering crash risk in adverse weather.
PEDESTRIAN & BICYCLISTS	✓ Medians & Pedestrian Crossing Islands ✓ Pedestrian Hybrid Beacons ✓ Crosswalk Visibility Enhancements ✓ Lighting Improvements ✓ Separated Bike Lanes ✓ Safe Pedestrian Refuge Areas	✓ Medians and crossing islands reduce pedestrian crashes by 46% and vehicle crashes by up to 39% ✓ Pedestrian Hybrid Beacons reduce pedestrian crashes at midblock crossings by up to 55% ✓ Enhanced lighting improves nighttime pedestrian visibility, cutting crashes by 20–30%. ✓ Separated bike lanes reduce bicycle-involved crashes by 30–40%.
CROSSCUTTING STRATEGIES	✓ Work Zone Safety Enhancements ✓ Rural Road Safety Treatments ✓ Systemic Safety Analysis Tools ✓ Complete Streets Integration	✓ Work zone strategies reduce crashes by 15–25%. ✓ Rural road safety treatments (e.g., paved shoulders, rumble strips) cut severe crashes by 30–40%. ✓ Systemic analysis tools help agencies proactively identify high-risk sites. ✓ Complete Streets policies improve safety for all users while supporting community livability.

Source: FHWA (https://highways.dot.gov/safety/proven-safety-countermeasures)

11.5. 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 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.

11.6. IMPLEMENTATION OF A ROADWAY SAFETY IMPROVEMENT PLAN



Form a Roadway Safety Committee to implement a safety improvement plan.

Forming a Roadway Safety Committee is a critical step in implementing a successful safety improvement plan. In accordance with DoDI 6055.04, installations are required to establish traffic safety councils or working groups to address roadway safety concerns. These groups are responsible for analyzing crash data, identifying hazards, and recommending corrective actions to improve traffic safety. Exhibit 11.4 outlines the steps to formulating the plan.

Exhibit 11.4: Steps to Formulating a Safety Improvement Plan

STEP 1	✓ Each installation is required to 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 and 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.

11.7. FIELD ASSESSMENTS



Field assessments by knowledgeable personnel are crucial to fully analyze problem areas.

Field observation by skilled personnel is one of the most underutilized methods for identifying traffic-related issues. Challenges such as pedestrian interference, driveway-related conflicts, visibility limitations, and driver behavior patterns are often only revealed through direct, on-site observation.

Field observation plays a critical role in evaluating potential geometric enhancements to improve traffic operations. For instance, observing actual vehicle movements can help determine proper channelization. Tire scouring on pavement often provides valuable insight into the "natural path" most drivers follow. These natural paths can be analyzed through direct field observation or aerial photographs prior to designing geometric improvements. Exhibit 11.5 highlights probable causes of crash patterns that can be identified through field assessments, along with general countermeasures to address these issues.

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.

Exhibit 11.5: General Crash Pattern

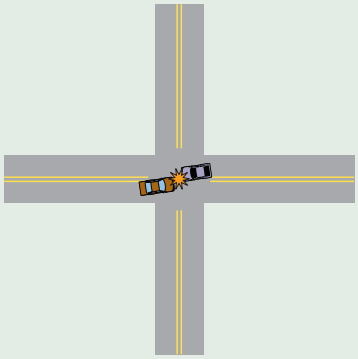
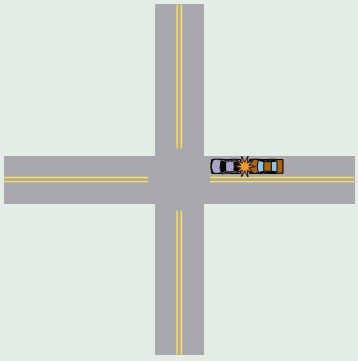
CRASH PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Left-turn head-on collisions 	✓ Large volume of left turns	✓ Create one-way street ✓ Widen road ✓ Provide left-turn signal phases ✓ Prohibit left turns ✓ Reroute left-turn traffic ✓ Channelize intersection ✓ Install STOP signs ✓ Revise signal sequence ✓ 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	✓ Implement traffic calming devices
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 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 11.5: General Crash Pattern (continued)

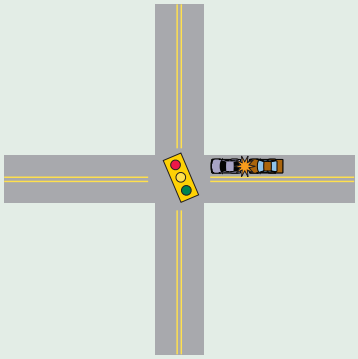
CRASH PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Rear-end collisions at unsignalized intersections (continued)	✓ Excessive speed on approaches	✓ Reduce speed limit on approaches
	✓ Inadequate gaps	✓ Provide traffic signal, if warranted by *MUTCD* ✓ Provide STOP signs ✓ Add a roundabout
	✓ Crossing 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
	✓ Inadequate roadway lighting	✓ Improve roadway lighting
	✓ Crossing pedestrians	✓ Install/improve signing or marking of pedestrian crosswalks ✓ Provide pedestrian WALK phase

Exhibit 11.5: General Crash Pattern (continued)

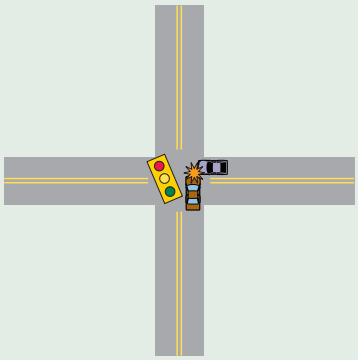
CRASH PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Right-angle collisions at signalized intersections 	✓ Restricted sight distance	✓ Remove sight obstructions ✓ Restrict parking near corners ✓ Install warning signs ✓ Reduce speed limit on approaches ✓ Channelize intersections ✓ Install advance markings 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 11.5: General Crash Pattern (continued)

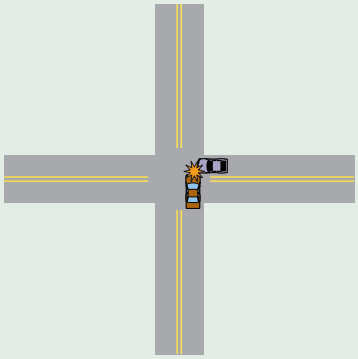
CRASH PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Right-angle collisions at unsignalized intersections 	✓ Restricted sight distance	✓ Remove sight obstructions ✓ Restrict parking near corners ✓ Install STOP signs ✓ Install warning signs ✓ Reduce speed limit on approaches ✓ Install signal ✓ Install YIELD signs ✓ Channelize intersection ✓ Install advance markings to supplement signs ✓ Install limit lines ✓ Add a roundabout
	✓ Large intersection volume	✓ Install signal ✓ Reroute through traffic
	✓ Excessive speed on approaches	✓ Reduce speed 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

Exhibit 11.5: General Crash Pattern (continued)

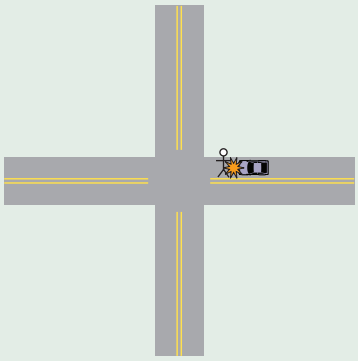
CRASH PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Pedestrian-vehicular collisions 	✓ Restricted sight distance	✓ Remove sign obstructions ✓ Install pedestrian high-visibility crosswalk markings ✓ Install/improve pedestrian crossing signs ✓ Reroute pedestrian paths ✓ Prohibit curb parking near crosswalks
	✓ Inadequate protection for pedestrians	✓ Add pedestrian refuge islands ✓ Install pedestrian barriers
	✓ School crossings	✓ Use guards at school crossings ✓ Install high-visibility crosswalks ✓ Add school-zone warning signs or beacons ✓ Reduce speed limit in school zone
	✓ Inadequate signals	✓ Install pedestrian signals
	✓ Inadequate signal phasing	✓ Change timing of pedestrian phase
	✓ Driver inadequately warned of mid-block crossings	✓ Prohibit parking ✓ Install warning signs ✓ Implement traffic calming devices ✓ Install pedestrian barriers
	✓ Inadequate pavement markings	✓ Install thermoplastic markings ✓ Supplement markings with appropriate signing ✓ Upgrade pavement markings
	✓ Inadequate gaps at unsignalized intersections	✓ Install traffic signal, if warranted ✓ Install pedestrian crosswalk signs and markings ✓ Install pedestrian WALK-DONT WALK signals
	✓ Inadequate roadway lighting	✓ Improve roadway lighting
	✓ Excessive vehicle speed	✓ Implement traffic calming devices ✓ Install proper warning signs ✓ Install pedestrian barriers ✓ Use enforcement

Exhibit 11.5: General Crash Pattern (continued)

CRASH PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
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	✓ Develop pavement maintenance plan
	✓ Poor visibility	✓ Increase size of signs ✓ Improve pavement markings, roadside delineators, centerline, and edgeline raised pavement markers
	✓ Excessive speed on approaches	✓ Implement traffic calming devices

Exhibit 11.5: General Crash Pattern (continued)

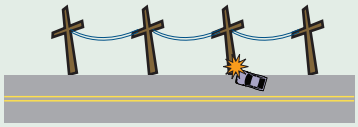
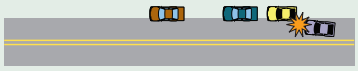
CRASH PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Fixed object collisions 	✓ Obstructions in or too close to roadway	✓ Remove obstacles ✓ Install breakaway features when applicable (signposts, light poles, fire hydrants, etc.) ✓ Protect drivers from obstacle with guardrail ✓ Install crash cushioning devices
	✓ Inadequate roadway lighting	✓ Improve roadway lighting
	✓ Inadequate pavement marking	✓ Install retroreflective pavement markings
	✓ Inadequate visual warning markers	✓ Install retroreflective object marker on obstacle
	✓ Inadequate road design	✓ Provide the necessary geometric improvements to the horizontal, vertical or superelevation component of the roadway ✓ Install appropriate warning signs and delineators
	✓ Slippery surface	✓ Improve skid resistance ✓ Provide adequate drainage ✓ Provide Slippery When Wet signs ✓ Improve skid resistance
	✓ Excessive vehicle speed	✓ Reduce speed ✓ Use enforcement
Collisions with parked or parking vehicles 	✓ Improper pavement markings	✓ Provide on-street parking pavement marking in accordance with PROWAG
	✓ Improper parking clearance at driveways	✓ Post parking restrictions near driveways
	✓ Angle parking	✓ Convert angle parking to parallel parking
	✓ Excessive vehicle speed	✓ Implement traffic calming devices
	✓ Illegal parking	✓ Use enforcement
	✓ Improper parking	✓ Prohibit parking ✓ Create off-street parking
	✓ Large parking turnover	✓ Create one-way streets ✓ Reroute through traffic

Exhibit 11.5: General Crash Pattern (continued)

CRASH PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Sideswipe or head-on collisions 	✓ Inadequate roadway design	✓ Create one-way streets, provide the necessary geometric improvements to the horizontal, vertical or superelevation component of the roadway
	✓ Improper road maintenance	✓ Perform preventative maintenance
	✓ Inadequate shoulders	✓ Improve shoulders
	✓ Excessive vehicle speed	✓ Reduce speed limit ✓ Provide traffic calming control devices
	✓ Inadequate pavement markings	✓ Restripe center lines, lane lines, and pavement edge lines ✓ Utilize retroreflective markings
	✓ 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 11.5: General Crash Pattern (continued)

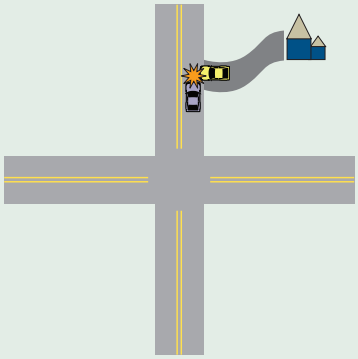
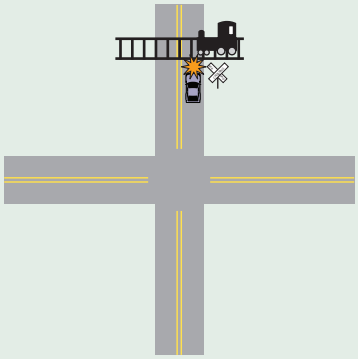
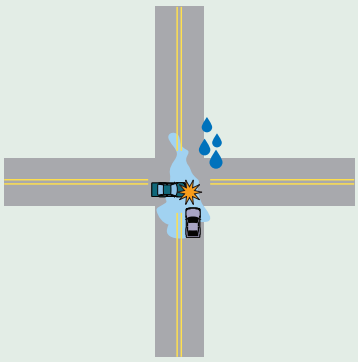
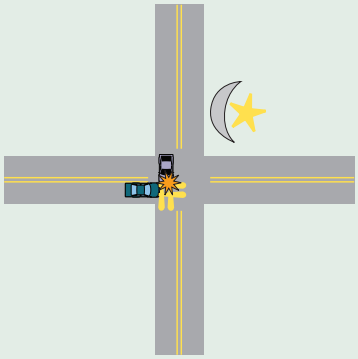
CRASH PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Driveway-related collisions 	✓ Left-turning vehicles	✓ Install median devices ✓ Install two-way left-turn lanes
	✓ Improperly located driveway	✓ Regulate minimum spacing of driveways ✓ Move driveway to side street ✓ Install curbing to define driveway 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 advance warning signs ✓ Implement traffic calming devices
	✓ Inadequate roadway lighting	✓ Improve roadway lighting
Train-vehicle crashes 	✓ Restricted sight distance	✓ Remove sight obstructions ✓ Reduce grade ✓ Install train-actuated signals ✓ Install STOP sign ✓ Install advance warning signs ✓ Install automated flashers and gates
	✓ Poor visibility	✓ Improve roadway lighting ✓ Increase size of signs ✓ Install retroreflective pavement markings
	✓ Improper traffic signal preemption timing	✓ Retime traffic signals
	✓ Excessive vehicle speeds on approaches	✓ Implement traffic calming devices

Exhibit 11.5: General Crash Pattern (continued)

CRASH PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Train-vehicle crashes (continued)	✓ Inadequate pavement markings	✓ Install advance markings to supplement signs ✓ Install stop lines ✓ Install/improve pavement markings
	✓ Slippery surface	✓ Improve skid resistance
	✓ 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 ✓ Improve skid resistance ✓ Reduce speed ✓ Provide Slippery When Wet signs
	✓ 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

11.8. BICYCLE SAFETY

Bicycles are classified as vehicles and are permitted to travel on various types of roadways. It is essential to plan for bicyclist accommodation in the design of new infrastructure and renovation projects, as it should be assumed that bicyclists will utilize these facilities. The FHWA has long advocated for the routine inclusion of accommodations for bicyclists and pedestrians, a concept that has been widely adopted by numerous state and local DOTs.

Bicycling can be promoted by reallocating space on existing streets commonly used by bicyclists. This may include removing parking, narrowing travel lanes to reduce motor vehicle speeds, and utilizing the reclaimed space to create bike lanes, paved shoulders, or wide curb lanes.

Bicycle facilities can often be integrated into site designs to enhance safety and accessibility. For instance, roadway shoulders should be paved and designed to be wide enough to accommodate a striped bike lane, with the generally accepted width for bicycle travel being four feet. As a short-term solution in areas where bicycle accommodation is needed, shoulders can be evaluated to ensure they are in suitable condition for safe bike travel and provide cyclists with a degree of separation from motor vehicle traffic.

Pavement markings designating bike lanes further enhance safety by visually deterring motorists and clearly defining roadway space allocated for cyclists. To provide bike lanes in both directions on a two-lane roadway, a minimum width of 32 feet is required, allowing for two 12-foot travel lanes and two 4-foot shoulders. If a roadway has at least 28 feet of width available, a bike lane can be provided in one direction. However, this arrangement carries a potential risk, as some cyclists may travel against the flow of traffic within the bike lane, leading to unsafe and hazardous conditions.

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 (https://highways.dot.gov/safety) can be used to assess bicycle facilities.

CHAPTER 12 – ROADSIDE SAFETY

12.1. FORGIVING ROADSIDE CONCEPT, CLEAR ZONE AND LATERAL CLEARANCE. 12-1
12.2. LATERAL OFFSETS FOR URBAN AREAS 12-4
12.3. COMMON ROADWAY HAZARDS AND MITIGATION STRATEGIES. 12-7
12.4. DRIVER-AID TREATMENTS. 12-19

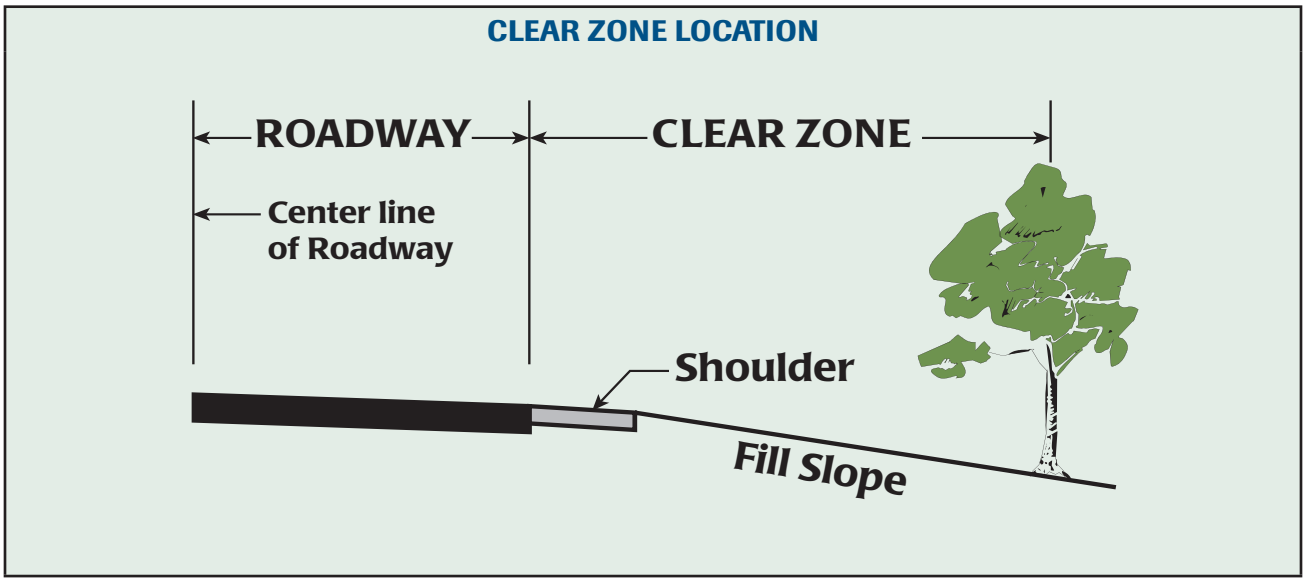
12.1. FORGIVING ROADSIDE CONCEPT, CLEAR ZONE AND LATERAL CLEARANCE

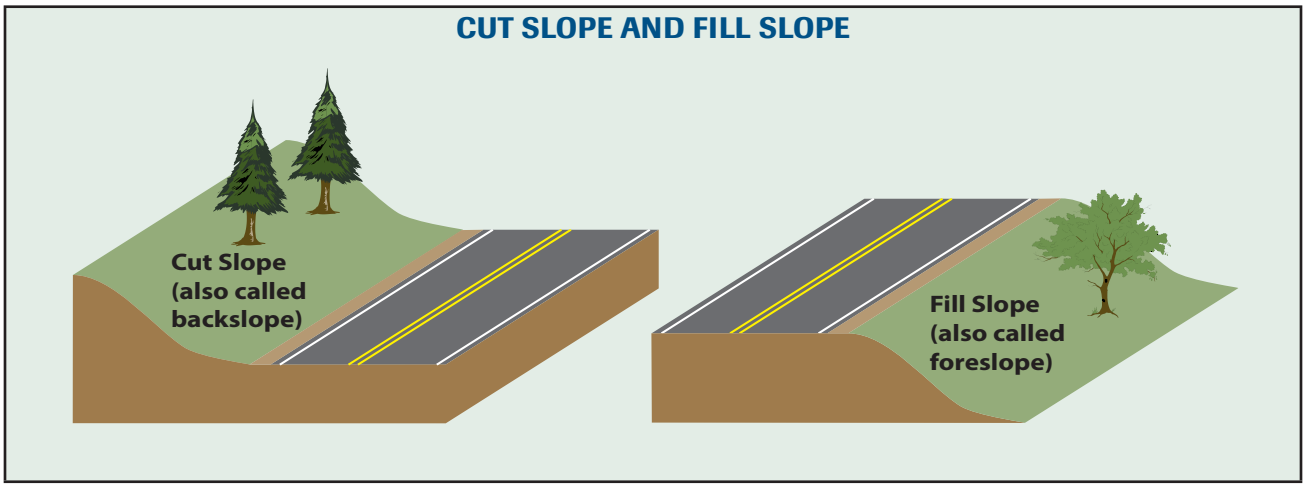
KEY POINT

Clear zone is a measured distance from the edge of the travel way that should be free from obstructions.

A clear zone is the unobstructed, relatively flat area alongside a roadway that provides space for drivers to safely recover if they leave the travel lane. It is designed to reduce the severity of crashes by minimizing hazards near the roadway.

The necessary clear zone distance is a function of the design speed of the roadway, ADT volumes, and roadway and roadside geometry.





The values presented in Exhibit 12.1 provide a range to be considered for clear zone, and generally applicable to rural highways and controlled-access facilities (such as freeways and interstates). In urban environments, these values should be applied where feasible. However, for arterials and other non-controlled access facilities in urban areas, limited right-of-way may make it impractical to apply the clear-zone guidance in this section In such cases, refer to Section 12.2 for alternative recommendations.

Exhibit 12.1: 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	*	10-12	10-12	10-12
	1500-6000	12-14	14-16	*	12-14	12-14	12-14
	Over 6000	14-16	16-18	*	14-16	14-16	14-16
45 - 50 MPH	Under 750	10-12	12-14	*	8-10	8-10	10-12
	750-1500	12-14	16-20	*	10-12	12-14	14-16
	1500-6000	16-18	20-26	*	12-14	14-16	16-18
	Over 6000	18-20	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 12.1 are appropriate for tangent sections and the inside of horizontal curves. On the outside of horizontal curves, a correction factor from Exhibit 12.2 should be applied to the value shown in Exhibit 12.1. For curves with a radius greater than 2,900 feet, a correction factor for the outside of the curve is not necessary. For design speeds greater than 50 mph, refer to the AASHTO *Roadside Design Guide.*

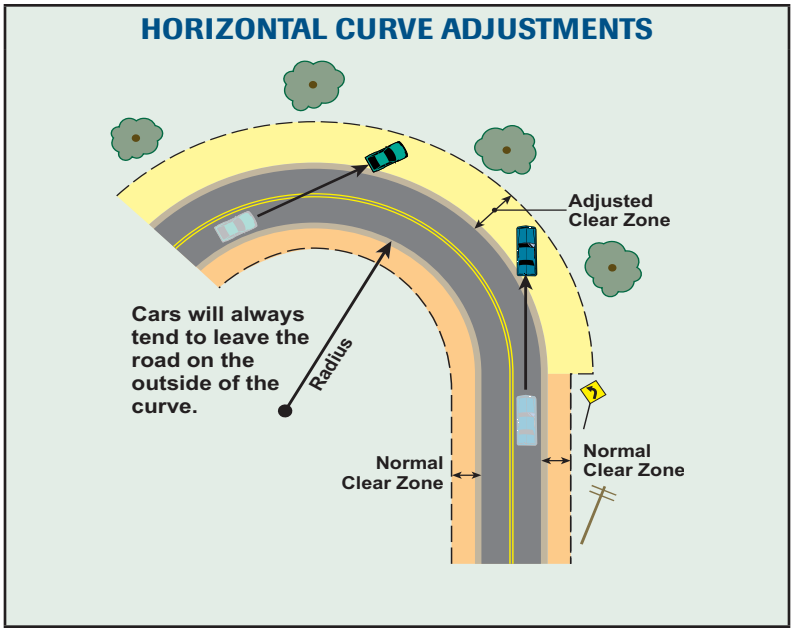


Exhibit 12.2: Horizontal Curve Adjustments*
(Clear zone curve corrections)

RADIUS (FEET)	DESIGN SPEED (MPH)		
	40	45	50
2900	1.08	1.10	1.12
2300	1.10	1.12	1.15
1950	1.11	1.15	1.18
1650	1.13	1.17	1.22
1450	1.15	1.19	1.25
1300	1.17	1.22	1.28
1150	1.19	1.24	1.31
1000	1.23	1.29	1.36
850	1.26	1.34	1.42
750	1.30	1.38	1.48
650	1.34	1.43	1.53
600	1.37	1.47	
400	1.54		

**Multiply the clear zone distance derived from Exhibit 12.1 by the curve correction factor derived from Exhibit 12.2 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 2900 feet do not require an adjusted clear zone.*

Source: AASHTO Roadside Design Guide, Table 3-2. For design speeds greater than 50 mph, refer to the AASHTO Roadside Design Guide.

12.2. LATERAL OFFSETS FOR URBAN AREAS

Urban environments are characterized by sidewalks, curb and gutter, stop and go traffic, pedestrians, low speed and on-street parking. In these constrained settings, it is frequently not feasible to obtain the appropriate clear zone described in Section 12.1 due to the limited right of way and roadside development. This section outlines strategies to improve safety on uncontrolled-access highways in urban areas or environments with limited space.

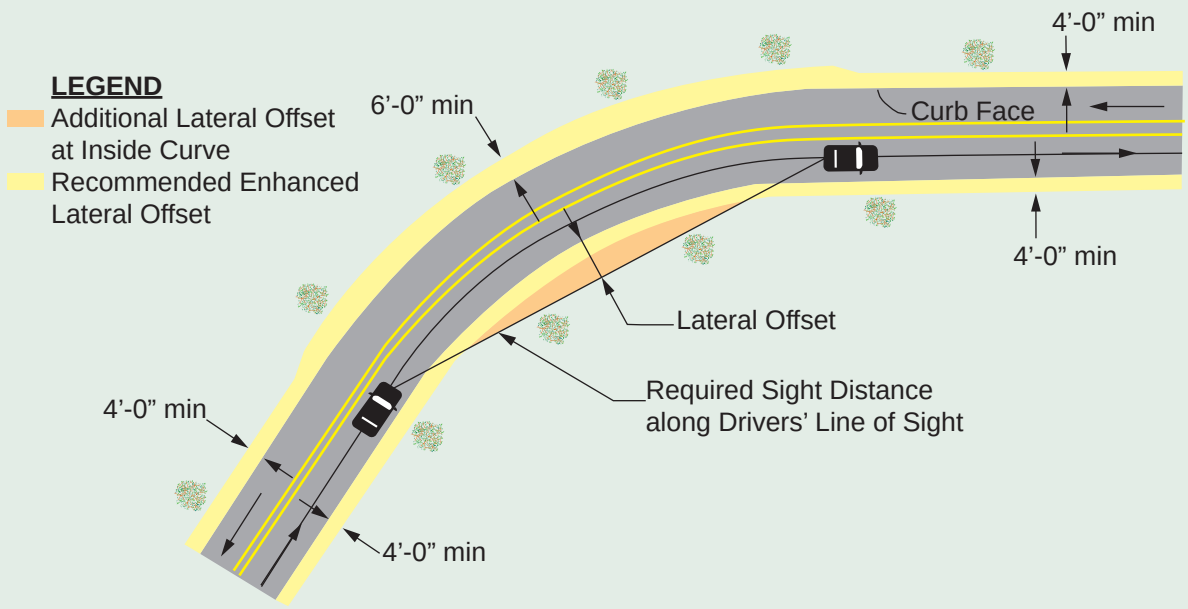
According to the AASHTO Roadside Design Guide, research indicates that in urban environments, approximately 80% of roadside crashes involve an object located within 4 feet of the curb face, and over 90% of urban roadside crashes occur within a lateral offset of 6 feet or less.

AASHTO has identified critical urban roadside locations that are more susceptible to crashes and, as shown in Exhibit 12.3, has established specific lateral offset guidelines for these areas. It is important to note that these offsets represent reasonable objectives when the clear zone widths outlined in Section 12.1 cannot be achieved. However, they should not be mistaken as fully meeting the clear roadside concept. To aid in understanding these offsets, illustrations from the AASHTO Roadside Design Guide are provided following Exhibit 12.3.

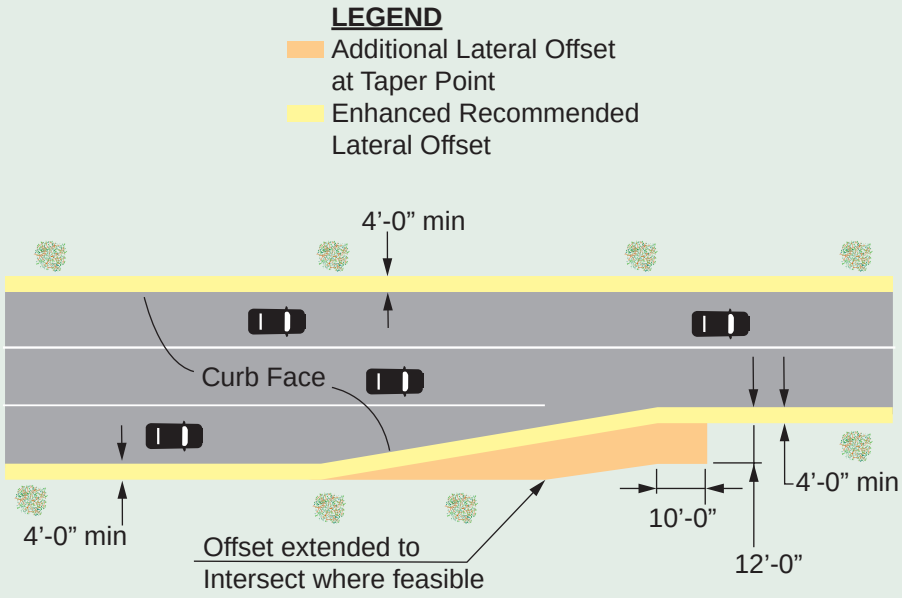
Exhibit 12.3: Urban Lateral Offset Distances, Based on Crash-Histories

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

LATERAL OFFSET FOR OBJECTS AT HORIZONTAL CURVES ON CURBED FACILITIES

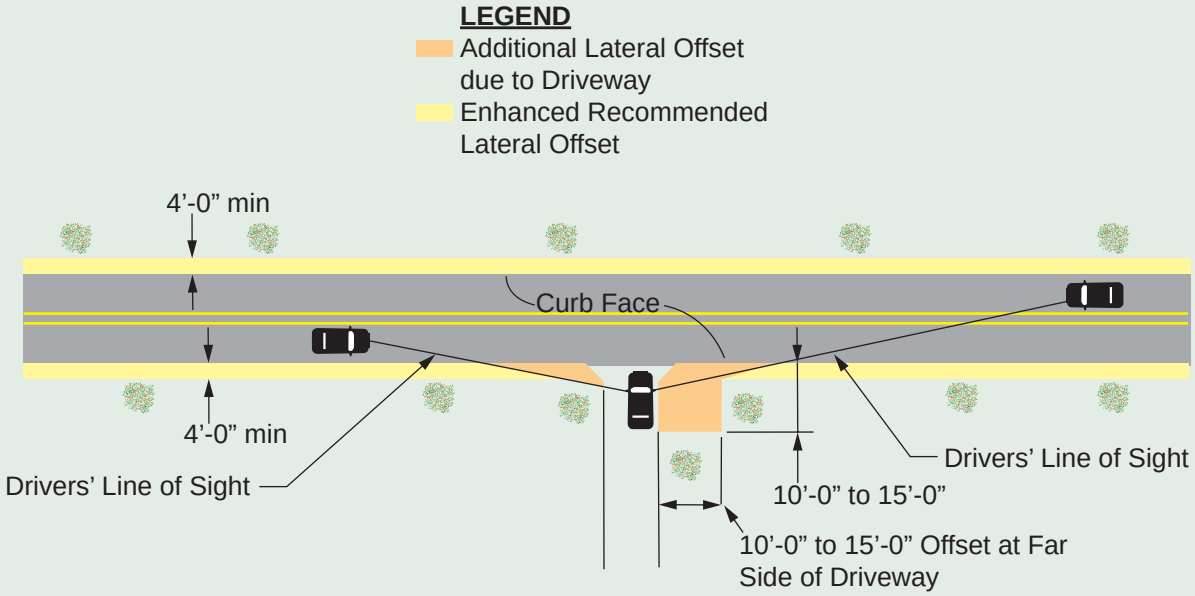


LATERAL OFFSETS AT MERGE POINTS



Lateral Offset configuration applies to Lane Merges, Acceleration Lanes, and Bus Bay Returns

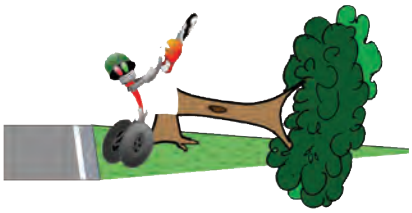
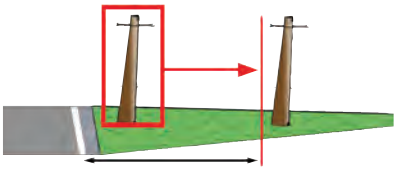
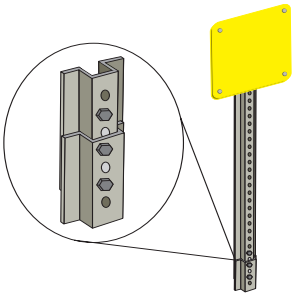
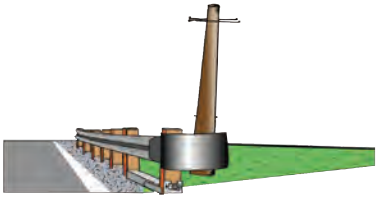
LATERAL OFFSETS AT DRIVEWAYS



12.3. 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 12.4, should be considered in the order in which they are presented.

Exhibit 12.4: 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.

12.3.1. Trees and Poles

14% of all traffic fatalities involve hitting a tree or pole. There are two primary methods to address the problem of roadside trees and poles.

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 to alert road users to unusual traffic conditions.
- ✓ **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 or pole is greater than the severity of striking the barrier; and when removal is not a viable option.
- ✓ **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.

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.

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.



Example of wide clear zone

12.3.2. 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.

Over half of motor vehicle deaths involve vehicles leaving the roadway and hitting fixed objects. In cases where fixed objects cannot be removed or relocated, implementing appropriate breakaway supports can help reduce the severity of impacts.

A breakaway support is a device designed to yield upon impact with a vehicle, minimizing the severity of the collision. These supports are intentionally engineered with a weak point to ensure controlled failure. Their performance is governed by three key criteria, ensuring they fail in a predictable and safe 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 important to understand that strict specifications exist for the performance of breakaway supports. Most states have established standard designs for breakaway supports that have been crash-tested and approved. It is recommended to consult your state's standards to select an appropriate design.

Breakaway supports are available for objects such as:

- ✓ Post mounted signs
- ✓ Luminaires
- ✓ Traffic signals
- ✓ Fire hydrants
- ✓ Mailboxes
- ✓ Utility poles

Give special care and consideration to breakaway supports for luminaires, traffic signals, and utility poles. If not designed or constructed properly, a falling support can be hazardous to other vehicles on the roadway.

12.3.3. Drainage Features

Drainage structures can pose as a significant roadside hazard when located near the roadway, as their rigid concrete design does not yield upon impact.

Exhibit 12.5: Common Deficiency Examples



Protruding endwalls for cross-drainage structure

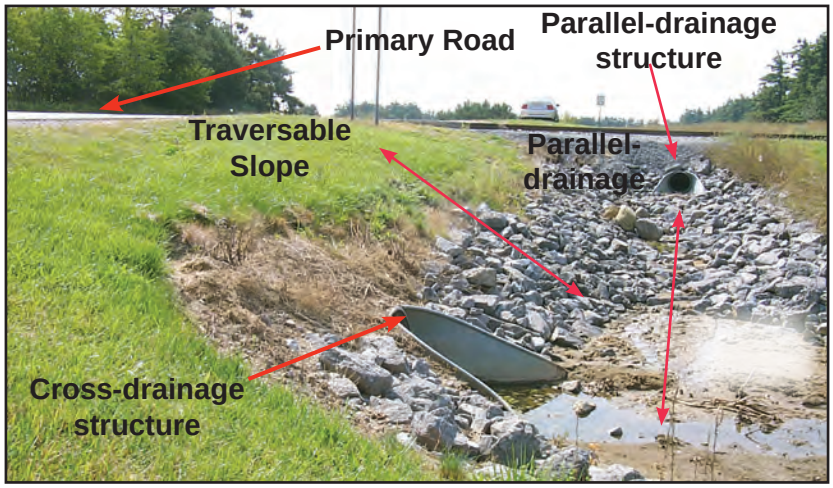


Endwalls too close to roadway edge for cross-drainage structures



Parallel-drainage ditches within the clear zone

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

12.3.4. 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 and utilize traversable end sections. 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 culvert end section is not 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 with a type 3 object marker as shown in the image to the right.



Delineate the structure

12.3.5. Parallel-Drainage Structures

For parallel-drainage structures, the following options should be considered to minimize their impact on safety:

- ✓ **Use a traversable end treatment** – Where possible, culvert end sections should be designed to be traversable. This may include:
  - Grated end sections designed to support errant vehicle loads
  - End sections that conform to the slope of the embankment. These treatments reduce the likelihood of vehicle snagging or abrupt deceleration.
- ✓ **Extend or reconfigure the structure** – Culverts should be extended so that end treatments are less likely to be struck by errant vehicles or positioned to better align with roadside slopes.
- ✓ **Relocate outside the clear zone** – Where feasible, move culvert ends or drainage structures outside the clear zone to eliminate the hazard.
- ✓ **Shield the structure** – If the structure cannot be made traversable or relocated, shielding (e.g., guardrail) should be considered.
- ✓ **Delineate the structure** – When other mitigation measures are not feasible, the structure should be clearly delineated to improve driver awareness.

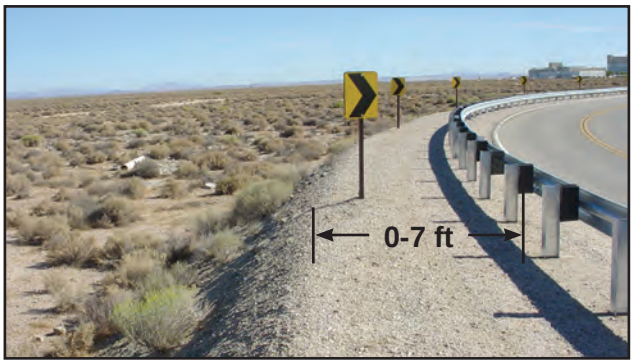
12.3.6. Barrier Basics

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. Common types of roadside barriers include guardrail, cable, and concrete barriers.

12.3.7. Barrier Design

When designing or selecting a roadside barrier system, consider the following:

- ✓ Lateral placement and deflection
- ✓ Length of need
- ✓ End treatment



Lateral placement and deflection

Lateral Placement and Deflection

Barrier selection depends on the deflection characteristics of the system and the location of the roadside hazard. The required offset between the barrier and the obstruction typically ranges from 0 to 7 feet, depending on the barrier type, as seen on the next page.

Rigid barriers (e.g., concrete) have little to no deflection, while semi-rigid and flexible systems require greater offset distances to accommodate deflection during impact.

Barriers should be placed as far from the travel lane as practical, and at a minimum beyond the "shy line," or the distance at which objects are not perceived as immediate hazards by drivers. The distance between the barrier and obstruction must always accommodate the expected dynamic deflection.

For barrier installations adjacent to steep side slopes, provide an offset of approximately 2 feet between the barrier posts and the slope hinge point to prevent post failure during impact.

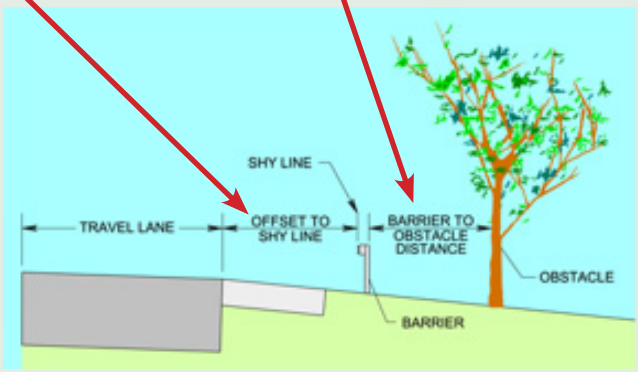
On high-speed roadways, avoid guardrail-curb combinations due to the potential for vehicle vaulting. Where curbing is required for drainage, the curb height should not exceed 4 inches, and the barrier should be a semi-rigid system aligned with the curb face. Use of curb-barrier combinations should be evaluated by a qualified engineer.

Recommended deflection distances for barrier systems are provided in the AASHTO Roadside Design Guide Table 5-7 and shown on the following page.

RECOMMENDED DEFLECTION DISTANCES FOR BARRIER SYSTEMS

DESIGN SPEED		SHY-LINE OFFSET (L_s)	
KM/H	[MPH]	M	[FT]
130	[80]	3.7	[12]
120	[75]	3.2	[10]
110	[70]	2.8	[9]
100	[60]	2.4	[8]
90	[55]	2.2	[7]
80	[50]	2.0	[6.5]
70	[45]	1.7	[6]
60	[40]	1.4	[5]
50	[30]	1.1	[4]

The required offset between the barrier and the obstruction typically ranges from **0 to 7 feet,** depending on the barrier type.



Consideration should also be given to life-cycle costs, as barrier systems require ongoing maintenance and repair.

Length of Need

To prevent a vehicle from striking a roadside hazard, a barrier system should be installed in advance of and alongside the obstruction. The distance over which the barrier is needed to shield the hazard is referred to as the length of need.

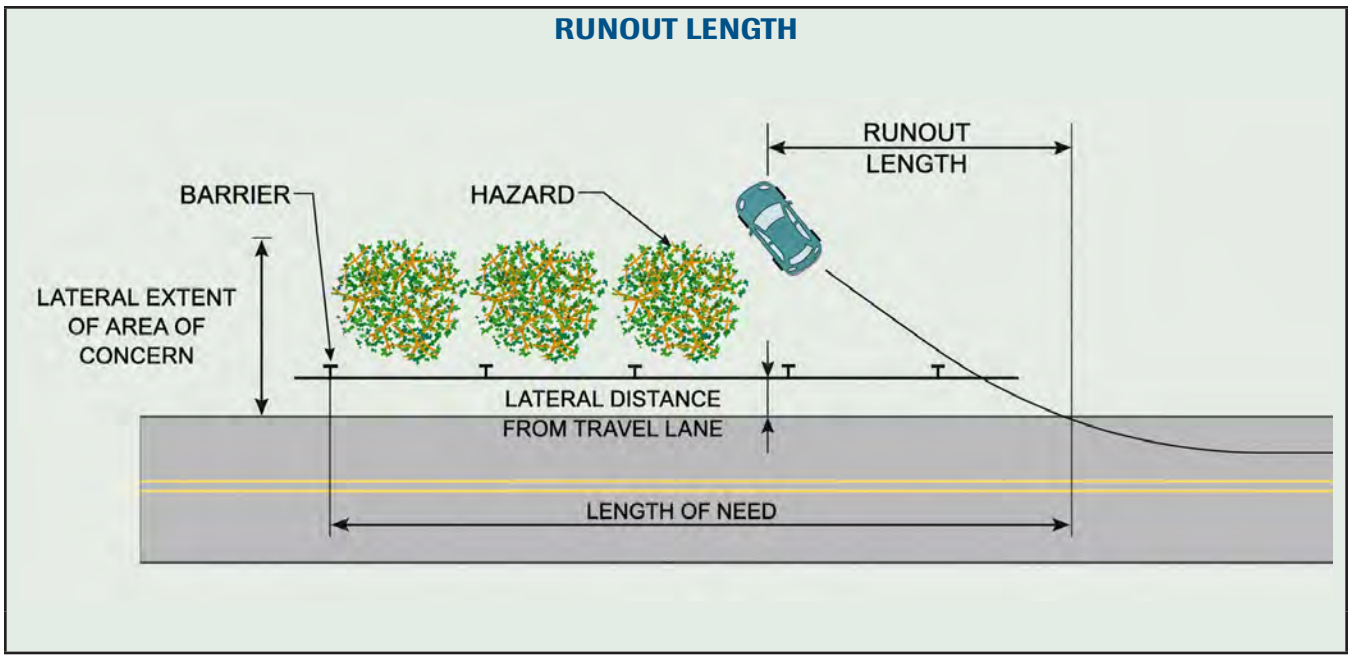
Length of need should be determined by a qualified engineer and depends on factors such as barrier offset, flare rate, and the distance between the roadway and the hazard.

The AASHTO runout length represents the distance required for an errant vehicle to decelerate and stop after leaving the roadway. This distance is measured from the upstream end of the hazard along the roadway to the point where a vehicle is assumed to depart the travel lane.

AASHTO provides recommended runout lengths based on roadway design speed and traffic volume. These values are used to determine the required barrier length of need.

Once the runout length and the lateral extent of the hazard are defined, the length of need is determined based on:

- ✓ the upstream tangent length,
- ✓ the lateral offset of the hazard, and
- ✓ the selected barrier flare rate.



Barrier End Treatments

Barrier systems that terminate within the clear zone require an appropriate end treatment or terminal designed to minimize the severity of impacts. These treatments provide a "forgiving" transition for exposed barrier ends. On two-lane, two-way roadways, both ends of a barrier installation typically require end treatments.

Barrier end treatments should meet current crashworthiness criteria as defined in the Manual for Assessing Safety Hardware (MASH). Legacy devices meeting NCHRP Report 350 criteria may still be in service; however, MASH-compliant devices are recommended for new installations.

Crashworthy end treatments can be categorized based on their behavior during impact:

- ✓ Gating terminals allow a vehicle to pass through or behind the barrier upon impact.
- ✓ Nongating terminals redirect or gradually decelerate the vehicle.

End treatments can also be installed as:

- ✓ Parallel to the roadway, or
- ✓ Flared away from the roadway.

An anchored backslope terminal is often a preferred treatment where site conditions allow, as it eliminates exposure to the leading edge of the barrier.

Turned-down end treatments are not crashworthy and should be avoided. Although they may be less expensive, they can cause vehicles to vault or overturn upon impact.

Exhibit 12.7 illustrates examples of barrier end treatments.

Exhibit 12.6: Guardrail End Treatment Examples

	Turndown end treatment
	Guardrail with no end treatment
	Proper end treatment
	Proper end treatment

12.3.8. Common Mistakes

Some common mistakes of guardrail installation include those in Exhibit 12.8.

Exhibit 12.7: 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)

12.3.9. Roadway Shoulders



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** – The proper design, construction, and grading of shoulders and road edges are essential for effective erosion control. Adequate construction ensures lateral support for the shoulder, minimizing the risk of edge cracking and erosion. Correct grading facilitates efficient drainage, preventing water from pooling and reducing the potential for shoulder or pavement edge erosion.
- ✓ **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

12.4. DRIVER-AID TREATMENTS

Driver-aid treatments play a critical role in minimizing highway crashes by assisting road users in staying within the travel lane. A significant number of severe crashes occur on curves and turns, often as a result of driver fatigue or impairment. The most commonly implemented driver-aid treatments include:

- ✓ Rumble strips
- ✓ Signs and pavement markings
- ✓ Roadway improvements/ITS
- ✓ Delineators and object markers
- ✓ Warning beacons

12.4.1. Rumble Strips

Rumble strips are raised or grooved patterns installed on road surfaces, typically along the edges, centerlines, or across the travel lane as transverse rumble strips. These features are designed to produce audible and tactile vibrations that alert drivers when their vehicles deviate from the travel lane or approach critical areas (Exhibit 12.9).

A rumble strip becomes a "rumble stripe" when an edge line or centerline pavement marking is applied directly over it. The grooved contour of the rumble strip facilitates water drainage by allowing air movement from passing vehicles to disperse the water. Additionally, the contour creates a reflective back wall, enabling the pavement marking to maintain its retroreflectivity during nighttime rain and post-rain conditions, when standard pavement markings typically lose their visibility.

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 condition, such as an unexpected intersection, work zones, ECFs, or a sharp curve.

Different DOTs locate edge line rumble strips at different points with respect to the actual travel lane. To accommodate bicyclists, avoid rumble strips if less than 4 feet of paved shoulder is available. Also, common modifications to edge line rumble strips include:

- ✓ Avoiding rumbles unless a minimum of 2 feet of paved shoulder is available.
- ✓ Periodic gaps are incorporated into rumble strips to allow bicycles to safely transition between the shoulder and the travel lane.
- ✓ Adjusting the depth and width of rumble strips is a common modification aimed at enhancing safety for cyclists, making it easier and more comfortable for them to traverse the rumble strips.

