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Traffic Signal General Information

A. Introduction

The purpose of this chapter is to supplement [SUDAS Specifications Section 8010](#) and to provide general guidance for traffic signal designs on roadways within Iowa. The information is provided as an overview for traffic signals design consideration.

B. Scope

There is no legal requirement to use the information within this chapter by local agencies. This document refers to a number of other resources available for the designer to be considered when designing a traffic control signal. The document loosely follows the format of the MUTCD, as published by The U.S. DOT, FHWA and as adopted or modified by the Iowa DOT. However, no attempt is made to re-print the content of the MUTCD herein. A variety of other technical resources are also noted for consideration by the designer.

By MUTCD definition, a traffic control signal is “any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed” with highway traffic signal being defined as “a power-operated traffic control device by which traffic is warned or directed to take some specific action. These devices do not include power-operated signs, illuminated pavement markers, barricade warning lights, or steady-burning electric lamps.” From an application standpoint traffic control signals are used to assign vehicular or pedestrian right-of-way.

The design for traffic control signals shall be in conformance with the current edition of the MUTCD as adopted or modified by the Iowa DOT. The following should be used as design standards as applicable to a project:

- [MUTCD Part 4 Highway Traffic Signals](#)
- Jurisdiction Design Standards and Construction Standards
- Iowa DOT and FHWA regarding the design of traffic control signals
- Institute of Transportation Engineers - “Manual of Traffic Signal Design,” “Traffic Engineering Handbook,” “Manual of Transportation Engineering Studies” and “Traffic Control Devices Handbook.”
- “[Signal Timing Manual](#)”, NCHRP Report 812
- Other standard references such as the National Electrical Code by the National Fire Protection Association (NFPA), and the National Electrical Manufacturers Association (NEMA) Standards Publications.

Other resources to consider and that are referenced within this document include:

- [MnDOT Traffic Engineering Manual](#)
- [MnDOT Signal Design Manual](#)
- [MnDOT Lighting and Signal Certification Field Guide](#)
- [Ohio DOT Traffic Engineering Manual](#)
- [FHWA Automated Traffic Signal Performance Measures](#)
- [FHWA Adaptive Traffic Signal Control Website](#)

Traffic Control Signal Needs Study

A. General

The MUTCD states that “A traffic control signal should not be installed unless an engineering study indicates that installing a traffic control signal will improve the overall safety and/or operation of the intersection.” The first question that must be answered is whether a traffic control signal is justified or is the most effective treatment option. It is the responsibility of the Engineer or agency to make this determination with serious consideration given to MUTCD [Section 4B](#).

B. Data Collection

The engineering study should be based upon current site and traffic data (vehicle, pedestrian, etc.) pertaining to the candidate location. The following studies may be helpful in assessing and demonstrating the need for a signal:

- Volume studies, including approach volumes, turning movements, and peak hour detail counts
- Pedestrian counts, including any unusual numbers of children, handicapped, and elderly
- Traffic gap studies
- Speed studies
- Crash studies
- Intersection delay studies

Procedures for completing various traffic studies are found in the ITE Manual of Transportation Engineering Studies.

MUTCD [Section 4C.01](#) provides a detailed description of engineering study data which may be needed to conduct a warrant analysis.

C. Warrants

MUTCD [Section 4C.01](#) “Studies and Factors for Justifying Traffic Control Signals” states, “An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location.

Ohio DOT’s Traffic Engineering Manual [Part 4-Signals](#) provides additional guidance for consideration of the reduction of minor approach right turning volume for traffic signal warrants to account for minor approach lane configurations, the proportion of right turns to other traffic, and the conflicting through volumes on the major street.

Guidelines regarding the installation of pedestrian hybrid beacons (HAWK signals) are provided in MUTCD [Chapter 4F](#). These guidelines consider vehicular and pedestrian crossing volumes, crosswalk length and traffic speeds.

Mn/DOT’s Traffic Signal Design Manual Section 9-4.02.03 provides additional guidance for advance warning flashers consideration.