Exhibit 12.8: Pavement Marking Detail for Rumble Strips and Stripes

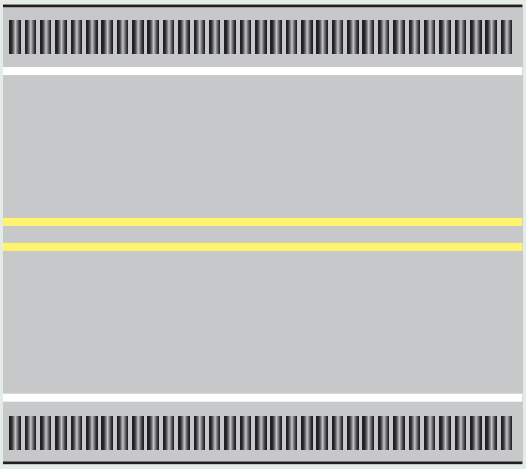
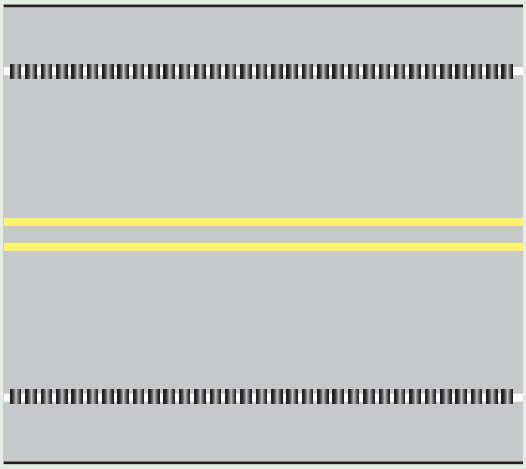
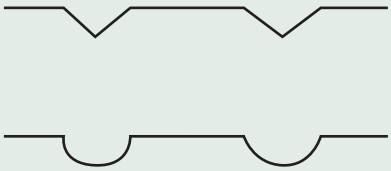
RUMBLE STRIP	RUMBLE STRIPE
	

Exhibit 12.9: Common Types of Rumble Strips*

TYPE	DESCRIPTION	COMMENTS
MILLED 	✓ Machine-milled ✓ Longitudinal width of 7 inches ✓ Transverse width of 16-17 inches ✓ Tires drop ½ inch into groove	✓ Preferred by most states due to easy 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 ✓ ½ inch 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 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 typically between $0.75 and $1.50 per linear foot.
- ✓ 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.

12.4.2. Signs and Pavement Markings

Signs

Signs are another effective driver-aid treatment. An example is the horizontal alignment warning signs, such as Turn, Curve, Reverse Turn, and Reverse Curve signs, which offer significant benefits to drivers by providing clear and timely information about upcoming roadway changes, enhancing safety and reducing the risk of crashes. Refer to the *MUTCD* criteria for determining the appropriate type of sign. 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 serve as the primary means of delineation and control, enabling road users to navigate the highway system effectively. These markings play a critical role in highway safety by regulating and guiding traffic movement. Pavement markings offer the most cost-effective system of roadway delineation, with an average cost of approximately $1 to $2 per linear foot for a four-inch-wide solid line using paint and glass beads. Chapter 8 of this pamphlet provides detailed information on the various types of pavement markings and the different marking materials available.

12.4.3. Roadway Improvements and Intelligent Transportation Systems

Roadway geometric and maintenance improvements are another effective form of driver-aid treatments, enhancing safety and assisting drivers in navigating the roadway more efficiently. Common improvements include:

- ✓ Enhancing roadway alignment
- ✓ Improve drainage by optimizing roadway crown and superelevation
- ✓ Rebuild deteriorated roadway surfaces.

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.

12.4.4. Delineators and Object Markers

Delineators

Delineators are retroreflective devices that offer reliable, all-weather guidance along roadway edges and are particularly useful in areas with potentially confusing alignments, such as lane reductions or curves. Their color must match the color of the pavement marking they supplement.

- ✓ 30% reduction in crashes
- ✓ Benefits outweigh costs on roadways with greater than 1,000 vehicles daily



Proper use of delineators

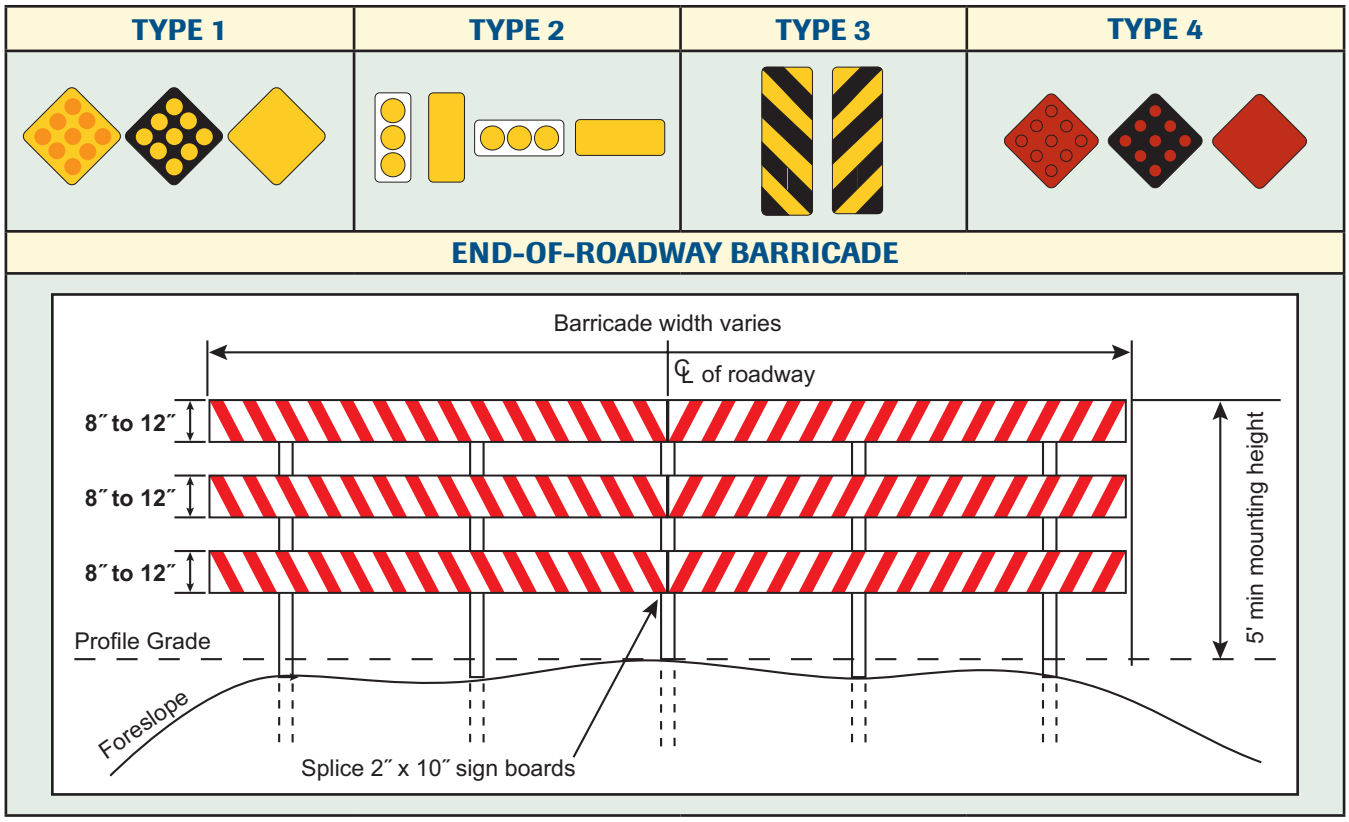
Object Markers

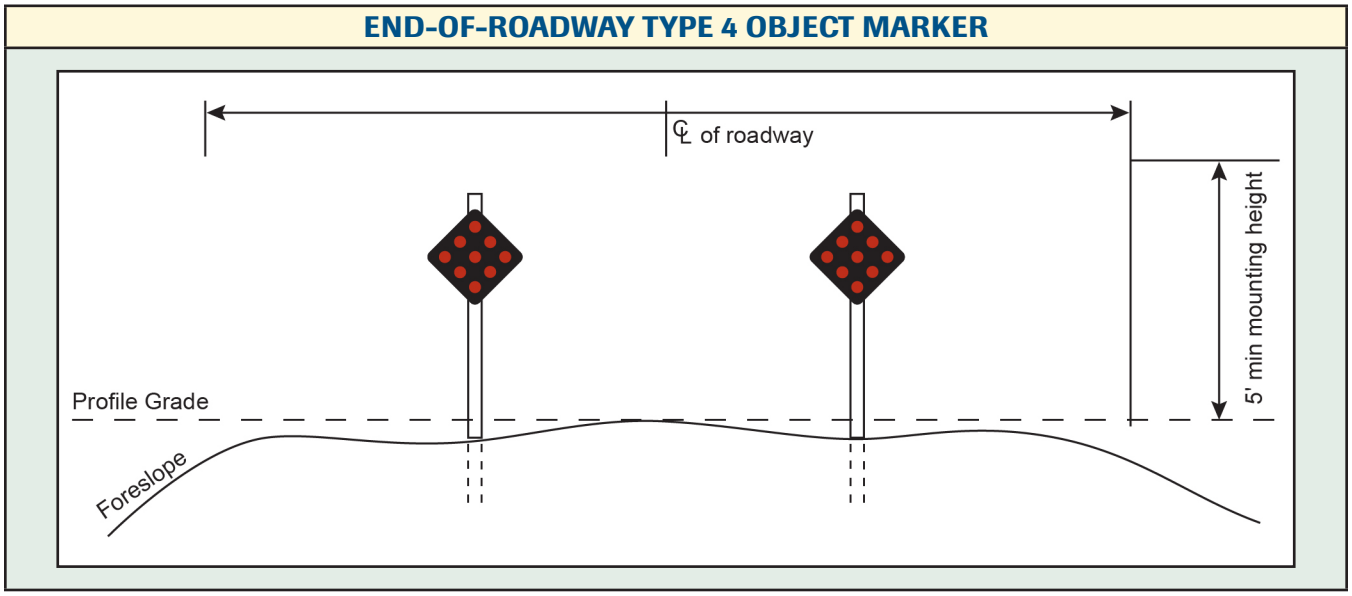
Object markers are used to identify obstructions within, near or at the end of a roadway.

Use Type 1 object markers to identify obstructions within the roadway, and Type 2 or Type 3 object markers to highlight roadside hazards adjacent to the roadway. These hazards include obstructions within the clear zone or urban lateral offset, such as underpass piers, bridge abutments, bollards, utility poles and culvert headwalls. Additionally, Type 2 and Type 3 markers can be used to indicate roadside conditions like narrow shoulder drop-offs, gores, small islands, and abrupt changes in roadway alignment.

Type 4 object markers are typically used to mark the end of a dead-end roadway outside of construction or maintenance areas. These markers are appropriate in situations where no alternate vehicular paths exist. When conditions warrant, multiple markers or larger markers, with or without a Type 3 barricade (refer to *MUTCD* Section 2B.75), may be installed at the roadway's end. Additionally, an end-of-roadway barricade can be supplemented with a ROAD CLOSED (R11-2) sign, as illustrated in Exhibit 7.24 on page 7-51. The advantage of Type 4 markers is their ability to delineate the entire width of the roadway. For further details, refer to Exhibit 12.11 and Section 7.3.13 for additional discussion on object markers

Exhibit 12.10: Object Markers





CHAPTER 13 – PEDESTRIAN SAFETY

13.1. SIDEWALKS 13-1
13.2. PEDESTRIAN-VEHICLE RIGHT-OF-WAY 13-7
13.3. CROSSWALKS 13-8
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13.5. SIGNING CROSSWALKS 13-12
13.6. USE OF TRAFFIC SIGNALS FOR PEDESTRIAN ACCOMMODATIONS 13-18

KEY POINT

Pedestrian crashes are a significant concern and can be effectively mitigated through a combination of engineering, education, and enforcement strategies.



According to the latest data from the National Highway Traffic Safety Administration (NHTSA), 7,314 pedestrian fatalities occurred nationwide in 2023, marking a significant increase from previous years. This represents a growing share of total traffic-related deaths. On average, a pedestrian was killed every 72 minutes in traffic crashes. As in past years, more pedestrian fatalities occurred at non-intersections than at intersections, and the majority happened during dark conditions, especially in areas lacking adequate street lighting. Urban areas continued to account for the majority of these incidents. The average age of pedestrians killed was in the mid-to-late 40s, and males made up more than two-thirds of the fatalities. These trends highlight ongoing challenges in pedestrian safety, particularly in urban environments and during nighttime hours.

13.1. SIDEWALKS

Sidewalks are one of the most common pedestrian accommodations and are typically more prevalent in urban areas than in rural ones. Built-up areas of military bases often resemble urban environments, while more open areas have a rural characteristic. Consequently, the necessity for sidewalks varies across different areas of a base. Sidewalks should be evaluated in the planning stage of any project and implemented if pedestrians are currently or forecasted to use the facility. Worn paths adjacent to roadways are a clear indicator of pedestrian demand and typically signal the need for a sidewalk in those locations.

Sidewalk width can vary from four feet to eight feet, depending on pedestrian demand.

- ✓ Under PROWAG, the minimum continuous clear width is 48 inches (4 feet).
- ✓ If the clear width is less than 60 inches (5 feet), a passing space of at least 60 inches by 60 inches 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 placing sidewalks, they should be positioned in relation to the adjacent roadway rather than the building. For instance, if a sidewalk is being added as part of a building project, it should be designed to function as a general pedestrian pathway rather than solely as an access route to the building. This ensures the sidewalk serves all pedestrians effectively.

Sidewalks should be continuous and free of gaps to ensure seamless pedestrian access. For instance, providing a sidewalk in front of one building but not in front of an adjacent building is undesirable. When a sidewalk must end, it should terminate at a logical, PROWAG-compliant location, such as a curb ramp, crosswalk, or other accessible pedestrian facility.



Worn path indicates need for sidewalk



Example of undesirable sidewalk termination

13.1.1. PT Accommodations

Physical Training (PT) is an essential component of military training and is often conducted during morning hours, which frequently coincides with peak vehicular traffic. This overlap increases the risk of vehicle-pedestrian conflicts. Pamphlet 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/Jogging Trails	Sidewalks and trails should be used to keep PT routes away from roadways. This is advantageous because it minimizes vehicle-pedestrian conflicts.
2. 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.
3. Moderate Volume Roadways	For roadways with higher traffic volumes, it is preferable to close the roadway to ensure the safety of troops. If closure is not feasible, implement a reduced speed limit that applies when troops are present. Additionally, use flaggers or a vehicular escort to clearly signal the presence of troops on the roadway.
4. High Volume Roadway	PT routes on high-volume roadways are not recommended. Closing key roadways through an installation, especially during the morning peak period, forces traffic to divert to adjacent, lower-classification roadways. This can lead to degraded traffic operations and increased congestion on those alternate routes.

13.1.2. Pedestrian Accessibility



If you cannot meet PROWAG standards, contact TEA.

Architectural Barriers Act (ABA) applies to facilities designed, built, altered, or leased with certain federal funds. Passed in 1968, the ABA is one of the first laws to address access to the built environment. The law applies to federal buildings, including post offices, social security offices, federal courthouses and prisons, and national parks. It also covers non-federal facilities, such as public housing units and mass transit systems, built or altered with federal grants or loans. Coverage is limited to those funding programs that give the federal agency awarding grants or loans the authority to establish facility standards. (United States Access Board website.)

It is the goal of the DoW 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: https://www.access-board.gov/files/aba/dod_memo_aba.pdf.

CHAPTER 13 – PEDESTRIAN SAFETY

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.

Per the October 31, 2008 Deputy Secretary of Defense (DepSECDEF) Memo, Subject: Access for People with Disabilities, the DoW 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. Specifically, DoW'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 DoW. Therefore, since DoW adopted the guidelines, they are now standards with which DoW must comply.

While ADA remains the legal foundation for accessibility, PROWAG now provides the governing technical standards for pedestrian facilities in the public right-of-way. To address design elements found in public rights-of-way and not fully covered by the ADA and ABA guidelines, the United States Access Board published the Final Public Right-of-Way Accessibility Guidelines (PROWAG) on August 8, 2023. These guidelines now govern pedestrian facilities such as sidewalks, crosswalks, shared use paths, and on-street parking. TEA recommends that DoW installations follow 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 Americans with Disabilities Act "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 Federal Highway Administration (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 contrast 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, provide a landing area at least 4-foot by 4-foot intended for wheelchair mobility. The maximum cross-slope of this landing area should be no greater than two percent.

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.



Pedestrian Features at Signalized Intersections

The above image illustrates how several accessibility requirements described previously are applied in a typical intersection. The intersection includes key accessibility features such as pedestrian signal heads, accessible pedestrian push buttons adjacent to a level landing area, a detectable warning surface at the curb ramp, and high-visibility crosswalk markings. These elements reflect the technical requirements for pedestrian facilities in the public right-of-way as established in PROWAG.

Although this image highlights common intersection features, pedestrian facilities include a broader range of accessibility elements—such as blended-transition curb ramps, accessible on-street parking, mid-block crossings, refuge islands, and shared-use paths—that may not be visible in this single example. PROWAG provides detailed guidance and illustrations for these and other pedestrian accessibility features.

13.1.3. PROWAG Design Elements

PROWAG establishes accessibility requirements for pedestrian facilities within the public right-of-way. The following table summarizes the major design elements addressed in PROWAG and provides a brief description of the type of guidance included. This section offers only a high-level overview; designers must refer directly to PROWAG for detailed technical requirements, measurements, and compliance criteria.

Exhibit 13.2: PROWAG Accessibility Requirements

DESIGN ELEMENT	PROWAG CONSIDERATIONS
Sidewalks & Walkways	Addresses surface firmness, stability, slip resistance, width considerations, cross-slope and grade limitations, and the need for a continuous accessible route separated from vehicular traffic
Crosswalks	Provides guidance on alignment, width, slope characteristics, marking visibility, and requirements for crossings at signalized, stop-controlled, and uncontrolled locations to ensure safe pedestrian movement.
Curb Ramps	Covers general ramp configurations, transitions between sidewalk and roadway, placement relative to crosswalks, and the use of detectable warning surfaces to alert visually impaired pedestrians.
Ramps & Landings	Outlines expectations for accessible ramp connections, including appropriate slopes, landing areas for maneuvering, and smooth transitions between walking surfaces.
Pedestrian Signals & Push Buttons	Establishes requirements for accessible pedestrian signals (APS), including placement, reach ranges, audible and vibrotactile features, and integration with pedestrian waiting areas.
Pedestrian-Activated Warning Devices	Provides general considerations for devices such as RRFBs and PHBs, including accessibility of activation points and integration with pedestrian routes.
On-Street Parking	Addresses the number, location, and layout of accessible parking spaces, including access aisles and connections to adjacent pedestrian routes.
Transit Stops & Shelters	Covers accessible boarding areas, clear spaces for mobility devices, and accessible paths connecting transit stops to sidewalks and other pedestrian facilities.
Temporary Pedestrian Routes	Establishes expectations for maintaining accessible routes during construction or maintenance activities, including continuity, surface conditions, and safe detours.

Detailed standards and illustrations are available from the U.S. Access Board (https://www.access-board.gov/prowag)

Additional elements such as pedestrian railroad crossings, roundabouts, overpasses/underpasses, and passenger loading zones are also addressed in PROWAG. Designers should consult the full guidelines for complete requirements.

13.1.4. 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: https://highways.dot.gov/safety/pedestrianbicyclist/safety-tools/lesson-3-designing-pedestrian-safety.

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.

13.2. PEDESTRIAN-VEHICLE RIGHT-OF-WAY

KEY POINT

At crosswalks, 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 Ordinance 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? At marked 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

13.3. CROSSWALKS

What is a crosswalk?

The formal definition of a crosswalk appears below. Summarized, a crosswalk basically is the connection of two sidewalks or designated pedestrian crossing across a roadway.

Crosswalks serve the purpose of collecting pedestrians into one location, and they encourage platoons of pedestrian crossings at that location.

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.

> 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.

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 (https://www.fhwa.dot.gov/publications/research/safety/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.

13.3.1. Crosswalks at Midblock Locations and on Uncontrolled Approaches to Intersections

Crosswalk lines 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, pamphlet Exhibit 13.3 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 pamphlet Exhibit 13.3 are for guidance purposes and should be applied with engineering judgment. Crosswalks at uncontrolled midblock locations must be marked. 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 13.3 for the given vehicle volume and roadway configuration to determine the number of the applicable **TEA-developed** drawing. All drawings (14 total) have been included in subsequent sections of this chapter based upon the recommended improvements.

Exhibit 13.3: 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 1-Hour Volume > 1,200											
	*2-Lanes Two-Way			3-Lanes Two-way			≥ 4-Lanes Divided With Raised Median			≥ 4-Lanes Undivided			2-Lanes Two-Way			3-Lanes Two-way			≥ 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																								
High-Visibility Crosswalk Marking	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Signing and Lighting																								
Pedestrian Crossing (W11-2) warning sign W/ Downward Diagonal Arrow (W16-7P) Plaque	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Yield Here To (Stop Here For) Pedestrians (R1-5, R1-5a, R1-5b, or R1-5c) signs with Yield (Stop) Line marking (Yield or Stop scenario is dictated by local state law)				X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X
An advance Pedestrian Crossing (W11-2) warning sign with Ahead (W16-9P) Plaque			✓			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lighting	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Midblock Drawing #	1	1	2	3	3	4	3	3	4	4	4	4	2	2	2	4	4	4	4	4	4	4	4	4
Uncontrolled Approach to Intersection Drawing #	5	5	6	7	7	8	7	7	8	8	8	8	6	6	6	8	8	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 **OR** Pedestrian Hybrid Beacons **OR** Pedestrian Overpass			✓			✓			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
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

* If the crossing is at an intersection that has a dedicated left and/or right turn lane, it is considered a multi-lane section and should follow drawing 7 or 8.

** The letters (C,P, or N) describe the baseline minimum enhancements for midblock crosswalks according to FHWA publication number HRT-04-100. TEA'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 thelocation 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 2023 National *MUTCD*
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)

13.4. MARKING CROSSWALKS

Crosswalks (at midblock locations and on uncontrolled approaches to intersections) that meet the installation criteria given in Section 13.1 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 13.3, 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.

13.5. SIGNING CROSSWALKS

Because pedestrian crossings on uncontrolled approaches 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 (W16-2)
- ✓ NEXT XX FEET (W16-4)

These plaques provide advance notice to road users of crossing activity. When used at mid-block crossings, warning signs shall be supplemented with a diagonal downward pointing arrow (W16-7) plaque showing the location of the crossing. Designated school crossings are signed in a similar fashion, but require a specific type of sign.



Typical pedestrian crossing signs with downward pointing arrow plaque

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 TEA-developed Signing and Striping Layouts (i.e., non-signalized) that correspond to Drawings #1–#8, as recommended enhancements given in Exhibit 13.3.

Exhibit 13.4: CROSSWALK SIGNING FOR NORMAL AND SCHOOL ACTIVITY

SIGNING AND STRIPING LAYOUTS (NON-SIGNALIZED)

GENERAL NOTES (APPLICABLE TO DRAWINGS 1-8):

1) ALL REFERENCES ARE TO THE 2023 NATIONAL MUTCD, UNLESS OTHERWISE NOTED.

2) STOP AND YIELD LINES SHALL BE IN ACCORDANCE WITH SECTION 3B.19

3) CROSSWALK MARKINGS SHALL BE IN ACCORDANCE WITH CHAPTER 3C

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.19)

6) UNLESS OTHERWISE NOTED, INTERSECTION PARKING RESTRICTIONS SHALL BE IN ACCORDANCE WITH SECTION 3B.27

7) 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.13 AND 2A.16

SIGN SPACING DISTANCE
TABLE 2C-3

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)

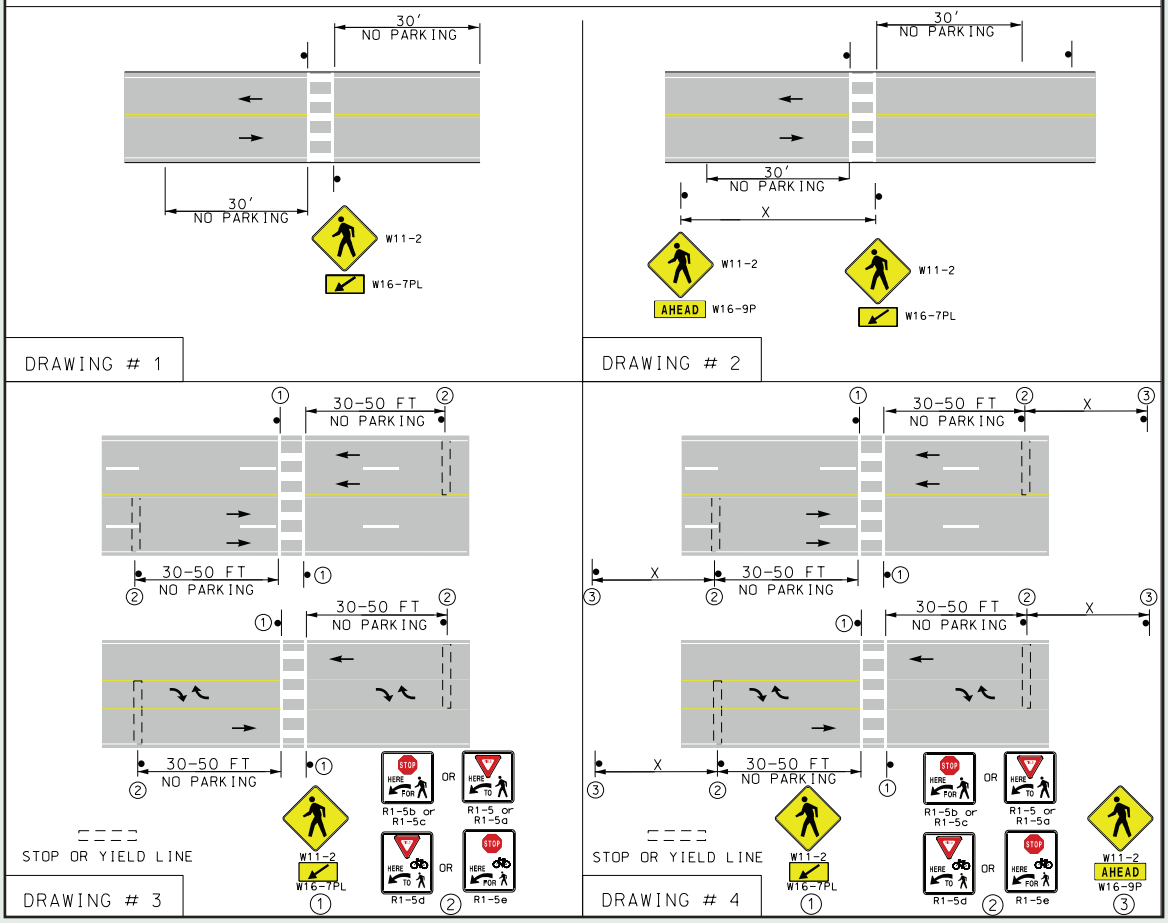
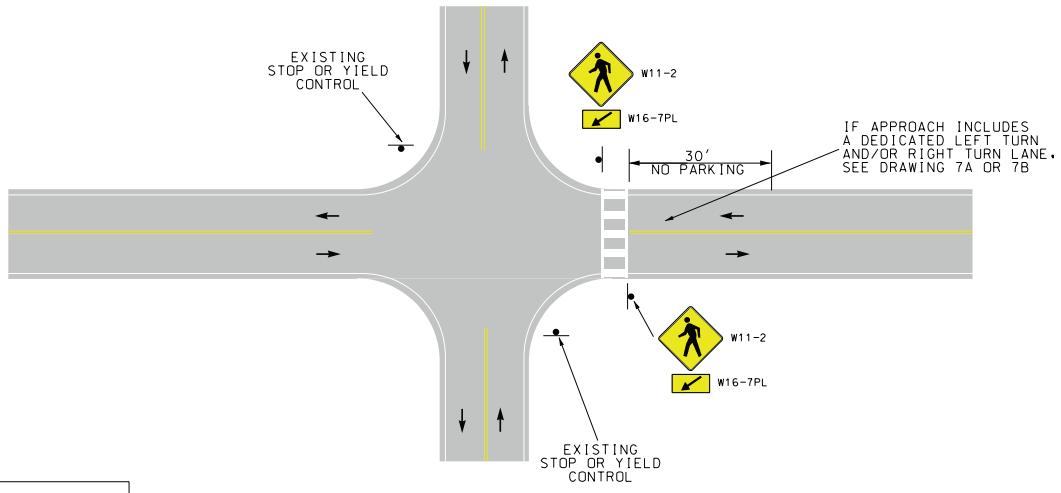


Exhibit 13.4: CROSSWALK SIGNING FOR NORMAL AND SCHOOL ACTIVITY (continued)

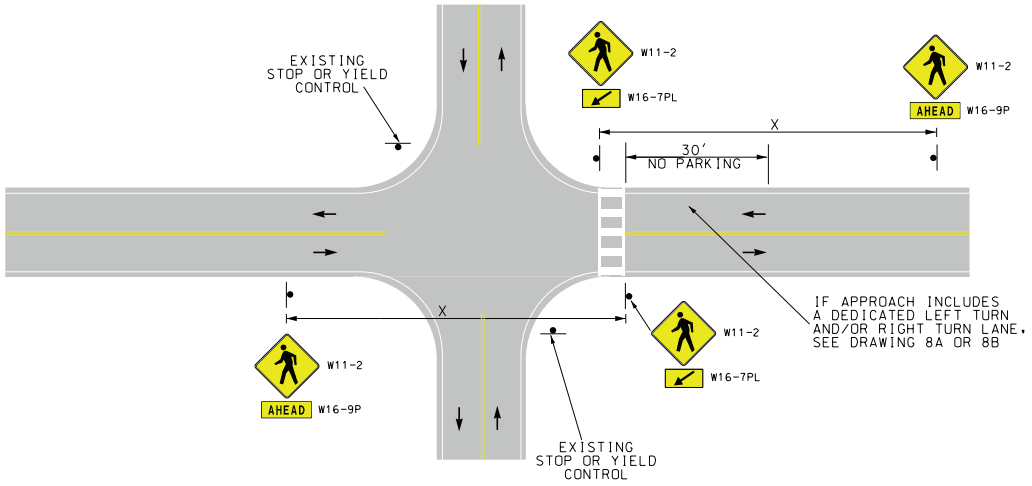
SIGNING AND STRIPING LAYOUTS
(UNCONTROLLED APPROACHES TO INTERSECTIONS)

PEDESTRIAN CROSSING LAYOUT



DRAWING # 5

PEDESTRIAN AHEAD CROSSING LAYOUT

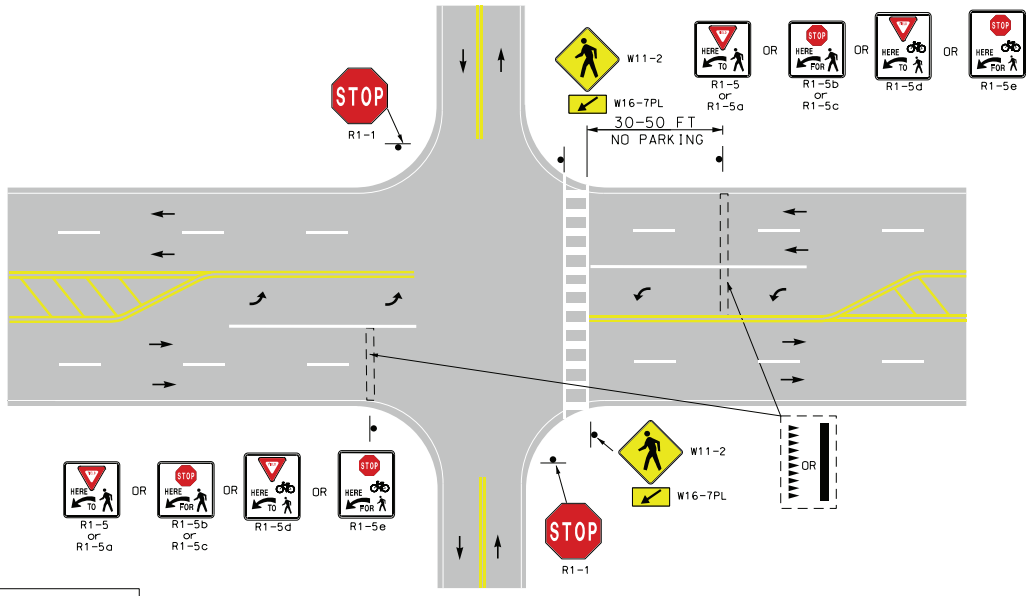


DRAWING # 6

Exhibit 13.4: CROSSWALK SIGNING FOR NORMAL AND SCHOOL ACTIVITY (continued)

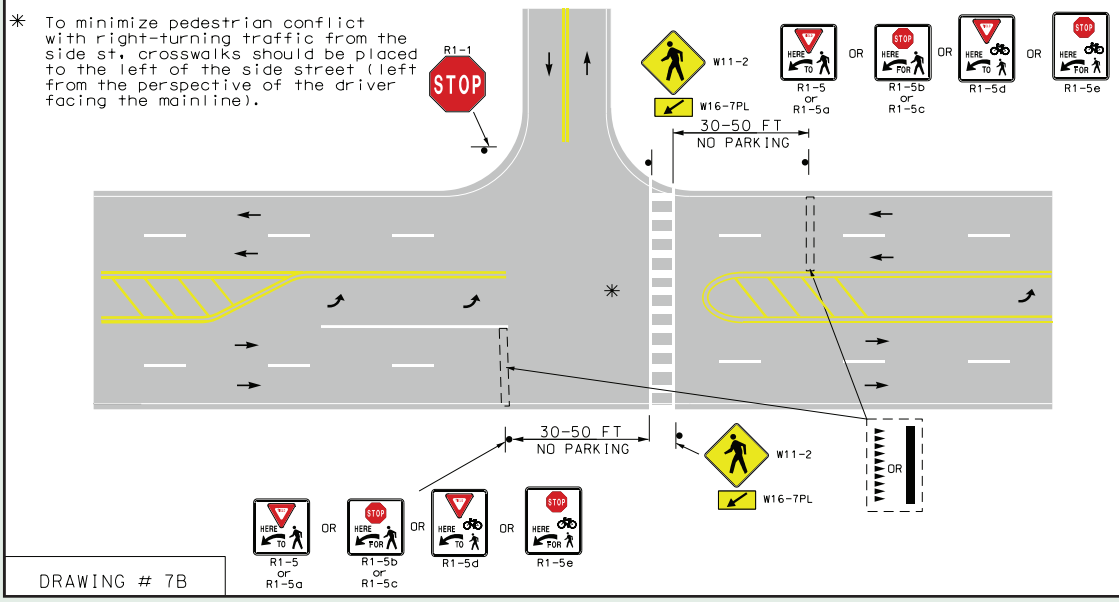
SIGNING AND STRIPING LAYOUTS
(UNCONTROLLED APPROACHES TO INTERSECTIONS)

YIELD TO (STOP FOR) PEDESTRIANS CROSSING LAYOUT



DRAWING # 7A

YIELD TO (STOP FOR) PEDESTRIANS CROSSING LAYOUT

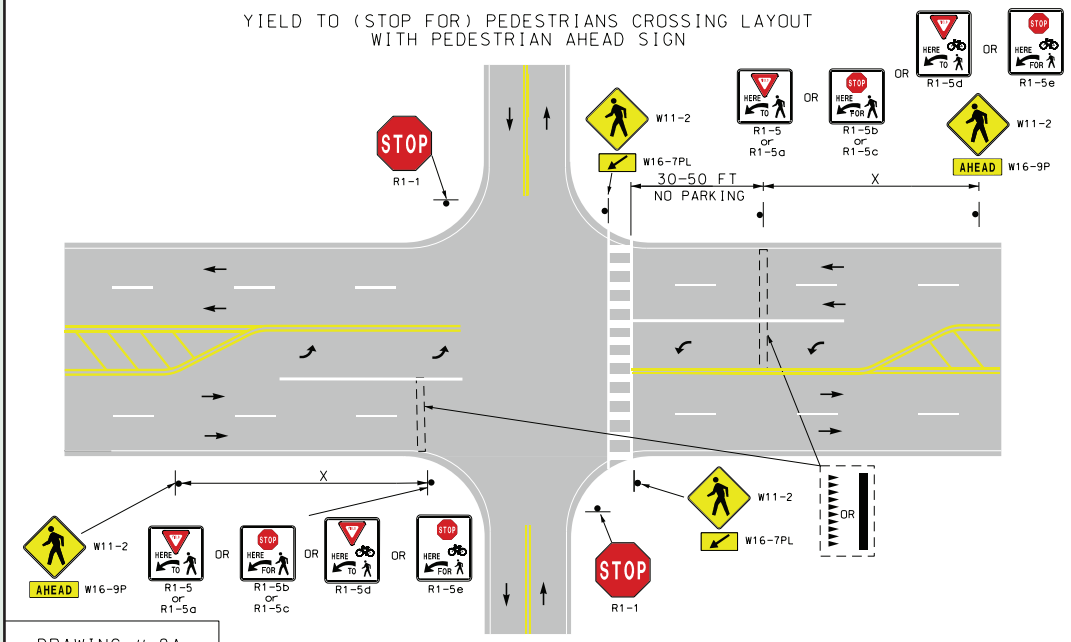


DRAWING # 7B

Exhibit 13.4: CROSSWALK SIGNING FOR NORMAL AND SCHOOL ACTIVITY (continued)

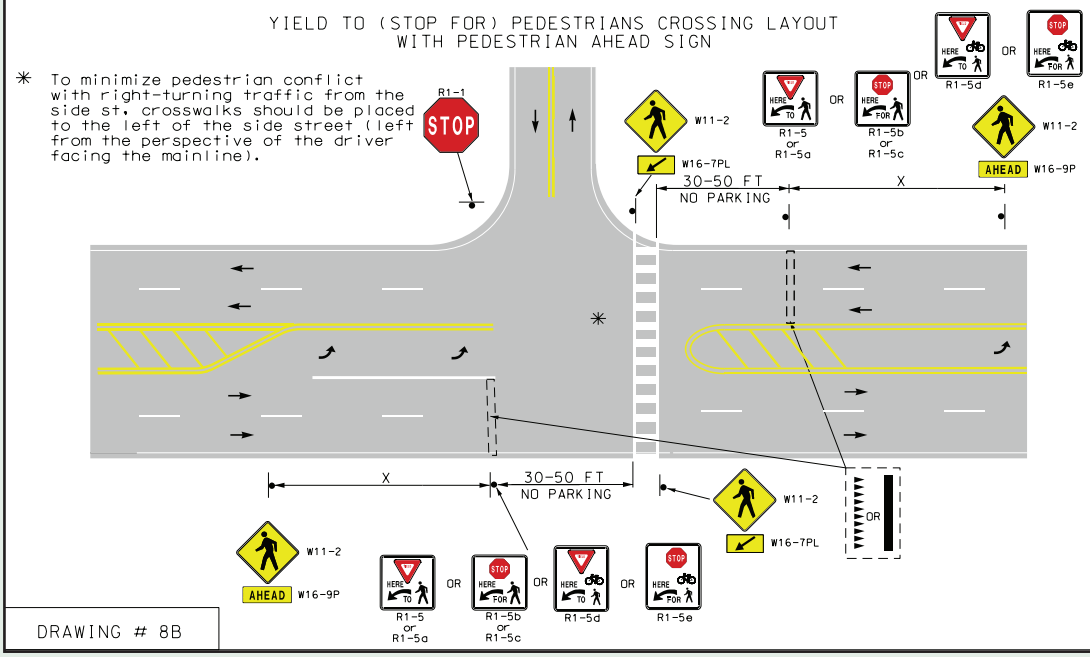
SIGNING AND STRIPING LAYOUTS
(UNCONTROLLED APPROACHES TO INTERSECTIONS)

YIELD TO (STOP FOR) PEDESTRIANS CROSSING LAYOUT
WITH PEDESTRIAN AHEAD SIGN



DRAWING # 8A

YIELD TO (STOP FOR) PEDESTRIANS CROSSING LAYOUT
WITH PEDESTRIAN AHEAD SIGN



DRAWING # 8B

13.6. USE OF TRAFFIC SIGNALS FOR PEDESTRIAN ACCOMMODATIONS



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 signalized locations 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 signalized locations; or
4. Where engineering judgment determines that multi-phase signal indications 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, titled "Guidelines for Enhancements of Crosswalks at Midblock Locations and Uncontrolled Approaches to Intersections," to assess whether a pedestrian signal is a suitable treatment for your crossing location. Ensure that the *MUTCD* warrants are met before considering this option.

13.6.1. 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 4J.02 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.

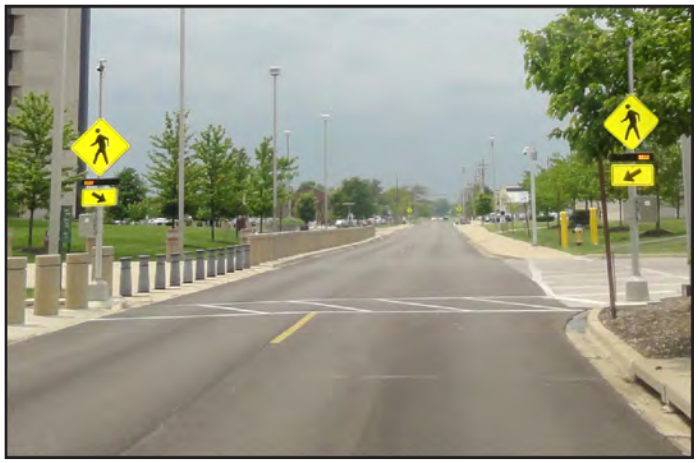
Where signal warrants are not met, or where signal warrants are met but the decision is made to not install a traffic signal, pedestrian hybrid beacons can be installed to facilitate pedestrian crossings. Per the *MUTCD*, a pedestrian hybrid beacon shall only be installed at a marked crosswalk. Minimum 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 4J.02 of the *MUTCD*.

13.6.2. Additional Crosswalk Enhancements

A variety of supplemental treatments can improve pedestrian visibility, reduce vehicle speeds, and increase driver yielding at crosswalks. The following subsections summarize commonly used enhancements. Designers should apply engineering judgment and refer to the *MUTCD* and state DOT guidance for specific requirements.

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.



Rectangular Rapid Flash Beacons

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 (RRFBs) enhance pedestrian safety by increasing driver awareness at unsignalized intersections and mid-block crossings, helping reduce vehicle-pedestrian crashes. RRFBs use yellow, user-actuated amber LEDs that supplement pedestrian and school crossing signs. They flash in an irregular pattern similar to emergency vehicle lights, improving conspicuity and driver response.

RRFBs were previously authorized under Interim Approval IA-11, which was terminated in 2017 due to patent concerns. However, following resolution of those issues, RRFBs were reinstated under IA-21 and are now officially included in the 11th Edition of the *MUTCD*. Their use is permitted at uncontrolled marked crosswalks and is governed by Chapter 4L of the *MUTCD*.

RRFBs may be activated manually via push button or passively through pedestrian detection systems. They are suitable for both two-lane and multi-lane roadways and are especially effective at crossings with speed limits under 40 mph. Studies show RRFBs significantly increase driver yielding behavior when used with standard pedestrian warning signs and pavement markings.

When installed, RRFBs should be placed between the W11-2 pedestrian warning sign and the W16-7P diagonal downward-pointing arrow placard. The sign assembly must be mounted at standard height. Note that RRFBs do not refer to flashing LEDs embedded in the border of a sign.

RRFBs remain a lower-cost alternative to traffic signals and pedestrian hybrid beacons, and their inclusion in the *MUTCD* ensures broader adoption and consistent application across jurisdictions.

Overhead Warning Beacons with Pedestrian Crossing Signs

Overhead beacons elevate the visibility of pedestrians by placing flashing indications directly in the driver's line of sight above the roadway. This is especially effective on wide roads or locations where pedestrians may be difficult to see from a distance. The overhead placement ensures pedestrians are highlighted well before a vehicle reaches the crossing.

Sign Illumination

Illuminated pedestrian signs increase the visibility of crossing locations during low-light conditions. By lighting the sign face or using internally illuminated signs, pedestrians become more noticeable at night or in areas with limited ambient lighting, reducing the likelihood that they blend into the background.

Rumble Stripes

Rumble stripes provide an auditory and tactile cue that alerts drivers to the presence of a pedestrian crossing ahead. While the treatment affects drivers, the safety benefit is for pedestrians, rumble stripes help ensure that pedestrians are recognized earlier, reducing the chance of a missed or late detection.

Raised Crosswalks

Raised crosswalks elevate pedestrians to a more prominent position, making them easier to see. The vertical deflection also slows vehicles, giving pedestrians more time to be noticed and reducing the severity of potential conflicts. The raised surface visually reinforces that pedestrians have priority.

Median Refuge Islands

Median refuge islands increase pedestrian safety by allowing pedestrians to cross one direction of traffic at a time. They also improve visibility by positioning pedestrians in a protected, central location where they are more easily seen by approaching vehicles from both directions.

Curb Extensions (Bulb-Outs)

Curb extensions move pedestrians closer to the travel lane, reducing the distance they must cross and improving their visibility around parked vehicles or roadside obstructions. By narrowing the roadway at the crossing, pedestrians become more prominent to approaching traffic.

Roadway Narrowing

Narrower roadway sections shorten crossing distances and make pedestrians more visible by reducing the width of the vehicle approach zone. This creates a more compact crossing environment where pedestrians stand out more clearly.

Pedestrian Crossing Flags

Crossing flags increase pedestrian visibility by providing a bright, highly noticeable object that pedestrians carry while crossing. This simple enhancement draws attention to the pedestrian's presence, especially at uncontrolled crossings.

Crosswalk Lighting

Crosswalk lighting is essential for ensuring pedestrians remain visible during nighttime or low-light conditions. Proper lighting highlights the pedestrian's body, movement, and crossing path, reducing the likelihood that they blend into shadows or roadside backgrounds. Well-designed lighting improves the pedestrian's visibility from a greater distance, giving approaching traffic more time to recognize and respond.

Sight Lines and Advance Stop/Yield Lines

Clear sight lines ensure pedestrians can be seen from an appropriate distance before a vehicle reaches the crossing. The 2023 *MUTCD* recommends placing yield or stop lines 20–50 feet in advance of an uncontrolled multilane crosswalk. FHWA guidance recommends 30–50 feet, and TEA typically uses 30–50 feet for design. At signalized mid-block crossings, approximately 40 feet is recommended.

Placing stop/yield lines within this range ensures pedestrians are visible in the crosswalk and reduces the risk of multiple-threat crashes. If lines are placed too far upstream, drivers tend to ignore them and stop closer to the crosswalk, reducing the visibility pedestrians rely on.

13.6.3. Effectiveness of Pedestrian Crossing Countermeasures

To support the selection of crosswalk enhancements, published research provides quantitative estimates of safety effectiveness for various treatments. These values are typically expressed as Crash Reduction Factors (CRFs) and Crash Modification Factors (CMFs) derived from empirical studies.

Exhibit 13.5 summarizes typical CRFs and CMFs for commonly applied pedestrian crossing countermeasures. These values should be used as general guidance and supplemented with engineering judgment and site-specific considerations.

Exhibit 13.6: Pedestrian Countermeasures CRFs and CMFs

COUNTERMEASURE	CRF	CMF	BASIS	REFERENCE
Crosswalk Visibility Enhancement*	–	–	–	–
Advance STOP/YIELD signs and markings	25%	0.75	Pedestrian crashes**	Zeeger, et. al., 2017
Add overhead lighting	23%	0.77	Total injury crashes	Harkey, et. al., 2008
High-visibility marking***	48%	0.52	Pedestrian crashes	Chen, et. al., 2012
High-visibility markings (school zone)***	37%	0.63	Pedestrian crashes	Feldman, et. al., 2010
Parking restriction on crosswalk approach	30%	0.70	Pedestrian crashes	Gan, et. al., 2005
In-street Pedestrian Crossing sign	UNK	UNK	N/A	N/A
Curb extension	UNK	UNK	N/A	N/A
Raised crosswalk (speed tables)	45%	0.55	Pedestrian crashes	Elvik, et. al., 2004
	30%	0.70	Vehicle crashes	
Pedestrian refuge island	32%	0.68	Pedestrian crashes	Zeeger, et. al., 2017
PHB	55%	0.45	Pedestrian crashes	Zeeger, et. al., 2017
Road Diet - Urban area	19%	0.81	Total crashes	Pawlovich, et. al., 2006
Road Diet - Suburban area	47%	0.53	Total crashes	Persaud, et. al., 2010

**This category of countermeasure includes treatments which may improve the visibility between the motorist and the crossing pedestrian.*

***Refers to pedestrian street crossing crashes, and does not include pedestrians walking along the road crashes or "unusual" crash types.*

****The effects of high-visibility pavement markings (e.g., ladder, continental crosswalk markings) in the "after" period are compared to pedestrian crashes with parallel line markings in the "before" period.*

Source: Crash Modification Factors Clearinghouse: http:www.cmfclearinghouse.org

CHAPTER 14 – TEMPORARY TRAFFIC CONTROL

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CHAPTER 14 – TEMPORARY TRAFFIC CONTROL

Temporary Traffic Control (TTC) refers to the traffic management measures used in construction work zones, ECF lane closures, roadway incidents, utility work, maintenance activities, and other scenarios requiring the 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 devices.



Work zone with lack of 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 Temporary Traffic Control (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 temporary traffic control plans, be sure to refer to your local and state temporary traffic control standards. There may be state-specific laws related to speed limits, cell phone use in work zones, and special work zone signing.