Traffic Signal Features

A. Traffic Control Signal Features

The MUTCD [Chapter 4D](#) Traffic Control Signal Features establishes traffic signal uniformity and serves as a critical resource for each traffic signal design. The features of traffic control signals of interest to road users are the location, design, and meaning of the signal indications. Uniformity in the design features that affect the traffic to be controlled, as set forth in the MUTCD, is especially important for reasonably safe and efficient traffic operations.

B. Pedestrian Control Features

The MUTCD [Chapter 4E](#) Pedestrian Control Features establishes pedestrian control uniformity and serves as a critical resource for each traffic signal design. Pedestrian signal heads provide special types of traffic signal indications exclusively intended for controlling pedestrian traffic. These signal indications consist of the illuminated symbols of a WALKING PERSON (symbolizing WALK), an UPRAISED HAND (symbolizing DONT WALK), and a countdown display.

Accessible pedestrian signals (APS) communicate information about pedestrian signal timing in nonvisual formats and are integrated with pedestrian pushbuttons. For jurisdictions complying with PROWAG, APS installation is required on any new traffic signal with a pedestrian signal or where there will be significant changes to an existing signal (R209.1). All intersections where pedestrians are expected, regardless of whether the pedestrian phase is automatic or requires actuation, shall be accessible for people with disabilities. This often means accessible pushbuttons are installed in locations with automatic pedestrian phases. APS should be installed at locations where signals are retimed to include a leading pedestrian interval (LPI) or exclusive pedestrian phase (EPP). Without APS units, pedestrians with low or no vision may not be able to maximize the advantage of these signal timing strategies, as they otherwise use the noise of concurrent vehicles to determine when to begin walking. Signal design guidance for pedestrian control and safety is provided in [Section 13A-4, E](#).

C. Agency Specific Information

Agencies often have different design requirements in addition to those found in the MUTCD. Therefore, one of the first steps in the traffic signal design process is to learn the design requirements by meeting with agency staff and studying agency specific design manuals, specifications, and/or standard details. Field observations of existing traffic signals within an agency's jurisdiction can also provide insight to specific design requirements.

Determining agency specific design requirements prior to design can be challenging. It can be difficult to ask all the right questions, give all the necessary answers, and not overlook any details. More challenges can arise when staff is less experienced or a new working relationship is being established. Most design requirements that are overlooked will be caught during the design process or review process. However, taking steps to prevent design requirements from being overlooked will accelerate the design process and minimize costs by eliminating or reducing change orders. The following are some examples of design requirements that can vary between agencies.

- The MUTCD requires a maximum distance of 180 feet from the stop line to the 12 inch signal faces unless a near side supplemental signal face is used. A previous version required a maximum distance of 150 feet and some agencies continue to follow the old requirement.
- Some agencies center mast arm mounted signal heads over the lane line and others center them over the center of the lane.
- Certain agencies elect to install supplemental signal heads on the vertical shaft of the mast arm pole and others elect not to.
- Doghouse style five section heads are used for protected/permissive left turns by some agencies but not others.
- Protected / permissive left turn operation can vary. Some agencies configure left turn lane detection to call the protected phase only when two to three vehicles are queued, while other agencies always call the protected phase.
- Detector types, sizes, and layouts vary between agencies.
- The size and number of conduits, handholes, and wiring varies greatly among agencies.
- Some agencies share conduit between signal cable, street light power, and/or interconnect while others keep these cables in separate conduits.
- Some agencies choose to install emergency vehicle preemption.
- Some agencies choose to install traffic monitoring (PTZ) cameras.
- Signal wiring details vary among agencies.
- Some agencies use the “astro” type brackets to mount all signal heads and others do not use this on side of pole mounted heads. Bracketing and banding of all hardware (typically to the poles) varies greatly among agencies.
- Traffic signal cabinets, cabinet risers, and controller types and preferences vary greatly among agencies.
- Mounting heights for signal heads, street light luminaires, detection cameras, monitoring cameras, etc. vary greatly among agencies.
- Pedestrian signals may or may not include assessible pedestrian signals (APS), with or without voice messages.
- Pedestrian signals may or may not have leading pedestrian intervals (LPI).
- Agencies use a variety of signal interconnect and communication systems including fiber optic cable, wireless systems, and GPS timeclocks.
- Pedestrian walking speed for crossing interval timing may vary.

D. Signal Design Criteria

Signal designers should coordinate with the agency regarding specific traffic signal elements to be included in a project. This is particularly important for a first project with a new agency. A list or memoranda regarding signal design criteria for review by and discussion with the agency early in the project development may be of significant benefit to both the engineer and agency. The following is a list of possible signal design criteria items to consider:

1. **General:** General nature of the signal project - new installation, replacement, minor modifications, or major modifications.
2. **Signal Phasing:**
 - a. Phase numbering (Phase 2 southbound or major through movement)
 - b. Left turn phasing for each approach (protected-only, protected-permissive, permissive-only, split-phase)
 - c. Leading pedestrian interval
 - d. Use of overlaps
 - e. Bicycle green time, if applicable

3. Signal Heads:

- a. Based on proposed left turn phasing
- b. Overhead locations relative to lane lines
- c. Side-of-pole locations
- d. Head configurations, displays, color
- e. Pedestrian signal head type (1-section or 2-section)
- f. Head mounting hardware and bracket types
- g. Backplates, visors

4. Poles:

- a. Pole types (mast arm, combination mast-arm/ lighting, pedestal)
- b. Pole locations considering clear zone, sidewalk, utilities and right-of-way constraints
- c. Pole base types (T-base or anchor base)
- d. Luminaire mounting height for combination poles
- e. Special pole finishes (paint, powdercoat)
- f. Special pole handhole needs

5. Detection:

- a. Type of vehicle detection (video, pavement loops, microwave, other)
- b. Advance detection based on approach speeds
- c. Detection to accommodate Automated Traffic Signal Performance Measures
- d. Emergency Vehicle Preemption (EVP) detectors
- e. Pedestrian pushbuttons (APS or non-APS)
- f. Pushbutton locations per ADA and MUTCD guidance
- g. Special detection needs (bicycles)

6. Controller/ Cabinet:

- a. Controller type or model (NEMA, ATC, 2070)
- b. Cabinet type or model (TS1, TS2, ATC, 2070)
- c. Cabinet location
- d. Pad or pole-mounted cabinet
- e. Battery back-up (UPS)
- f. Cabinet riser height
- g. Meter location
- h. Misc. cabinet equipment
- i. Voltage output
- j. Number of inputs/outputs

7. Conduit and Wiring:

- a. Conduit sizes and types
- b. Separate conduits for lighting, power and/or fiber optic cable
- c. Signal cable configurations (number of conductors)
- d. Lighting cable sizes
- e. Ground wire, tracer wire and pull tape
- f. Fiber optic cable configuration, routing, termination and splicing
- g. Misc. cables (video, EVP, Cat 5/6, etc.)

8. Handholes: Handhole types and locations, including whether to provide one near the controller, and for the ground rod near the foundation.

9. Interconnect:

- a. Need for coordinated signal operation
- b. Type of interconnect
- c. Modifications needed at adjacent signalized intersections

10. Power Service:

- a. Coordination with utility company for exact location of power service and identification on plans
- b. Power source location and type (overhead or pad-mounted transformer)
- c. Meter requirements
- d. Metered or un-metered lighting

11. Signs:

- a. Street name signs
- b. Lane use signs
- c. Traffic signal signs
- d. Pedestrian pushbutton signs

12. Construction Staging:

- a. Potential need for temporary signals and/or detection
- b. Lane closures
- c. Special requirements

13. Miscellaneous:

- a. Potential need for advanced warning flasher
- b. Construction schedule and anticipated pole and equipment lead times
- c. Supplemental specifications and/or plan notes as needed
- d. Signal turn-on procedure, possible portable dynamic message signs
- e. Luminaires for combination poles

E. Additional Information

In addition to typical vehicle and pedestrian signals, the MUTCD also provides guidance on the following types of traffic signals:

[Chapter 4F](#) Pedestrian Hybrid Beacons

[Chapter 4G](#) Traffic Control Signals and Hybrid Beacons for Emergency-Vehicle Access

[Chapter 4H](#) Traffic Control Signals for One-Lane, Two-Way Facilities

[Chapter 4I](#) Traffic Control Signals for Freeway Entrance Ramps

[Chapter 4J](#) Traffic Control for Movable Bridges

[Chapter 4K](#) Highway Traffic Signals at Toll Plazas

[Chapter 4L](#) Flashing Beacons

[Chapter 4M](#) Lane-Use Control Signals

[Chapter 4N](#) In-Roadway Lights

Traffic Signal Design Considerations

In addition to basic MUTCD requirements, the safe and efficient operation of a signalized intersection requires careful attention and balance of a number of design parameters. This section provides some reference resources for the traffic signal designer in consideration of these features.

A. Geometrics

The geometrics of an intersection are a critical consideration given the potential impact on intersection safety and performance. Geometrics directly impact sight distance, vehicle separation, operations, and capacity. As a result, intersection geometrics should always be considered whether dealing with existing, reconstructed, or new signalized intersections.

References are made to [Signalized Intersections: Informational Guide](#), Second Edition, FHWA-SA-13-027, July 2013, which provides a single, comprehensive document with methods for evaluating the safety and operations of signalized intersections and tools to remedy deficiencies. The treatments in this guide range from low-cost measures such as improvements to signal timing and signage, to high-cost measures such as intersection reconstruction or grade separation. While some treatments apply only to higher volume intersections, much of this guide is applicable to signalized intersections of all volume levels.

1. **Basic Geometric Considerations:** The geometric design section of the Signalized Intersections: Informational Guide provides the following comments:

Geometric design profoundly influences roadway safety; it shapes road user expectations and defines how to proceed through an intersection where many conflicts exist. In addition to safety, geometric design influences the operational performance for all road users. Minimizing impediments, reducing the need for lane changes and merge maneuvers, and minimizing the required distance to traverse an intersection all improve intersection safety and operational efficiency.

All possible road users' ([Chapter 2](#) of the guide) needs must be considered to achieve optimal safety and operational levels at an intersection. When road user groups' design objectives conflict, the practitioner must carefully examine the needs of each user, identify the tradeoffs associated with each element of geometric design, and make decisions with all road user groups in mind. However, one user's convenience or mobility should not be prioritized over another user's safety. For instance, practitioners may design corner radii to accommodate large vehicles. However, these larger radii could be detrimental to pedestrian safety due to the increase in walking distances and the increase in speed of turning vehicles. Stop bars may be adjusted or truck aprons added to allow for larger vehicle turning movements while keeping speeds lower, which prioritizes the safety of all users. In areas of high pedestrian activity and/or where vulnerable users are likely to be present, e.g. near schools, hospitals, church, etc., or when a local jurisdiction's adopted transportation plan calls for prioritizing pedestrian safety, designers should incorporate geometric design features to improve safety for pedestrians, see [Section 12A-5](#).

The geometric design chapter ([Chapter 4 of the guide](#)) addresses the following design topics to be considered when designing traffic signal controlled intersections:

- [4.1 Number of Intersection Legs](#)
- [4.2 Channelization](#)
- [4.3 Horizontal and Vertical Alignment](#)
- [4.4 Corner Radius](#)
- [4.5 Sight Distance](#)
- [4.6 Pedestrian Treatments](#)
- [4.7 Bicycle Facilities](#)
- [4.8 Transit Facilities](#)