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 geometry 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, TTC 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 public relations 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

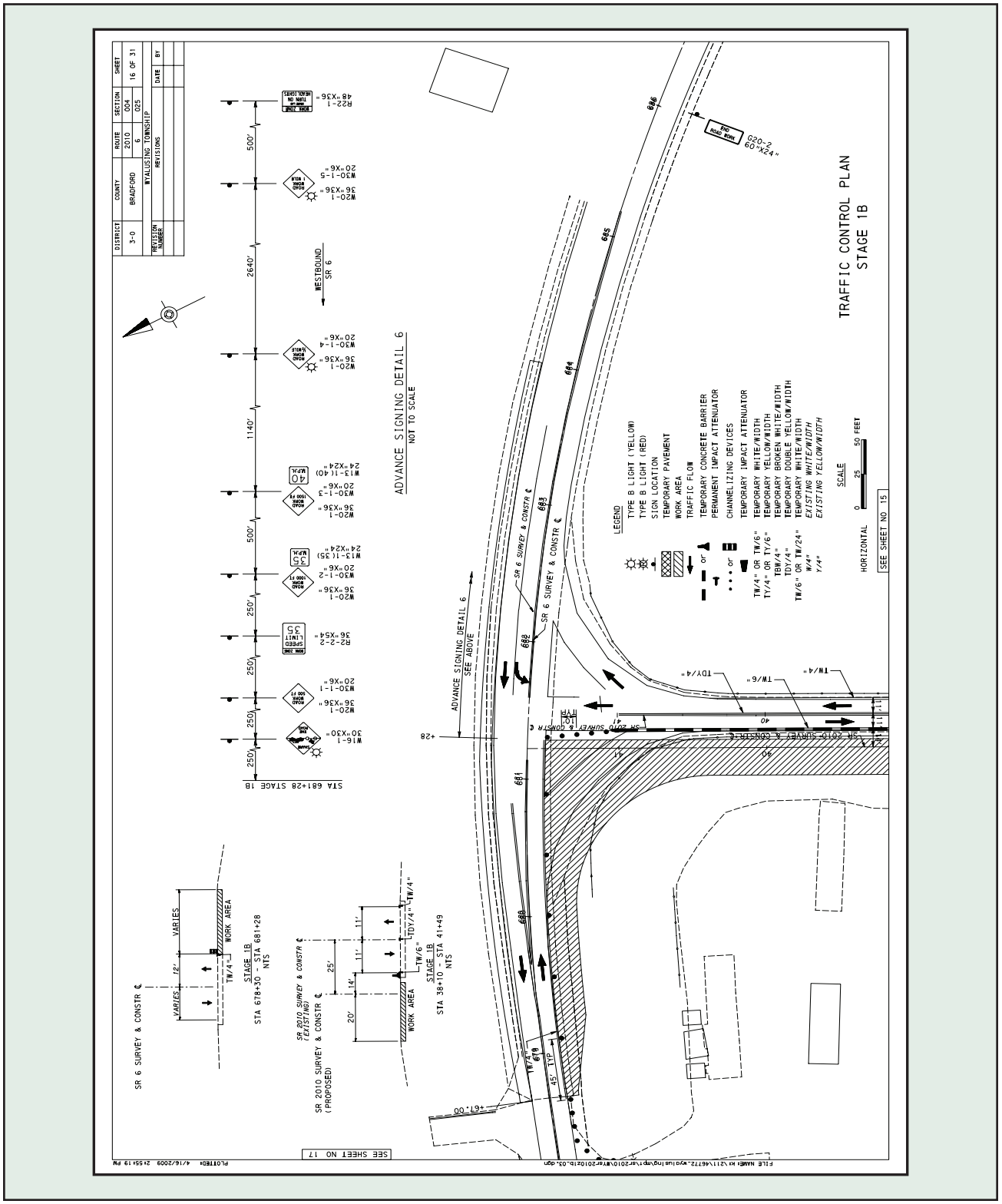
Temporary Traffic Control Plans (TTCPs) should describe the TTC measures that are to be used for safely facilitating roadway users through a work zone or incident area.

TTCPs should be developed by an experienced individual, and should follow design criteria set forth by the *MUTCD*. TTCPs can be developed in multiple types of formats, including:

- Written in a TTCP project specification
- Referencing by citation to other policies or documents
- Displayed graphically on the construction project plans
- Developing a standalone TTCP including graphics and written narrative.

An example of a TTCP is shown as Exhibit 14.2.

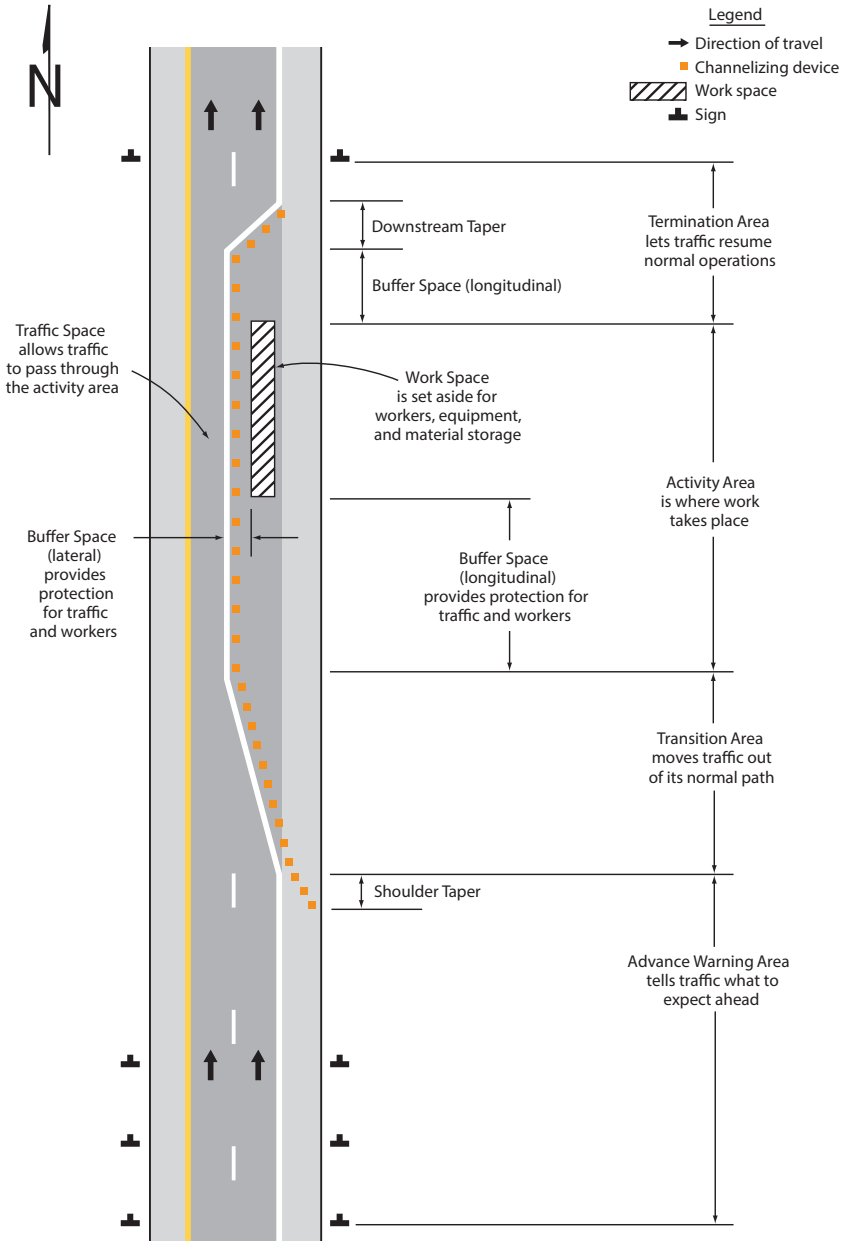
Exhibit 14.2: Example Temporary Traffic Control Plan



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: Component Parts of a Temporary Traffic Control Zone



Source: MUTCD Figure 6B-1

14.4.1. Advance Warning Area

The advance warning area is the section of roadway located ahead of a construction zone or unplanned incident area, where drivers are notified of upcoming changes to road conditions. Providing advance warning is essential for ensuring safety and smooth traffic flow.

Typically, this is achieved through the use of advance signage, but for short-term work zones, it may also include a vehicle equipped with warning beacons. As motorists approach a work zone, several steps are taken to convey critical information:

1. Initial Notification: The first step is to alert drivers to the changing conditions ahead, often through a "ROAD WORK AHEAD" sign.
2. Traffic Flow Changes: The second step informs drivers of specific changes to traffic flow, such as "LANE CLOSED AHEAD" or "DETOUR AHEAD" signs.
3. Immediate Instructions: The final step provides instructions for the immediate situation, such as "Merge Left" or "STOP HERE ON RED" signs.

Exhibit 14.8 outlines the recommended spacing for these signs to ensure effective communication with roadway users.

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 6B.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 6B and *MUTCD* Table 6B-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 the section of the roadway where the work activity or incident is taking place. It consists of three key components: the work space, traffic space, and buffer space (refer to Exhibit 14.3). This area often involves direct interaction between motorized and nonmotorized traffic, workers, and equipment, which can present significant safety risks.

To mitigate these risks, it is crucial to provide adequate lateral and/or longitudinal buffer space to separate road user flow from the work space or any unsafe areas. The length of the longitudinal buffer space can be determined using the required stopping sight distance for the roadway, as outlined in Exhibit 14.4. The width of the lateral buffer space should be established based on engineering judgment to ensure sufficient separation and safety.

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.	

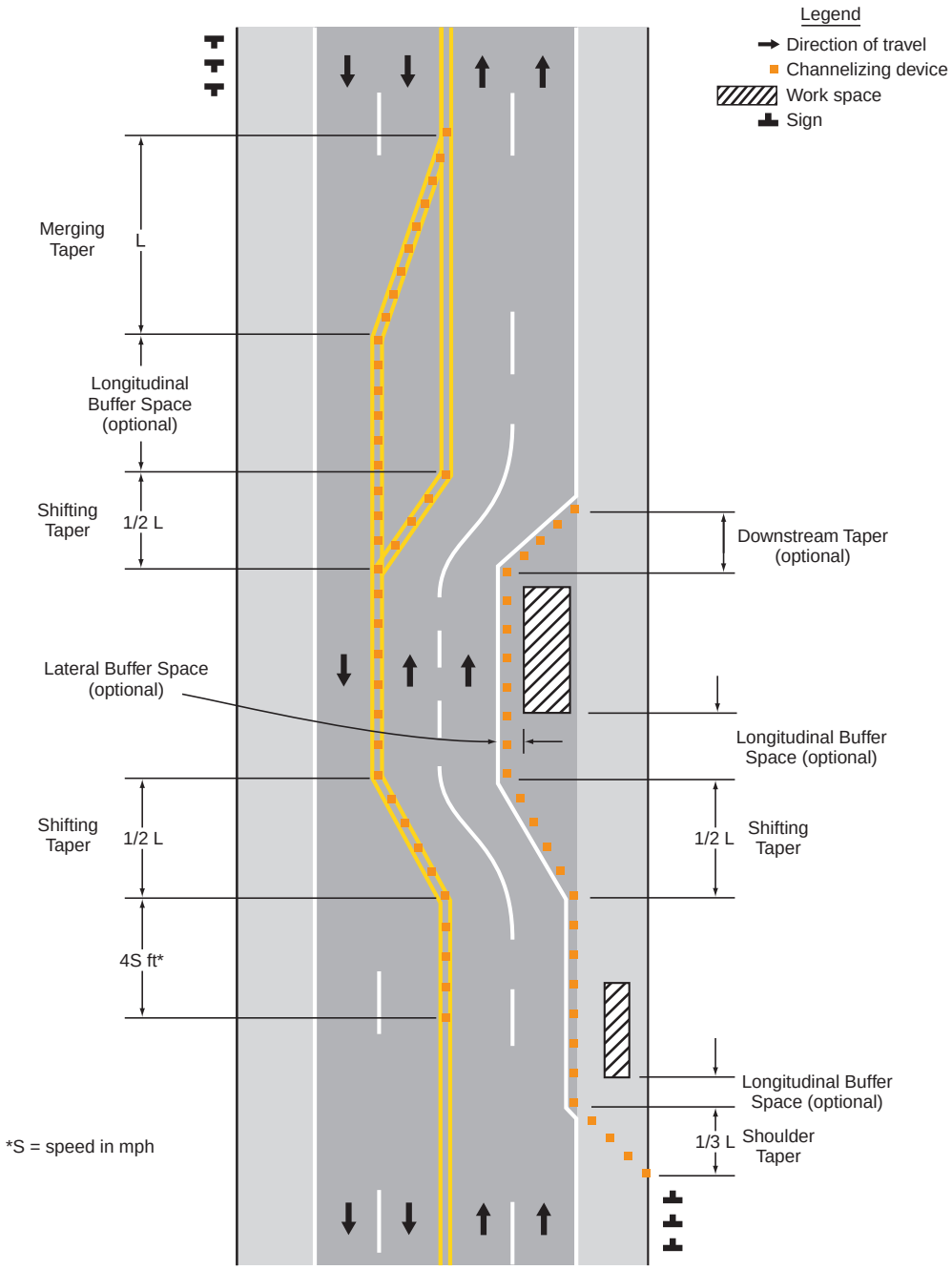
Source: MUTCD Table 6B-2

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 6B-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	$L = \frac{WS}{60}$
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 6B-3, 6B-4

14.6. TYPICAL TTC APPLICATIONS

Every TTC zone is unique. The needs can vary 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 activities that occupy a location for more than three days, including nighttime hours, require the use of retroreflective and/or illuminated devices to ensure visibility and safety. Necessary traffic control measures may include temporary pavement markings, temporary signals, signed detour routes, or traffic diversions.

Intermediate-term stationary – Construction activities that occupy a location for one to three days, or nighttime work lasting longer than one hour, typically involve maintenance or utility operations.

Short-term stationary – Construction or incidents that occupy a location for one hour to one day, limited to daylight hours, are typically short-term activities requiring minimal traffic control measures.

Short duration – Construction or incidents that occupy a location for up to one hour should utilize vehicles equipped with appropriate signage and lighting, along with easily deployable channelizing devices. These measures can be implemented in lieu of signs or temporary pavement markings, which require more time to install and remove.

Mobile – Work that involves continuous movement, such as pothole patching, roadway cleaning, or certain utility operations, requires mobile traffic control measures. Traffic control devices suitable for mobile operations include flaggers and shadow vehicles equipped with appropriate signage and high-visibility devices, such as 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 advance warning signs and should be illuminated at night.

14.6.3. Work Location

TTC applications vary based on roadway type, traffic volumes, operating speeds, work duration, roadway geometry, and the nature of the work activity. The *MUTCD* provides detailed guidance and typical applications for a wide range of TTC scenarios. Because site-specific conditions can significantly affect the selection and design of TTC measures, users should refer to Part 6 of the *MUTCD* for complete application details, device requirements, sign spacing, taper lengths, and other design criteria.



W20-7 and W16-2P

Exhibit 14.7 provides a legend explaining the symbols used throughout the *MUTCD*, while Exhibit 14.8 illustrates the recommended distances between signs. It is important to note that these distances are minimum requirements.

Use Exhibits 14.5 and 14.6 to determine the length of the tapers.

Exhibit 14.7: Symbol Legend for Work Location Drawings

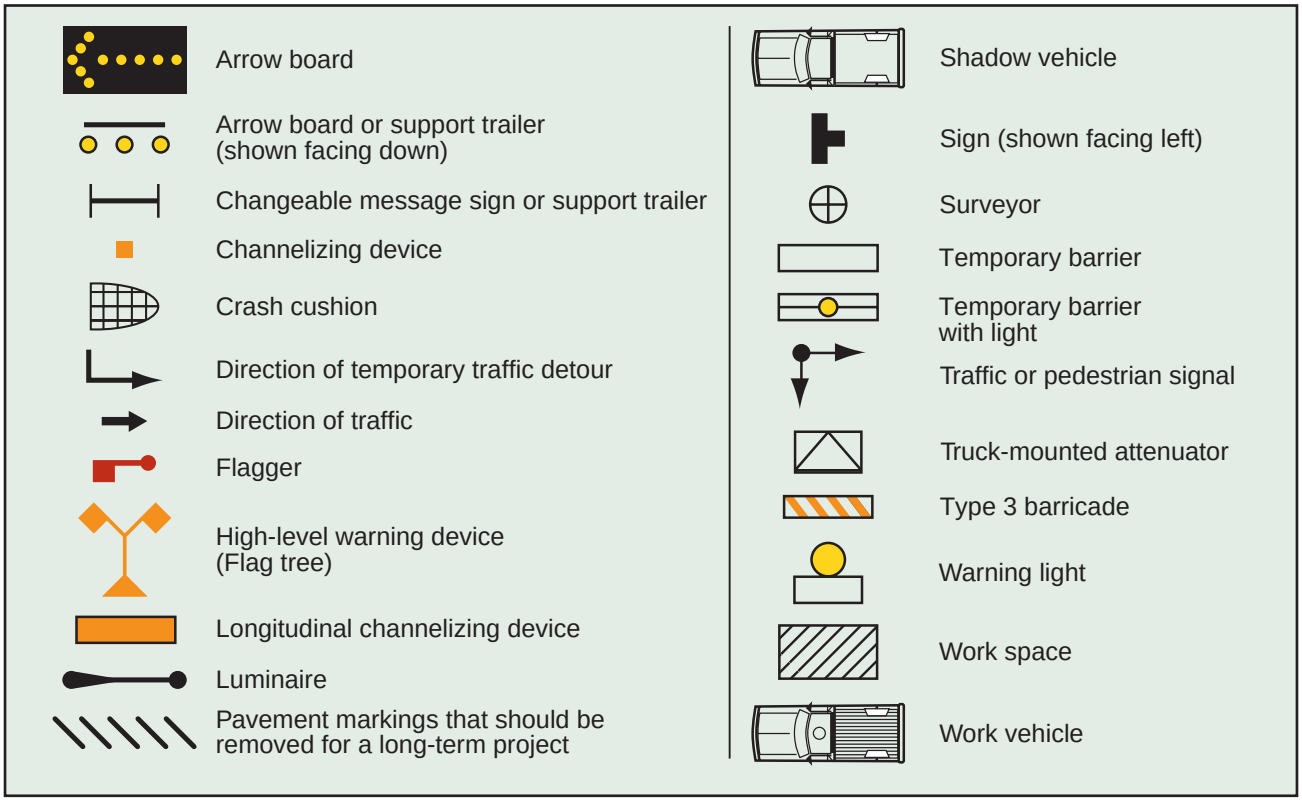


Exhibit 14.8: Recommended Advance Warning Sign Minimum Spacing (Reference for Letter Code Designations on Work Location Drawings)

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 6P-1 through 6P-54, 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 Table 6B-1

Common TTC applications frequently encountered on military installations are listed in Exhibit 14.9 for reference.

Exhibit 14.9: Common TTC Applications and *MUTCD* References

COMMON TTC APPLICATION	*MUTCD* REFERENCE
Work Beyond Shoulder	Chapter 6P, Figure 6P-1 (TA-1)
Work on Shoulder (No Encroachment)	Chapter 6P, Figure 6P-4 (TA-4)
Work on Shoulder (Minor Encroachment)	Chapter 6P, Figure 6P-6 (TA-6)
One-lane Closure on Two-Way Roadway	Chapter 6P, Figure 6P-10 (TA-10)
Low-Volume One-lane Closure	Chapter 6P, Figure 6P-11 (TA-11)
Work in Center of Road	Chapter 6P, Figure 6P-15 (TA-15)
Temporary Diversion	Chapter 6P, Figure 6P-7 (TA-7)
Temporary Road Closure	Chapter 6P, Figure 6P-13 (TA-13)
Detour Route	Chapter 6P, Figure 6P-8 (TA-8)
Interior Lane Closure on Multi-Lane Street	Chapter 6P, Figure 6P-30 (TA-30)

The references in Exhibit 14.9 are provided for convenience only and do not replace the requirements of Part 6 of the *MUTCD*. Designers shall consult the *MUTCD* and applicable state or local standards when developing Temporary Traffic Control Plans.

14.7. TTC DEVICES

The *MUTCD* defines traffic control devices as all signs, signals, markings, 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 the same standards as 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* Part 2.

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

14.8. CHANNELIZING DEVICES

KEY POINTS

Channelizing devices are typically used to close sections of roadway from travel.

Channelizing devices are used to guide traffic patterns and safely direct pedestrians. These devices include drums, tubular markers, vertical panels, cones, and Type I, II, or III barricades.

Traffic cones and markers are particularly effective for temporary traffic channelization, such as during lane reversals. Traffic cones and markers are lightweight, easy to place and remove, and designed to minimize damage to vehicles if struck. Their flexibility and portability make them ideal for short-term traffic control applications while maintaining safety and compliance with traffic guidelines.

The color, size, and placement of temporary traffic control devices must comply with the guidelines outlined in Part 6 of the *MUTCD*.

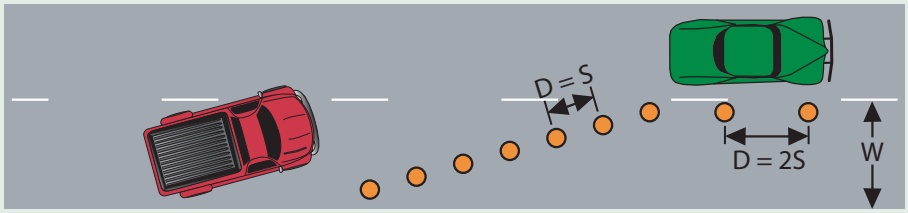
In transition areas, such as taper channelization, the spacing between cones in feet should not exceed the posted speed limit in miles per hour. For instance, if the posted speed limit is 25 mph, the maximum spacing between channelizers would be 25 feet. In other areas, such as tangent channelization adjacent to closed lanes, the channelizer spacing in feet may be up to twice the posted speed limit in miles per hour.

The use of channelizers 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 14.5 for additional information regarding the design of tapers in work zones.

Barricades (Type I, II, and III) are used to close roads, block lanes, or guide traffic and pedestrians around work areas. They should be equipped with retroreflective sheeting and lights when required, and placed to provide clear, consistent channelization in accordance with *MUTCD*.

The next page shows different channelizing devices.

LANE REDUCTION TAPER LENGTHS

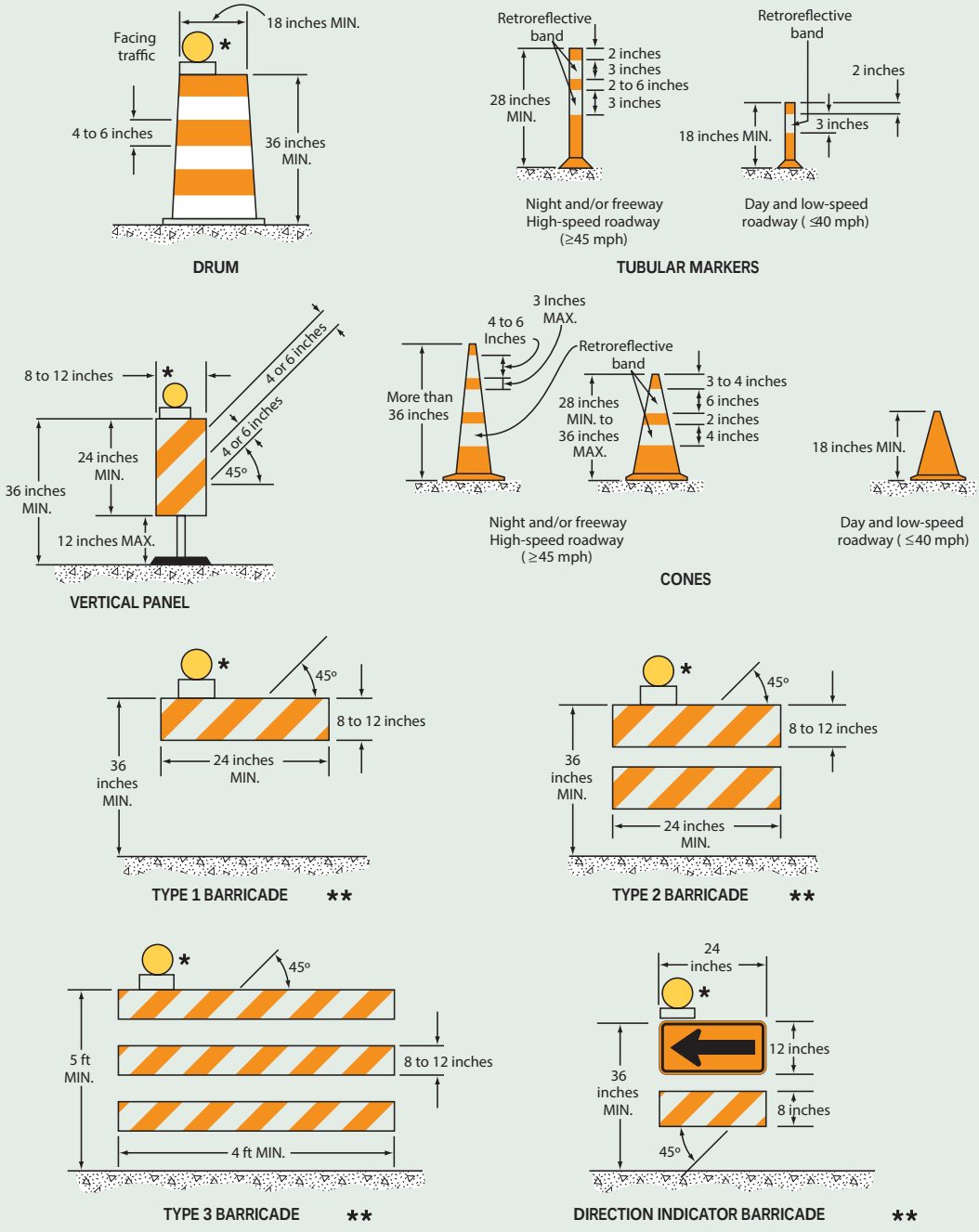


W = Width of Transition (feet)
S = Speed Limit (mph)
L = Length of Transition (feet)
D = Distance Between Channelizing Devices (feet)

$L = \frac{WS^2}{60}$ (For S≤40 mph)

L = WS (For S>40 mph)

TYPICAL CHANNELIZING DEVICES

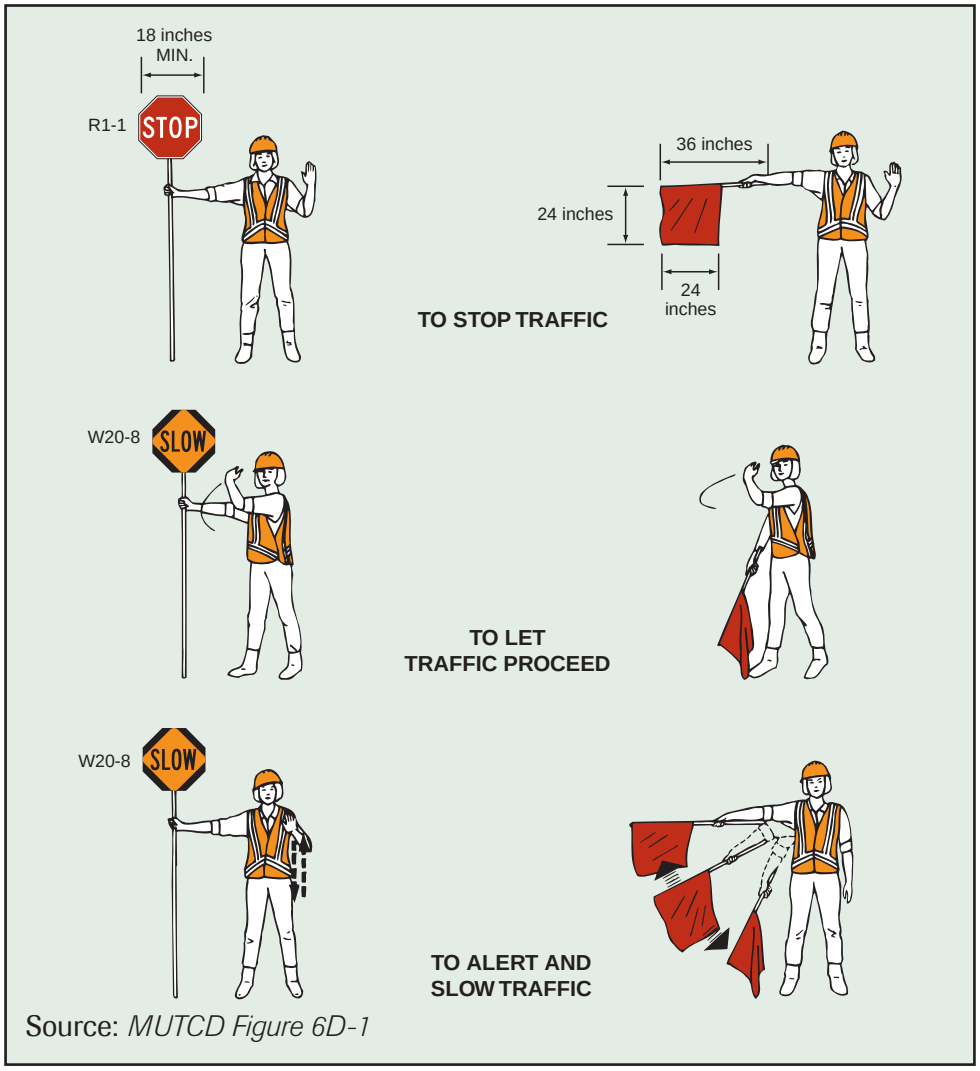


* Warning lights (optional)

** Rail stripe widths shall be 6 inches, except that 4-inch wide stripes may be used if rail lengths are less than 36 inches. The sides of barricades facing traffic shall have retroreflective rail faces.

Source: MUTCD Figure 6K-1

Exhibit 14.10: Flagger Hand Signals



Source: *MUTCD Figure 6D-1*

14.8.1. 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

14.9. WORKER SAFETY CONSIDERATIONS

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 safety elements shown in pamphlet Exhibit 14.11 should be implemented in order to improve worker safety.

Exhibit 14.11: Worker Safety Elements

TRAINING	All workers should be trained on how to safely work next to motorized traffic.
TEMPORARY TRAFFIC BARRIERS	Temporary traffic barriers should be placed along the work zone based on several factors, including the lateral clearance between workers and adjacent traffic, traffic speed and volume, the duration and type of operations, and the time of day.
SPEED REDUCTION	Reduced speed zoning should be avoided whenever feasible, as drivers tend to lower their speeds only when they clearly perceive a need to do so. If site constraints necessitate speed reduction for safety, refer to Part 6 of the *MUTCD* for guidance.
ACTIVITY AREA	Minimize exposure to risk by planning internal work area to minimize backing-up maneuvers of construction vehicles.
WORKER SAFETY PLANNING	A trained individual should conduct a basic hazard assessment of the worksite and the job classifications required within the activity area.
SAFETY APPAREL	All workers within the TTC zone shall wear high-visibility safety apparel that meets the appropriate classification for day and night work.
ROAD CLOSURE	If a detour route is available, temporarily closing the road can be considered to reduce worker vulnerability.
LIGHTING	For nighttime work, the TTC zone may be lighted.

All daytime and nighttime workers, including flaggers and emergency responders, within the right-of-way who are within the TTC zone shall wear high-visibility safety apparel that meets the latest ANSI/ISEA 107 Performance Class 2 or Class 3 requirements. A person designated by the employer to be responsible for worker safety shall select the appropriate class of garment.

High-visibility safety apparel shall use background and retroreflective colors consistent with *MUTCD* Section 6C.05.

- ✓ Class 2 apparel: Minimum requirement for workers within the highway right-of-way in typical TTC zones, generally appropriate for lower-speed or lower-volume roadways.
- ✓ Class 3 apparel: Provides the highest level of visibility and is recommended for high-risk environments such as high-speed roadways, congested areas, complex lane shifts, adverse weather, or complex work zones. Class 3 performance may be achieved through a Class 3 garment or by combining Class 2

apparel with high-visibility pants.

Exhibit 14.12: Safety Apparel Classes

CLASS 1	
CLASS 2	
CLASS 3	

ANSI Class 1 apparel is outdated and should not be used because it does not provide the same level of visibility due to its lower background and retroreflective material requirements.

ANSI Class 2 apparel is the minimum requirement for all workers within the highway right-of-way. It is typically used in environments with lower speeds, lower traffic volumes, and secondary roads.

ANSI Class 3 apparel provides the highest level of visibility and is recommended for high-risk environments, such as high-speed roadways, highly congested areas, complex lane shifts, adverse weather conditions, and

intricate work zones. Class 3 vests must include sleeves, but retroreflective pants can be worn alongside a Class 2 vest to meet Class 3 standards.

A fluorescent hard hat is also recommended for head gear for additional visibility. Hard hats are usually necessary in work zones.



Workers within an active work zone

14.10. FLAGGER CONSIDERATIONS

Flaggers play a critical role in ensuring public safety and face the highest exposure to vehicles compared to other roadway workers, making proper training and qualifications essential. Flaggers should be able to receive and communicate specific instructions clearly, maneuver quickly to avoid danger, effectively operate signaling devices, understand and implement safe traffic control practices, and identify hazardous traffic situations in time to warn workers and prevent injuries. Daytime and nighttime flaggers shall wear high-visibility safety apparel (meets ANSI/ISEA 107, Class 2 or 3 risk exposures).

14.11. PEDESTRIAN CONSIDERATIONS

KEY POINT

People working in traffic must always at a minimum wear an ANSI-approved reflective vest.

If pedestrian traffic is disrupted by a TTC zone, temporary pedestrian access and walkways must be provided, ensuring accessibility and detectability are maintained in the affected area. When planning for pedestrians in a TTC zone, the following factors should be considered:

- ✓ Pedestrians should be guided in a manner that avoids conflicts with vehicles, equipment, and operations, including vehicles navigating through or around the worksite.
- ✓ Pedestrians should be provided with a temporary pathway that is comparable to the existing conditions, including maintaining the width of the walkway.
- ✓ A smooth, continuous hard surface should be provided throughout the entire length of the temporary facility.
- ✓ Temporary pedestrian facilities must meet PROWAG requirements for accessibility.
- ✓ If pedestrians with disabilities are anticipated, route closures and alternate crossings should be communicated using devices such as signs, audible information systems, accessible pedestrian signals, barriers, and channelizing devices, all of which must comply with PROWAG requirements.
- ✓ If channelization is used to delineate a pathway, a continuous detectable edging should be provided for the disabled.
- ✓ Objects shall not overhang or protrude into any portion of a pedestrian access route or shared-use path within the required clear width, and vertical clearance shall be maintained to at least 8 feet above the surface.



Undesirable example of temporary pedestrian accommodations

CHAPTER 15 – SPEED LIMITS

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15.2. WHAT ARE STATUTORY SPEED LIMITS? 15-2

15.3. WHAT IS SPEED ZONING? 15-2

15.4. SPEED STUDIES 15-3

CHAPTER 15 – SPEED LIMITS

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



Speed limit sign example

Most motorists choose a speed that balances their desire to reach their destination quickly with the need to avoid endangering themselves and others. Drivers typically select their speed based on roadway and environmental conditions (such as roadway width and alignment, presence of intersections and driveways, roadside conditions, parked vehicles, pedestrian traffic, mix and density of vehicular traffic, weather), and not solely on posted limits. The posted speed limit is the numerical speed limit noted on regulatory signs placed along the roadway to which it applies. However, studies have shown that drivers often pay limited attention to posted speed limits, and that changing the speed limit - either raising or lowering it - has little effect on the speeds most drivers choose to travel. Regardless of posted limits, all states have "basic speed law" statutes requiring a driver to operate his or her vehicle at a speed that is reasonable and prudent for existing conditions.

Speed variance is a known factor in crash risk and severity. Variations in vehicle speeds increase the likelihood of crashes, and collisions tend to be more severe when there are larger differences in speed between vehicles. Ideally, all drivers would travel at a consistent speed appropriate for the location, minimizing risk. Posted speed limits are intended to encourage uniformity in driving speeds, minimizing these speed differences. Additionally, posted speed limits serve as a legal basis for addressing drivers who travel at excessive speeds and endanger others.

Traditionally, research has shown 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. The 85th-percentile speed has been a widely accepted engineering standard for setting speed limits. This method was historically used under the assumption that most drivers choose a safe and reasonable speed for conditions, and that setting speed limits at this level would maximize safety and compliance among drivers. The 85th-percentile speed has been used as a design guideline because it represents the speed at which most drivers feel comfortable under free-flow conditions. However, it does not necessarily account for the vulnerability of pedestrians. Recent research has raised concerns that the 85th-percentile speed may not always be the safest speed for environments with significant pedestrian exposure. Newer studies and safety organizations have found that the 85th percentile approach may not adequately protect vulnerable road users like pedestrians and cyclists, particularly in urban or mixed-use environments. Higher speed limits, even if they reflect driver behavior, can increase the risk and severity of crashes involving pedestrians.

Studies show that the risk of severe injury or death for pedestrians increases dramatically with vehicle speed. For example, a pedestrian struck at 40 mph has a much higher risk of fatality than one struck at 20 or 30 mph. As

a result, the FHWA now recommends a more holistic approach to setting speed limits, especially in areas with high pedestrian or bicycle activity. Context-sensitive speed setting is recommended, which considers land use, pedestrian activity, and crash history, rather than relying solely on the 85th percentile speed.

15.2. WHAT ARE STATUTORY SPEED LIMITS?



Consult your state's vehicle code to ensure that all posted speed limits align with your state code.

Statutory speed limits are speed limits established by law for specific types of roads or areas, rather than being set by individual engineering studies or posted signs. These limits are defined in state or local statutes and apply automatically, even if there are no speed limit signs present. Statutory speed limits serve as the default speed limits for certain road types or locations, such as residential streets, school zones, urban areas, or highways.

All states (except Hawaii) have at least one statutory speed limit. For example, a state may have statutory speed limits such as:

- ✓ 25 mph in residential or business districts
- ✓ 55 mph on rural highways
- ✓ 70 mph on interstate highways
- ✓ 20 mph in school zones (during certain hours)

Statutory speed limits are specific to each state as they are established by state and local vehicle codes. Although older, the *Summary of State Speed Laws* (Twelfth Edition) distributed by the U.S. DOT, National Highway Traffic Safety Administration (NHTSA) remains a valuable resource. It provides concise overviews of each state's regulations and includes the exact vehicle code and statute section numbers, which can otherwise be difficult to locate. Nonetheless, individual state vehicle codes should always be reviewed to verify the information retrieved.

15.3. WHAT IS SPEED ZONING?

Statutory speeds are enforceable by law, even if not posted with signs. As drivers are legally expected to know these default (statutory) limits, signs are only strictly required when the speed limit on a specific road differs from the state's statutory default. Road authorities generally have the power to revise (override) a statutory speed limit if it does not fit the road/traffic/land-use conditions. This is referred to as speed zoning and is done typically by performing a traffic engineering (speed) study that documents why the speed limit should be higher or lower than the statutory provisions, and also documents the safe maximum reasonable speed proposed to be posted.

Speed zoning is the process of establishing and posting speed limits on a roadway segment based on engineering studies and analysis of roadway, traffic, and environmental conditions. The goal of speed zoning is to set speed limits that are safe, reasonable, and appropriate for the specific characteristics of the road and its surroundings. Speed zoning helps promote uniform driving behaviors within each zone, thereby reducing speed differentials and enhancing overall road safety. Speed zoning results in the posting of regulatory speed limit signs, which are legally enforceable.

15.4. SPEED STUDIES



Use a spot speed study to determine the 85th-percentile speed.

Speed zoning typically involves a formal engineering study. The 85th percentile speed has traditionally been used as a guideline for setting speed limits, though recent practices may take into account the unique characteristics and needs of the surrounding environment and its users. With modern speed zoning, decisions are not made solely based on standard guidelines or traffic flow, but are tailored to the specific conditions and uses of the area. Criteria given in the 2023 *MUTCD* states, "Speed zones (other than statutory speed limits) shall only be established on the basis of an engineering study that has been performed in accordance with traffic engineering practices. The engineering study shall consider the roadway context."

Per the *MUTCD*, the following factors are to be considered in the engineering study:

- ✓ Roadway environment (such as roadside development, driveway density, ped/bike activity, public transit volume, parking practices)
- ✓ Roadway characteristics (such as lane widths, shoulder condition, grade, alignment, median type, sight distance)
- ✓ Geographic context (such as an urban district, rural town center, non-urbanized rural area, or suburban area)
- ✓ Speed distribution of free-flowing vehicles (including the 10-mph pace, 50th-%, and 85th-% speeds)
- ✓ Crash history (for at least a 12-month period)
- ✓ A review of past speed studies to identify any trends in operating speeds

The design and physical factors of the roadway place a definite limitation on the safe operating speed of vehicles so the engineering study must address these factors. In addition, the study must identify (and analyze) the prevailing vehicle speeds, crash rates, and review past speed studies. Nonetheless, per the *MUTCD*, "The engineering study will determine which factors will prevail in setting the speed limit."

The basis for setting a non-statutory speed limit focuses on the 85th percentile speed. To determine the vehicular speed distribution at a specific location, a spot speed study must be conducted. The most common technique for measuring vehicle speeds is the use of a radar speed gun. Alternatively, automated traffic recorders (ATRs) may be used to capture vehicle speeds. ATRs are typically installed temporarily or permanently in the roadway and can continuously record data over extended periods. This allows for larger sample sizes, less observer influence on driver behavior, and the ability to analyze variations in speed by time of day, day of week, or traffic conditions. While radar guns are useful for short-term spot studies, ATRs provide a broader dataset that can complement or validate radar-based measurements.

For the purpose of establishing regulatory speed limits, spot speed studies should be performed on straight, uninterrupted segments of roadway, away from intersections or areas where congestion may artificially reduce speeds. The study design should minimize any influence on driver behavior; for example, operators using radar guns should remain inconspicuous to passing motorists. Speed data should be collected under optimal weather, roadway, and traffic conditions, and in the absence of police vehicles or other factors that could affect typical driving speeds.

As a general guideline, spot speed studies should include a minimum sample of 100 free-flowing vehicles. In cases of low traffic volumes, the sample size may be reduced to approximately 50 vehicles or a two-hour observation period. When observing platoons of vehicles, only the speed of the lead vehicle should be recorded, as following vehicles are not considered free-flowing.

Data should be recorded on a standardized data sheet, such as the example provided in Exhibit 15.1. Recording the speeds of exactly 100 vehicles simplifies the determination of the 85th-percentile speed. For instance, in Exhibit 15.1, the 85th-percentile speed is between 35 and 36 mph, as 83 vehicles are traveling at or below 35 mph and 90 vehicles are traveling 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.*



Recent studies and guidance indicate that the 85th percentile speed is not always the safest for pedestrians, and speed limits should be set with consideration for all road users, especially in pedestrian-rich environments.

Using a context sensitive approach, the calculated 85th percentile speed is the starting point for the recommended posted speed limit prior to considering the *MUTCD*-recommended factors. While the 85th-percentile speed can be a useful parameter for road design, modern safety research suggests that when pedestrian safety is a priority, it is often advisable to consider lower speed limits than those indicated by the 85th-percentile. The determination of an appropriate speed limit should therefore balance the natural driving speeds with the need to protect vulnerable road users.

Refer to Chapter 7 for common speed-related signage, including standard speed limit signs, speed limit reduction signs, and advisory speed postings. Also, refer to TEA *Pamphlet 55-8* for more information on conducting and analyzing speed studies, as well as determining the advisory speed on horizontal curves.

CHAPTER 16 – TRAFFIC CALMING

16.1. TOP FIVE RECOMMENDED TRAFFIC CALMING DEVICES 16-1

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Traffic calming increases vehicle, bicyclist, and pedestrian safety by reducing vehicle speeds.

Traffic calming involves the implementation of physical measures designed to reduce speeding and high-volume cut-through traffic on neighborhood streets. Excessive speeds and cut-through traffic can create an environment where non-motorists, such as pedestrians and bicyclists, feel intimidated or endangered by motor vehicle activity. By mitigating high speeds and traffic volumes, traffic calming measures enhance both the actual and perceived safety of non-motorists while improving the overall quality of life within neighborhoods.

It is important to note that traffic calming measures are generally unsuitable for higher-speed, high-volume roadways such as arterial streets. However, they may be appropriate for the following roadway types:

- ✓ Local residential streets
- ✓ Collector streets with predominantly residential land uses
- ✓ Arterial roads located within downtown districts or commercial areas, provided the posted speed limit is 40 mph or less
- ✓ Main cantonment roads, provided the posted speed limit is 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, intersection sight distance, and crosswalk 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 which eliminate 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



Multi-way stop control shall never be used to reduce vehicle speeds.

A frequent request from the general public is to implement multi-way stop control as a method to reduce vehicle speeds. However, the *MUTCD* explicitly states that STOP signs should not be used for speed control purposes.

The decision to install multi-way stop control must be based on a comprehensive engineering study. This study should evaluate traffic conditions and determine if the location meets one or more of the specific warrants for multi-way stop installation as defined in the *MUTCD*. 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 pamphlet Chapter 6 for additional information pertaining to multi-way stop control.

16.3. VEHICLE SPEED FEEDBACK SIGNS

Vehicle Speed Feedback (W13-20) signs or (W13-20aP) plaques, also known as driver feedback signs or radar speed displays, are electronic signs that detect and display the speed of approaching vehicles in real time. These devices are highly effective in reducing average vehicle speeds and improving driver awareness, particularly in areas where traditional physical calming measures may not be feasible. *MUTCD* requires these signs to have a yellow background and mounted below a regulatory Speed Limit (R2-1) sign.

Benefits and Effectiveness:

- ✓ Studies show radar speed signs can reduce average speeds by 5 to 9 mph, with some locations reporting reductions up to 20%.
- ✓ They are especially effective at slowing down "super speeders"—drivers exceeding the posted limit by 20+ mph.
- ✓ Unlike physical measures such as speed humps, radar signs do not impede emergency vehicles or snow removal operations.
- ✓ Radar signs promote voluntary compliance without requiring police presence, making them a cost-effective and low-maintenance solution.



Vehicle Speed Feedback sign and plaque

Best Practices for Implementation:

Install in areas with documented speeding issues, such as school zones, residential streets, and gate

approaches.

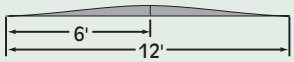
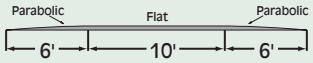
- ✓ Ensure signs are highly visible to approaching drivers, with no obstructions such as trees, poles, or other signs.
- ✓ Set the feedback sign to activate only when vehicles exceed a certain speed (e.g., 5 mph over the posted speed limit).
- ✓ Limit the displayed speed to discourage drivers from treating the sign as a "challenge" to achieve higher speeds.
- ✓ Feedback signs works well in conjunction with law enforcement, public education, and other traffic calming measures.

Radar speed signs are a proven tool for enhancing safety and reducing speeds in targeted areas. Their flexibility, visibility, and data collection capabilities make them a valuable addition to any traffic calming strategy.

16.4. 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 7-16 states: "Hazardous features such as transverse ridges, speed bumps, or dips on pavement surfaces shall not be installed or maintained as a means of controlling or reducing the speed of traffic on Army installations." However, an exception is provided for speed bumps at access control points (ACPs), where their use may be appropriate for security and operational purposes. This regulation supersedes AR 420-71, and current Unified Facilities Criteria (UFC) no longer prohibit speed bumps on Army installations, provided they are used in accordance with approved design standards and location-specific requirements.

16.5. 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

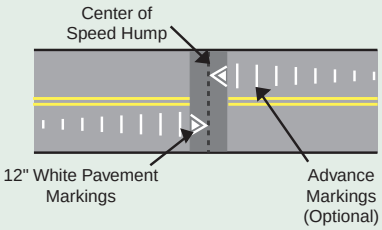
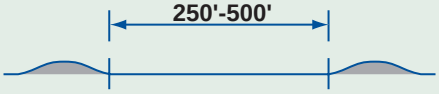
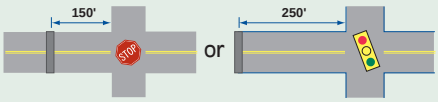
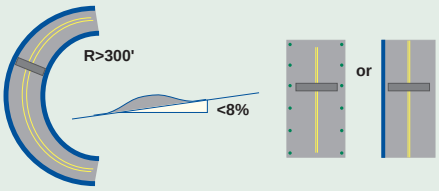
SIGNING 	✓ The SPEED HUMP (W17-1) sign shall be used to provide advance warning of a speed hump. When installed, the SPEED HUMP sign must be supplemented with an Advisory Speed (W13-1) plaque. However, for a series of speed humps in close proximity, this plaque is only required on the first sign in the series.
PAVEMENT MARKINGS 	✓ Standard pavement markings are placed directly on the speed hump to enhance its visibility. These typically consist of a series of 12-inch white markings. The *MUTCD* illustrates several allowable configurations for these on-hump markings. Advance speed hump markings, which must be white, may be installed ahead of a speed hump to enhance visibility or in locations where deflection is not anticipated.
NUMBER AND SPACING 	✓ A single speed hump serves as a point speed control measure. To achieve sustained speed reduction along an extended section of roadway, a series of speed humps is typically required. ✓ Speed humps should be spaced at intervals of 250 to 500 feet. Research indicates that spacing humps at 275-foot intervals results in 85th-percentile speeds of approximately 25 mph, while spacing them at 550-foot intervals leads to 85th-percentile speeds of around 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)

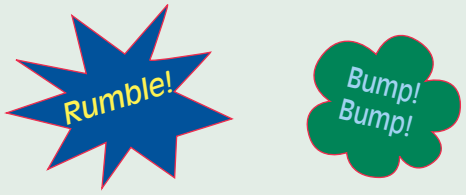
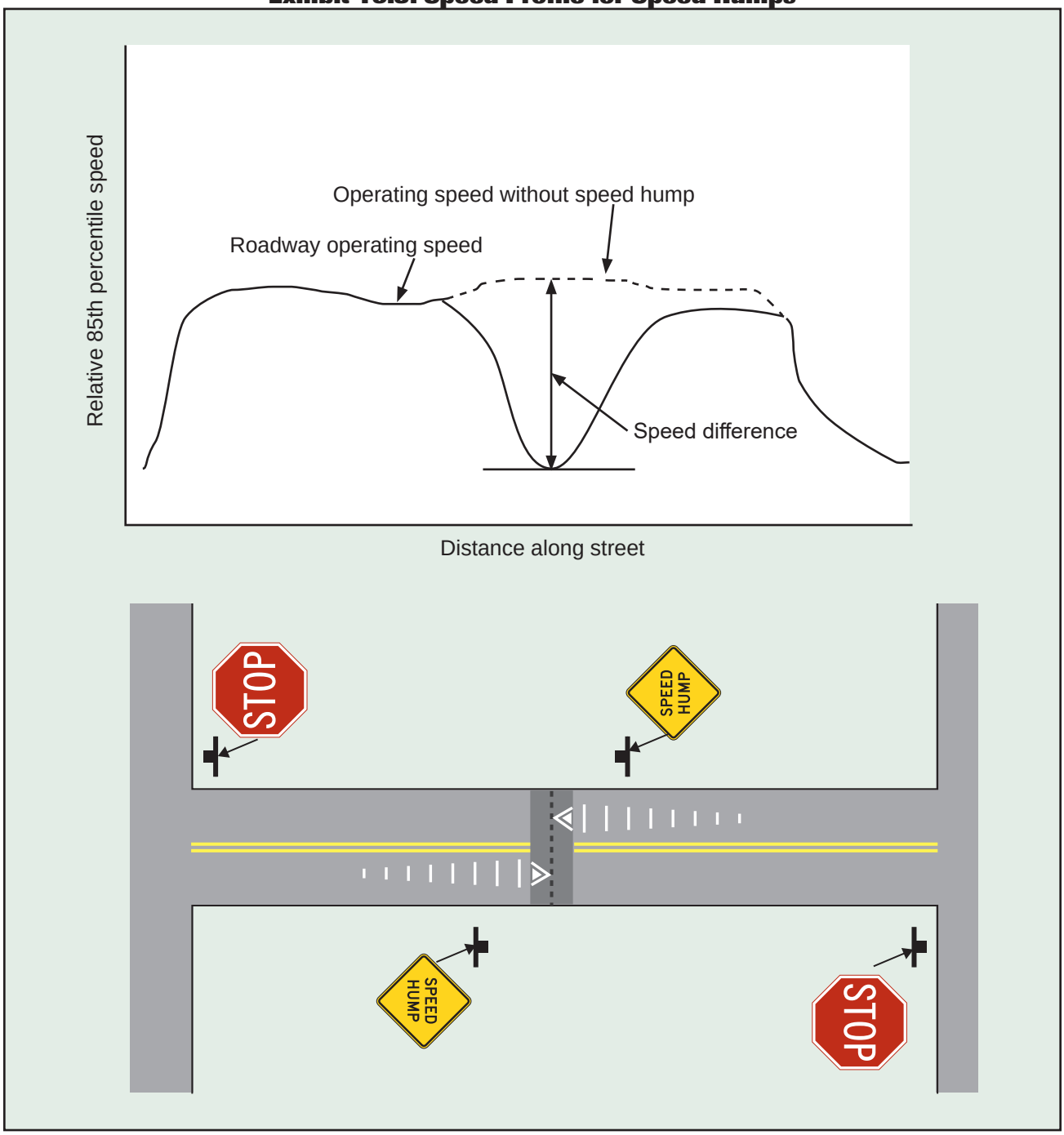
BICYCLES AND DRAINAGE	✓ Ideally, speed humps should extend across the entire width of the roadway, from curb to curb. This design is preferred by bicyclists and prevents motorists from driving with one wheel in the gutter to avoid the hump. However, if drainage cannot be accommodated with the preferred design, the hump may be modified to allow water to flow around it toward 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 	✓ While speed humps may generate noise from vehicles passing over them, the overall noise levels on the street are often reduced due to the decrease in vehicle speeds.

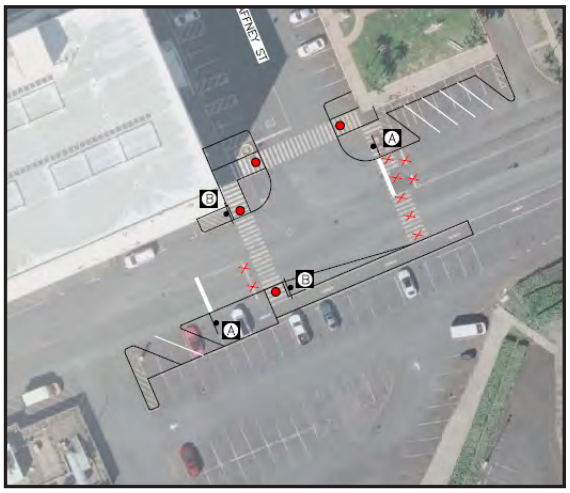
Exhibit 16.3 shows a typical speed profile for a speed hump, as well as the speed differential if the speed hump was not used. Although this depicts a speed hump, it is similar to any traffic calming device.

Exhibit 16.3: Speed Profile for Speed Humps



16.6. BULBOUTS

Bulbouts are curb extensions designed to shorten pedestrian crossing distances. They can be located at intersections or midblock and are appropriate for all street classifications. Typically, a bulbout extends the curb about six feet into the parking lane. This design also improves visibility for both pedestrians and drivers, creating a safer crossing environment.



Bulbout example

When designing bulbouts at intersections, several critical factors must be evaluated to ensure both safety and functionality. The appropriateness of a bulbout can be limited by site constraints, such as narrow intersection geometry or significant truck turning volumes. Therefore, vehicle turning simulations are essential to verify that the proposed design can accommodate the turning movements of the designated design vehicle. Vertical curbs are commonly used for bulbouts, but mountable curbs may be necessary at intersections to facilitate truck turning. However, mountable curbs must be structurally designed to withstand repeated vehicle loads; otherwise, they may deteriorate over time.

Additionally, drainage impacts should be carefully evaluated during bulbout design. Improperly designed bulbouts can disrupt water flow between curb inlets in curb-and-gutter sections, potentially leading to ponding and localized flooding.

Another crucial aspect of bulbout design is ensuring accessibility. When a bulbout is part of a marked crosswalk, it must include curb ramps that are fully compliant with the ADA.

Bulbouts located midblock, also called “chockers” or “neckdowns”, 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 into the roadway but ensure bulbout does not encroach into the travel lanes.
- ✓ 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.
- ✓ Ensure adequate pedestrian sight distance is provided at crosswalks and that bulbout designs comply with ADA accessibility requirements.

In addition, check with the local DOT to obtain an applicable design manual and to obtain local design

practice.

KEY POINT

FHWA has additional web resources on traffic calming: http://safety.fhwa.dot.gov/speedmgt/traffic_calm.cfm

16.7. TRAFFIC CALMING TECHNIQUES

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.

16.7.1. 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 outlined in Exhibit 16.4.

Bulbout/Curb Extension - Areas of expanded curbing that extend across a parking lane, resulting in a narrower travel lane.

Chicane - Series of three bulbouts, staggered at midblock 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. ABA-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



Raised Median Island



Roundabout



Curb Extension

Horizontal Deflection Examples

circle (in countries where vehicles travel on the right-hand side of the road).

Exhibit 16.4: Horizontal Deflection Techniques

■ Significant Effect ◣ Moderate Effect ☐ Minimal or No Effect

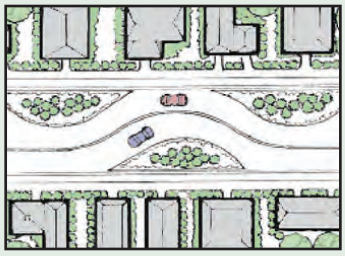
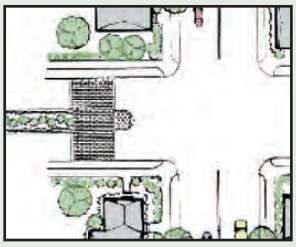
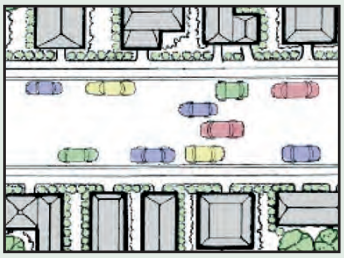
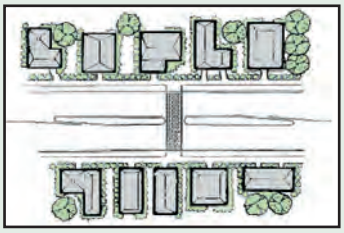
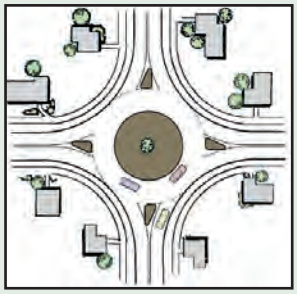
		VOLUME REDUCTION	SPEED REDUCTION	CONFLICT REDUCTION	EMERGENCY RESPONSE
BULBOUT/CURB EXTENSION		☐	◣	◣	◣
CHICANE		◣	◣	☐	◣
GATEWAY		☐	☐	☐	◣

Exhibit 16.4: Horizontal Deflection Techniques (continued)

■ Significant Effect ◣ Moderate Effect ☐ Minimal or No Effect

		VOLUME REDUCTION	SPEED REDUCTION	CONFLICT REDUCTION	EMERGENCY RESPONSE
ON-STREET PARKING		☐	◣	☐	◣
RAISED MEDIAN ISLAND/ PEDESTRIAN REFUGE		☐	◣	◣	☐
ROUNDABOUT		◣	◣	■	■

16.7.2. Vertical Deflection



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.

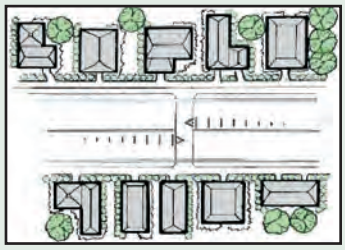
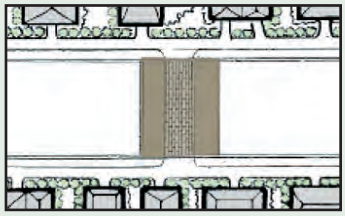
Textured Crosswalk - Use of pavers or other materials to define crosswalks and alert motorists that they are entering a pedestrian-friendly area.

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 midblock. 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
TEXTURED CROSSWALK		□	□	□	□
SPEED HUMPS		◣	■	◣	■
RAISED CROSSWALK		◣	■	◣	■
RAISED INTERSECTION		□	◣	◣	■

16.7.3. 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 but is designed with breaks to allow full access for pedestrians and bicyclists.

Forced Turn Island or Right-In/Right-Out Island - Use of raised islands to prevent left turns and through movements, to and from side streets or entrances, 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 but has breaks to permit pedestrian and bicycle traffic full movement.

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.

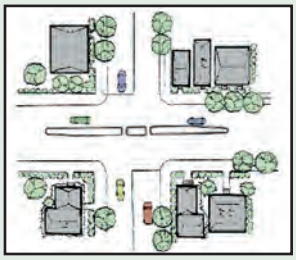
Exhibit 16.6: Physical Obstruction Techniques

■ Significant Effect ◣ Moderate Effect ☐ Minimal or No Effect

		VOLUME REDUCTION	SPEED REDUCTION	CONFLICT REDUCTION	EMERGENCY RESPONSE
SEMI-DIVERTER		■	◣	◣	◣
DIAGONAL DIVERTER		■	◣	◣	◣

Exhibit 16.6: Physical Obstruction Techniques (continued)

■ Significant Effect ◣ Moderate Effect □ Minimal or No Effect

		VOLUME REDUCTION	SPEED REDUCTION	CONFLICT REDUCTION	EMERGENCY RESPONSE
FORCED TURN ISLAND (RIGHT-IN/RIGHT-OUT ISLAND)		◣	□	◣	◣
RAISED MEDIAN THROUGH INTERSECTION		■	□	◣	■
STREET CLOSURE		■	◣	■	■

16.7.4. 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 travel 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
SPEED LIMIT SIGNING	☐	◣	☐	☐
TURN PROHIBITIONS	◣	☐	◣	☐
ROADWAY NARROWING WITH EDGE LINES	☐	◣	☐	☐
TRANSVERSE MARKINGS	☐	◣	☐	☐

16.8. TRAFFIC CALMING PLANNING AND DESIGN CONSIDERATIONS



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.

16.9. 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.

Agencies should also recognize that liability exposure can arise from additional design and implementation issues. These may include non-compliance with ADA requirements (such as improperly designed curb ramps or the creation of pedestrian obstructions), inadequate or improper warning of traffic calming features, and drainage impacts resulting in ponding water or flooding of adjacent properties. Poor drainage design, particularly where ponding occurs at crosswalks, can create hazardous conditions for pedestrians.

CHAPTER 17 – PARKING

17.1. COMMON DEFICIENCIES 17-1
17.2. OFF-STREET PARKING FACILITIES. 17-2
17.3. PARKING GARAGES 17-12
17.4. ON-STREET PARKING 17-13

CHAPTER 17 – PARKING

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

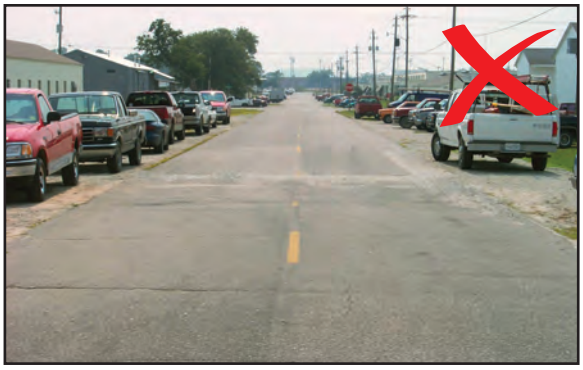
The ten most common parking deficiencies are discussed below.

- ✓ **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 ABA and PROWAG guidelines** – The absence of accessible stalls and routes leading to intended destinations can create significant challenges for pedestrians with disabilities.
- ✓ **Parking lots not properly maintained** – Broken pavement and excessive vegetative growth discourage driver utilization.
- ✓ **Absence of markings** – When parking stalls are not clearly marked, motorists tend to park randomly, leading to inefficient use of available space.
- ✓ **Lack of off-street parking areas** – When drivers are unable to find off-street parking, they may resort to parking roadside, potentially creating a hazard for other motorists.



Undesirable on-street parking



Example of too many access points

- ✓ **Poor lighting in parking areas** – Poor lighting in parking areas can increase the risk of conflicts between pedestrians and vehicles. Additionally, inadequate lighting may make drivers feel unsafe, discouraging them from using the parking facilities.
- ✓ **Poor access design** – Providing too many access points can lead to unnecessary vehicular conflicts, as well as disruptions between parking and traffic circulation.
- ✓ **Not enough buffer zone between parking lots and adjacent land uses** – Adequate buffer is necessary to provide room for sight lines, stand-off distances, and 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 due to lower associated crash rates.

Additionally, planners should consider that people are generally unwilling to walk more than 1,000 feet from their parking space to their destination.

Parking lots are governed by the ABA guidelines, while on-street parking must adhere to the *MUTCD* and PROWAG guidelines. While parking lots are not required to follow *MUTCD* standards for signing and pavement markings, applying these guidelines is considered a best practice.

17.2.1. Demand

Future parking demand can be determined by using parking generation rates. Parking generation rates determine the required number of parking stalls based on facility square footage, number of employees, or units served (such as customers, patients, or renters). These rates have been developed for many types of facilities, and are published in ITE's *Parking Generation,* 2023.

In addition, the UFC 3-201-01 "Civil Engineering" provides military-specific facilities parking requirements.

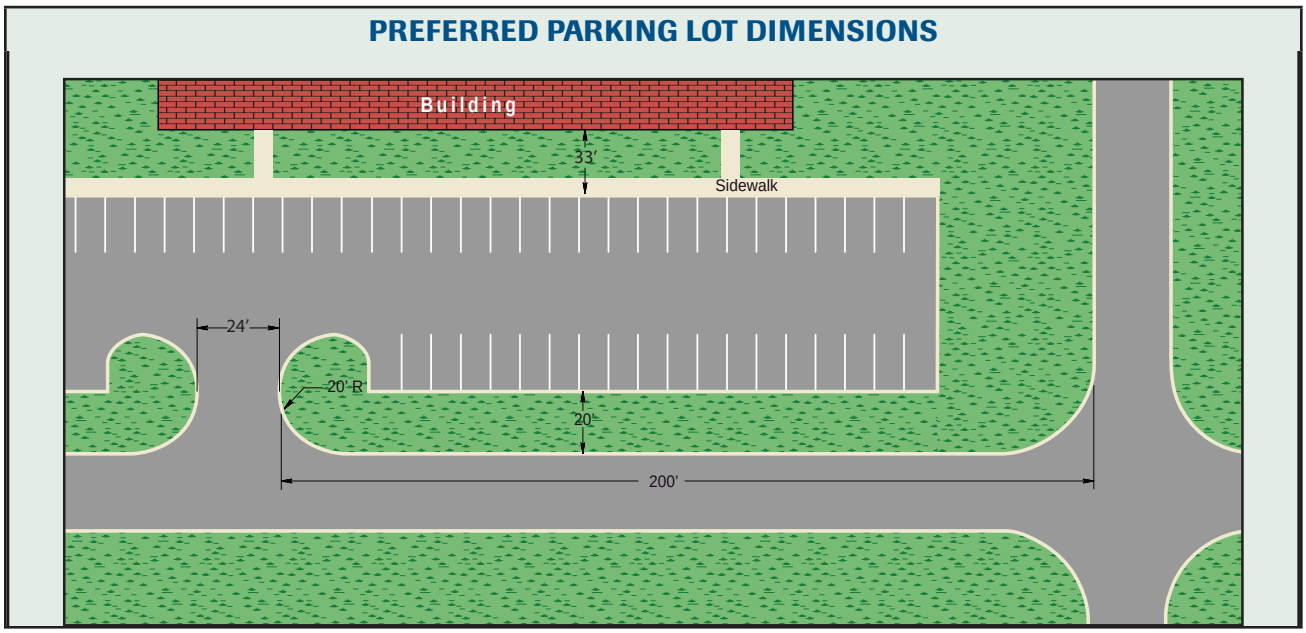
Reserved parking spaces are commonly allocated for higher-ranking personnel, expecting mothers, or fuel-efficient vehicles. When including these types of spaces, they should be added in addition to the minimum required parking spaces calculated for the parking lot. Additionally, per ABA regulations, the required number of ABA-accessible spaces can be counted as part of the total required spaces. For more guidance on determining the appropriate number of parking spaces, refer to TEA *Pamphlet 55-8*.

For existing facilities, demand can be measured by conducting 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 one to two 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

The design of parking facilities, particularly the placement of entry and exit points, is influenced by factors such as pedestrian activity, traffic control measures, turning restrictions, and traffic volumes. For optimal functionality, a minimum driveway turning radius of 20 feet is recommended, along with a driveway width of 24 feet to accommodate two-way traffic flow. Additionally, as outlined in Chapter 15, driveways should ideally be located at least 200 feet away from intersections, especially for facilities with high traffic generation. The exact spacing and placement of access points should be determined by a qualified engineer.

When designing access points for parking lots, ensure that the standards for signage and pavement markings adhere to the *MUTCD*.



17.2.3. Setbacks

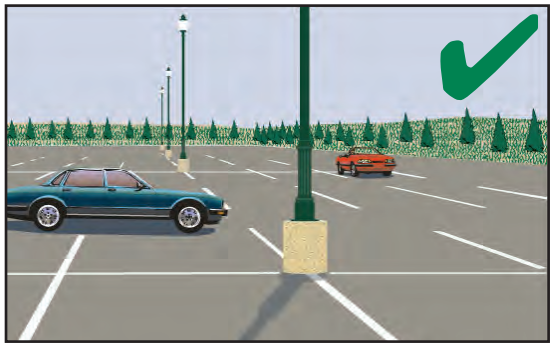
KEY POINT

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 33 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.

17.2.4. Lighting

Parking lot light fixtures should be positioned away from traffic aisles and parking stalls to minimize obstructions and enhance safety. Ideally, light poles should be placed in center or side islands and protected by raised curbs. When light poles are located within parking rows, they should be positioned at the junctions of adjacent stalls, as illustrated below.



Preferred light fixture location

Poles and fixtures should be appropriately scaled to complement the setting and surrounding area while delivering the required level of nighttime illumination. The mounting height and spacing of luminaires should be carefully planned to ensure uniform lighting intensity across the entire parking area. Refer to UFC 3-530-01 Interior and Exterior Lighting Systems for illumination requirements.

See pamphlet Chapter 20 for additional information on parking lot lighting.

17.2.5. Stall Layout

KEY POINT

See UFC 4-010-01 for information on standoff distances to parking areas.

The most efficient parking lot design is a rectangular layout featuring spaces perpendicular (90°) to two-way access aisles. The overall efficiency of the lot decreases as this parking angle is reduced.

In cases with high turnover rates or where site limitations exist, angle parking (e.g., 45° or 60°) with one-way aisles may be used. However, while angled parking allows for easier pull-in and pull-out, this benefit is often outweighed by the inconvenience of one-way aisles and the risk of motorists attempting to enter spaces from the wrong direction. Exhibit 17.1 provides detailed stall layout dimensions for various parking angles.

TEA recommends that parking spaces adhere to the dimensions outlined in Exhibit 17.1, based on a 90-degree parking angle with a standard size of 9 feet by 18.5 feet. Additionally, TEA offers the following recommendations for installations:

- ✓ **Parking Analysis**: When a parking analysis is conducted, the ITE Parking Generation Manual should be utilized as the standard reference.

- ✓ **Remarking Existing Parking Lots**: When re-striping an existing parking lot, maintain the current dimensions to avoid impacts on drainage, light pole placement, and access aisles.
- ✓ **Alternative Dimensions**: If the dimensions outlined in Exhibit 17.1 cannot be achieved, a parking study should be conducted to determine the appropriate design vehicle. Using a different design vehicle may allow for reduced parking space sizes.
- ✓ **Compact Spaces**: Compact spaces may be provided if there is consistent demand for compact vehicles at the facility. These spaces can be as small as 8 feet by 16 feet. Compact spaces should only be considered when space constraints prevent the use of standard 9 feet by 18.5 feet spaces. Compact spaces are often criticized because they are not enforceable like accessible spaces, and non-compact vehicles frequently use them, increasing the risk of door dings.
- ✓ **Motorcycle Spaces**: Motorcycle spaces may be provided under the following conditions: If a parking study identifies consistent motorcycle demand, spaces may be allocated for motorcycles. The study should be conducted during adverse weather conditions (e.g., winter in northern climates) to account for reduced motorcycle usage. Motorcycle spaces may also be provided at the installation's discretion for convenience. Motorcycle spaces should be 4.5 feet wide and at least 9 feet long. Motorcycle parking should use 90-degree parking only, as angled parking offers no benefit due to the shorter length of motorcycle spaces.
- ✓ **Accessible Spaces**: The number and dimensions of accessible spaces must comply with ABA requirements (refer to Section 17.2.9). Accessible spaces cannot be included as part of compact car spaces.

By adhering to these guidelines, parking facilities can be designed to meet safety, accessibility, and efficiency while accommodating diverse vehicle types and user needs.

Exhibit 17.1: Stall Layout Dimensions

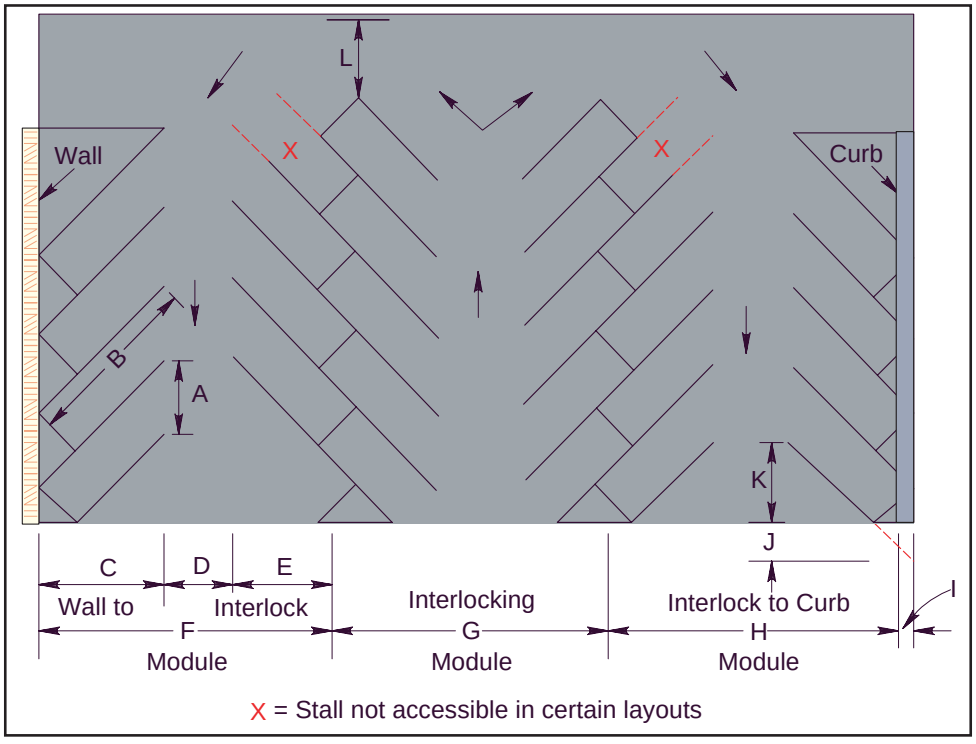


Exhibit 17.1: Stall Layout Dimensions

PARKING LAYOUT DIMENSION (IN FEET) FOR 9 BY 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

PARKING LAYOUT DIMENSION (IN FEET) FOR COMPACT CARS, FOR 8X16 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

Exhibit 17.1: Stall Layout Dimensions (continued)

PARKING LAYOUT DIMENSION FOR MOTORCYCLES, BASED ON 4.5X9 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

Landscaping in parking lots improves aesthetics, provides shade, and helps manage stormwater to reduce flooding and pollution. It also enhances air quality, mitigates heat, and creates a more inviting and environmentally friendly space. 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.



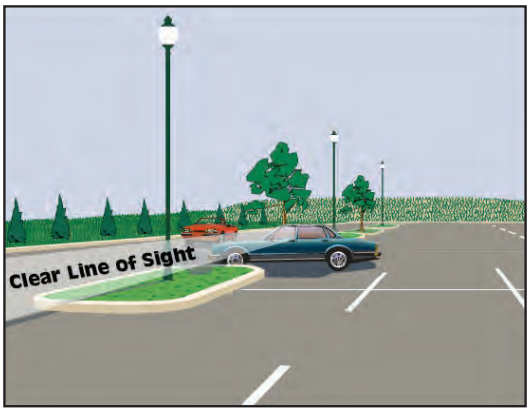
Proper drainage is important!

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 20 feet. Raised end islands also provide a location for signs and light fixtures.

Adequate sight distance must be provided within parking lots, particularly at the intersections of access aisles with cross aisles. Sight distance may be obstructed by parked cars. When sized correctly, the end islands can provide a buffer allowing proper sight distance, while also providing refuge for pedestrians.



End aisle configuration

End islands also enhance aesthetics by breaking up the "sea of pavement" and providing space for plantings. However, maintaining adequate sight distance for motorists remains the priority.

17.2.9. Accessibility Requirements

The Public Rights-of-Way Accessibility Guidelines (PROWAG) (R211 and R310) serve as the primary standard for accessible parking spaces, providing the latest federal guidance. For off-street parking facilities, the Architectural Barriers Act (ABA) Standards (Section F208 and 502), adopted by the DoW, establish the minimum number of required accessible parking spaces based on the total spaces in the lot. On-street parking should adhere to PROWAG (R214 and R309), while surface parking lots and other off-street facilities should comply with ABA Standards. Ensure that every parking facility meets or exceeds the minimum number of designated accessible parking spaces as outlined in Exhibit 17.2.

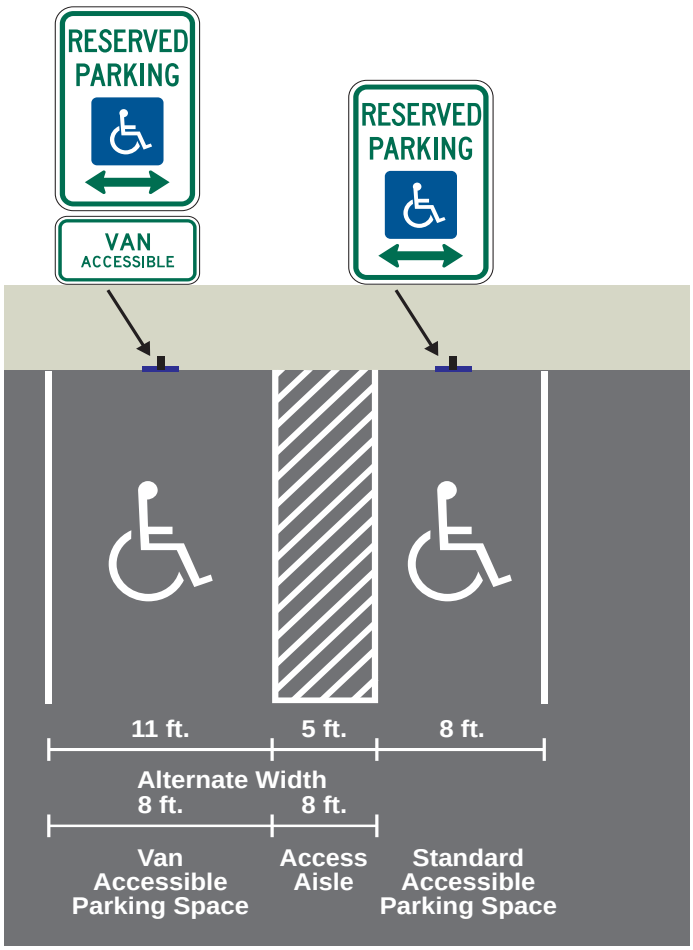
Exhibit 17.2: Minimum Designated Accessible Parking Spaces

TOTAL NUMBER OF PARKING SPACES IN A PARKING LOT OR STRUCTURE, OR ON-STREET ALONG THE BLOCK PERIMETER	MINIMUM NUMBER OF REQUIRED ACCESSIBLE PARKING SPACES FOR PARKING LOT OR STRUCTURE	MINIMUM NUMBER OF REQUIRED ACCESSIBLE PARKING SPACES FOR ON-STREET
1–25	1	1
26–50	2	2
51–75	3	3
76–100	4	4
101–150	5	5
151–200	6	6
201–300	7	4 percent of total

301–400	8	4 percent of total
401–500	9	4 percent of total
501–1,000	2 percent of the total	4 percent of total
1,001 and over	20, plus 1 for each 100, or fraction thereof, over 1,000	4 percent of total

Designated accessible parking spaces must be located to provide the most convenient access to building entrances or the nearest curb cut. Each parking lot must include at least one designated van-accessible parking space, with a minimum of one van space for every six or fraction of six required accessible parking spaces.

While some locales paint the entire parking space blue, this practice is discouraged as painted surfaces can become slippery when wet. Instead, use the accessibility symbol specified in Figure 3B-19 of the *MUTCD* and detailed in the "Pavement Marking Chapter" of the Standard Highway Signs and Marking Book (SHSM). The standard size for the accessible parking space marking is approximately 24 inches wide by 28 inches high without the optional border and blue background, or 38 inches square with the blue background and white border.



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.

Accessible 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 accessible 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 of 8 feet wide, although TEA recommends a minimum width of 9 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; 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: Other Off-Street Parking Design Considerations

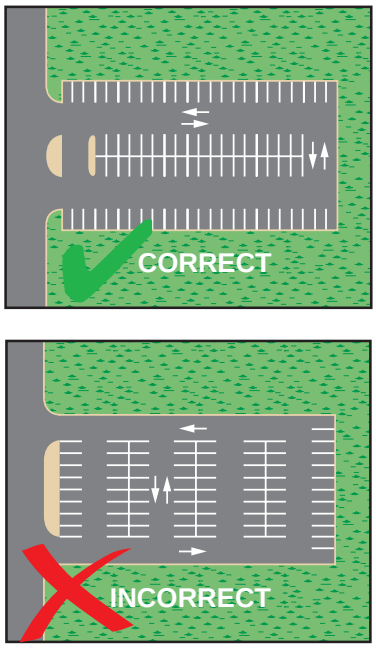
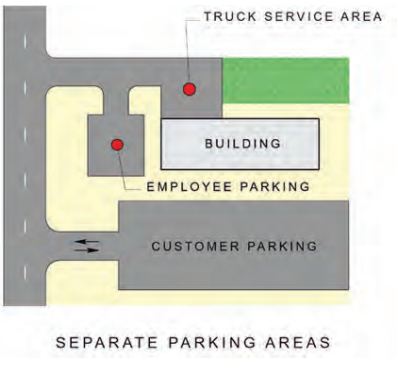
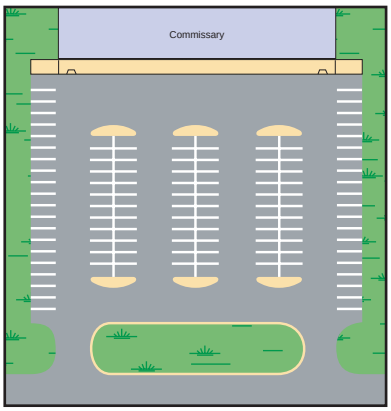
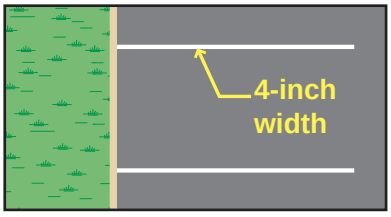
AISLES	
Provide aisles parallel to the long side of the lot with cross aisles every 30 spaces in large parking areas. This layout results in a 20 percent increase in lot capacity compared to aisles oriented parallel to the short side of the lot.	
EMPLOYEE PARKING	
The employee parking lot for a facility 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.	

Exhibit 17.3: Other Off-Street Parking Design Considerations (continued)

ENTRANCES AND EXITS	ROWS	
Design entrances and exits to align with traffic aisles, ensuring smooth vehicle flow and minimizing sharp turns. Additionally, avoid placing parking stalls near entry or exit points to prevent parking maneuvers from obstructing traffic.	For pedestrian safety and convenience, parking rows should be perpendicular to buildings. However, if the rows are less than 130 feet long, it is more practical to design them parallel to the front of buildings.	
PAVEMENT MARKINGS		
White is normally used for marking stall lines. All lines should be 4 inches wide.		
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		
Maintain parking lots by repainting markings as needed and replacing worn signs to ensure visibility. Clean light fixtures annually and replace bulbs before they burn out. Regularly inspect the pavement for cracks or potholes and address them promptly, keep drainage systems clear, and remove debris to maintain a clean and functional space. A consistent maintenance plan helps keep the lot in good condition over time.		

17.3. PARKING GARAGES

Parking garages are commonly used in areas with high parking demand but limited available land. From a master planning perspective, they offer the advantage of providing the same number of parking spaces as surface lots while using significantly less land.

However, the primary drawback of parking garages is their cost, which often exceeds $15,000 per parking space. As a result, they are typically not the first choice when addressing parking shortages. When space for parking is unavailable, it is important to explore alternative solutions.

- ✓ 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.

When planning for a parking garage, ensure entrances are spaced at least 100 feet apart to maximize the available space between the access points and the adjacent street. Position exits on low-volume streets to minimize delays for vehicles leaving and entering the garage. The most common circulation pattern in the United States is the continuous ramp design, which features sloping floors with aisles and parking spaces on both sides, allowing easy access to parking spaces and smooth circulation within the garage.

In multilevel garages, it is generally recommended to provide one elevator for every 250 parking spaces to ensure accessibility.

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.

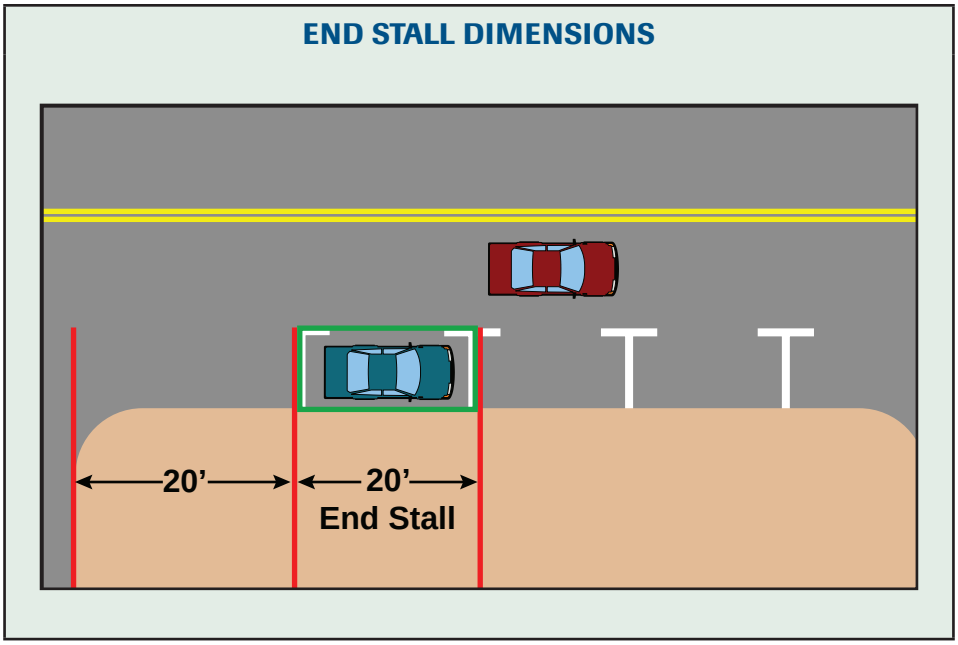
Angle parking can create safety hazards as empty stalls are difficult for motorists to spot. Drivers may either proceed slowly while searching for a space or stop abruptly upon finding one, increasing the risk of accidents. Due to these challenges, the use of angle parking should be avoided.



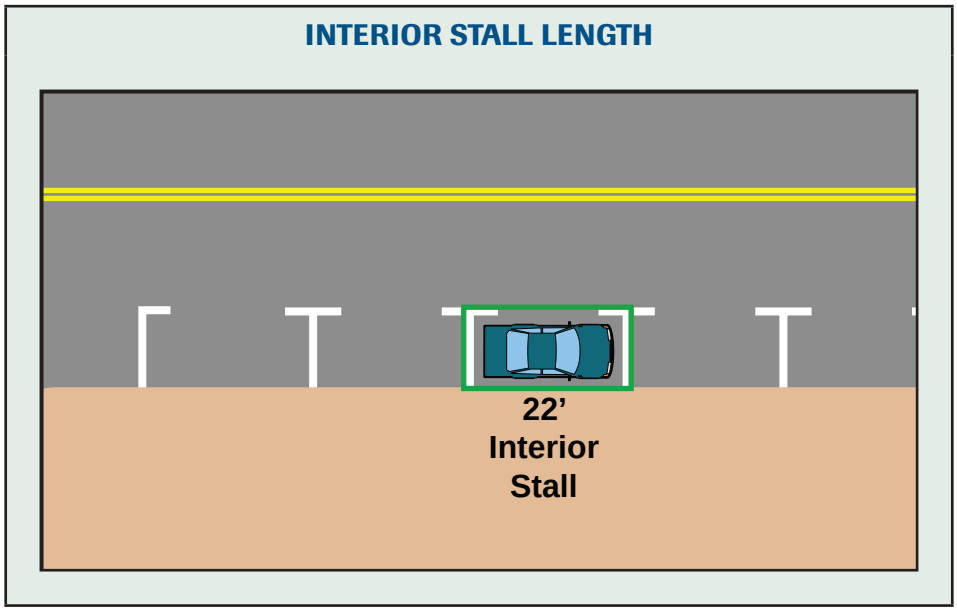
Angle parking

17.4.2. Layout for 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*. TEA 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.

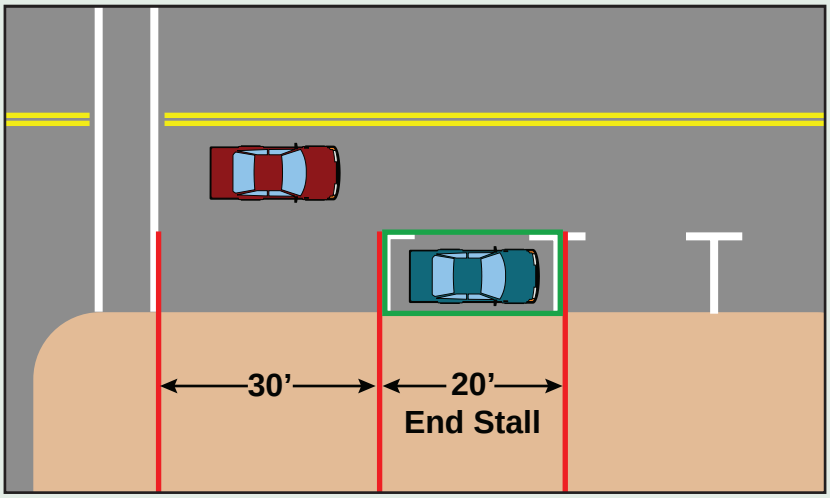


An interior stall requires room for maneuvering into and out of the parking space; therefore, a 22-foot-long stall is recommended.

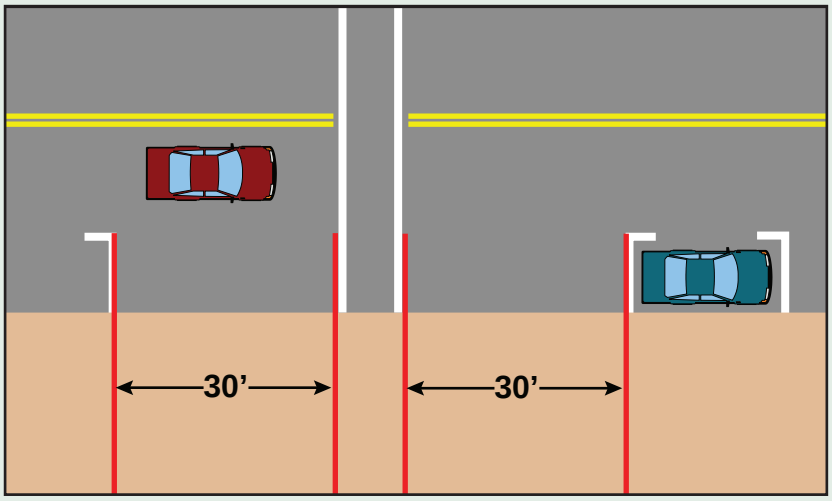


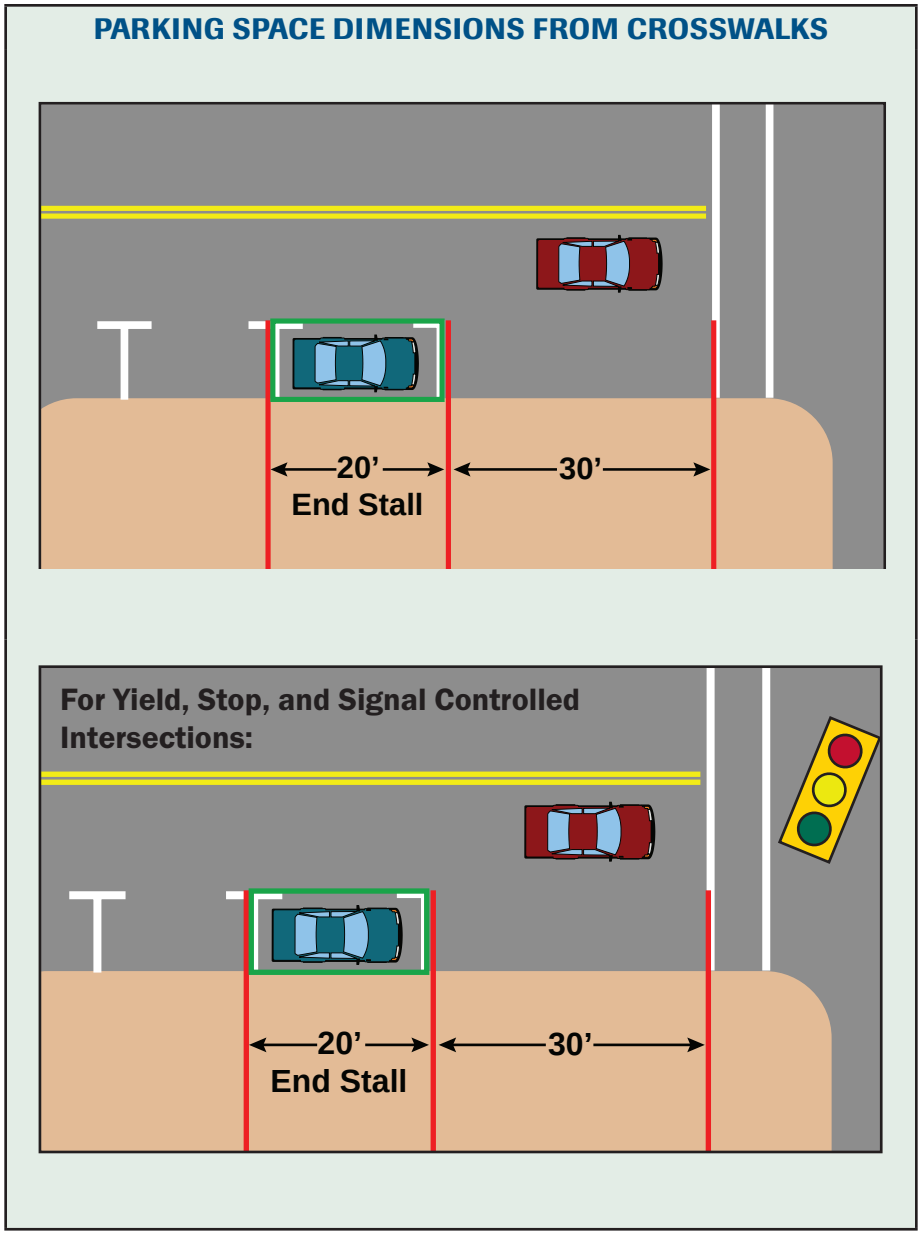
When on-street parking is located near a crosswalk, leave a buffer strip of 30 feet between the crosswalk and the parking space (on both the approaching side and the departing side of the intersection) to maximize visibility between pedestrians and motorists. This applies to crosswalks located at intersections, as well as for midblock crosswalks.

PARKING SPACE DIMENSIONS FROM CROSSWALKS



PARKING SPACE DIMENSIONS FROM MIDBLOCK CROSSWALKS

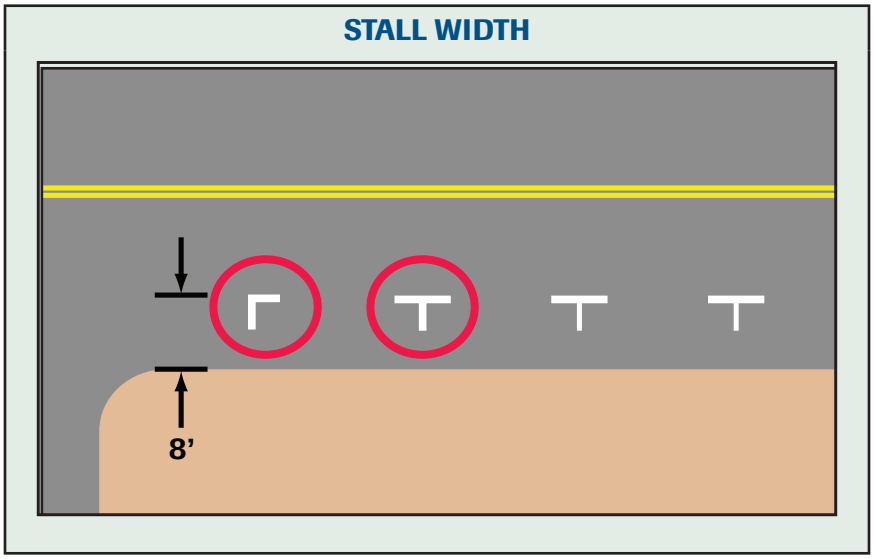




For all of the dimensions discussed in this section, note that they are minimum distances. When laying out actual distances, field-verify all parking spaces to ensure that acceptable sight distance is provided.

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. On-Street Acccessibility Requirements

Where on-street parking is provided on the block perimeter and the parking is marked or metered, accessible parking spaces complying with R310 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, R211 and R310 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 crosswalk at an intersection
- ✓ Within 50 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

18.1. WHAT IS ACCESS MANAGEMENT? 18-1

18.2. WHY IS ACCESS MANAGEMENT NEEDED? 18-2

18.3. PRINCIPLES OF ACCESS MANAGEMENT 18-4

18.4. ACCESS MANAGEMENT STRATEGIES 18-6

18.5. ACCESS DESIGN 18-9

18.1. WHAT IS ACCESS MANAGEMENT?



Access management ensures safe and efficient access to properties while reducing disruptions to traffic flow and improving overall roadway performance.

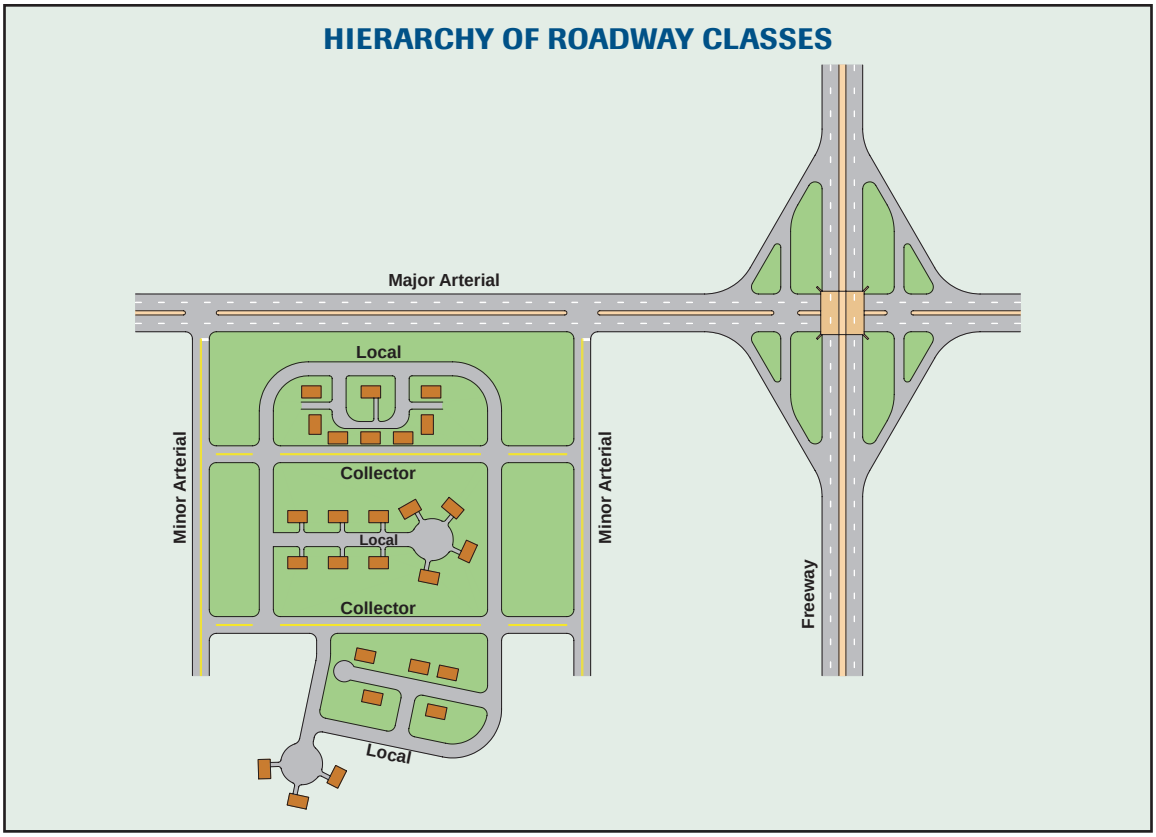
The *Access Management Manual*, published by the Transportation Research Board (TRB), defines access management as "the systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway." In simple terms, it is the management 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 achieved by carefully managing entrance/access points to reduce the number of conflict points.

Roadways are designed to balance access and mobility, with different classifications serving distinct purposes. For high-capacity roadways like freeways, access is strictly controlled and limited to interchanges, prioritizing mobility.

On the opposite end of the spectrum are local streets in residential neighborhoods, which prioritize access over mobility. These streets primarily provide direct access to homes and properties, with limited emphasis on facilitating through traffic or high-speed travel.

The hierarchy of roadway classifications illustrates the varying degrees of access and mobility, ranging from freeways with restricted access and high mobility to local streets with high access and minimal mobility. The illustration on the following page shows an example of the different roadway classifications and how they are interconnected.



18.2. WHY IS ACCESS MANAGEMENT NEEDED?

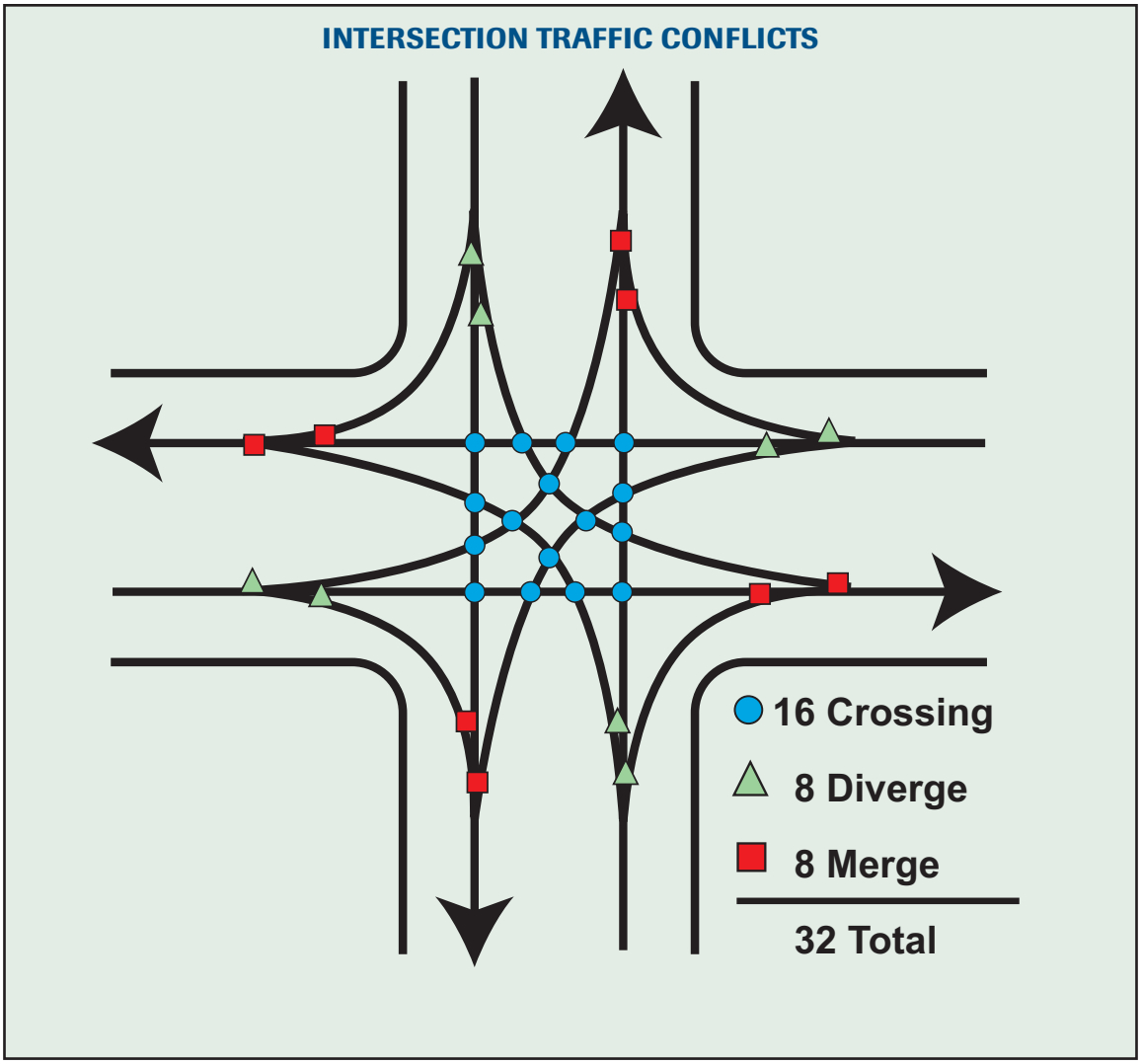
KEY POINT

A standard four-leg intersection has 32 possible conflict points.

Without proper access control, the number of access points along a roadway is likely to increase, leading to a greater number of conflict points. Access management plays a critical role in minimizing these conflicts and enhancing roadway safety and efficiency.

Traffic conflicts occur when vehicle paths intersect, such as when vehicles stop, cross, enter, or exit the traffic stream. Each conflict point introduces the potential for collisions. As the number of conflict points increases along a roadway segment, driving becomes more complex, increasing the likelihood of driver errors, congestion, and reduced safety.

Effective access management helps preserve roadway capacity, improve traffic flow, and reduce the risk of crashes, ensuring safer and more efficient travel for all users.


INTERSECTION TRAFFIC CONFLICTS
16 Crossing
8 Diverge
8 Merge
32 Total

18.3. PRINCIPLES OF ACCESS MANAGEMENT

KEY POINT

TRB's Access Management Manual outlines the objectives for optimizing roadway access and traffic flow.

Access management focuses on limiting and consolidating access points along major roadways while ensuring that the supporting roadway network provides safe and efficient access. The objectives of access management can be achieved by following the principles outlined in the Access Management Manual. The principles most relevant to access management within military installations are detailed below:

- ✓ **Limit direct access onto major roadways** – Roadways designed to accommodate high traffic volumes require stricter access control to preserve their primary function of facilitating through traffic. Access to major roadways should be limited and instead directed to lower-classification roadways, such as local and 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 an 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

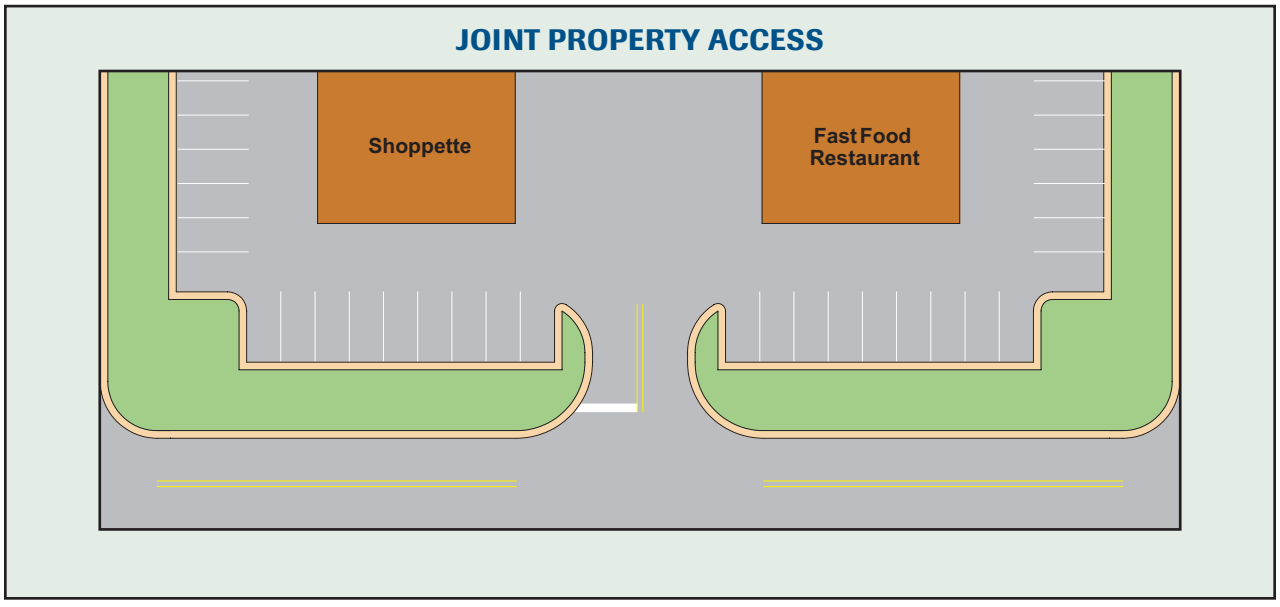


Wide driveway slightly offset from opposite street results in many conflicts.



Driveways too close to a signalized intersection become blocked by stopped vehicles.

- ✓ **Separate conflict areas** – Conflict areas located in close proximity can obstruct traffic movements and contribute to increased congestion. Drivers need adequate time to react to each conflict area. As travel speeds increase along a roadway, the spacing between access points must also increase to account for driver perception and reaction times. Once a potential hazard is identified, drivers need sufficient time to respond effectively. Ensuring adequate distance between access points is critical for maintaining safety and traffic flow.
- ✓ **Remove turning vehicles from through lanes** – Turning lanes enhance safety and efficiency by diverting slower-moving vehicles from higher-speed through lanes. These lanes provide a protected space where turning vehicles can wait safely to complete their turn, reducing disruptions to traffic flow and improving the overall performance of intersections with streets or driveways.
- ✓ **Provide a supporting street and circulation system** – During planning stages it is important to include a supporting network of local and collector streets to provide access to new development such as restaurants or a PX/Commissary.
- ✓ **Eliminate the need for multiple driveways** - Shared property access plays a crucial role in reducing the need for individual driveways for each property. As shown below, this connectivity enables motorists to travel between adjacent properties without the need to re-enter the roadway, improving traffic flow and reducing congestion.
- ✓ **Preserve the functional area of intersections** – The functional area of an intersection is essential for ensuring safe and efficient vehicle movement. This area encompasses the space where drivers perform necessary maneuvers, such as lane changes and turning movements. When access points are placed too close to this critical area, they can create traffic conflicts that significantly impair the intersection's performance and safety.



18.4. ACCESS MANAGEMENT STRATEGIES

When constructing new access points or upgrading existing ones, it is important to consider location and spacing. These components are critical for ensuring safe and efficient roadway operation.

18.4.1. Access Location

Determining proper access location requires careful consideration of several factors:

- ✓ Sight distance
- ✓ Adhering to the roadway hierarchy.
- ✓ Functional area of intersections

Sight Distance

Ensuring adequate sight distance at driveways is essential for safe entry and exit onto roadways. Proper sight distance allows motorists to navigate safely while providing approaching drivers enough time to react to vehicles entering or exiting the roadway. For more details, refer to Section 4.5.

Roadway Hierarchy

Connections between roadways should align with their functional classifications to maintain efficient traffic flow and safety. Ideally, roadways of similar classifications should be connected, such as a minor arterial to a major arterial. However, connecting a local road to a major arterial should be avoided whenever possible to prevent disruptions to the higher-class roadway's intended function.

Functional Area of Intersections

Constructing access points in the functional area of an intersection should be avoided. This area extends to at least the end of the turning lanes and includes the space where queued traffic typically accumulates.

18.4.2. Access Spacing

Wide spacing between successive driveways is the single most critical component of access management, as each new access point introduces multiple traffic conflicts that can reduce travel speeds, increase congestion, and elevate crash risks. The closer these access points are to one another, the more significant these negative effects become. Minimum access spacing requirements are designed to mitigate these impacts and enhance roadway safety and efficiency.

Guidelines for access point spacing vary but most if not all consider factors such as traffic volume, speed limits, and roadway classification. General spacing recommendations are outlined in TRB's NCHRP Report 348, with unsignalized access guidelines illustrated in Exhibit 18.1.

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.	

Exhibit 18.2: Distance from Major Intersections Based on Roadway Classification and ADT

ROADWAY CLASSIFICATION	AVERAGE DAILY TRAFFIC (ADT)	DESIRABLE
Major Arterials	>12,000	1,320
Minor Arterials	6,000 - 12,000	660
Collectors	2,500 - 6,000	330
Local Streets	2,500 or less	100

The spacing guidelines shown above provide a range of values. The lower values apply to lower classification roads or roadways with raised medians where no left turns are permitted.

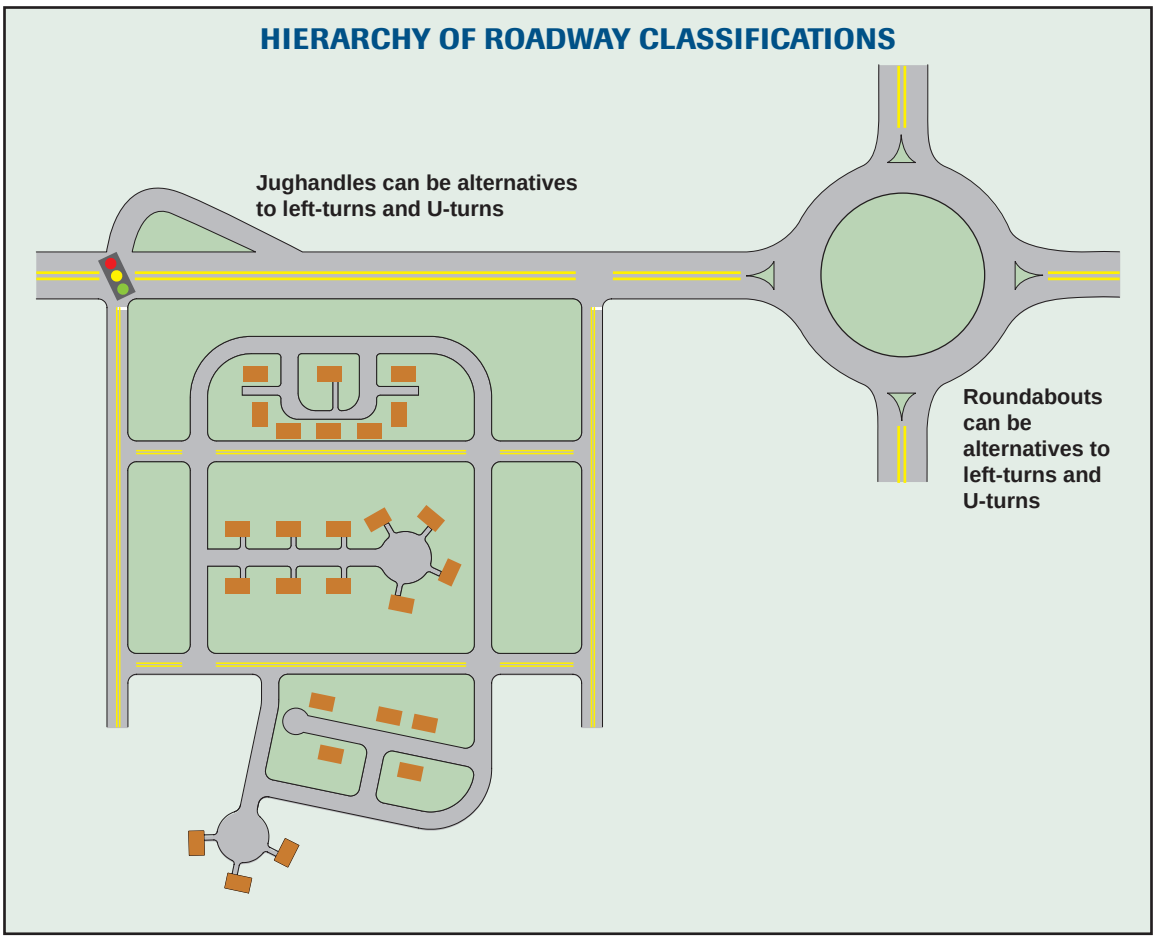
18.4.3. Additional Considerations

Restricting certain turning movements at intersections with access points, particularly left turns to and from busier roadways, is often necessary to improve safety and traffic operations. Left-turn restrictions are beneficial because high traffic volumes can make it difficult for motorists to find safe gaps, leading to risky decisions and increased crash potential. Additionally, vehicles waiting to turn left can cause significant delays for right-turning and through traffic, further disrupting intersection efficiency.

When left-turn restrictions are implemented, accommodations must be made for traffic that would otherwise require these movements. This can be achieved by providing alternative access points to side streets or enabling U-turn capabilities along the major roadway. U-turn options can be facilitated through the following methods:

- ✓ U-turn capabilities at an adjacent traffic signal.
- ✓ Jughandle designs at signalized intersections.
- ✓ Roundabouts at nearby intersections, allowing U-turns without conflicting with opposing traffic.

The figure below illustrates these alternative solutions for accommodating restricted left-turn movements.


HIERARCHY OF ROADWAY CLASSIFICATIONS
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 access design components 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

Access width must be carefully designed to accommodate the intended traffic movements. While sufficient width is necessary, excessively wide access points can create conflicts over a larger area, leading to driver uncertainty about proper vehicle positioning. A recommended width of 12 feet per lane is generally appropriate, though wider lanes may be required in areas with significant truck traffic.

18.5.3. Throat Length

The throat length refers to the distance between the adjacent roadway and the internal point where drivers encounter conflicts. At PX/Commissary complexes, throat lengths are often insufficient, providing limited space for vehicles to queue when faced with internal conflicts. As illustrated on page 18-9 (below), this lack of adequate throat length can result in vehicles backing up onto the adjacent street, significantly increasing the risk of crashes and disrupting traffic flow.

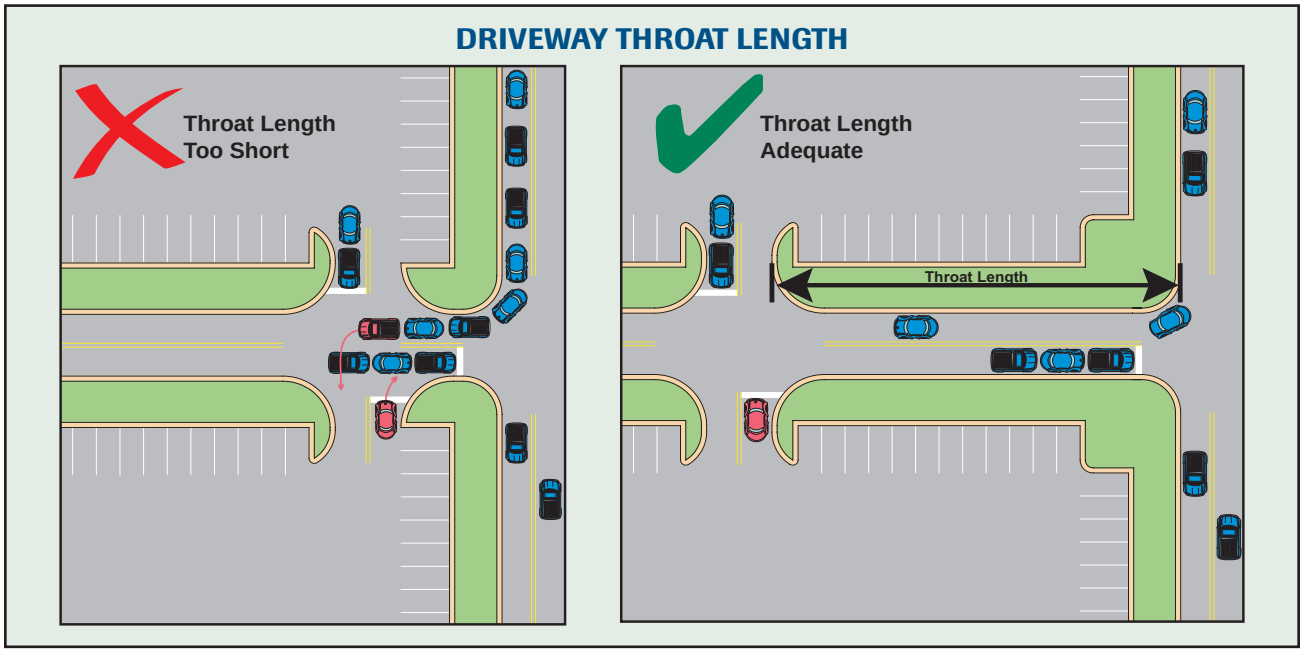


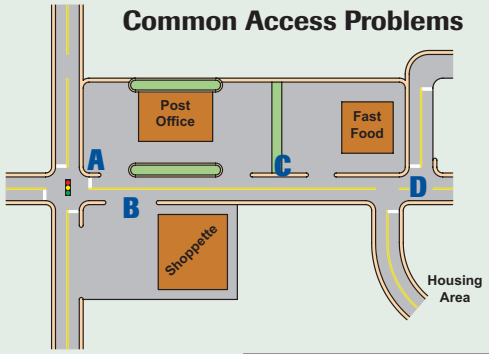
Exhibit 18.3 provides some general guidelines for throat lengths. Exhibit 18.4 illustrates the many problems encountered in access management and the corresponding mitigation strategies.

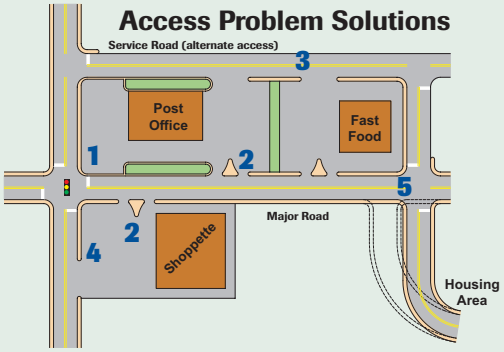
Exhibit 18.3: Throat Length Requirements

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 (PX/Commissary)	200 feet	11

Source: Access Management Manual

Exhibit 18.4: Access Problems and Solutions





Common Access Problems \ Access Problem Solutions	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. **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. **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. **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. **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

19.1. CONGESTION 19-1

19.2. TRAVEL ALTERNATIVES. 19-4

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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

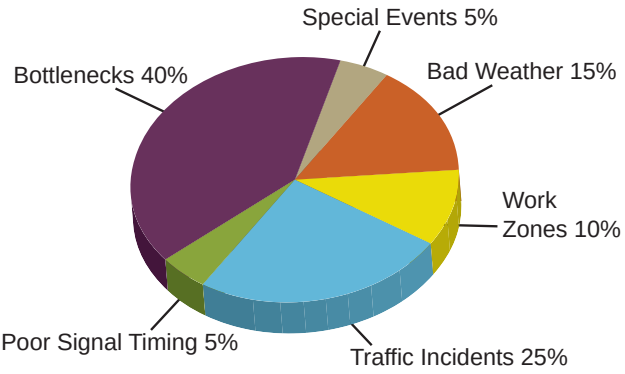
According to the 2023 Urban Mobility Report, travel delays due to traffic congestion caused drivers to spend 8.5 billion hours of extra travel time and purchase an additional 3.6 billion gallons of fuel. These delays resulted in a nationwide economic impact of approximately $210 billion, or about $1,200 per commuter.

Source: 2023 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

A comprehensive strategy for reducing traffic congestion, as referenced in Exhibit 19.2, relies on a combination of three distinct approaches:

Increasing Road Capacity: This traditional "build option" is often a limited solution. Experts widely recognize that new capacity is frequently consumed by induced demand—where new lanes encourage more driving—ultimately failing to provide long-term congestion relief on its own.

Improving Operational Efficiency: This approach optimizes existing infrastructure by eliminating physical bottlenecks and deploying intelligent transportation systems (ITS), such as synchronized traffic signals and real-time traffic management. These technologies have demonstrated a high return on investment by saving both time and fuel.

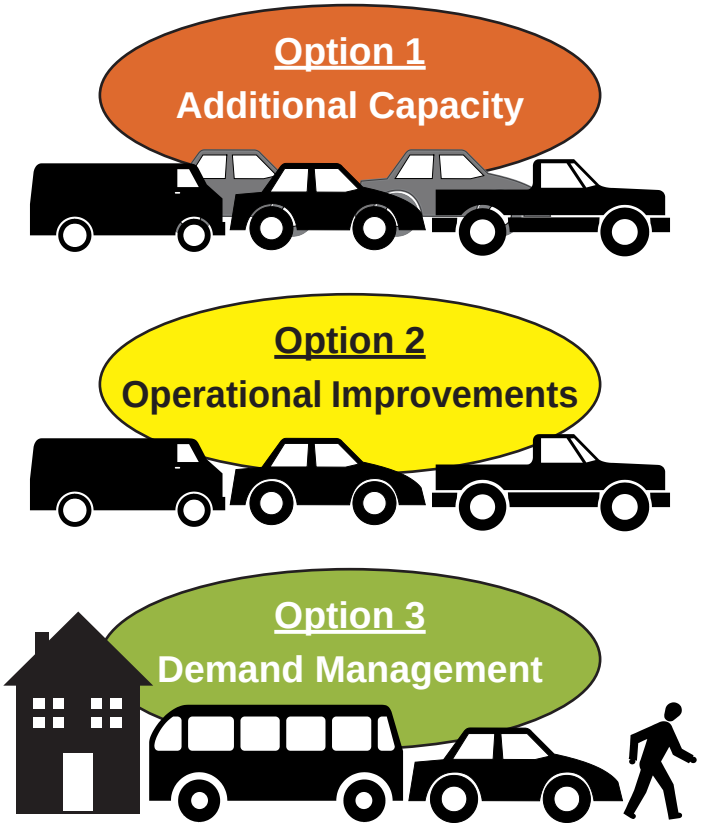
Managing Travel Demand: This strategy aims to reduce the overall number of vehicles on the road and is formally known as travel demand management (TDM). TDM encourages alternative transportation modes, adjusting travel behavior, and promoting policies such as carpooling, telecommuting, flexible work schedules, and public transit use.

In practice, the most effective strategy for reducing congestion is a balanced approach that integrates all three options. Combining infrastructure improvements, technological advancements, and demand management ensures a comprehensive solution to traffic congestion challenges.

Most recently, in 2025, the administration issued the "Unleashing American Energy" Executive Order (EO), which revoked EO 14057 and several related directives. The current policy removes mandatory clean energy and electric vehicle procurement goals, suspends support for federal renewable energy programs, and shifts focus toward conventional energy production and infrastructure deregulation.

As a result, while sustainability remains an important operational consideration for many agencies, the original 2015 targets are no longer active federal mandates. Agencies may pursue energy and emissions reductions voluntarily but are not bound by the previous executive directives.

Exhibit 19.2: Congestion Mitigation Options



TDM 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.

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

Military installations, as both the owners of their road networks and the employers of large workforces, are uniquely positioned to improve daily travel for employees while reducing the need for costly additional travel lanes and parking infrastructure. The following sections introduce a range of techniques that installations can use to help employees and partners significantly reduce energy consumption, travel time, and air pollution, creating a genuine win-win for the installation and its workforce.

19.2.1. Telework

Telework allows employees to perform their duties from locations outside the traditional office, reducing the need for daily commuting and lowering overall travel demand. It is supported by technologies such as laptops, broadband Internet, collaborative software, videoconferencing, and voice over internet protocol. Telework can also expand opportunities for employees in remote areas or those with caregiving responsibilities or disabilities.

Telework is most suitable for positions that involve information-based tasks, including programming, data entry, planning, analysis, and design. In 2025, an estimated 32.6 million Americans worked remotely in some capacity, and a significant portion of the workforce holds jobs that could be performed remotely.

From a transportation perspective, telework offers several advantages. It eliminates commuting trips, reduces congestion, lowers air pollution, and decreases energy use. It can also reduce employer and employee costs and minimize disruptions caused by weather-related or security-related closures. Many organizations have adapted to increased workforce mobility by redesigning office space and surveys consistently show strong employee interest in at least part-time telework.

Federal agencies have expanded the use of telework compared to pre-2014 levels, but current policy emphasizes situational telework rather than routine remote work. Participation varies by agency, mission needs, and the number of employees with approved telework agreements. These policies continue to evolve, and future federal telework practices may change as guidance and operational requirements shift.

Within the DoW, approximately 76 percent of employees are considered eligible for telework. If 80 percent of these employees teleworked half of the time, there would typically be about 225,825 teleworkers, resulting in an estimated 30 percent reduction in work-related travel.

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 Exchange, commissary, credit union, library, gym, etc., instead of relying on 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, and they should coordinate with the appropriate state or local DOT to ensure safe and efficient connections to off-installation roadways and facilities.

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. Workers often organize carpools with neighbors employed at the same military installation. To supplement these informal arrangements, installations can create a website to help more people find ridesharing opportunities.

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.

Installations can also promote existing DoW commuter programs, such as the Transportation Incentive Program (TIP), to further reduce single-occupant vehicle travel.

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.
- ✓ Promote participation in TIP.

19.3.2. GRH Program

The GRH program provides employees who carpool or use transit with a reliable way to return home when unexpected situations arise, such as emergencies or unplanned overtime. This program removes one of the most common barriers to ridesharing by ensuring that commuters are not stranded at work. Transportation may be provided through a government vehicle, a taxi, a rental vehicle, or a ride-sharing service, depending on installation policy and available resources.

Most carpoolers and transit riders consider a GRH program essential when deciding whether to participate in ridesharing. Installations may choose to begin with a broad definition of qualifying situations and refine the program over time based on usage patterns and applicable federal or DoW guidance. Although employees value the reassurance that GRH provides, actual use of the program is typically low. Any cost-recovery approach, including whether a fee may be charged, should follow current federal policy and installation-level guidelines.

19.3.3. Incentives to Encourage HOV

To encourage the use of HOVs, installations may consider parking-related incentives where permitted by federal and DoW policy. These could include charging a parking fee, offering a parking cash-out option for employees who carpool or use transit, or providing preferred parking spaces for HOV vehicles. Any such incentive must comply with applicable regulations, and the monetary value should reflect the cost of providing parking. These measures are separate from the TIP, which provides mass transit and vanpool benefits but does not authorize parking subsidies, parking cash-out payments, or incentives for carpools.

19.3.4. Instant Ridesharing

Beyond traditional carpool-matching websites, on-demand ride-matching has become a dominant technology. These services, accessed via smartphone apps, allow users to request a ride for immediate or short-notice pickup. The platform's network instantly matches the passenger's request with a nearby driver, providing real-time location tracking and payment processing. While the technical term for this is dynamic carpooling or real-time ridesharing, it is now commonly known as ride-hailing, ride-sharing, ad-hoc ridesharing, single-trip ridesharing or casual carpooling.

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. 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. Some installations have also tested autonomous shuttle systems as a way to improve internal mobility and reduce reliance on conventional shuttle fleets. These pilot programs have demonstrated potential benefits such as lower operating costs, reduced emissions, and improved service frequency on fixed routes. While still emerging, autonomous shuttles may offer installations an additional option for enhancing transit service in the future.

A recent analysis by the U.S. Department of Transportation and the Clean Air Task Force finds that CNG buses can save transit agencies between $50,000 and $80,000 over a typical 12–15 year lifespan, largely due to fuel savings and reduced maintenance costs. Technological advancements have led to up to 90% reductions in particulate matter emissions and 30–50% reductions in nitrogen oxides, compared to conventional diesel buses. With cleaner combustion and lower long-term costs, CNG buses continue to be a reliable and environmentally favorable alternative in public transit fleets.

While clean diesel buses have improved significantly, they still produce higher emissions than CNG and electric alternatives. However, they may offer lower upfront costs and remain a viable option for agencies with limited infrastructure or funding.

When replacing buses, many installations should consider smaller shuttle buses, especially in areas with tight turning radii or constrained layouts. These vehicles not only improve maneuverability but also contribute to lower fuel consumption and operating costs.

It is important to publicize any internal shuttle service, providing the specifics as to who can ride, where it goes and when.

For transit arrangements 2 and 3 (discussed on previous page), 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. SMART GROWTH AND LAND USE ON MILITARY INSTALLATIONS

Smart growth principles emphasize sustainable, efficient, and community-focused development, and these ideals are increasingly relevant to military installations. By applying smart growth strategies, installations can optimize land use, reduce environmental impacts, and enhance the quality of life for service members and their families. These principles are particularly important in the main cantonment areas, where administrative, operational, and training facilities are concentrated, as well as in housing areas that serve military personnel and their families.

19.5.1. Main Cantonment Areas

In main cantonment areas, smart growth focuses on creating compact, efficient layouts that minimize land consumption while maximizing functionality. This includes clustering administrative buildings, training facilities, and support services to reduce travel distances and improve accessibility. Mixed-use development is a key strategy, integrating office spaces, retail services, and recreational facilities within walking distance to promote convenience and reduce reliance on vehicles. Smart growth also encourages the use of sustainable building practices, such as energy-efficient designs and renewable energy systems, to reduce the environmental footprint of cantonment areas.

Transportation planning is another critical aspect of smart growth in cantonment areas. By incorporating pedestrian-friendly pathways, bike lanes, and efficient transit systems, installations can reduce traffic congestion and improve mobility. These measures not only enhance operational efficiency but also contribute to the overall well-being of personnel by fostering a healthier, more connected environment.

19.5.2. Housing Areas

Smart growth principles in military housing areas prioritize livability, community cohesion, and environmental sustainability. Compact, well-planned neighborhoods with a mix of housing types can accommodate diverse family needs while preserving open spaces for parks, playgrounds, and community centers. These shared spaces foster a sense of community and provide opportunities for social interaction, which is vital for the morale and mental health of military families.

Connectivity is another cornerstone of smart growth in housing areas. Well-designed transportation networks, including pedestrian paths and bike-friendly routes, ensure that residents can easily access schools, commissaries, medical facilities, and recreational amenities. Additionally, integrating housing areas with the broader installation through efficient transit options reduces commuting times and enhances the overall quality of life.

19.5.3. Environmental and Operational Benefits

Smart growth strategies also align with the military's commitment to sustainability and mission readiness. By reducing sprawl and preserving natural habitats, installations can minimize their environmental impact while maintaining compliance with federal regulations. Efficient land use reduces infrastructure costs, freeing up resources for mission-critical activities. Furthermore, compact, well-connected layouts improve emergency response times and operational efficiency, ensuring that installations remain resilient and adaptable to changing needs.

CHAPTER 20 – LIGHTING

20.1. BASICS 20-1

20.2. INTERSECTION AND CROSSWALK LIGHTING 20-6

20.3. PARKING LOT LIGHTING 20-8

20.4. MISCELLANEOUS CONSIDERATIONS 20-9

CHAPTER 20 – LIGHTING

Lighting for security purposes is very important on DoW installations, especially at entry control facilities (ECFs), at sensitive locations within the installation, and around the perimeter of 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 *Interior and Exterior Lighting Systems*, 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 DoW installations has historically relied on high-pressure sodium (HPS) lamps; however, per the latest UFC criteria, installations should no longer 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, pulse start metal halide (MH) lamps were previously favored because of their better efficiency, reduced maintenance, and improved visibility.

LED lighting has become the preferred option for new exterior applications on military installations. LEDs offer similar benefits to MH lamps, higher energy efficiency, longer lifespan, lower maintenance, and superior visibility, and are now widely adopted due to their alignment with DoW sustainability and performance goals.

20.1. 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 following resources provide useful guidance for roadway lighting design:

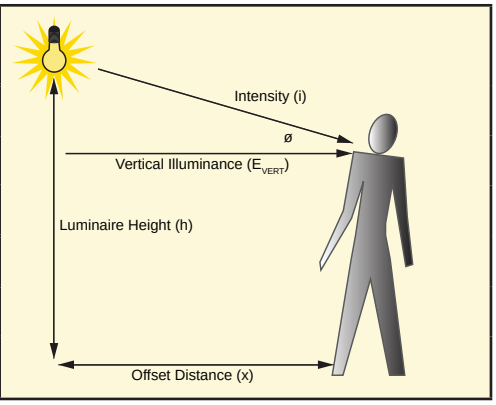
- ✓ Illuminating Engineering Society (IES) – IES RP-8-22 Lighting Roadway and Parking Facilities
- ✓ AASHTO Roadway Lighting Design Guide
- ✓ FHWA Roadway Lighting Handbook
- ✓ State DOT Design Manuals
- ✓ UFC 3-530-01 Interior and Exterior Lighting Systems
- ✓ UFGS 26 56 00 Exterior Lighting

20.1.1. 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 20.1 shows a range of some illumination levels.

Exhibit 20.1: 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 is measured at a location 6 inches above the ground. Although illuminance is typically measured on a horizontal surface, the term "vertical illuminance" is used for the ID check areas, 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 faces, 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 20.2 shows minimum illuminance levels at select locations within DoW installations.

Exhibit 20.2: Minimum Illuminance

LOCATION	MINIMUM ILLUMINANCE (FOOT-CANDLES)	NOTES
Parking Lots	✓ 1-2 (average illuminance)	✓ The maximum-to-minimum uniformity ratio should be not greater than 15:1
Pedestrian Areas	✓ 0.1 - 1.0 vertical illuminance	✓ 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 6-2 in UFC 3-530-01

20.1.2. 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 were once the most common lamp type, but they are now discouraged for new applications due to limited efficiency, longevity, and poor color rendering.
- ✓ Pulse-start metal halide (MH) lamps were previously the lamp of choice for most exterior lighting due to their excellent color and high efficiency. These HID lamps produce light primarily through radiation of metal halides and their dissociation products, often combined with metallic vapors such as mercury. However, due to long restrike and warm-up periods, they require backup lighting when used for security purposes. (Note: Standard MH lamps are less efficient and durable than pulse-start types.)
- ✓ Quartz-halogen lamps remain inefficient but offer excellent color and fast startup, making them suitable for backup lighting applications.
- ✓ Incandescent lamps provide excellent color rendering but are highly inefficient and rarely used in modern exterior lighting systems.
- ✓ Fluorescent lamps offer good color and can be rapid start but are generally being phased out in favor of more efficient technologies.
- ✓ Light emitting diode (LED) lighting is now the preferred choice for most exterior applications. LED luminaires are widely available to replace traditional cobrahead fixtures or to be used in new lighting systems. LEDs consume significantly less power than legacy luminaires and have become more reliable, with gradual lumen depreciation now better managed through improved driver and thermal designs. Agencies are increasingly confident in LED performance, and modern systems include monitoring to detect illumination loss.

LEDs are replacing other lamp types. Some advantages of LEDs include:

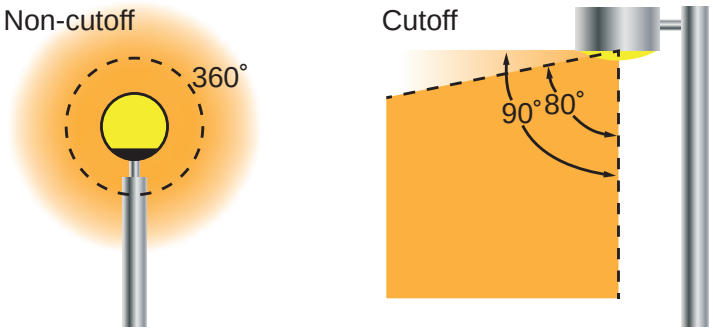
- ✓ Reduced energy consumption
- ✓ Lower maintenance costs
- ✓ More uniform illuminance
- ✓ Elimination of backup lamp requirements
- ✓ Reduced insect attraction due to lower UV output

20.1.3. Light Trespass

Light trespass is unwanted spill light that extends beyond the property boundary or intended area. Direct visibility of a light source that causes excessive brightness is glare.To help promote dark skies and minimize light trespass, whenever possible, use full cutoff luminaires as addressed in Exhibit 20.3.

Exhibit 20.3: 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



In addition to the traditional cutoff classifications shown in Exhibit 20.3, the Illuminating Engineering Society (IES) currently evaluates outdoor luminaires using the Luminaire Classification System (LCS). This system assigns Backlight, Uplight, and Glare (BUG) ratings to quantify a luminaire's potential for light trespass, sky glow, and visual glare. Lower BUG ratings indicate greater control of light outside the intended area. The BUG rating system is summarized in Exhibit 20.4 and may be used when evaluating or specifying outdoor luminaires.

Exhibit 20.4: IES BUG Luminaire Classification System

COMPONENT	RATING RANGE
Backlight (B)	B0-B5
Uplight (U)	U0-U5
Glare (G)	G0-G5

Notes:
- ✓ *BUG ratings are expressed as Bx-Ux-Gx (e.g., B1-U0-G1).*
- ✓ *Lower ratings indicate greater control of backlight, uplight, and glare.*
- ✓ *BUG ratings are determined from photometric testing and zonal lumen calculations.*

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 20.3 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.

20.1.4. 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 closed circuit television (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.

20.1.5. 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 20.4 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 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 larger restrike and warm-up times.

Exhibit 20.5: 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	Previously 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

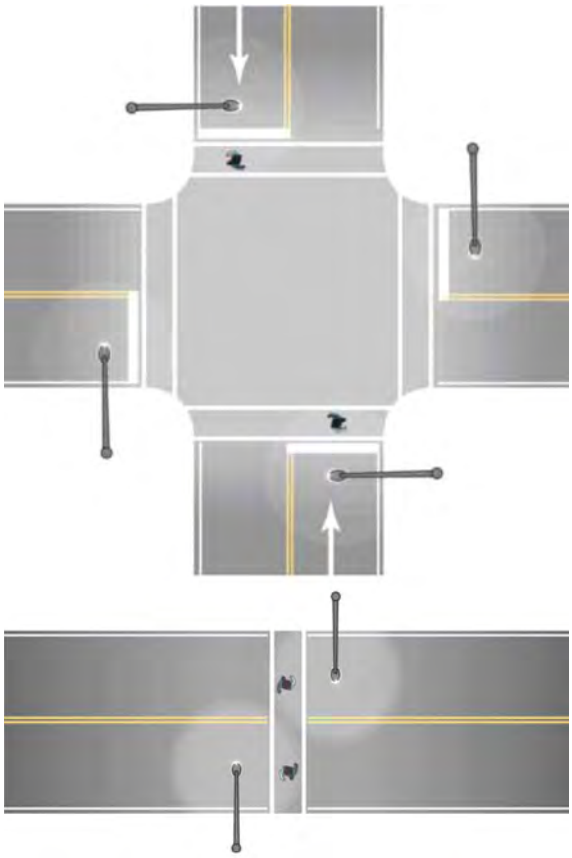
20.2. INTERSECTION AND CROSSWALK LIGHTING

Intersection lighting increases motorist and pedestrian visibility and reduces crash potential. Although the *MUTCD* does not address warrants, it suggests implementing 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.

Numerous lighting guidelines have been established by city, state, and federal agencies, as well as independent national organizations, to ensure proper illumination standards are met. 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 requirements.

Pedestrians are the most vulnerable road users at night. Based on average crash data, pedestrians are between three and seven times more vulnerable in the dark than during daylight hours. In an effort to improve visibility of pedestrians, the preferred location of light standards for intersection and midblock crosswalks is as illustrated in Exhibit 20.5.

Exhibit 20.6: Recommended Location for Luminaires at Intersections and Midblock Crosswalks



According to the TEA *Crosswalk Warrant and Guidelines*, all crosswalks spanning uncontrolled approaches without stop, yield, or signal control at intersections and midblock locations must be equipped with lighting. This requirement is particularly critical for uncontrolled approaches, as traffic is not obligated to stop or slow unless a pedestrian is present, emphasizing the need for pedestrian visibility to drivers. Lighting is also recommended for controlled crossing locations to further enhance safety.

To improve pedestrian visibility, the preferred placement of luminaires for intersection and midblock crosswalks is illustrated above. This configuration positions the lighting between the vehicle and the pedestrian, effectively illuminating the pedestrian's front as seen by the approaching driver. Conversely, placing the pedestrian between the vehicle and the light source is undesirable, as it only creates a silhouette, reducing visibility and safety for the pedestrian.

In the absence of mast arms, lighting is often installed on utility poles or dedicated light poles. All poles, including signal mast arms, light poles, and utility poles should be positioned outside the clear zone, shielded by a barrier, or designed as breakaway structures (refer to Section 11). Common errors include placing non-breakaway pole bases too close to the roadway or elevating concrete foundations too high, creating roadside hazards even when the pole base is breakaway.

For continuous roadway lighting, light poles can be installed in parallel runs along the roadway. To ensure effective illumination, spacing should prevent shadowing effects caused by gaps that are too wide. The conical lighted area from one luminaire should slightly overlap with the lighted area of the adjacent luminaire. The appropriate spacing depends on the height and wattage of the luminaires. For example, a lighting design using 200-watt luminaires mounted at a height of 40 feet should maintain a spacing of 225 feet between poles.

20.3. PARKING LOT LIGHTING

In addition to enhancing security, parking lot lighting is essential for improving visibility between motorists and pedestrians, particularly as pedestrians often walk alongside vehicle parking aisles. In large PX and commissary parking lots, lighting also aids shoppers as they transfer goods from shopping carts to their vehicles.

The mounting height and spacing of luminaires should be designed to evenly distribute the desired lighting intensity across the entire parking area. Pole heights typically range from 20 to 50 feet or more, with standard lighting levels between 1 to 2 foot-candles and a maximum-to-minimum uniformity ratio not exceeding 15. Light fixtures should be positioned away from traffic aisles and parking stalls whenever possible, ideally located in islands protected by raised curbs.

For poles placed within parking rows, they should be installed at the junctions of adjacent stalls and mounted on 3-foot high concrete bases to prevent accidental knockdowns. While this approach is suitable for parking lots, high concrete bases should not be used on open roadways, where breakaway designs are required to accommodate higher travel speeds.

Poles and fixtures should be appropriately scaled to the setting and surrounding area while ensuring sufficient illumination of the parking lot. As shown in Exhibit 20.6, luminaires should be designed to direct light downward, promoting dark skies and minimizing light pollution.

Exhibit 20.7: Parking Lot Lighting utilizing Full Cutoff Lamps



20.4. 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 to provide vertical illuminance without producing disabling glare for approaching road users, flaggers, or workers.

APPENDIX A – SAMPLE SIGN LAYOUTS

Refer to *DoW Supplement to the MUTCD* for additional information.

Note: Refer to pamphlet pages 7-9 for details on sign designs. For example, the designation "6D" in the dimensions table means a 6-inch letter height designed using Series D typography, and a "3B" designation means a 3-inch text height using Series B typography.

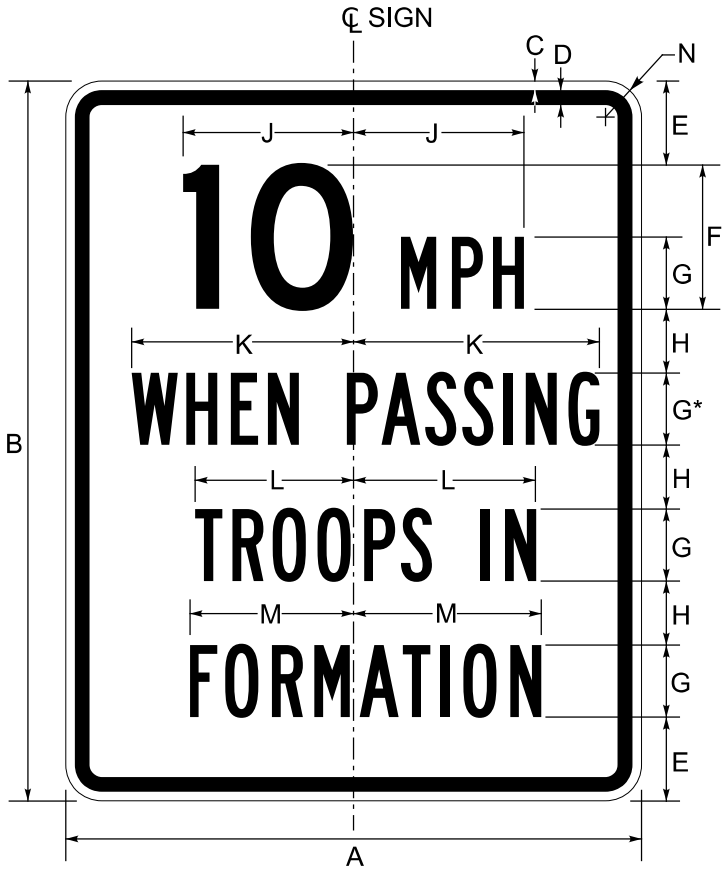
APPENDIX A – STANDARD TEA SIGNS

SIGN CODE	SIGN NAME	PAGE NUMBER
R2-1aP-TEA	10 MPH WHEN PASSING TROOPS INFORMATION PLAQUE	A-1
R2-5hP-TEA	BASE PLAQUE	A-2
R2-5iP-TEA	INSTALLATION PLAQUE	A-3
R4-31-TEA	VISITORS (RIGHT)	A-4
R4-31-TEA	VISITORS (45)	A-5
R4-31-TEA	VISITORS (STRAIGHT)	A-6
R4-31-TEA	TRUCKS (RIGHT)	A-7
R4-31-TEA	TRUCKS (45)	A-8
R4-31-TEA	TRUCKS (STRAIGHT)	A-9
R4-32-TEA	VISITORS/TRUCKS (RIGHT)	A-10
R4-32-TEA	VISITORS/TRUCKS (STRAIGHT)	A-11
R4-32-TEA	VISITORS/TRUCKS (LEFT)	A-12
R4-32-TEA	VISITORS/TRUCKS (45)	A-13
R4-33-TEA	VISITORS/TRUCKS/POVS (RIGHT)	A-14
R4-33-TEA	VISITORS/TRUCKS/POVS (STRAIGHT)	A-15
R4-33-TEA	VISITORS/TRUCKS/POVS (LEFT)	A-16
R4-33-TEA	VISITORS/TRUCKS/POVS (45)	A-17
R5-11a-TEA	GOVERNMENT VEHICLES ONLY	A-18
R5-11b-TEA	NO TACTICAL VEHICLES	A-19
R5-29-TEA	SEVERE TIRE DAMAGE	A-20
R5-30-TEA	DO NOT BACK UP – ONE-WAY TIRE SPIKES	A-21
R10-13a-TEA	BARRIER SIGNAL	A-22
R11-2d-TEA	GATE CLOSED	A-23
R11-5-TEA	ROAD CLOSED FOR PT	A-24
R16-16-TEA	USE SEAT BELTS	A-25
R16-17-TEA	USE PARKING LIGHTS AT GATE	A-26
R16-18P-TEA	PROCEED ONLY WHEN DIRECTED BY GUARD PLAQUE	A-27
R16-19-TEA	STAY IN VEHICLE	A-28
R16-20-TEA	GATE ARM IN USE – ONE VEHICLE AT A TIME	A-29
R22-2-TEA	TURN OFF 2-WAY RADIO AND CELL PHONE	A-30
R22-3-TEA	NO RADIO TRANSMISSIONS	A-31
R22-4-TEA	RADIO TRANSMISSIONS PERMITTED	A-32
W1-5P-TEA	CHICANE PLAQUE	A-33
W3-3a-TEA	BARRIER ACTIVATED AHEAD	A-34
W3-10a-TEA	CHECKPOINT	A-35
W3-10b-TEA	CHECKPOINT (___) FEET—BE PREPARED TO STOP	A-36
W11-26-TEA	LOW AIRCRAFT	A-37
W11-27-TEA	TAXIWAY	A-38
W11-28-TEA	TANK CROSSING	A-39
W11-29-TEA	HAZARDOUS CARGO CROSSING	A-40
W16-22P-TEA	APPLICABLE HOURS	A-41
W20-3g-TEA	GATE CLOSED AHEAD	A-42

APPENDIX A - STANDARD TEA SIGNS

R2-1aP-TEA
10 MPH WHEN PASSING TROOPS INFORMATION PLAQUE

The 10 MPH WHEN PASSING TROOPS IN FORMATION (R2-1aP-TEA) plaque may be used along roads where troops periodically walk in formation on the roadway. When a lower speed limit is determined to be necessary due to troop movement in the roadway, the R2-1aP-TEA sign should be used. The sign shall only be used as a supplement and mounted below the R2-1 speed limit sign.



DIMENSIONS (INCHES)												
A	B	C	D	E	F	G	H	J	K	L	M	N
24	30	.38	.62	3.50	6D	3B	2.67	7.02	9.75	7.10	7.32	1.50

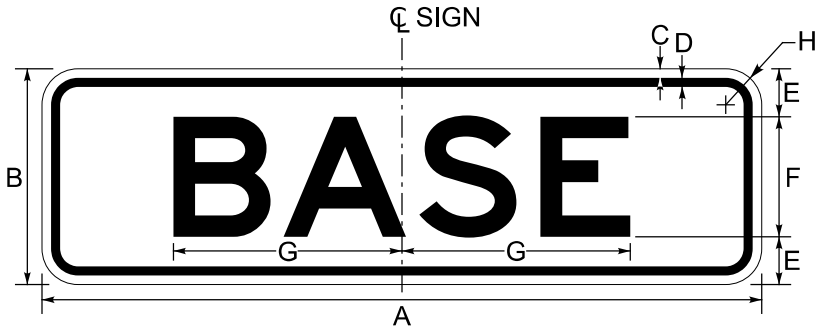
*Reduce spacing 15%

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 to reduce the number of Speed Limit signs throughout the installation. In lieu of the word "BASE," an INSTALLATION (R2-5iP-TEA) plaque may be installed above the R2-1 sign. If there are roadways within this boundary with a different regulatory speed limit, then an UNLESS OTHERWISE POSTED (R2-5P) plaque should also be mounted below the R2-1 sign. A RESIDENTIAL (R2-5cP) plaque may also be installed above the R2-1 sign when the posting is at a residential area.

When Speed Limit supplemental signs are used to establish speed boundaries or areas, military installations are recommended 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 should be mounted on the left side 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.



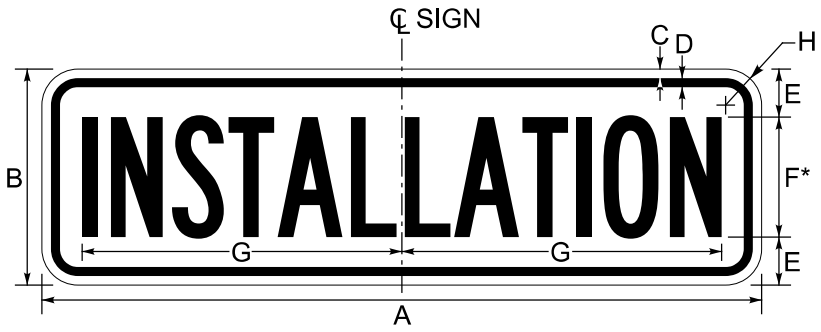
DIMENSIONS (INCHES)							
A	B	C	D	E	F	G	H
24	6	.38	.38	1.25	3.5B	6.67	1.50
30	9	.38	.38	2.00	5E	9.525	1.50

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 to reduce the number of Speed Limit signs throughout the installation. In lieu of the word "INSTALLATION," a BASE (R2-5hP-TEA) plaque may be installed above the R2-1 sign due to the shorter message. If there are roadways within this boundary with a different regulatory speed limit, then an UNLESS OTHERWISE POSTED (R2-5P) plaque should also be mounted below the R2-1 sign. A RESIDENTIAL (R2-5cP) plaque may also be installed above the R2-1 sign when the posting is at a residential area.

When Speed Limit supplemental signs are used to establish speed boundaries or areas, military installations are recommended 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 should be mounted on the left side 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.



DIMENSIONS (INCHES)							
A	B	C	D	E	F	G	H
24	6	.38	.38	1.25	3.5B	9.33	1.50
30	9	.38	.38	2.00	5B	13.325	1.50

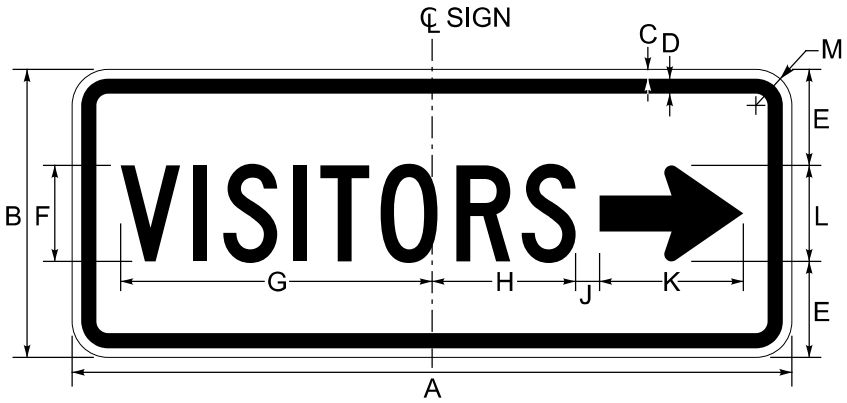
*Reduce spacing 50%

COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-31-TEA
VISITORS (RIGHT)

The VISITORS (R4-31-TEA) sign may be used to guide visitor traffic toward designated entry control points, visitor centers, or parking areas. The R4-31-TEA sign is intended to provide clear directional information for non-regular drivers who may be unfamiliar with an installation layout. The sign should normally be installed at intersections or decision points where visitors must turn or continue in a specific direction.

Left arrows should be placed to the left side of the word, and right and straight-ahead arrows should be placed to the right side of the word.



DIMENSIONS (INCHES)											
A	B	C	D	E	F	G	H	J	K	L	M
30	12	.38	.63	4.00	4C	12.98	5.98	1.00	6.00	4.00	1.50

NOTE: For a left-turning sign, the design is simply mirrored horizontally (i.e., the entire layout is flipped across the vertical centerline). Relocate the arrow block (K = 6.00") and the gap (J = 1.00") to be on the left side of the text.

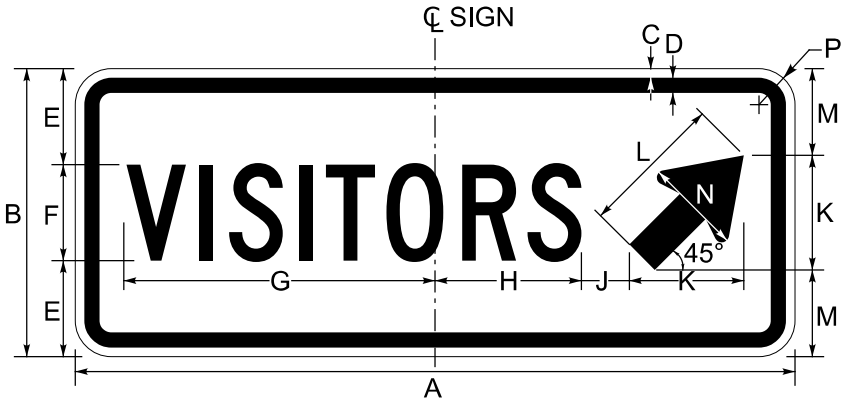
COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-31-TEA

VISITORS (45)

The VISITORS (R4-31-TEA) sign may be used to guide visitor traffic toward designated entry control points, visitor centers, or parking areas. The R4-31-TEA sign is intended to provide clear directional information for non-regular drivers who may be unfamiliar with an installation layout. The sign should normally be installed at intersections or decision points where visitors must turn or continue in a specific direction.

Left arrows should be placed to the left side of the word, and right and straight-ahead arrows should be placed to the right side of the word.



DIMENSIONS (INCHES)													
A	B	C	D	E	F	G	H	J	K	L	M	N	P
30	12	.38	.63	4.00	4C	12.98	5.98	2.00	4.78	6.00	3.61	4.00	1.50

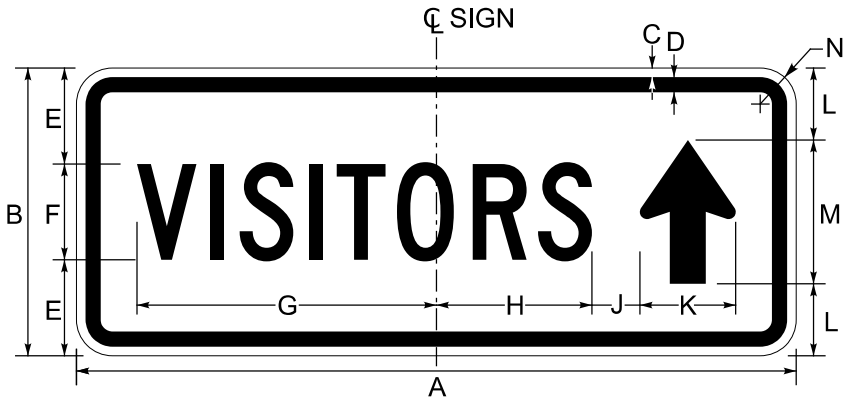
COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-31-TEA

VISITORS (STRAIGHT)

The VISITORS (R4-31-TEA) sign may be used to guide visitor traffic toward designated entry control points, visitor centers, or parking areas. The R4-31-TEA sign is intended to provide clear directional information for non-regular drivers who may be unfamiliar with an installation layout. The sign should normally be installed at intersections or decision points where visitors must turn or continue in a specific direction.

Left arrows should be placed to the left side of the word, and right and straight-ahead arrows should be placed to the right side of the word.



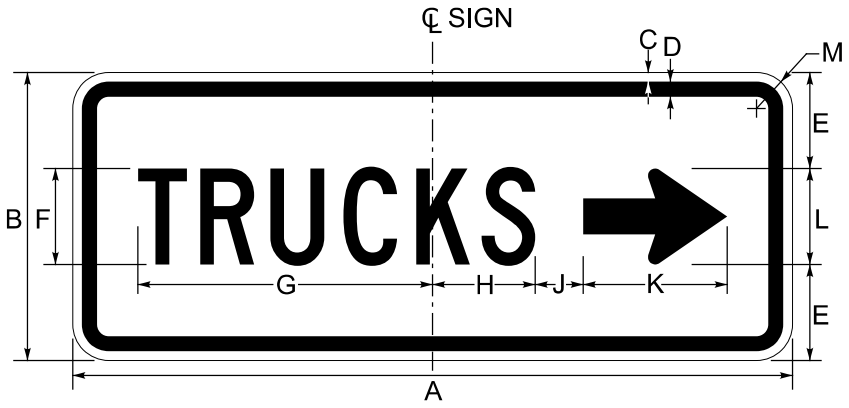
DIMENSIONS (INCHES)												
A	B	C	D	E	F	G	H	J	K	L	M	N
30	12	.38	.63	4.00	4C	12.48	6.48	2.00	4.00	3.00	6.00	1.50

COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-31-TEA
TRUCKS (RIGHT)

The VISITORS (R4-31-TEA) sign may be used to guide visitor traffic toward designated entry control points, visitor centers, or parking areas. The R4-31-TEA sign is intended to provide clear directional information for non-regular drivers who may be unfamiliar with an installation layout. The sign should normally be installed at intersections or decision points where visitors must turn or continue in a specific direction.

Left arrows should be placed to the left side of the word, and right and straight-ahead arrows should be placed to the right side of the word.



DIMENSIONS (INCHES)											
A	B	C	D	E	F	G	H	J	K	L	M
30	12	.38	.63	4.00	4C	12.28	4.28	2.00	6.00	4.00	1.50

NOTE: For a left-turning sign, the design is simply mirrored horizontally (i.e., the entire layout is flipped across the vertical centerline). Relocate the arrow block (K = 6.00") and the gap (J = 1.00") to be on the left side of the text.

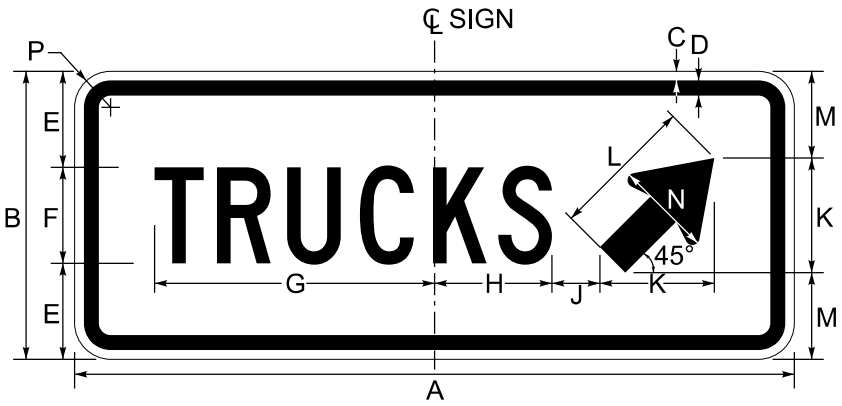
COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-31-TEA

TRUCKS (45)

The VISITORS (R4-31-TEA) sign may be used to guide visitor traffic toward designated entry control points, visitor centers, or parking areas. The R4-31-TEA sign is intended to provide clear directional information for non-regular drivers who may be unfamiliar with an installation layout. The sign should normally be installed at intersections or decision points where visitors must turn or continue in a specific direction.

Left arrows should be placed to the left side of the word, and right and straight-ahead arrows should be placed to the right side of the word.



DIMENSIONS (INCHES)													
A	B	C	D	E	F	G	H	J	K	L	M	N	P
30	12	.38	.63	4.00	4C	11.67	4.89	2.00	4.78	6.00	3.61	4.00	1.50

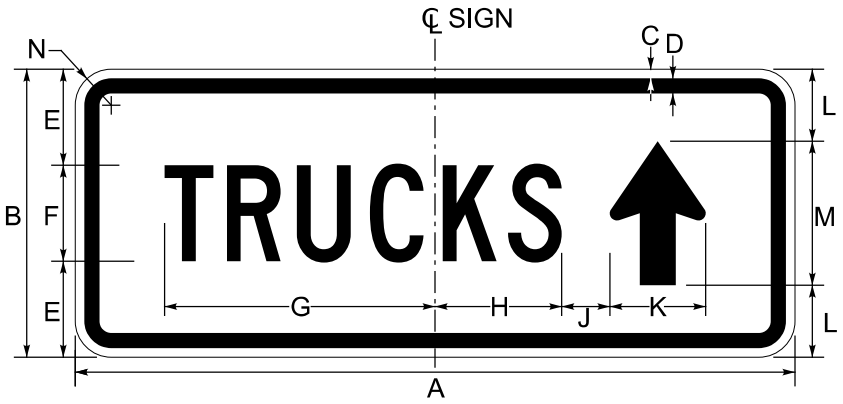
COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-31-TEA

TRUCKS (STRAIGHT)

The VISITORS (R4-31-TEA) sign may be used to guide visitor traffic toward designated entry control points, visitor centers, or parking areas. The R4-31-TEA sign is intended to provide clear directional information for non-regular drivers who may be unfamiliar with an installation layout. The sign should normally be installed at intersections or decision points where visitors must turn or continue in a specific direction.

Left arrows should be placed to the left side of the word, and right and straight-ahead arrows should be placed to the right side of the word.



DIMENSIONS (INCHES)												
A	B	C	D	E	F	G	H	J	K	L	M	N
30	12	.38	.63	4.00	4C	11.28	5.28	2.00	4.00	3.00	6.00	1.50

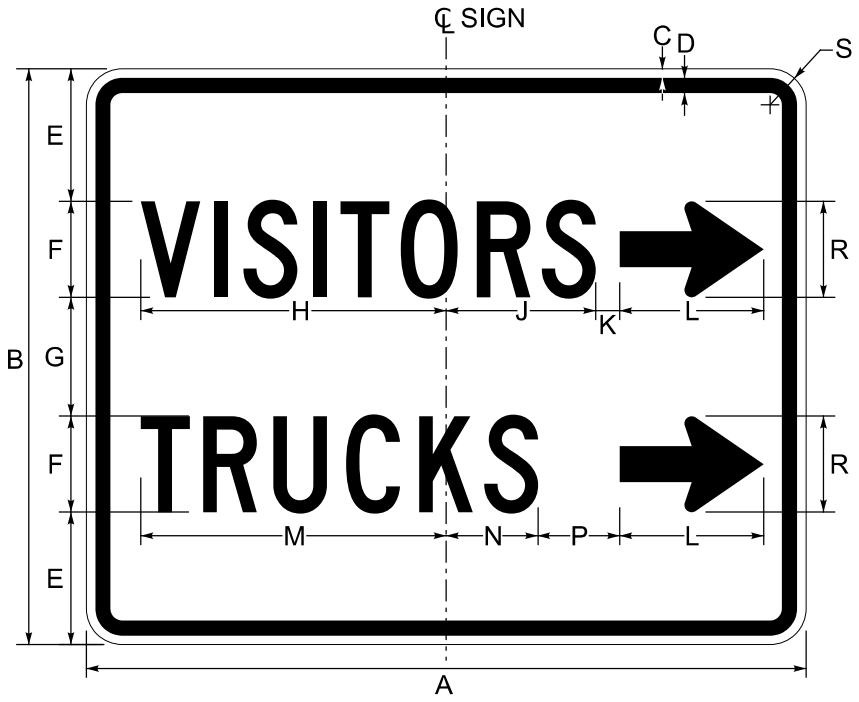
COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-32-TEA

VISITORS/TRUCKS (RIGHT)

The VISITORS/TRUCKS (R4-32-TEA) sign may be used to guide visitor traffic and truck traffic toward designated entry control points, inspection areas, or parking facilities. The R4-32-TEA sign is intended to provide clear directional information for drivers who may be unfamiliar with an installation layout.

Left arrows should be placed to the left side of the word, and right and straight-ahead arrows should be placed to the right side of the word.



DIMENSIONS (INCHES)															
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
30	24	.38	.63	5.52	4C	4.96	12.73	6.23	1.00	6.00	12.73	3.83	3.40	4.00	1.50

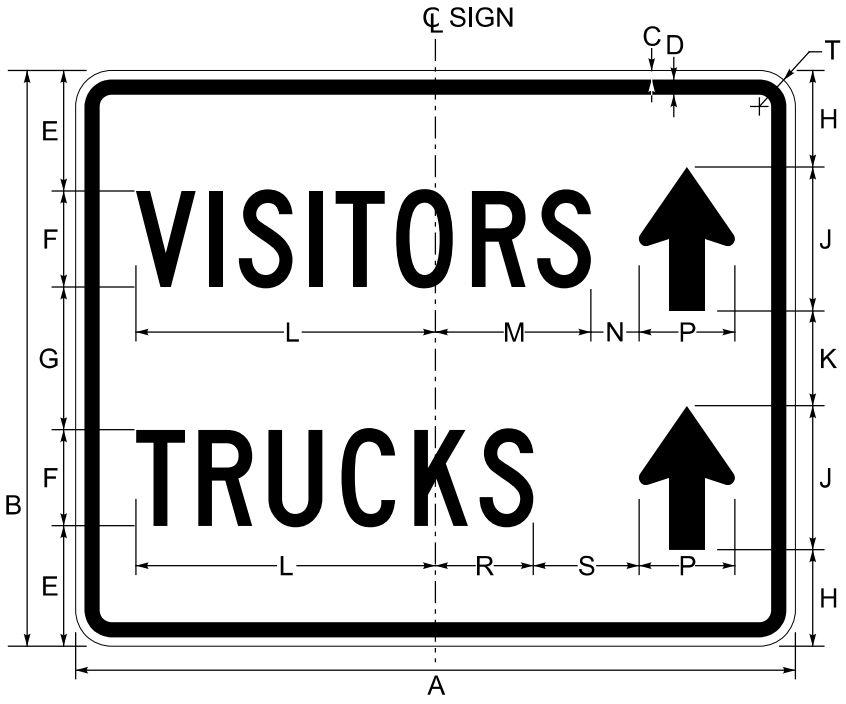
COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-32-TEA

VISITORS/TRUCKS (STRAIGHT)

The VISITORS/TRUCKS (R4-32-TEA) sign may be used to guide visitor traffic and truck traffic toward designated entry control points, inspection areas, or parking facilities. The R4-32-TEA sign is intended to provide clear directional information for drivers who may be unfamiliar with an installation layout.

Left arrows should be placed to the left side of the word, and right and straight-ahead arrows should be placed to the right side of the word.



DIMENSIONS (INCHES)																
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T
30	24	.38	.63	5.02	4C	5.96	4.02	6.00	3.96	12.48	6.48	2.00	4.00	4.08	4.40	1.50

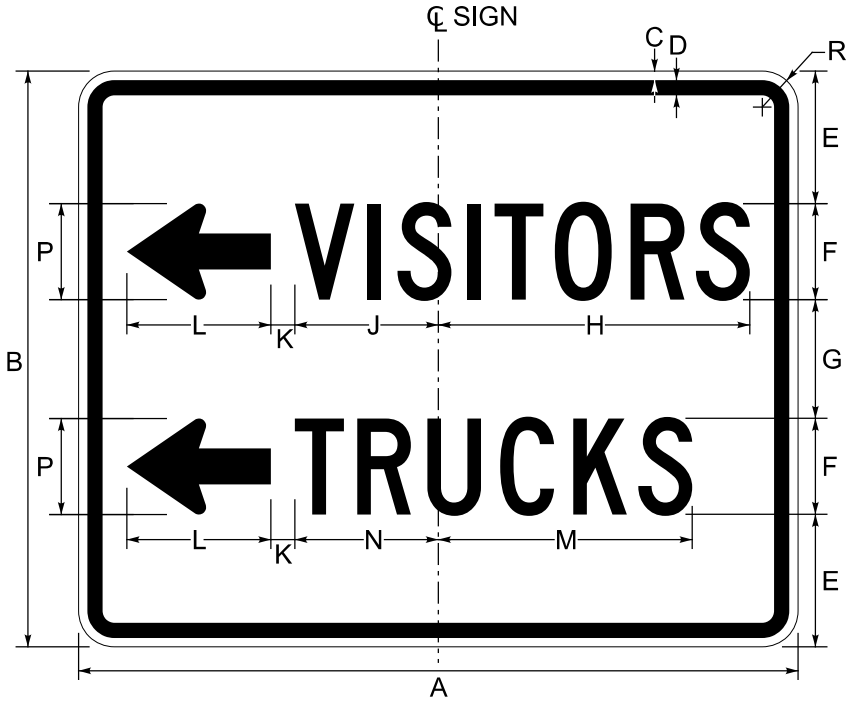
COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-32-TEA

VISITORS/TRUCKS (LEFT)

The VISITORS/TRUCKS (R4-32-TEA) sign may be used to guide visitor traffic and truck traffic toward designated entry control points, inspection areas, or parking facilities. The R4-32-TEA sign is intended to provide clear directional information for drivers who may be unfamiliar with an installation layout.

Left arrows should be placed to the left side of the word, and right and straight-ahead arrows should be placed to the right side of the word.



DIMENSIONS (INCHES)														
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
30	24	.38	.63	5.52	4C	4.96	12.98	5.98	1.00	6.00	10.58	5.98	4.00	1.50

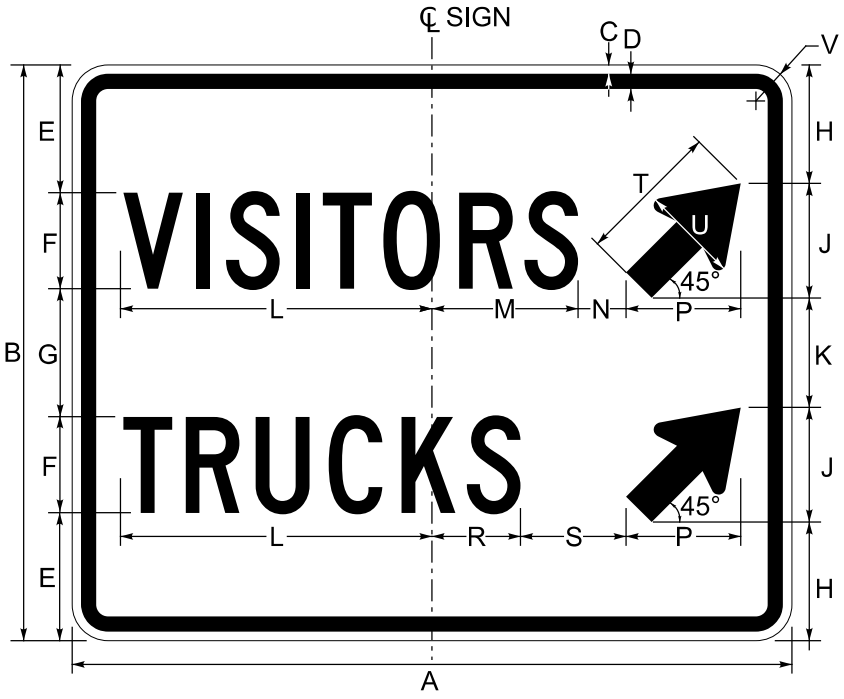
COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-32-TEA

VISITORS/TRUCKS (45)

The VISITORS/TRUCKS (R4-32-TEA) sign may be used to guide visitor traffic and truck traffic toward designated entry control points, inspection areas, or parking facilities. The R4-32-TEA sign is intended to provide clear directional information for drivers who may be unfamiliar with an installation layout.

Left arrows should be placed to the left side of the word, and right and straight-ahead arrows should be placed to the right side of the word.



DIMENSIONS (INCHES)																		
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V
30	24	.38	.63	5.33	4C	5.34	4.94	4.77	4.58	12.98	6.09	2.00	4.78	3.69	4.40	6.00	4.00	1.50

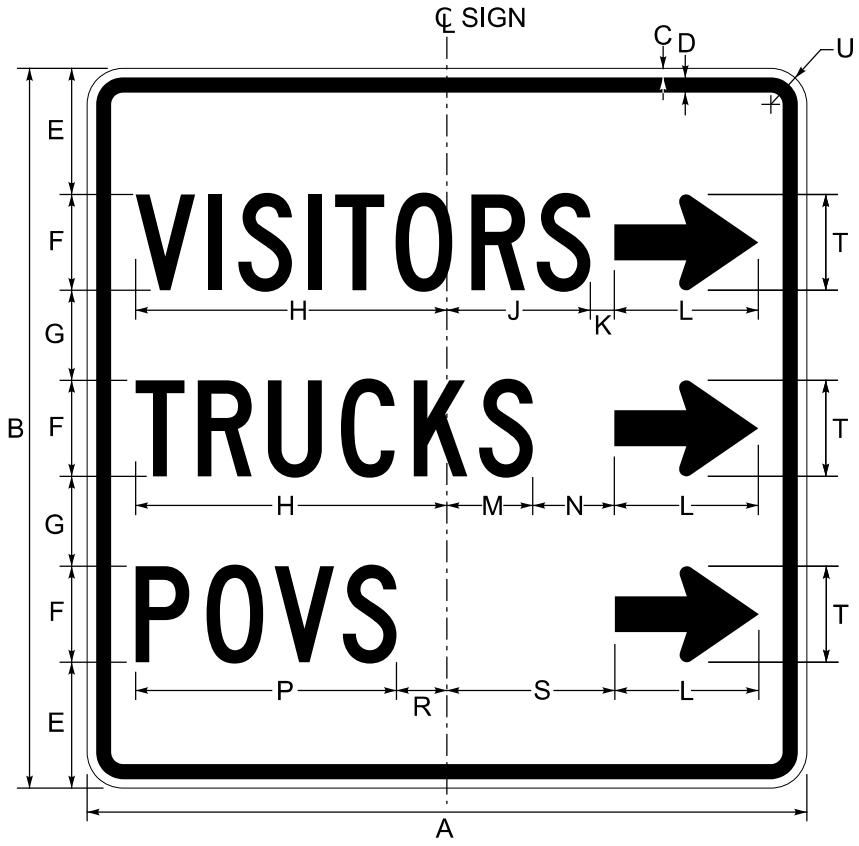
COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-33-TEA

VISITORS/TRUCKS/POVS (RIGHT)

The VISITORS/TRUCKS/POVs (R4-33-TEA) sign may be used to guide visitor traffic, truck traffic, and privately owned vehicle (POV) traffic toward designated entry control points, inspection areas, visitor centers, or parking facilities. The R4-33-TEA sign is intended to provide clear directional information for drivers who may be unfamiliar with an installation layout.

Left arrows should be placed to the left side of the words, and right and straight-ahead arrows should be placed to the right side of the words.



DIMENSIONS (INCHES)																	
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U
30	30	.38	.63	5.25	4C	3.75	12.98	5.98	1.00	6.00	3.58	6.98	10.88	3.15	10.50	4.00	1.50

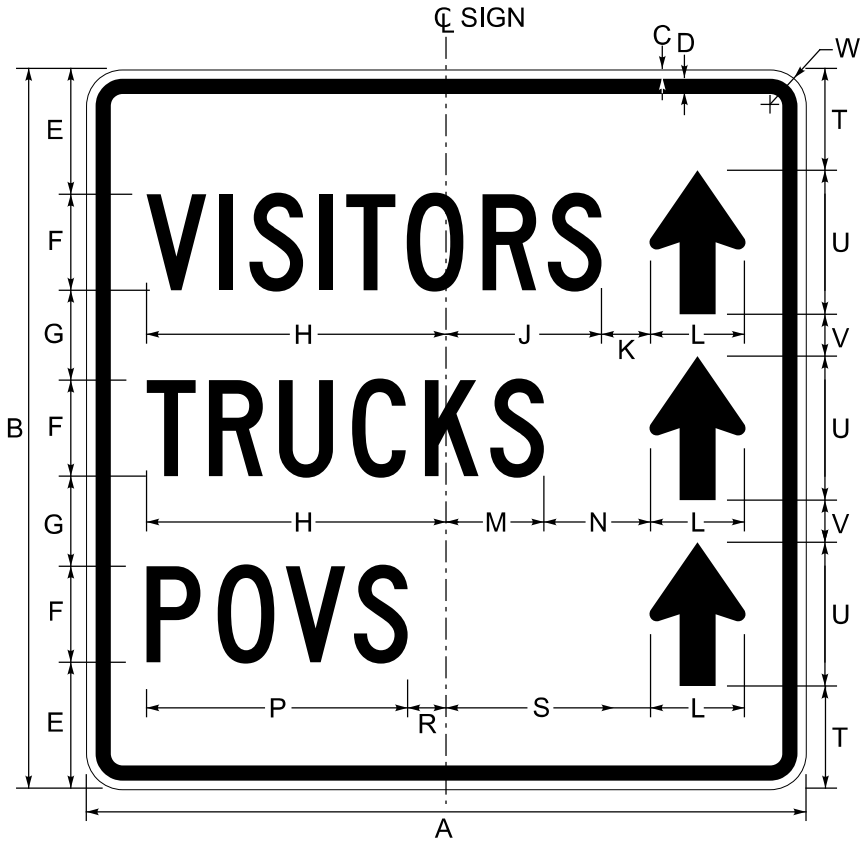
COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-33-TEA

VISITORS/TRUCKS/POVS (STRAIGHT)

The VISITORS/TRUCKS/POVs (R4-33-TEA) sign may be used to guide visitor traffic, truck traffic, and privately owned vehicle (POV) traffic toward designated entry control points, inspection areas, visitor centers, or parking facilities. The R4-33-TEA sign is intended to provide clear directional information for drivers who may be unfamiliar with an installation layout.

Left arrows should be placed to the left side of the words, and right and straight-ahead arrows should be placed to the right side of the words.



DIMENSIONS (INCHES)																		
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W
30	30	.38	.63	5.25	4C	3.75	12.48	6.48	2.05	6.00	4.08	4.45	10.88	1.60	8.53	4.25	6.00	1.75	1.50

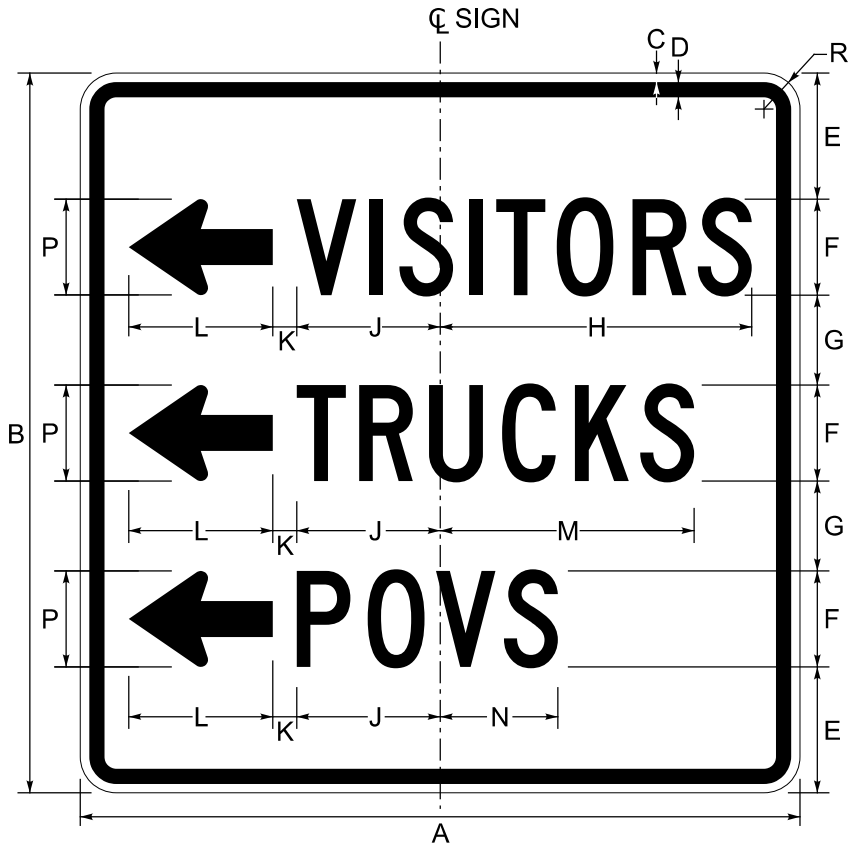
COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-33-TEA

VISITORS/TRUCKS/POVS (LEFT)

The VISITORS/TRUCKS/POVs (R4-33-TEA) sign may be used to guide visitor traffic, truck traffic, and privately owned vehicle (POV) traffic toward designated entry control points, inspection areas, visitor centers, or parking facilities. The R4-33-TEA sign is intended to provide clear directional information for drivers who may be unfamiliar with an installation layout.

Left arrows should be placed to the left side of the words, and right and straight-ahead arrows should be placed to the right side of the words.



DIMENSIONS (INCHES)														
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
30	30	.38	.63	5.25	4C	3.75	12.98	5.98	1.00	6.00	10.58	4.90	4.00	1.50

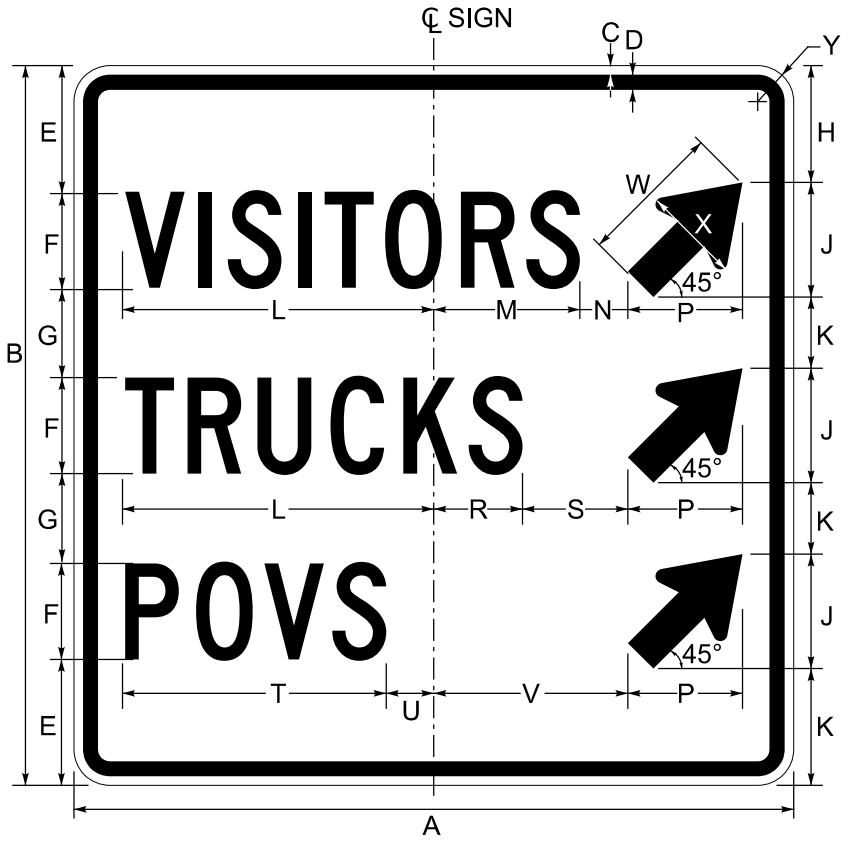
COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R4-33-TEA

VISITORS/TRUCKS/POVS (45)

The VISITORS/TRUCKS/POVs (R4-33-TEA) sign may be used to guide visitor traffic, truck traffic, and privately owned vehicle (POV) traffic toward designated entry control points, inspection areas, visitor centers, or parking facilities. The R4-33-TEA sign is intended to provide clear directional information for drivers who may be unfamiliar with an installation layout.

Left arrows should be placed to the left side of the words, and right and straight-ahead arrows should be placed to the right side of the words.



DIMENSIONS (INCHES)																				
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y
30	30	.38	.63	5.25	4C	3.75	4.87	4.77	2.97	12.87	6.09	2.00	4.78	3.69	4.40	10.88	1.99	8.09	6.00	4.00	1.50

COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R5-11a-TEA
GOVERNMENT VEHICLES ONLY

The GOVERNMENT VEHICLES ONLY (R5-11a-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 R5-11a-TEA sign is on a Type III barricade that is placed close to the traveled way for added emphasis.



DIMENSIONS (INCHES)										
A	B	C	D	E	F	G	H	J	K	L
30	24	.38	.63	3.50	4C	2.50	12.96	10.32	5.75	1.50

* Reduce spacing 45%

COLORS:
BORDER & LEGEND –BLACK
BACKGROUND – WHITE (RETROREFLECTIVE)

R5-11b-TEA

NO TACTICAL VEHICLES

The NO TACTICAL VEHICLES (R5-11b-TEA) sign may be used at locations where tactical vehicles are excluded from regular use on the roadway.



DIMENSIONS (INCHES)										
A	B	C	D	E	F	G	H	J	K	L
30	24	.38	.63	3.50	4C	2.50	2.70	9.94	10.32	1.50

COLORS:
BORDER & LEGEND –BLACK
BACKGROUND–WHITE (RETROREFLECTIVE)

R5-29-TEA

SEVERE TIRE DAMAGE

The SEVERE TIRE DAMAGE (R5-29-TEA) sign SHALL be used in the wrong-way direction of a one-way roadway that has tire spikes in place. When used, the R5-29-TEA sign should be mounted below a DO NOT ENTER (R5-1) sign that is installed adjacent to or in advance of the tire spikes. The DO NOT BACK UP - ONE-WAY TIRE SPIKES (R5-30-TEA) sign shall be used for the correct direction of travel. These signs may be mounted back-to-back on the same post.



DIMENSIONS (INCHES)									
A	B	C	D	E	F	G	H	J	K
30	24	.75	3.50	4E	2.50	11.34	6.24	12.40	1.50

COLORS:
BORDER & LEGEND – WHITE (RETROREFLECTIVE)
BACKGROUND – RED (RETROREFLECTIVE)

R5-30-TEA

DO NOT BACK UP – ONE-WAY TIRE SPIKES

The DO NOT BACK UP – ONE-WAY TIRE SPIKES (R5-30-TEA) sign shall be used when tire spikes are in place to instruct drivers not to back up. The SEVERE TIRE DAMAGE (R5-29-TEA) sign shall be used for the wrong-way direction of travel. These signs may be mounted back-to back on the same post.



DIMENSIONS (INCHES)																
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T
30	30	.38	.63	2.70	5C	2.50	1.85	.75	3D	1.65	9.78	11.68	10.00	8.52	11.49	1.50

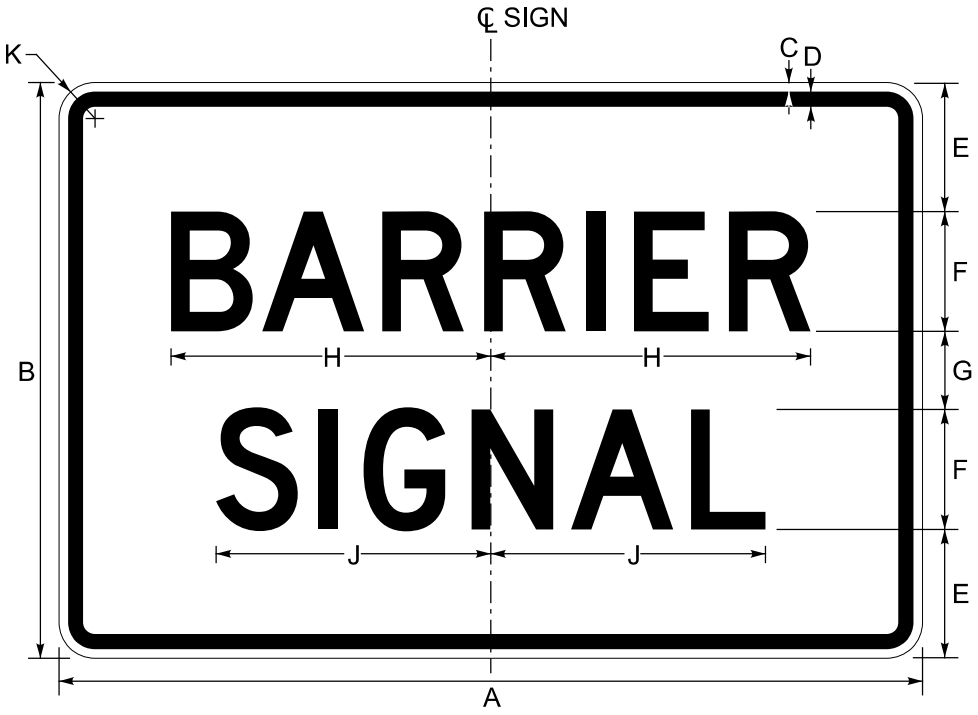
COLORS:
BORDER & LEGEND – BLACK
BACKGROUND – WHITE (RETROREFLECTIVE)

R10-13a-TEA

BARRIER SIGNAL

The BARRIER SIGNAL (R10-13a-TEA) sign shall be used in conjunction with traffic control signals or hybrid beacons located at active vehicle barriers (AVBs).

All approaches to AVBs shall conform substantially to a TEA AVB Safety Scheme as detailed in TEA Pamphlet 55-15, with the latest edition of the schemes provided on the TEA website. The R10-13a-TEA sign shall be mounted adjacent to the overhead signal face when required by the TEA AVB Safety Scheme selected for use.



DIMENSIONS (INCHES)									
A	B	C	D	E	F	G	H	J	K
36	24	.38	.63	5.37	5D	3.26	13.33	11.45	1.50

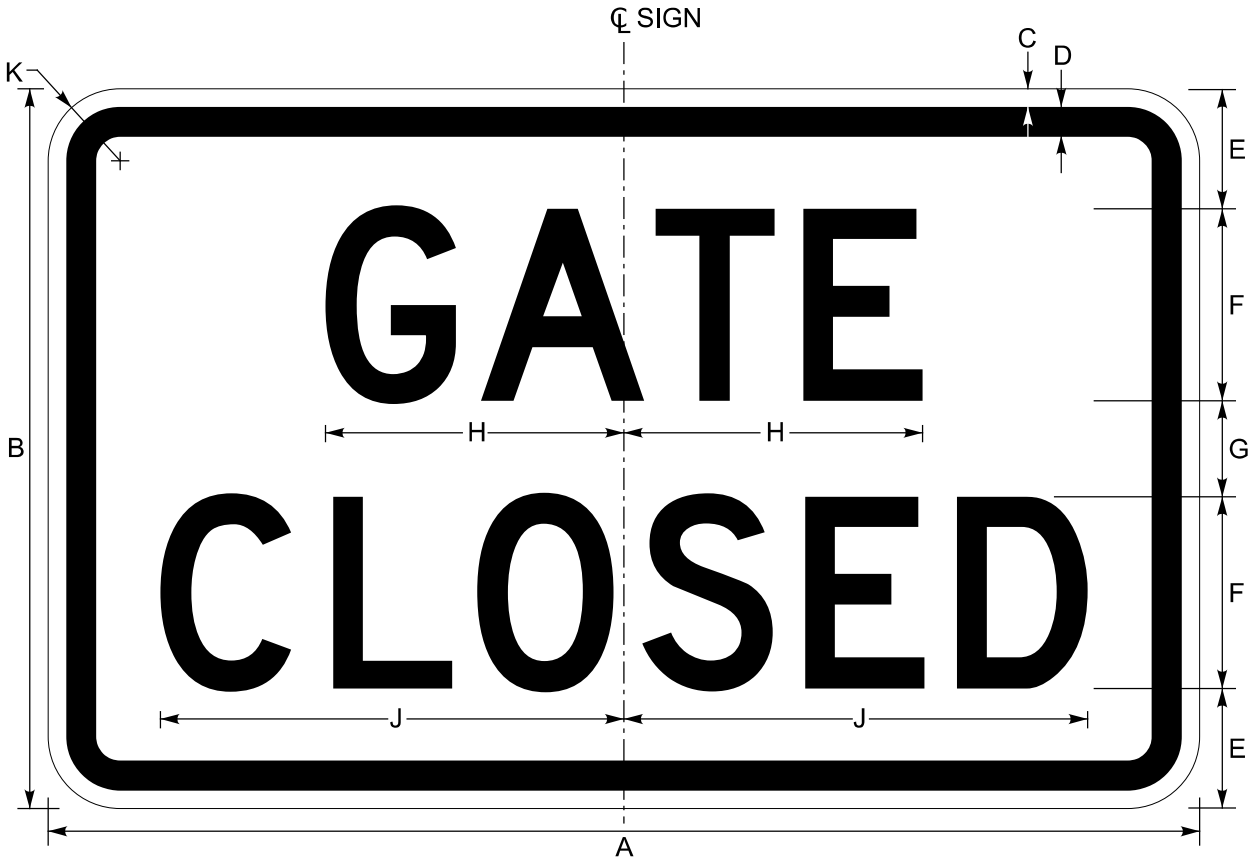
COLORS:
BORDER & LEGEND—BLACK
BACKGROUND—WHITE (RETROREFLECTIVE)

R11-2d-TEA

GATE CLOSED

The GATE CLOSED (R11-2d-TEA) sign shall be attached to a gate when the gate is used to close off a roadway. The R11-2d-TEA sign shall be used in combination with a horizontal sign panel (4 inches in height minimum) of retroreflective, alternating red and white vertical stripes (16 inches in width).

A minimum of two GATE CLOSED signs are required, one for the inbound approach and one for the outbound approach. STOP signs shall not be used in lieu of the GATE CLOSED sign.



DIMENSIONS (INCHES)									
A	B	C	D	E	F	G	H	J	K
48	30	.75	1.25	5.00	8D	4.00	12.44	19.32	1.88

COLORS:
BORDER & LEGEND – BLACK
BACKGROUND – WHITE (RETROREFLECTIVE)

R11-5-TEA

ROAD CLOSED FOR PT

The ROAD CLOSED FOR PT (R11-5-TEA) sign may be used to prohibit vehicular traffic during hours of physical training (PT) when the activity requires the prohibition of traffic for safety reasons. When used, the R11-5-TEA sign should be placed at the ends of the restriction where vehicles can turn to avoid the area.

When the road is routinely closed for PT, the R11-5-TEA shall be used.



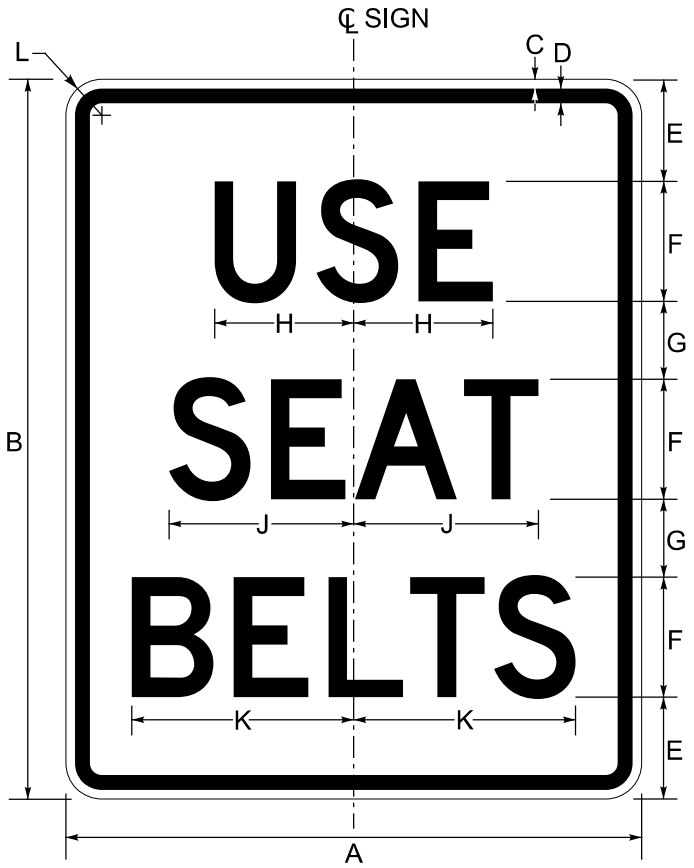
DIMENSIONS (INCHES)											
A	B	C	D	E	F	G	H	J	K	L	M
48	30	.75	1.25	3.25	8D	2.00	4D	13.40	19.32	19.44	1.88

COLORS:
BORDER & LEGEND - BLACK
BACKGROUND - WHITE (RETROREFLECTIVE)

R16-16-TEA

USE SEAT BELTS

The USE SEAT BELTS (R16-16-TEA) sign should 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. Note that if state laws require the use of seat belts, this sign is not required.



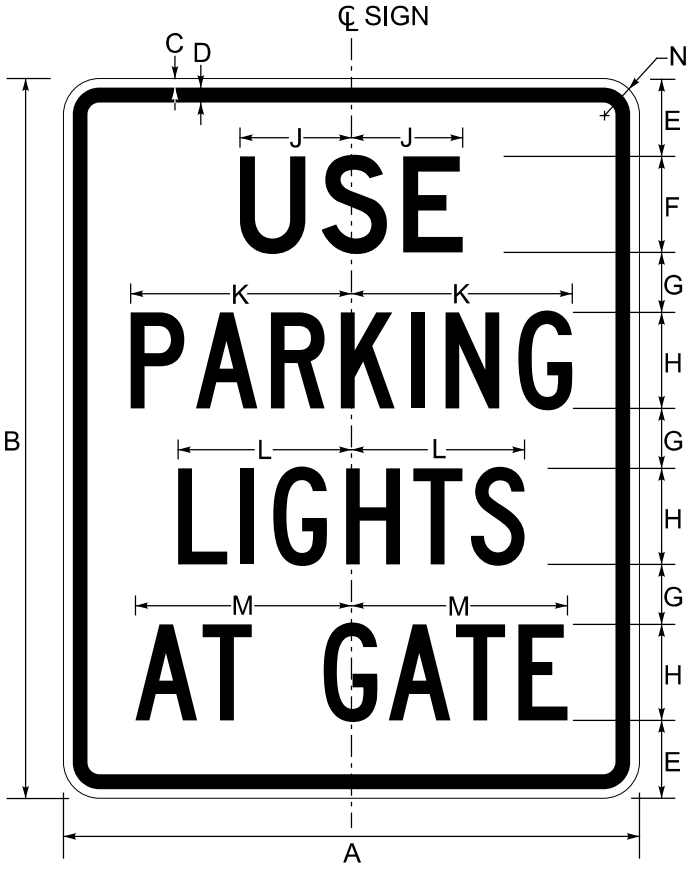
DIMENSIONS (INCHES)										
A	B	C	D	E	F	G	H	J	K	L
24	30	.38	.63	4.25	5D	3.25	5.80	7.70	9.25	1.50

COLORS:
BORDER & LEGEND –BLACK
BACKGROUND – WHITE (RETROREFLECTIVE)

R16-17-TEA

USE PARKING LIGHTS AT GATE

The USE PARKING LIGHTS AT GATE (R16-17-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.



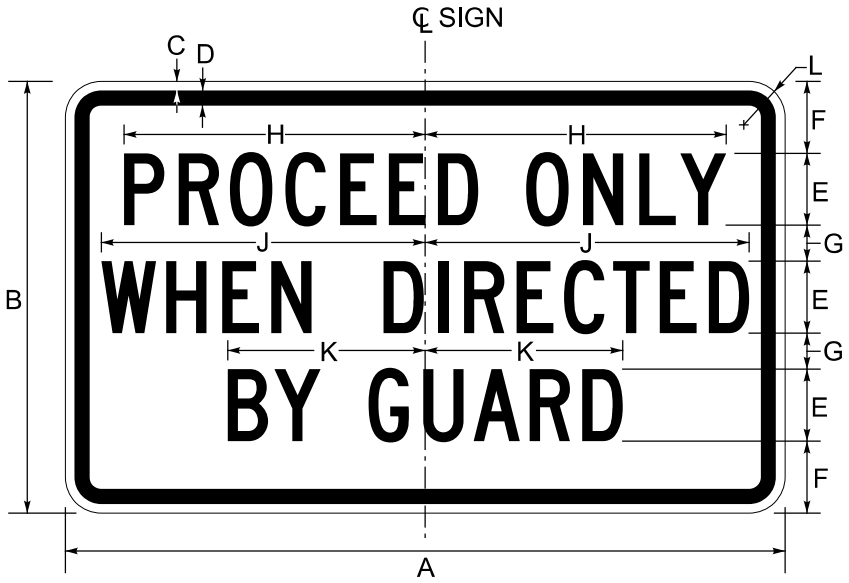
DIMENSIONS (INCHES)												
A	B	C	D	E	F	G	H	J	K	L	M	N
24	30	.38	.62	3.25	4D	2.50	4C	4.62	9.20	7.22	9.00	1.50

COLORS:
BORDER & LEGEND – BLACK
BACKGROUND – WHITE (RETROREFLECTIVE)

R16-18P-TEA

PROCEED ONLY WHEN DIRECTED BY GUARD PLAQUE

The PROCEED ONLY WHEN DIRECTED BY GUARD (R16-18P-TEA) plaque is intended as a supplemental sign to be used in conjunction with a STOP (R1-1) sign within the identification check area of an ECF. The R16-18P-TEA plaque shall be mounted directly below the STOP sign to provide clear instructions to drivers that they may only proceed when directed by the guard.



DIMENSIONS (INCHES)										
A	B	C	D	E	F	G	H	J	K	L
30	18	.38	.63	3C	3.00	1.50	12.55	13.50	8.23	1.50

COLORS:
BORDER & LEGEND –BLACK
BACKGROUND – WHITE (RETROREFLECTIVE)

R16-19-TEA

STAY IN VEHICLE

The STAY IN VEHICLE (R16-19-TEA) sign may be used at ECFs and vehicle inspection locations to instruct occupants to remain inside their vehicle unless directed otherwise by security personnel. When used, the sign should be placed at the inspection location where the instruction applies.



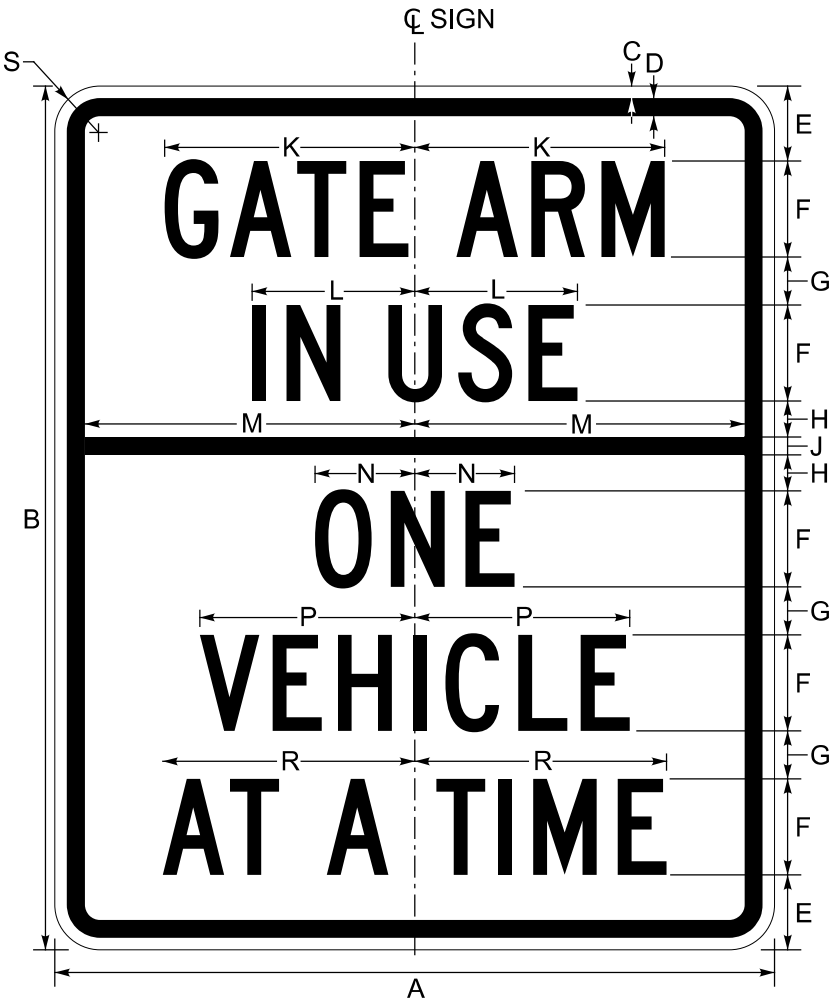
DIMENSIONS (INCHES)											
A	B	C	D	E	F	G	H	J	K	L	M
30	30	.50	.75	3.50	6D	2.50	6C	9.63	2.76	12.80	1.88

*Reduce spacing 20%

COLORS:
BORDER & LEGEND –BLACK
BACKGROUND – WHITE (RETROREFLECTIVE)

R16-20-TEA
GATE ARM IN USE – ONE VEHICLE AT A TIME

The GATE ARM IN USE – ONE VEHICLE AT A TIME (R16-20-TEA) sign may be used at ECFs, gated access points, and similar locations where gate arms are installed. The sign is intended to warn motorists that only one vehicle should proceed through the gate-controlled area at a time. When used, the sign should be installed in advance of the gate arm and prior to the ID check or inspection station.



DIMENSIONS (INCHES)															
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S
30	36	.50	.75	3.13	4C	2.00	1.50	.75	10.42	6.78	13.75	4.16	8.96	10.50	1.88

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 where localized restrictions on the use of two-way radios and cell phones exist due to the proximity of explosives or other sensitive areas. When used, the sign should be installed in advance of the restricted area.

When the R22-2-TEA sign is used, the RADIO TRANSMISSIONS PERMITTED (R22-4-TEA) sign should also be used, as appropriate, to inform drivers when the prohibition no longer applies.



DIMENSIONS (INCHES)													
A	B	C	D	E	F	G	H	J	K	L	M	N	P
42	36	.63	.75	5.00	7C	4.00	4C	1.50	18.34	14.68	4.24	14.40	2.25

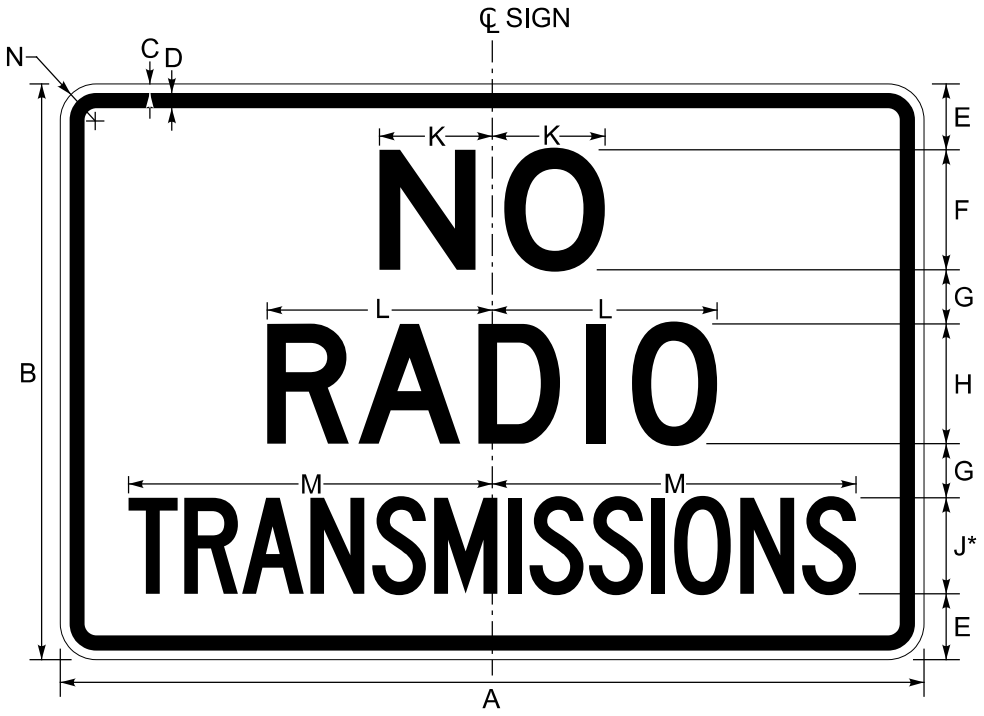
COLORS:
BORDER & LEGEND – BLACK
BACKGROUND – WHITE (RETROREFLECTIVE)

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.



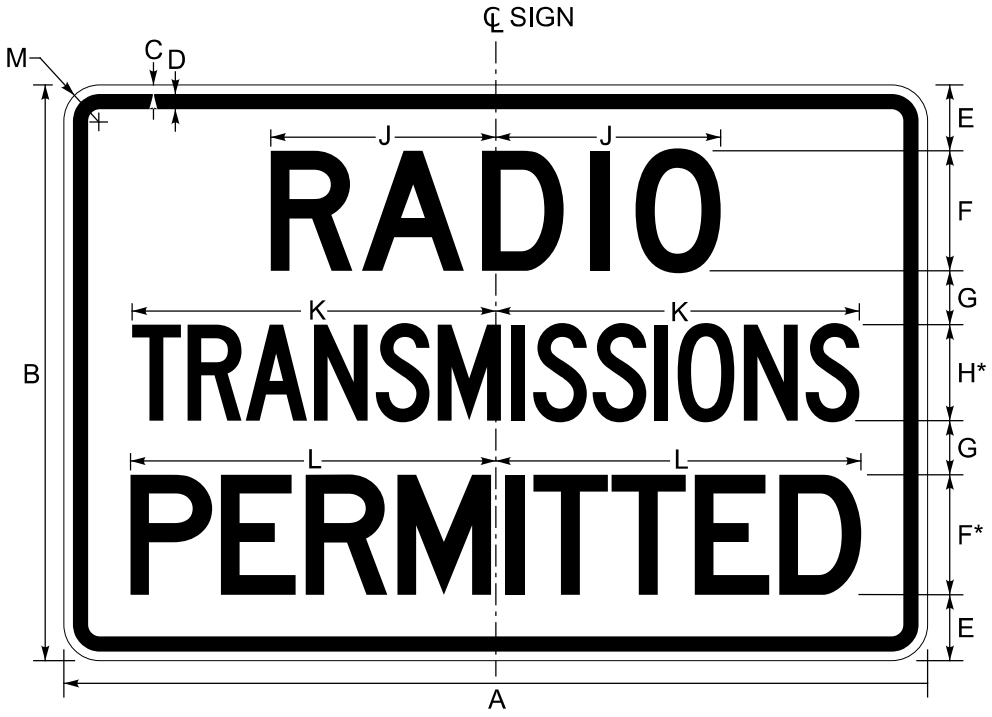
DIMENSIONS (INCHES)												
A	B	C	D	E	F	G	H	J	K	L	M	N
36	24	.38	.63	2.75	5E	2.25	5D	4C	4.70	9.375	15.16	1.50

*Reduce spacing 50%

COLORS:
BORDER & LEGEND – BLACK
BACKGROUND – WHITE (RETROREFLECTIVE)

R22-4-TEA
RADIO TRANSMISSIONS PERMITTED

The RADIO TRANSMISSIONS PERMITTED (R22-4-TEA) sign should 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 the prohibition no longer applies and it is again safe to make radio transmissions.



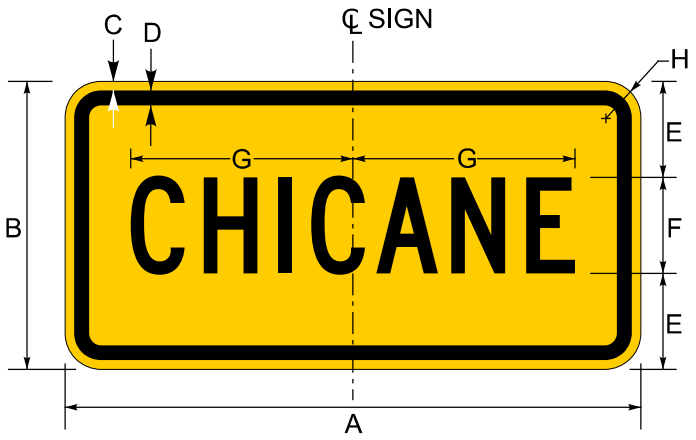
DIMENSIONS (INCHES)											
A	B	C	D	E	F	G	H	J	K	L	M
36	24	.38	.63	2.75	5D	2.25	4C	9.375	15.16	15.225	1.50

*Reduce spacing 50%

COLORS:
BORDER & LEGEND – BLACK
BACKGROUND – WHITE (RETROREFLECTIVE)

W1-5P-TEA
CHICANE PLAQUE

The CHICANE (W1-5P-TEA) plaque 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.



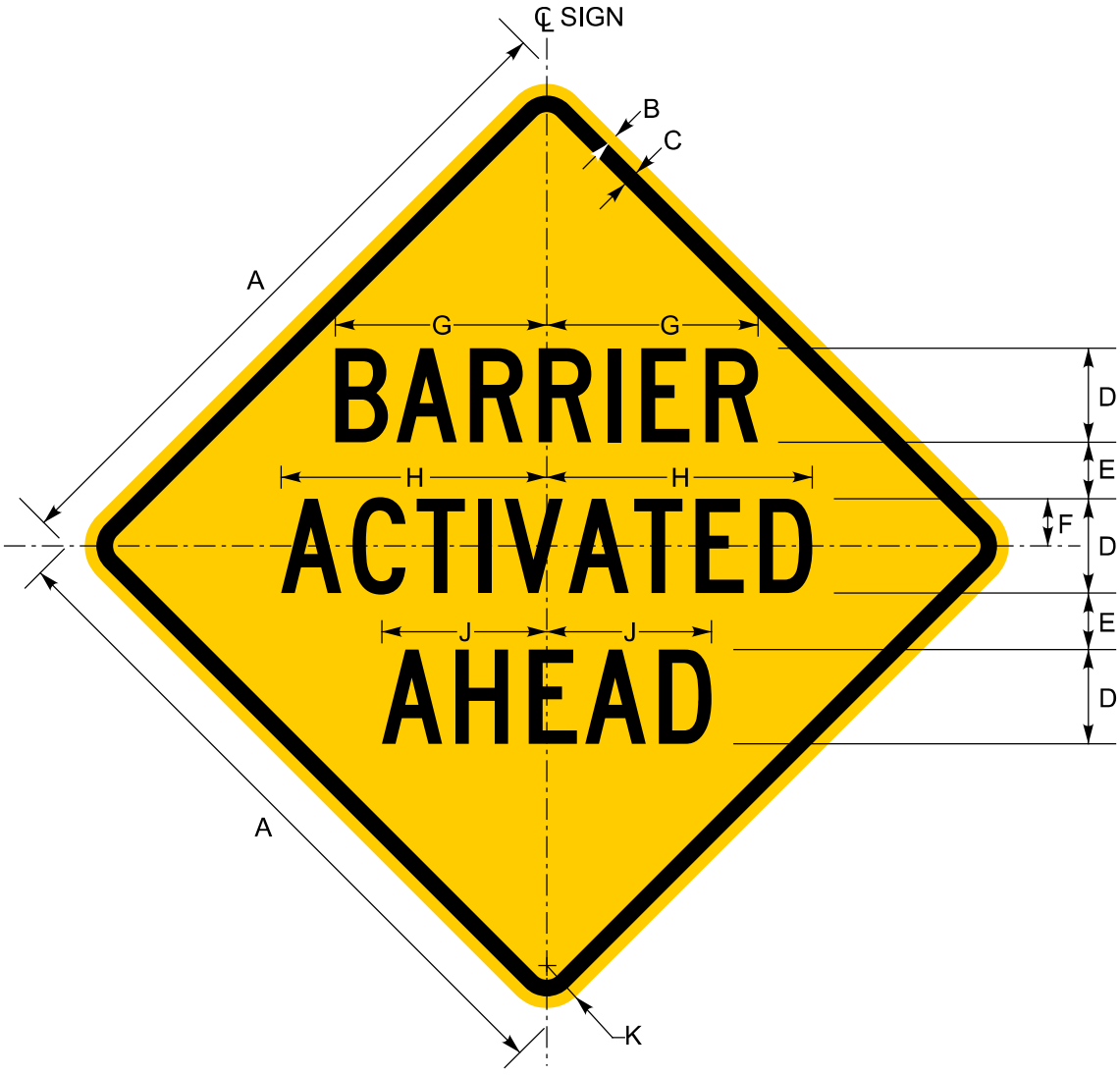
DIMENSIONS (INCHES)							
A	B	C	D	E	F	G	H
24	12	.38	.63	4.00	4C	9.26	1.50

COLORS:
BORDER & LEGEND – BLACK
BACKGROUND – YELLOW (RETROREFLECTIVE)

W3-3a-TEA
BARRIER ACTIVATED AHEAD

The BARRIER ACTIVATED AHEAD (W3-3a-TEA) sign shall be used to warn drivers that they are approaching an active vehicle barrier (AVB). The W3-3a-TEA sign is the first sign to alert drivers as they approach the AVB.

The WHEN FLASHING (W16-13P) plaque shall be installed below the W3-3a-TEA sign to advise drivers that the warning applies only when the amber flashing beacons are operating. Amber flashing beacons, which are activated simultaneously with the activation of the AVB, shall be used in conjunction with the sign assembly to provide clear and unmistakable warning to drivers.



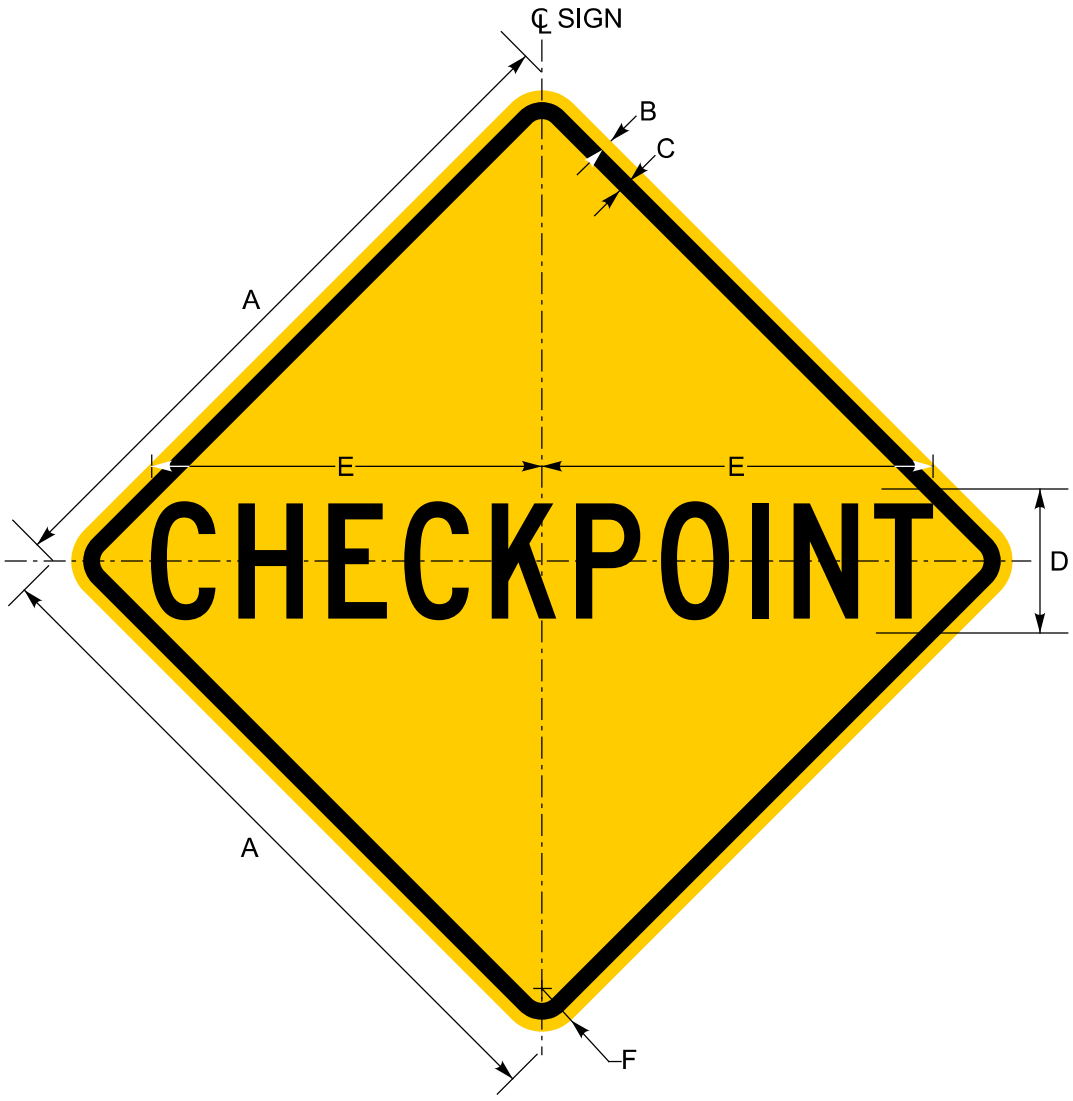
DIMENSIONS (INCHES)									
A	B	C	D	E	F	G	H	J	K
36	.62	.88	5C	3.00	2.50	11.225	14.10	8.75	2.25

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 TEA *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.



DIMENSIONS (INCHES)					
A	B	C	D	E	F
36	.62	.88	4C	20.37	2.25

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.

ECFs shall have a CHECKPOINT (W3-10a-TEA) sign with the AHEAD (W16-9P) plaque or with the XX FEET (W16-2P) plaque in advance of the checkpoint. The CHECKPOINT XX FEET – BE PREPARED TO STOP (W3-10b-TEA) sign may be used in addition to the CHECKPOINT AHEAD sign (W3-10a-TEA and W16-9P) to emphasize approaching checkpoint, especially on long roadway approaches, high speed roadways and multi-lane facilities.

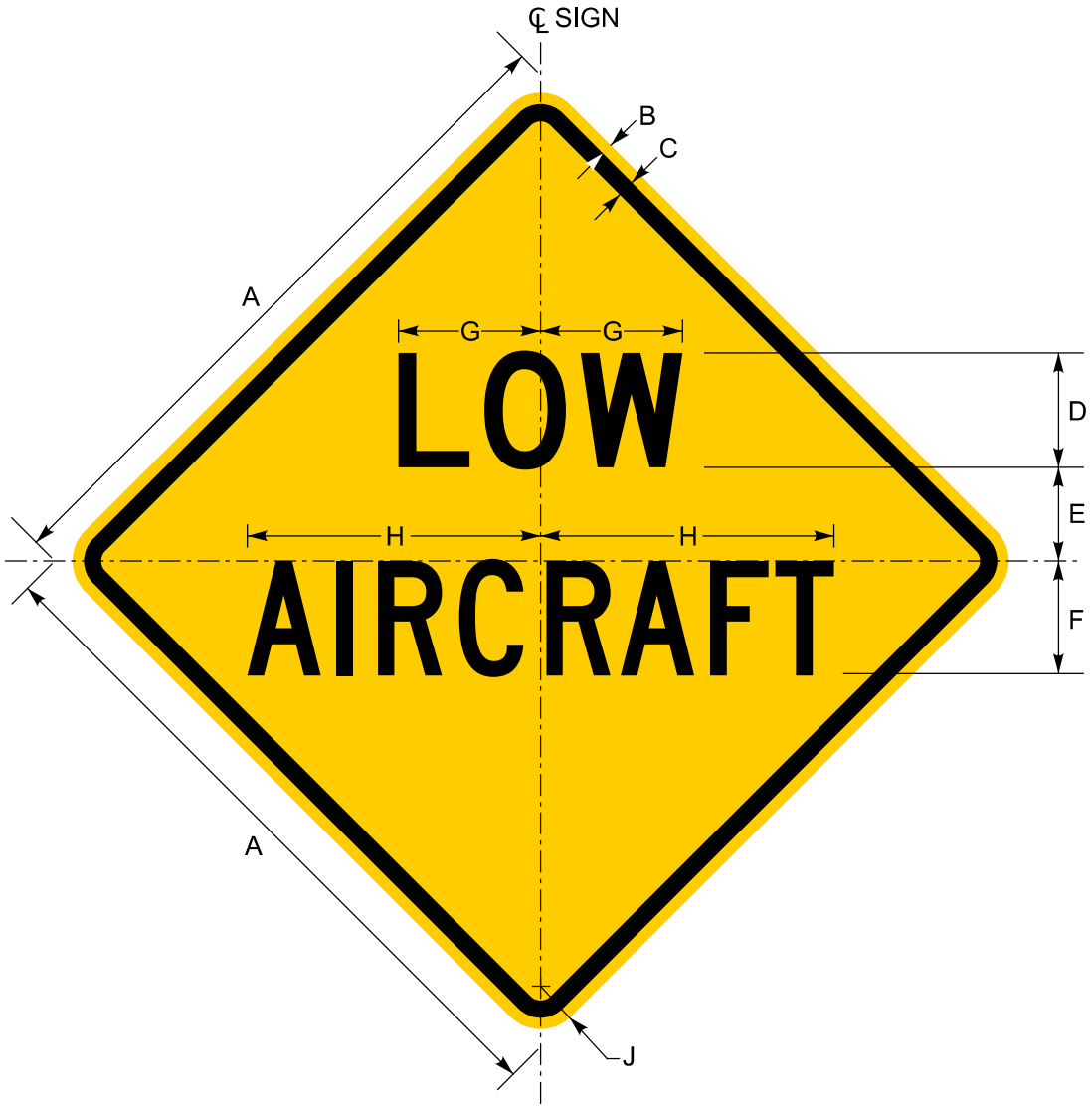


DIMENSIONS (INCHES)														
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
84	60	.75	1.25	5.32	8D	4.75	3.30	1.26	31.80	29.04	32.00	36.00	22.32	3.00

COLORS:
BORDER & LEGEND – BLACK
BACKGROUND – YELLOW (RETROREFLECTIVE)

W11-26-TEA
LOW AIRCRAFT

The LOW AIRCRAFT (W11-26-TEA) sign may be used in advance of a runway 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.



DIMENSIONS (INCHES)								
A	B	C	D	E	F	G	H	J
30	.50	.75	5D	4.10	5C	6.20	12.80	1.88
36	.63	.88	6D	4.81	6C	7.44	15.36	2.25

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 alongside of the road.

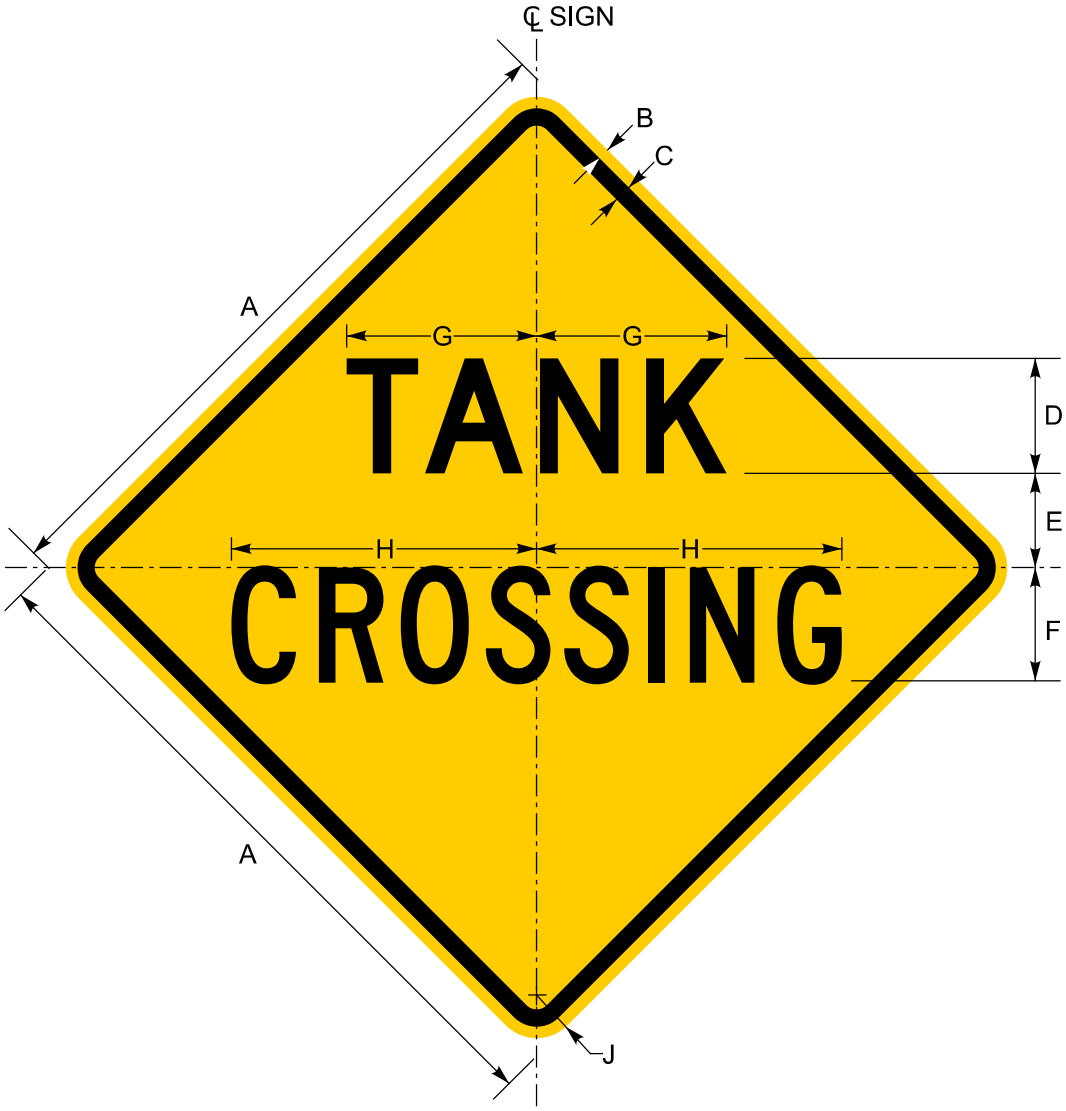


DIMENSIONS (INCHES)						
A	B	C	D	E	F	G
30	.50	.75	6C	3.00	13.32	1.88
36	.63	.88	8C	4.00	17.76	2.25

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.

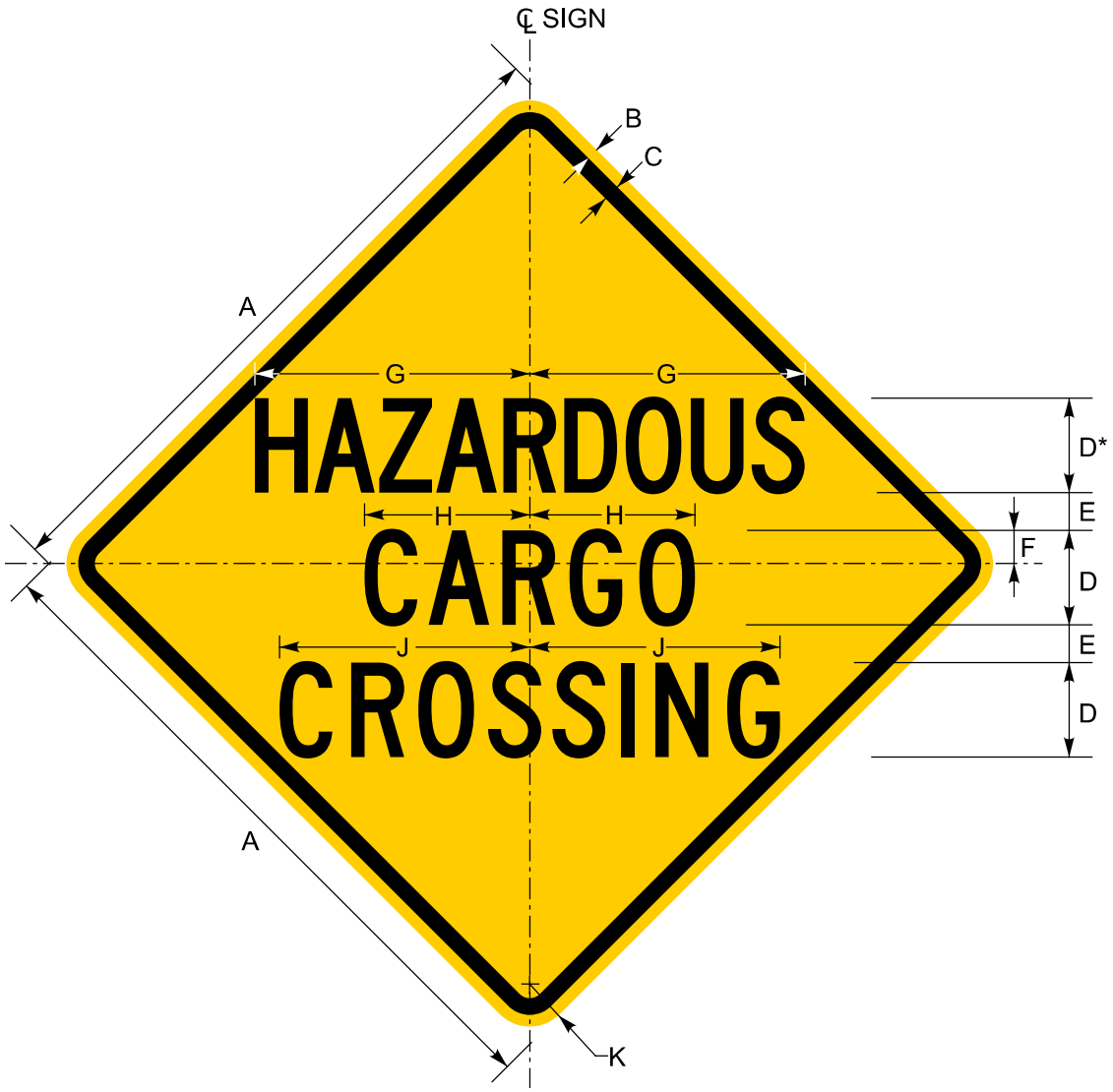


DIMENSIONS (INCHES)								
A	B	C	D	E	F	G	H	J
30	.50	.75	5D	4.10	5C	8.25	13.25	1.88
36	.63	.88	6D	4.81	6C	9.90	15.90	2.25

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.



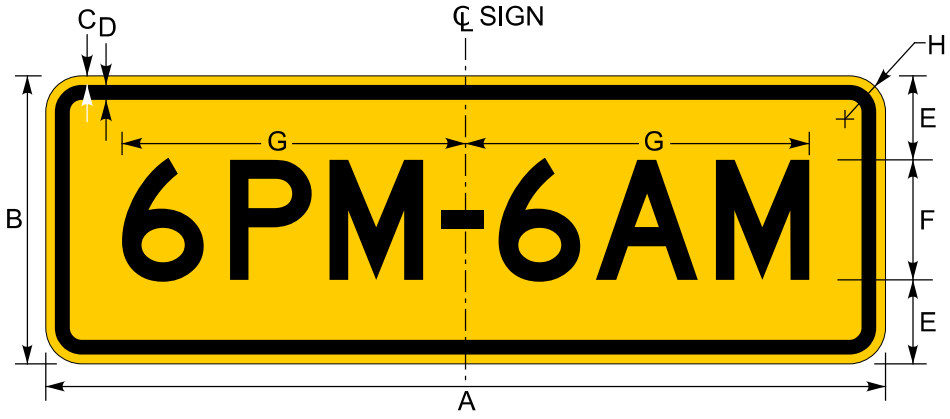
DIMENSIONS (INCHES)									
A	B	C	D	E	F	G	H	J	
30	.50	.75	4C	2.00	1.50	11.64	7.00	10.60	1.88
36	.63	.88	5C	2.00	1.75	14.55	8.75	13.25	2.25

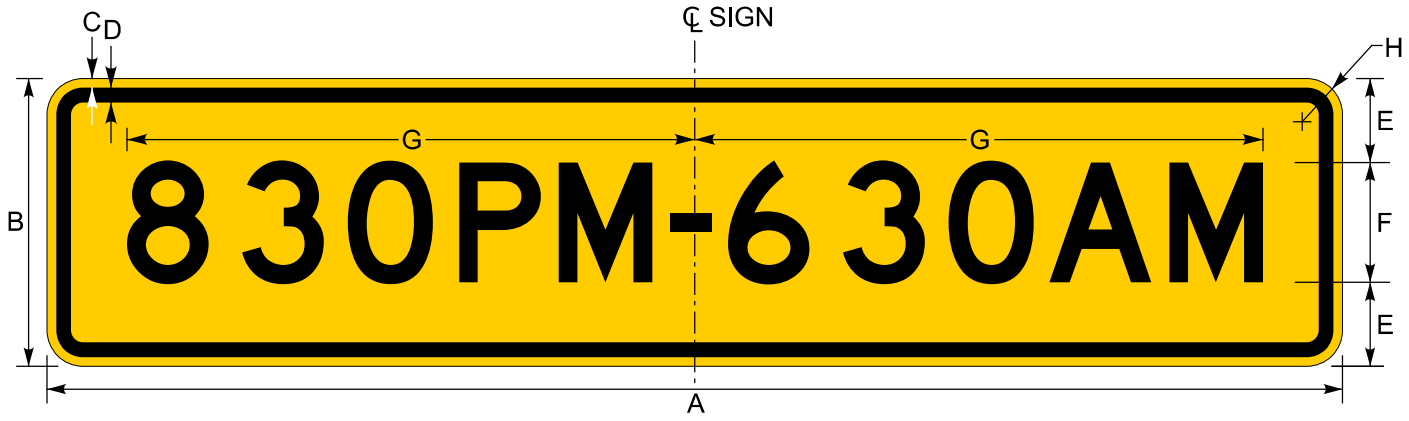
*Reduce spacing 50%

COLORS:
BORDER & LEGEND – BLACK
BACKGROUND – YELLOW (RETROREFLECTIVE)

W16-22P-TEA
APPLICABLE HOURS

The Applicable Hours (W16-22P-TEA) plaque may be used below any warning sign to identify the effective hours of the message.



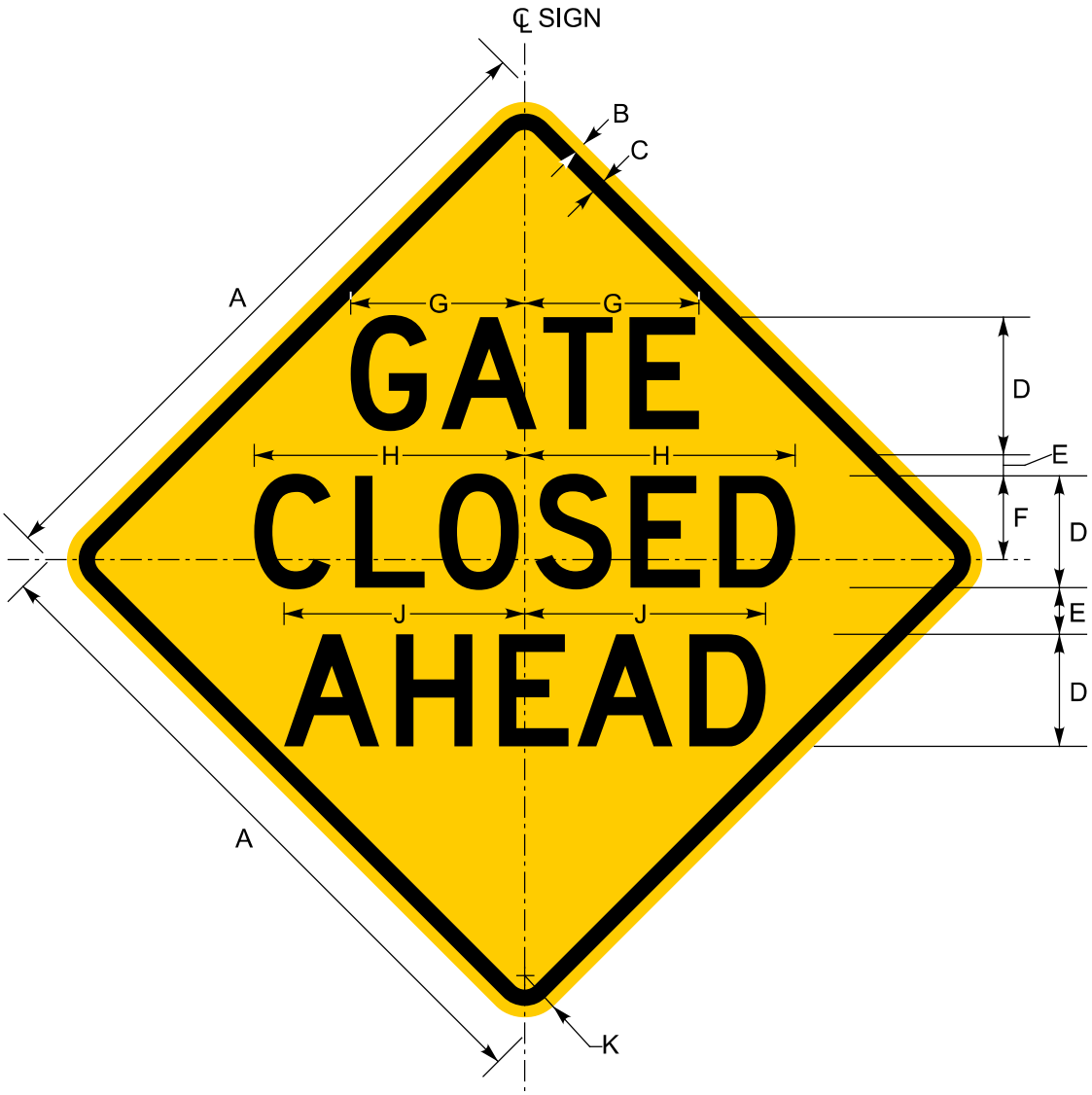


DIMENSIONS (INCHES)							
A	B	C	D	E	F	G	H
36	12	.38	.62	3.50	5D	14.33	1.50
54	12	.38	.62	3.50	5D	23.675	1.50

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 is closed ahead. The W20-3g-TEA sign shall be used for gates that are closed on a routine basis. The Applicable Hours (W16-22P-TEA) plaque, displaying the hours, should be installed below the W20-3g-TEA sign.



DIMENSIONS (INCHES)									
A	B	C	D	E	F	G	H	J	K
36	.63	.88	6D	2.50	4.50	9.33	14.49	12.90	2.25

COLORS:
BORDER & LEGEND – BLACK
BACKGROUND – YELLOW (RETROREFLECTIVE)

APPENDIX B – SAMPLE SIGN LAYOUTS

Note: Every state DOT publishes its own Standard Specifications for Road and Bridge Construction to establish structural mandates tailored to regional wind loads and frost lines. Sign fabricators and installers must comply with these localized requirements for material gauge and aluminum thickness. This is especially critical for tall signs, which face severe wind loads and are highly prone to warping or bending. For example, a state DOT may require a standard 0.080-inch (14-gauge) thickness for basic street signs, but strictly mandate a heavier 0.125-inch (11-gauge) thickness for signs with horizontal spans exceeding 48 inches.

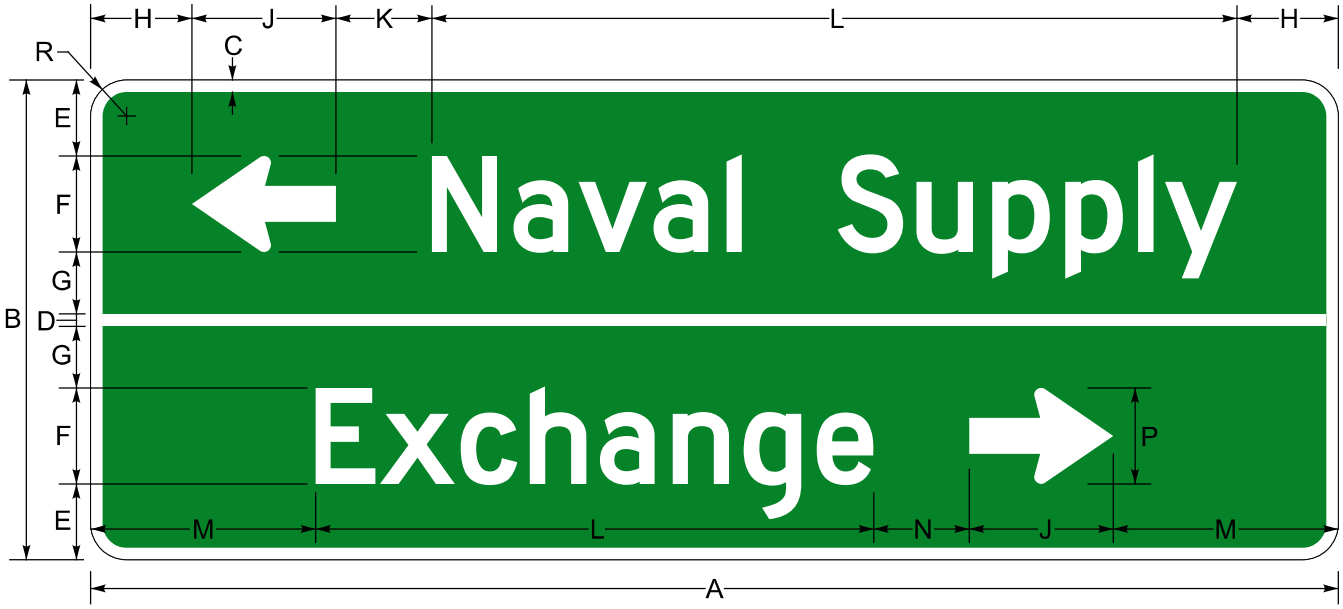
APPENDIX B – SAMPLE GUIDE SIGN LAYOUTS

SIGN NAME	PAGE NUMBER
TWO-LINE DESTINATION	B-1
THREE-LINE DESTINATION	B-2
INSTALLATION APPROACH WITH TWO GATES	B-3
INSTALLATION APPROACH WITH THREE GATES	B-4
GATE DESTINATION WITH HOURS OF OPERATION	B-5
ONE-LINE STREET NAME	B-6
TWO-LINE STREET NAME	B-7

TWO-LINE DESTINATION

The Two-Line Destination (*MUTCD* sign designation D1-2) 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 25 mph.



DIMENSIONS (INCHES)														
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
VAR***	30	.75	.75	4.75	6D	3.875	6 MIN*	9.00	6.00	VAR	6MIN**	6MIN, 9MAX	6.00	2.25
VAR***	42	1.00	1.00	6.75	8D	5.75	8MIN*	12.00	8.00	VAR	8MIN**	8MIN, 12MAX	8.00	3.00

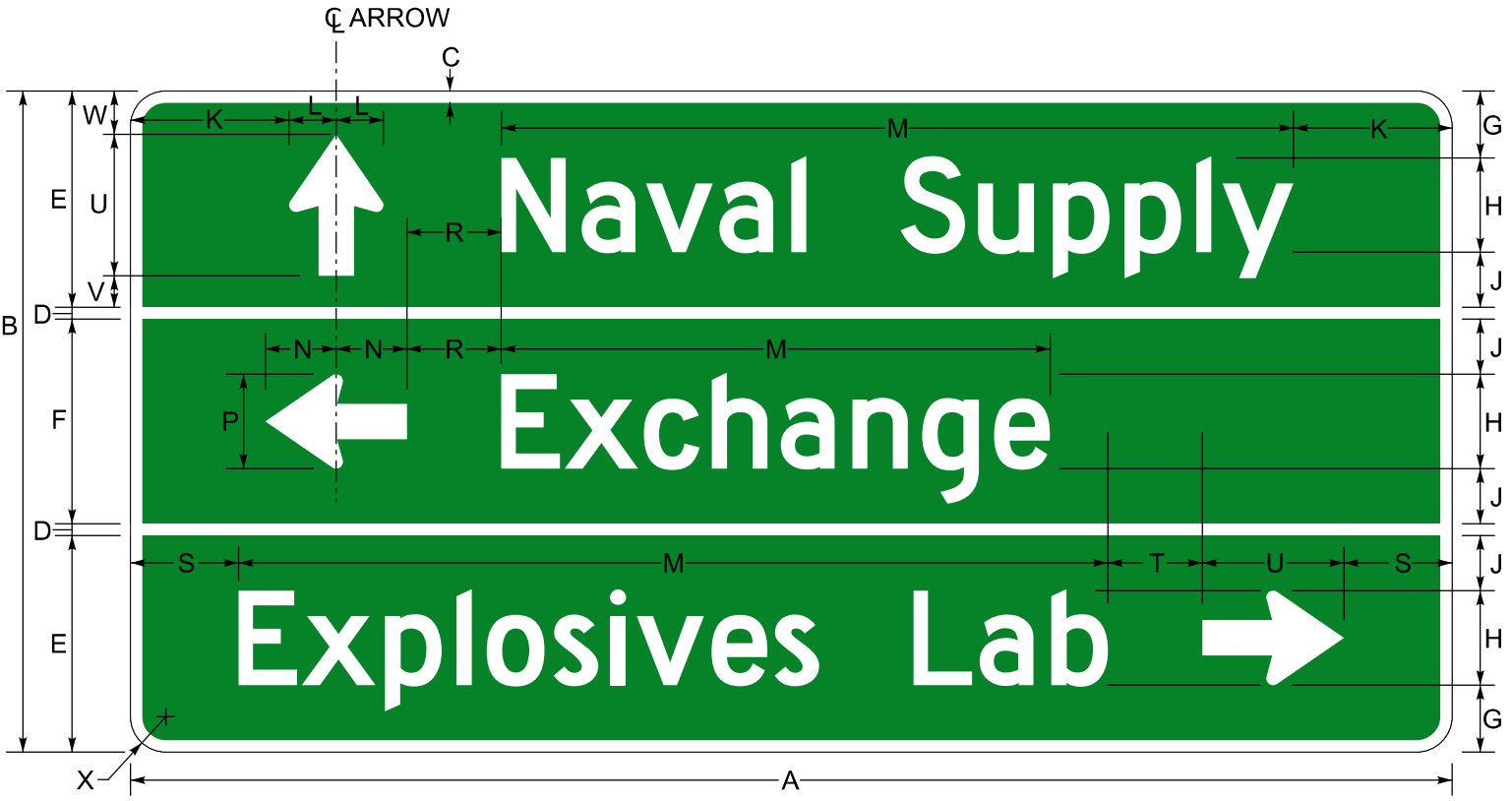
**CONTROLLING LINE OF LEGEND*
***OPTICALLY SPACED NON-CONTROLLING LINE*
****BASED ON THE LENGTH OF THE MESSAGE BUT ROUNDED UPWARD TO A MULTIPLE OF 6 INCHES*

COLORS:
BORDER & LEGEND – WHITE (RETROREFLECTIVE)
BACKGROUND – GREEN (RETROREFLECTIVE)

THREE-LINE DESTINATION

The Three-Line Destination (*MUTCD* sign designation D1-3) 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 25 mph.



DIMENSIONS (INCHES)										
A	B	C	D	E	F	G	H	J	K	L
VAR***	42	.75	.75	13.75	13.00	4.25	6D	3.50	6MIN,**	3.00
VAR***	60	1.00	1.00	19.625	18.75	4.25	8D	3.375	8MIN**	4.00
M	N	P	R	S	T	U	V	W	X	
VAR	4.50	6.00	6MIN, 9MAX	6MIN*	6.00	9.00	2.00	2.75	2.25	
VAR	6.00	8.00	9MIN, 12MAX	8MIN*	8.00	12.00	3.375	4.250	3.00	

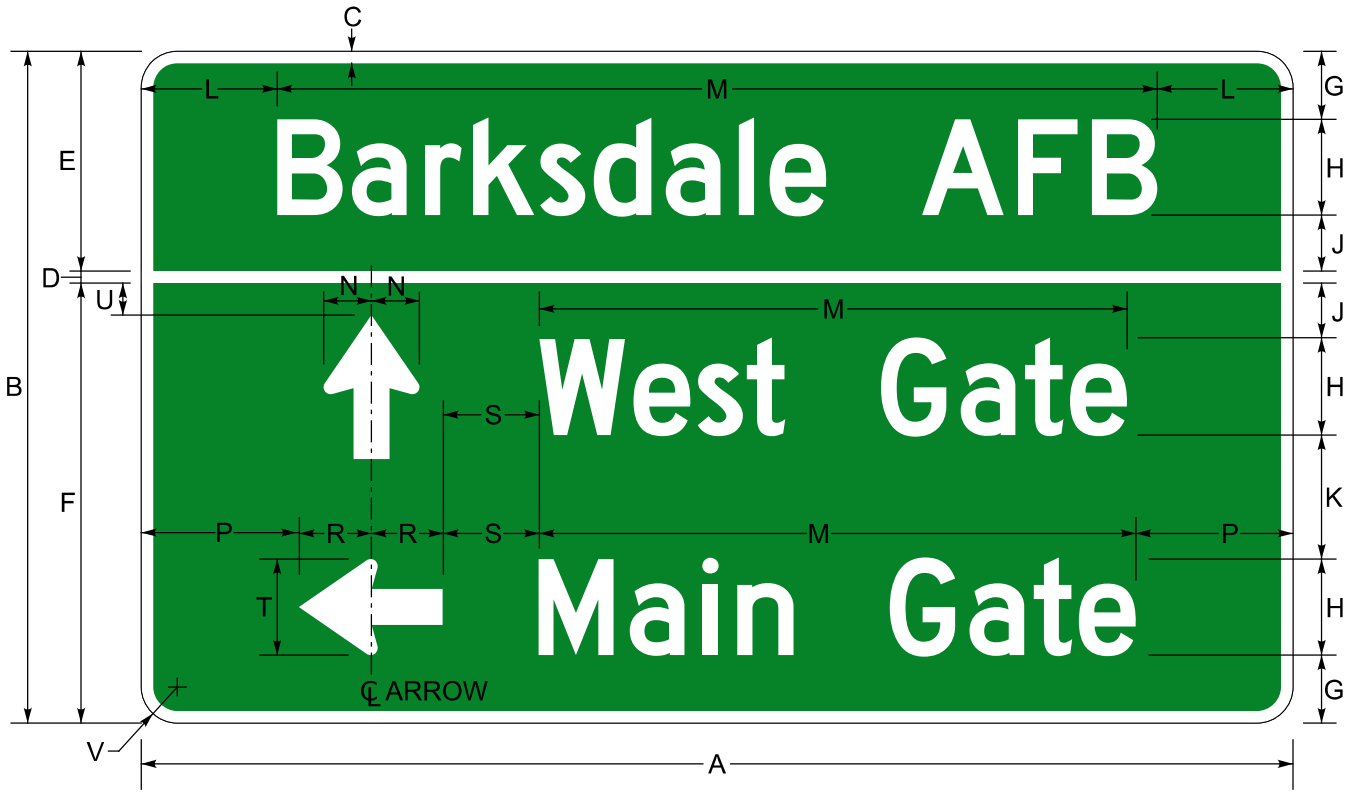
**CONTROLLING LINE OF LEGEND*
***OPTICALLY SPACED NON-CONTROLLING LINE*
****BASED ON THE LENGTH OF THE MESSAGE BUT ROUNDED UPWARD TO A MULTIPLE OF 6 INCHES*

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 25 mph. Larger and bolder legends should be used on expressways and freeways.



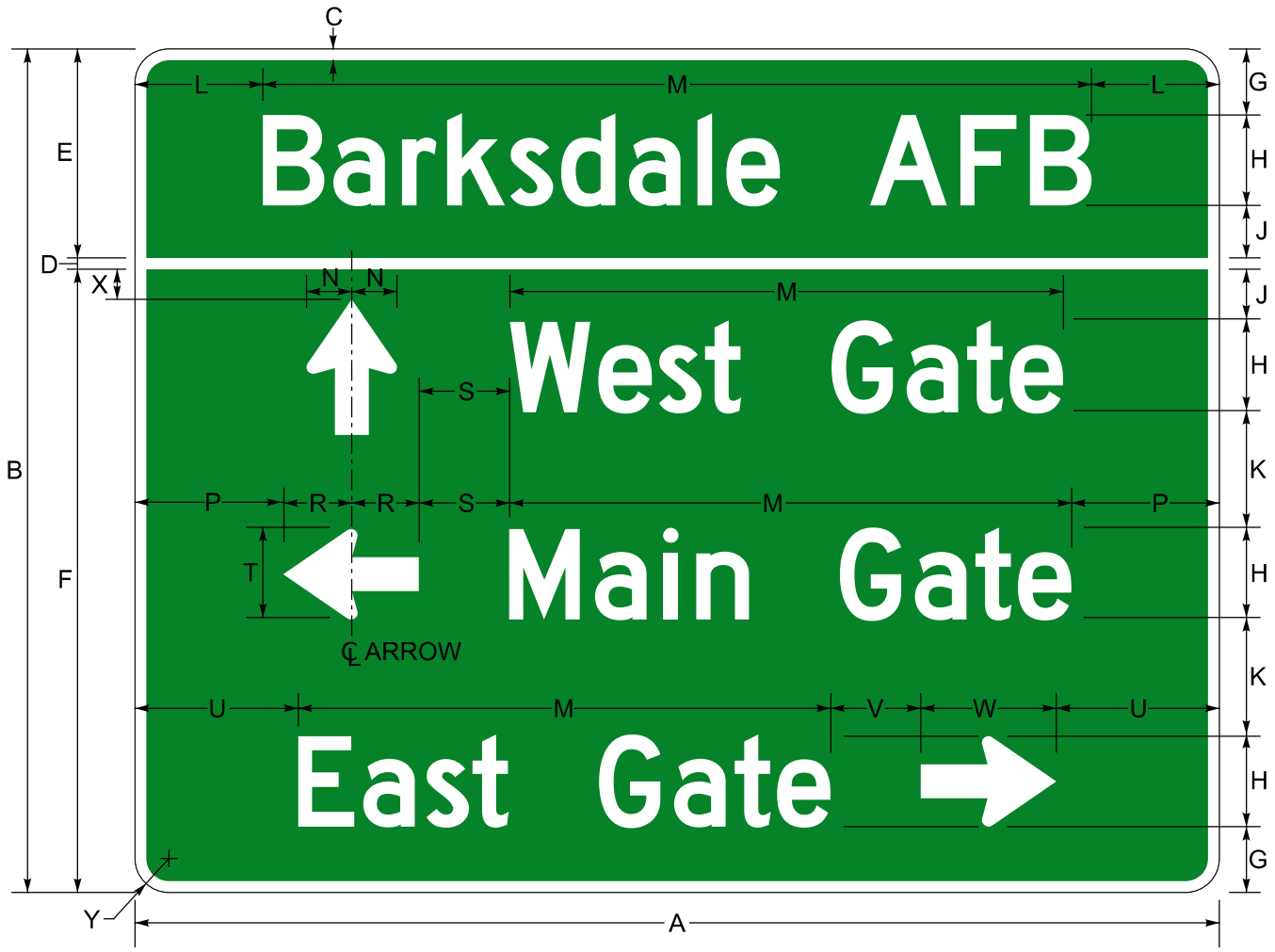
DIMENSIONS (INCHES)																		
A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V
VAR***	42	.75	.75	13.75	27.50	4.25	6D	3.50	7.75	6MIN*	VAR	3.00	6MIN**	4.50	6MIN, 9MAX	6.00	2.00	2.25
VAR***	60	1.00	1.00	19.625	39.375	6.25	8D	5.375	11.75	8MIN*	VAR	4.00	8MIN**	6.00	9MIN, 12MAX	8.00	3.375	3.00

**CONTROLLING LINE OF LEGEND*
***OPTICALLY SPACED NON-CONTROLLING LINE*
****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 25 mph. Larger and bolder legends should be used on expressways and freeways.



DIMENSIONS (INCHES)										
A	B	C	D	E	F	G	H	J	K	L
VAR***	56	.75	.75	13.875	41.375	4.375	6D	3.50	7.750	6MIN*
VAR***	78	1.00	1.00	19.752	57.25	6.375	8D	5.375	10.75	8MIN*
M	N	P	R	S	T	U	V	W	X	Y
VAR	3.00	6MIN**	4.50	6.00	6.00	6MIN**	6MIN, 9MAX	9.00	2.00	2.25
VAR	4.00	8MIN**	6.00	8.00	8.00	8MIN**	8MIN, 12MAX	12.00	3.375	3.00

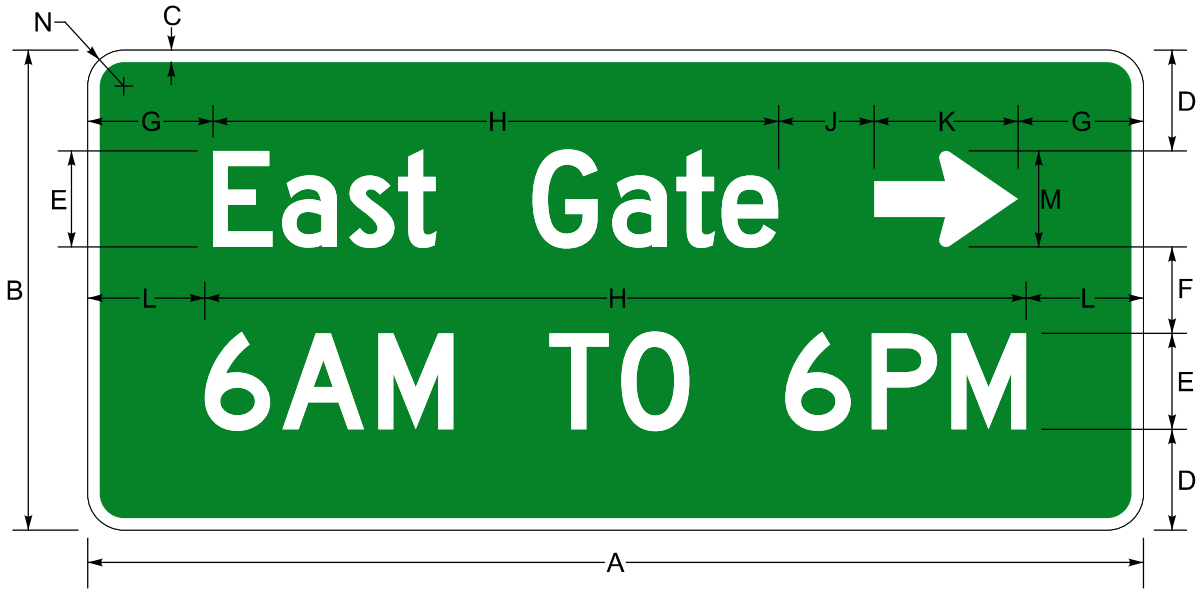
**CONTROLLING LINE OF LEGEND*
***OPTICALLY SPACED NON-CONTROLLING LINE*
****BASED ON THE LENGTH OF THE MESSAGE BUT ROUNDED UPWARD TO A MULTIPLE OF 6 INCHES*

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 25 mph.



DIMENSIONS (INCHES)												
A	B	C	D	E	F	G	H	J	K	L	M	N
VAR***	30	.75	6.30	6D	5.40	6MIN**	VAR	6MIN, 9MAX	9.00	6MIN*	6.00	2.25
VAR***	36	1.00	7.00	8D	6.00	8MIN**	VAR	8MIN, 12MAX	12.00	8MIN*	8.00	3.00

**CONTROLLING LINE OF LEGEND*
***OPTICALLY SPACED NON-CONTROLLING LINE*
****BASED ON THE LENGTH OF THE MESSAGE BUT ROUNDED UPWARD TO A MULTIPLE OF 6 INCHES*

COLORS:
BORDER & LEGEND – WHITE (RETROREFLECTIVE)
BACKGROUND – GREEN (RETROREFLECTIVE)

ONE-LINE STREET NAME

The Street Name *MUTCD* sign designation D3-1 sign may be used to identify street or road names to assist unfamiliar motorists find their destination. Conventional abbreviations (such as Rd, St, Ave, and Blvd) should be used for street name descriptors to optimize panel space, except for the primary street name itself, which must be spelled out in full.

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 25 mph.



DIMENSIONS (INCHES)								
A	B	C	D	E	F	G	H	J
VAR*	8	.375	1.75	4D	2.25	VAR	4MIN	1.00
VAR*	12	.50	2.75	6D	3.25	VAR	6MIN	1.50
VAR*	18	.75	5.00	8D	5.00	VAR	8MIN	1.875
VAR*	24	1.00	5.50	12D	6.50	VAR	12MIN	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 *MUTCD* sign designation D3-1sign may be used to identify street or road names at an intersection where the street or road name changes. Conventional abbreviations (such as Rd, St, Ave, and Blvd) should be used for street name descriptors to optimize panel space, except for the primary street name itself, which must be spelled out in full.

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 25 mph.



DIMENSIONS (INCHES)													
A	B	C	D	E	F	G	H	J	K	L	M	N	P
VAR***	15	.375	2.25	4D	2.50	VAR	4MIN**	6.00	4MIN, 6MAX	4MIN*	4.00	4.00	1.00
VAR***	24	.50	4.00	6D	4.00	VAR	6MIN**	9.00	6MIN, 9MAX	6MIN*	6.00	6.00	1.50
VAR***	33	.75	5.50	8D	6.00	VAR	8MIN**	12.00	8MIN, 12MAX	8MIN*	8.00	8.00	1.875
VAR***	48	1.00	8.00	12D	8.00	VAR	12MIN**	18.00	12MIN, 15MAX	12MIN*	12.00	12.00	2.25

**CONTROLLING LINE OF LEGEND*
***OPTICALLY SPACED NON-CONTROLLING LINE*
****BASED ON THE LENGTH OF THE MESSAGE BUT ROUNDED UPWARD TO A MULTIPLE OF 3 INCHES*

COLORS:
BORDER & LEGEND – WHITE (RETROREFLECTIVE)
BACKGROUND – GREEN (RETROREFLECTIVE)

APPENDIX C – SPACING CHARTS FOR SIGN LEGEND

APPENDIX C – SPACING CHARTS FOR SIGN LEGEND

Series B 2000 . . . . . C-1
Series C 2000 . . . . . C-2
Series D 2000 . . . . . C-3
Series E 2000. . . . . C-4
Series EM 2000 . . . . . C-5
Series F 2000. . . . . C-6
Clearview 1-W C-7
Clearview 2-W C-8
Clearview 3-W C-9
Clearview 4-W C-10
Clearview 5-W C-11
Clearview 5-WR C-12
Clearview 6-W C-13

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
ç	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

Clearview 1-W

Measurements based on 4-inch uppercase letter height. The use of Clearview requires FHWA approval and is only authorized for white legends (words and numbers only) on guide signs. Refer to Chapter 7 for additional information.

	Left (in.)	Width (in.)	Right (in.)
A	0.28	2.28	0.28
B	0.52	1.88	0.36
C	0.40	1.96	0.24
D	0.52	1.96	0.40
E	0.52	1.44	0.36
F	0.52	1.40	0.32
G	0.40	2.08	0.40
H	0.52	1.88	0.52
I	0.52	0.52	0.52
J	0.24	1.28	0.52
K	0.52	1.92	0.24
L	0.52	1.36	0.32
M	0.52	2.24	0.52
N	0.52	2.04	0.52
O	0.40	2.32	0.40
P	0.52	1.80	0.32
Q	0.40	2.32	0.40
R	0.52	1.84	0.40
S	0.28	1.80	0.36
T	0.20	1.68	0.20
U	0.52	1.92	0.52
V	0.28	2.12	0.28
W	0.32	3.20	0.32
X	0.20	2.08	0.20
Y	0.20	2.08	0.20
Z	0.28	1.72	0.28
a	0.36	1.88	0.40
b	0.52	1.84	0.40
c	0.40	1.68	0.28
d	0.40	1.84	0.52
e	0.40	1.84	0.40
f	0.28	1.24	0.24
g	0.40	1.84	0.52
h	0.52	1.76	0.52
i	0.44	0.64	0.44
j	0.00	1.08	0.44
k	0.52	1.72	0.28
l	0.52	0.80	0.32
m	0.52	2.92	0.52
n	0.52	1.76	0.52

	Left (in.)	Width (in.)	Right (in.)
o	0.40	1.92	0.40
p	0.52	1.84	0.40
q	0.40	2.00	0.36
r	0.52	1.16	0.28
s	0.28	1.64	0.32
t	0.24	1.24	0.32
u	0.52	1.76	0.52
v	0.28	1.88	0.28
w	0.32	3.08	0.32
x	0.24	1.88	0.24
y	0.28	1.88	0.28
z	0.32	1.40	0.32
1	0.16	1.16	0.52
2	0.20	1.68	0.32
3	0.20	1.68	0.40
4	0.28	1.96	0.32
5	0.28	1.64	0.36
6	0.40	1.84	0.36
7	0.24	1.68	0.24
8	0.40	1.92	0.40
9	0.36	1.84	0.40
0	0.40	2.04	0.40
&	0.48	2.16	0.28
!	0.44	0.64	0.44
“	0.40	1.44	0.40
#	0.40	2.24	0.40
$	0.36	1.68	0.36
¢	0.40	1.60	0.28
/	0.24	1.72	0.24
*	0.32	1.44	0.32
.	0.36	0.56	0.36
,	0.36	0.68	0.36
:	0.36	0.68	0.36
(	0.32	1.00	0.48
)	0.48	2.68	0.32
-	0.48	1.48	0.48
@	0.52	2.68	0.52
=	0.32	1.48	0.32
+	0.32	1.88	0.32
?	0.40	1.52	0.40

Clearview 2-W

Measurements based on 4-inch uppercase letter height. The use of Clearview requires FHWA approval and is only authorized for white legends (words and numbers only) on guide signs. Refer to Chapter 7 for additional information.

Character	Left (in.)	Width (in.)	Right (in.)
A	0.28	2.76	0.28
B	0.56	2.28	0.40
C	0.44	2.44	0.28
D	0.56	2.40	0.44
E	0.56	1.80	0.44
F	0.56	1.72	0.40
G	0.44	2.56	0.44
H	0.56	2.32	0.56
I	0.56	0.60	0.56
J	0.24	1.60	0.56
K	0.56	2.36	0.24
L	0.56	1.64	0.28
M	0.56	2.80	0.56
N	0.56	2.52	0.56
O	0.44	2.84	0.44
P	0.56	2.20	0.36
Q	0.44	2.84	0.44
R	0.56	2.24	0.44
S	0.24	2.20	0.32
T	0.28	2.08	0.28
U	0.56	2.36	0.56
V	0.28	2.60	0.28
W	0.36	4.00	0.36
X	0.24	2.60	0.24
Y	0.20	2.56	0.20
Z	0.32	2.00	0.32
a	0.40	2.32	0.44
b	0.56	2.24	0.44
c	0.44	2.04	0.20
d	0.44	2.24	0.56
e	0.44	2.32	0.44
f	0.28	1.44	0.28
g	0.44	2.28	0.56
h	0.56	2.16	0.56
i	0.48	0.76	0.48
j	-0.04	1.32	0.48
k	0.56	2.12	0.24
l	0.56	0.96	0.32
m	0.56	3.64	0.56
n	0.56	2.16	0.56

Character	Left (in.)	Width (in.)	Right (in.)
o	0.44	2.40	0.44
p	0.56	2.24	0.44
q	0.44	2.48	0.36
r	0.56	1.40	0.28
s	0.28	1.96	0.32
t	0.28	1.44	0.32
u	0.56	2.16	0.56
v	0.24	2.32	0.24
w	0.32	3.80	0.32
x	0.16	2.32	0.16
y	0.24	2.32	0.24
z	0.28	1.72	0.28
1	0.24	1.36	0.60
2	0.32	2.08	0.48
3	0.28	2.04	0.44
4	0.28	2.44	0.36
5	0.36	2.04	0.44
6	0.44	2.28	0.40
7	0.32	2.04	0.36
8	0.44	2.36	0.44
9	0.40	2.28	0.44
0	0.48	2.52	0.48
&	0.44	2.64	0.24
!	0.56	0.76	0.56
“	0.48	1.72	0.48
#	0.48	2.72	0.48
$	0.44	2.04	0.44
¢	0.44	1.96	0.32
/	0.28	2.08	0.28
*	0.44	1.76	0.44
.	0.48	0.68	0.48
,	0.48	0.76	0.44
:	0.48	0.68	0.48
(	0.40	0.84	0.52
)	0.52	0.84	0.40
-	0.52	1.08	0.52
@	0.44	3.40	0.44
=	0.40	2.28	0.40
+	0.40	2.28	0.40
?	0.36	1.88	0.40

Clearview 3-W

Measurements based on 4-inch uppercase letter height. The use of Clearview requires FHWA approval and is only authorized for white legends (words and numbers only) on guide signs. Refer to Chapter 7 for additional information.

Character	Left (in.)	Width (in.)	Right (in.)
A	0.24	3.32	0.24
B	0.60	2.72	0.36
C	0.44	2.88	0.24
D	0.60	2.84	0.44
E	0.60	2.20	0.36
F	0.60	2.12	0.32
G	0.44	3.04	0.44
H	0.60	2.72	0.60
I	0.60	0.68	0.60
J	0.24	1.88	0.60
K	0.60	2.72	0.20
L	0.60	2.04	0.28
M	0.60	3.28	0.60
N	0.60	2.92	0.60
O	0.44	3.32	0.44
P	0.60	2.60	0.44
Q	0.44	3.32	0.44
R	0.60	2.64	0.40
S	0.32	2.56	0.36
T	0.24	2.52	0.24
U	0.60	2.76	0.60
V	0.28	3.04	0.28
W	0.36	4.68	0.36
X	0.24	3.04	0.24
Y	0.20	3.04	0.20
Z	0.36	2.48	0.36
a	0.44	2.68	0.44
b	0.60	2.60	0.44
c	0.44	2.40	0.28
d	0.44	2.60	0.60
e	0.44	2.64	0.44
f	0.36	1.68	0.32
g	0.44	2.64	0.60
h	0.60	2.48	0.60
i	0.52	0.84	0.52
j	-0.16	1.52	0.52
k	0.60	2.48	0.24
l	0.60	1.12	0.32
m	0.60	4.12	0.60
n	0.60	2.48	0.60

Character	Left (in.)	Width (in.)	Right (in.)
o	0.44	2.80	0.44
p	0.60	2.60	0.44
q	0.44	2.84	0.36
r	0.60	1.64	0.32
s	0.32	2.32	0.36
t	0.24	1.72	0.40
u	0.60	2.44	0.60
v	0.24	2.72	0.24
w	0.32	4.24	0.32
x	0.24	2.72	0.24
y	0.24	2.76	0.24
z	0.36	2.12	0.36
1	0.20	1.60	0.60
2	0.28	2.44	0.44
3	0.24	2.44	0.44
4	0.28	2.84	0.32
5	0.36	2.44	0.44
6	0.48	2.60	0.40
7	0.28	2.48	0.32
8	0.44	2.68	0.44
9	0.40	2.64	0.48
0	0.44	2.92	0.44
&	0.44	3.08	0.24
!	0.60	0.88	0.60
“	0.48	1.92	0.48
#	0.44	3.12	0.44
$	0.40	2.40	0.40
¢	0.44	2.32	0.36
/	0.24	2.52	0.24
*	0.40	1.80	0.40
.	0.52	0.60	0.52
,	0.40	0.92	0.40
:	0.40	0.84	0.40
(	0.44	0.96	0.48
)	0.48	0.96	0.44
-	0.56	1.36	0.56
@	0.44	3.72	0.44
=	0.40	2.16	0.40
+	0.40	2.48	0.40
?	0.36	2.24	0.48

Clearview 4-W

Measurements based on 4-inch uppercase letter height. The use of Clearview requires FHWA approval and is only authorized for white legends (words and numbers only) on guide signs. Refer to Chapter 7 for additional information.

Character	Left (in.)	Width (in.)	Right (in.)
A	0.28	3.48	0.28
B	0.72	2.84	0.48
C	0.56	3.04	0.36
D	0.72	3.00	0.56
E	0.72	2.36	0.52
F	0.72	2.24	0.52
G	0.56	3.20	0.56
H	0.72	2.88	0.72
I	0.72	0.72	0.72
J	0.32	1.96	0.72
K	0.72	2.92	0.28
L	0.72	2.16	0.36
M	0.72	3.44	0.72
N	0.72	3.08	0.72
O	0.56	3.48	0.56
P	0.72	2.72	0.52
Q	0.56	3.48	0.56
R	0.72	2.80	0.52
S	0.44	2.68	0.52
T	0.36	2.68	0.36
U	0.72	2.92	0.72
V	0.32	3.16	0.32
W	0.48	4.92	0.48
X	0.32	3.20	0.32
Y	0.28	3.24	0.28
Z	0.40	2.64	0.40
a	0.56	2.80	0.52
b	0.72	2.72	0.56
c	0.56	2.52	0.36
d	0.56	2.72	0.72
e	0.56	2.76	0.56
f	0.36	1.76	0.32
g	0.56	2.72	0.72
h	0.72	2.60	0.72
i	0.64	0.88	0.64
j	-0.12	1.64	0.64
k	0.72	2.64	0.28
l	0.72	1.20	0.40
m	0.72	4.28	0.72
n	0.72	2.60	0.72

Character	Left (in.)	Width (in.)	Right (in.)
o	0.56	2.92	0.56
p	0.72	2.72	0.56
q	0.56	3.00	0.48
r	0.72	1.72	0.36
s	0.44	2.40	0.48
t	0.36	1.84	0.48
u	0.72	2.56	0.72
v	0.32	2.84	0.32
w	0.40	4.40	0.40
x	0.28	2.88	0.28
y	0.32	2.88	0.32
z	0.40	2.28	0.40
1	0.28	1.68	0.72
2	0.36	2.56	0.52
3	0.32	2.60	0.52
4	0.32	2.96	0.36
5	0.44	2.56	0.52
6	0.52	2.72	0.48
7	0.36	2.60	0.36
8	0.56	2.80	0.56
9	0.48	2.72	0.52
0	0.56	3.08	0.56
&	0.52	3.20	0.32
!	0.64	0.92	0.64
“	0.56	2.04	0.56
#	0.52	3.24	0.52
$	0.44	2.52	0.44
¢	0.56	2.44	0.40
/	0.36	2.68	0.36
*	0.48	1.88	0.48
.	0.52	0.88	0.52
,	0.48	1.00	0.44
:	0.52	0.88	0.52
(	0.48	1.04	0.56
)	0.56	1.04	0.48
-	0.68	1.40	0.68
@	0.56	3.80	0.56
=	0.60	2.28	0.60
+	0.44	2.56	0.44
?	0.40	2.36	0.56

Clearview 5-W

Measurements based on 4-inch uppercase letter height. The use of Clearview requires FHWA approval and is only authorized for white legends (words and numbers only) on guide signs. Refer to Chapter 7 for additional information.

Character	Left (in.)	Width (in.)	Right (in.)
A	0.36	3.76	0.36
B	0.80	3.04	0.60
C	0.64	3.28	0.44
D	0.80	3.24	0.64
E	0.80	2.56	0.56
F	0.80	2.44	0.52
G	0.64	3.48	0.64
H	0.80	3.08	0.80
I	0.80	0.80	0.80
J	0.32	2.24	0.80
K	0.80	3.12	0.36
L	0.80	2.36	0.48
M	0.80	3.68	0.80
N	0.80	3.32	0.80
O	0.64	3.72	0.64
P	0.80	2.92	0.48
Q	0.64	3.72	0.64
R	0.80	3.00	0.60
S	0.48	2.88	0.52
T	0.40	2.88	0.40
U	0.80	3.12	0.80
V	0.36	3.40	0.36
W	0.40	5.32	0.40
X	0.32	3.44	0.32
Y	0.28	3.52	0.28
Z	0.52	2.88	0.52
a	0.52	2.96	0.52
b	0.76	2.88	0.60
c	0.60	2.72	0.40
d	0.60	2.92	0.76
e	0.60	2.96	0.60
f	0.44	1.92	0.40
g	0.60	2.92	0.76
h	0.76	2.76	0.76
i	0.68	0.92	0.68
j	-0.12	1.76	0.68
k	0.76	2.84	0.28
l	0.76	1.28	0.44
m	0.76	4.52	0.76
n	0.76	2.76	0.76

Character	Left (in.)	Width (in.)	Right (in.)
o	0.60	3.08	0.60
p	0.76	2.92	0.60
q	0.60	3.20	0.48
r	0.76	1.84	0.40
s	0.44	2.56	0.52
t	0.36	1.96	0.44
u	0.76	2.72	0.76
v	0.28	3.04	0.28
w	0.32	4.64	0.32
x	0.24	3.08	0.24
y	0.28	3.12	0.28
z	0.48	2.44	0.48
1	0.40	1.80	0.80
2	0.48	2.76	0.64
3	0.44	2.80	0.64
4	0.48	3.16	0.52
5	0.60	2.76	0.64
6	0.64	2.92	0.60
7	0.40	2.84	0.40
8	0.64	2.92	0.64
9	0.60	2.92	0.64
0	0.68	3.28	0.68
&	0.64	3.44	0.40
!	0.72	1.00	0.72
“	0.56	2.16	0.56
#	0.56	3.44	0.56
$	0.48	2.72	0.48
¢	0.60	2.60	0.40
/	0.44	2.88	0.44
*	0.60	1.92	0.60
.	0.56	1.00	0.56
,	0.52	1.08	0.52
:	0.56	1.00	0.56
(	0.60	1.08	0.60
)	0.60	1.08	0.60
-	0.80	1.56	0.80
@	0.64	4.04	0.64
=	0.72	2.40	0.72
+	0.60	2.68	0.60
?	0.56	2.56	0.56

Measurements based on 4-inch uppercase letter height. The use of Clearview requires FHWA approval and is only authorized for white legends (words and numbers only) on guide signs. Refer to Chapter 7 for additional information.

Character	Left (in.)	Width (in.)	Right (in.)
A	0.24	3.76	0.24
B	0.68	3.04	0.48
C	0.52	3.28	0.32
D	0.68	3.24	0.52
E	0.68	2.56	0.44
F	0.68	2.44	0.40
G	0.52	3.48	0.52
H	0.80	3.08	0.80
I	0.68	0.80	0.68
J	0.20	2.24	0.68
K	0.68	3.12	0.24
L	0.68	2.36	0.36
M	0.68	3.68	0.68
N	0.68	3.32	0.68
O	0.52	3.72	0.52
P	0.68	2.92	0.36
Q	0.52	3.72	0.52
R	0.68	3.00	0.48
S	0.36	2.88	0.40
T	0.28	2.88	0.28
U	0.68	3.12	0.68
V	0.24	3.40	0.24
W	0.28	5.32	0.28
X	0.20	3.44	0.20
Y	0.16	3.52	0.16
Z	0.40	2.88	0.40
a	0.40	2.96	0.40
b	0.64	2.88	0.48
c	0.48	2.72	0.28
d	0.48	2.92	0.64
e	0.48	2.96	0.48
f	0.32	1.92	0.28
g	0.48	2.92	0.64
h	0.64	2.76	0.64
i	0.56	0.92	0.56
j	-0.24	1.76	0.56
k	0.64	2.84	0.16
l	0.64	1.28	0.32
m	0.64	4.52	0.64
n	0.64	2.76	0.64

Character	Left (in.)	Width (in.)	Right (in.)
o	0.48	3.08	0.48
p	0.64	2.92	0.48
q	0.48	3.20	0.36
r	0.64	1.84	0.28
s	0.28	2.56	0.40
t	0.24	1.96	0.36
u	0.64	2.72	0.64
v	0.16	3.04	0.16
w	0.20	4.64	0.20
x	0.12	3.08	0.12
y	0.16	3.12	0.16
z	0.36	2.44	0.36
1	0.28	1.80	0.68
2	0.36	2.76	0.52
3	0.32	2.80	0.52
4	0.36	3.16	0.40
5	0.48	2.76	0.52
6	0.52	2.92	0.48
7	0.28	2.84	0.28
8	0.52	2.92	0.52
9	0.48	2.92	0.52
0	0.56	3.28	0.56
&	0.52	3.44	0.28
!	0.60	1.00	0.60
“	0.44	2.16	0.44
#	0.44	3.44	0.44
$	0.36	2.72	0.36
ç	0.48	2.60	0.28
/	0.32	2.88	0.32
*	0.48	1.92	0.48
.	0.44	1.00	0.44
,	0.40	1.08	0.40
:	0.44	1.00	0.44
(	0.48	1.08	0.48
)	0.48	1.08	0.48
-	0.60	1.56	0.60
@	0.52	4.04	0.52
=	0.60	2.40	0.60
+	0.48	2.68	0.48
?	0.44	2.56	0.44

Measurements based on 4-inch uppercase letter height. The use of Clearview requires FHWA approval and is only authorized for white legends (words and numbers only) on guide signs. Refer to Chapter 7 for additional information.

Character	Left (in.)	Width (in.)	Right (in.)
A	0.44	3.96	0.44
B	0.88	3.20	0.60
C	0.72	3.44	0.56
D	0.88	3.40	0.72
E	0.88	2.72	0.60
F	0.88	2.60	0.56
G	0.72	3.64	0.72
H	0.88	3.24	0.88
I	0.88	0.80	0.88
J	0.52	2.24	0.88
K	0.88	3.28	0.44
L	0.88	2.52	0.60
M	0.88	3.84	0.88
N	0.88	3.48	0.88
O	0.72	3.92	0.72
P	0.88	3.04	0.64
Q	0.72	3.96	0.72
R	0.88	3.16	0.56
S	0.52	3.04	0.60
T	0.48	3.08	0.48
U	0.88	3.28	0.88
V	0.44	3.52	0.44
W	0.52	5.64	0.52
X	0.40	3.64	0.40
Y	0.32	3.72	0.32
Z	0.60	3.04	0.60
a	0.68	3.12	0.60
b	0.88	3.04	0.72
c	0.72	2.88	0.52
d	0.72	3.04	0.88
e	0.72	3.08	0.72
f	0.48	2.04	0.44
g	0.72	3.04	0.88
h	0.88	2.92	0.88
i	0.80	0.96	0.80
j	-0.08	1.88	0.80
k	0.88	3.00	0.36
l	0.88	1.32	0.52
m	0.88	4.76	0.88
n	0.88	2.92	0.88

Character	Left (in.)	Width (in.)	Right (in.)
o	0.72	3.24	0.72
p	0.88	3.04	0.72
q	0.72	3.32	0.60
r	0.88	1.92	0.48
s	0.52	2.68	0.60
t	0.48	2.08	0.68
u	0.88	2.84	0.88
v	0.44	3.20	0.44
w	0.52	4.80	0.52
x	0.40	3.24	0.40
y	0.44	3.28	0.44
z	0.56	2.60	0.56
1	0.48	1.88	0.88
2	0.56	2.92	0.64
3	0.56	2.96	0.68
4	0.56	3.32	0.60
5	0.68	2.92	0.68
6	0.72	3.04	0.68
7	0.40	3.00	0.40
8	0.68	3.04	0.68
9	0.68	3.04	0.72
0	0.72	3.40	0.72
&	0.72	3.60	0.40
!	0.80	1.04	0.80
“	0.68	2.24	0.68
#	0.68	3.52	0.68
$	0.60	2.88	0.60
¢	0.72	2.72	0.48
/	0.52	3.08	0.52
*	0.60	1.96	0.60
.	0.64	1.04	0.64
,	0.56	1.12	0.64
:	0.64	1.04	0.64
(	0.72	1.16	0.68
)	0.68	1.16	0.72
-	0.80	1.68	0.80
@	0.72	4.20	0.72
=	0.72	2.56	0.72
+	0.64	2.76	0.64
?	0.56	2.72	0.72

APPENDIX D – COMMONLY USED ACRONYMS

APPENDIX D – COMMONLY USED ACRONYMS

This pamphlet uses many different acronyms throughout the document. For ease of reference, below is a list summarizing commonly used acronyms.

AASHTO	American Association of State Highway and Transportation Officials
ABA	Architectural Barriers Act
ACP	Access Control Point
ADA	Americans with Disabilities Act
ADT	Average Daily Traffic
AIE	Automated Installation Entry
ANSI	American National Standards Institute
AT	Antiterrorism
ATR	Automated Traffic Recording
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)
DoW	Department of War
DOT	Department of Transportation
ECF	Entry Control Facility
FC	Foot-candle
FHWA	Federal Highway Administration
FPCON	Force Protection Condition
ft	Feet
HAR	Highway Advisory Radio
HCS	Highway Capacity Software
HCM	Highway Capacity Manual
HID	High Intensity Discharge
HOV	High Occupancy Vehicle
IES	Illuminating Engineering Society
IESNA	Illuminating Engineering Society of North America

APPENDIX D – COMMONLY USED ACRONYMS

ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
LED	Light Emitting Diode
LOS	Level of Service
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	Accessibility guidelines for pedestrian facilities in the public right-of-way
PT	Physical Training
RDG	Roadside Design Guide
RPM	Raised Pavement Marker
RRPM	Retroreflective Raised Pavement Marker
RSA	Roadway Safety Audit
TEA	Transportation Engineering Agency
SHS	Standard Highway Signs
SHSM	Standard Highway Signs and Markings Book
TMC	Turning Movement Count
TRB	Transportation Research Board
TTC	Temporary Traffic Control
TTCP	Temporary Traffic Control Plan
UFC	Unified Facilities Criteria
UFS	United Facilities Supplement

**This pamphlet uses the term POV to refer to any vehicle that is not a truck, commercial vehicle, or heavy vehicle, which may be government owned in addition to privately owned.*

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