2. Additional Sight-Distance Considerations:

- a. Sight distance is a safety requirement that impacts intersection geometrics as fundamental as horizontal and vertical alignments. It is a design requirement that is discussed in detail as it relates to the visibility of traffic signal indications in the MUTCD. In addition to the sight distance requirements of the MUTCD, the AASHTO “Policy on Geometric Design of Highways and Streets 2018” states that at signalized intersections, the first vehicle stopped on one approach should be visible to the driver of the first vehicle stopped on each of the other approaches. It also states that left turning drivers need sufficient sight distance to decide when to turn left across the lane(s) used by opposing traffic. This requires consideration of offset left turn lanes for permissive left turns to provide adequate left turn sight distance. If right turns are allowed on a red signal indication, the appropriate sight distance to the left of the right turning vehicle should be provided. See Chapter 9 - Intersections in the AASHTO “Policy on Geometric Design of Highways and Streets 2018” for additional sight distance information.
- b. One sight distance issue that deserves additional consideration is the sight triangle and the sight obstructions found within it. Certain obstructions are obvious like structures near the street. Other obstructions are not always obvious or are installed after the traffic signal is designed and constructed. These obstructions seem to blend into the background. They are obstructions like entrance monuments, parked vehicles, special street name signs, business signs, and landscape vegetation that may not be a problem initially but become a problem as the plants reach maturity. Finally, be aware of the signal cabinet size and location including the height of the footing or cabinet riser so it does not become a sight obstruction.
- c. Sight distance requirements are less restrictive at signalized intersections as drivers are required by law to obey the signal indications; however, there are instances when drivers do not obey traffic signals. A traffic signal should be designed to exceed minimum sight distance requirements when possible. Drivers are taught to drive defensively and providing additional sight distance will only aid drivers in collision avoidance.

3. Turn Lanes:

- a. Traffic volumes, turning movement counts, and crash history are used to complete intersection capacity and safety analyses. The results of the analyses determine the need for and length of turn lanes. The turn lane information is used to properly design the geometrics of signalized intersection approaches.
- b. Turn lane capacity issues often create safety problems. Left or right turning vehicle queues blocking through traffic create increased potential for rear-end crashes. Sideswipe potential also increases as traffic attempts to maneuver out of defacto turn lanes or around left turn queues blocking through lanes. High volumes of turning vehicles combined with high

volumes of opposing vehicles significantly reduce the number and size of available gaps needed to complete turning maneuvers increasing the potential for right angle collisions. As a result, properly designed turn lanes improve safety as well as capacity.

- c. The need for turn lanes, turn lane storage lengths, and other geometric or traffic control improvements should be determined based on traffic operations analyses of existing and projected design year peak hour traffic. Traffic engineers typically use traffic analysis and/or simulation software for these analyses.

B. Operational Characteristics

The behavior of the traffic at an intersection is another highly important element of signal design. The MnDOT Traffic Engineering Manual [Section 9-7.03](#) notes the various elements that should be considered.

C. System (Arterial) Considerations

In many cases, an individual traffic control signal must be considered as part of a system, either as one of a series of signals along a linear route, or as one signal in a grid network. MnDOT [Section 9-7.04](#) notes the elements to be considered. In addition, note the following:

Traffic actuated controllers are most often used. The actuated controller tends to reduce the number of stops and does not cut off platoons of vehicles. In the suburban environment, the arterial streets tend to be very wide, and traffic volumes are often significant.

Signals are typically timed to prioritize the “major” street movements, which under certain conditions may increase delay for pedestrians and bicyclists waiting to cross the major street. Streets in lower density, suburban settings often do not have comparable pedestrian volumes as more dense, urban networks. However, these corridors may have transit operation or land uses across the major street to encourage pedestrian crossings (e.g. a park across from a residential neighborhood), which may make road crossing decisions challenging without appropriate crossing opportunities.

In some instances, where pedestrians routinely experience long delays at signals, they may elect to cross away from the crosswalk at locations where conflicts are not controlled by a signal. Therefore, strategies to reduce overall cycle length and provision of safe crossing based on the surrounding land use is important for pedestrian safety. Designers should also evaluate the frequency and location of crossing opportunities along a linear route and provide safe crossings where needed based on the roadway context; see [Section 12A-5](#).

A split is the relative percentage of green, yellow, and red clearance time allocated to each of the various phases at a single intersection. An offset is a system reference time, usually expressed in seconds but sometimes in percent of cycle length.

D. Signal Design Elements

The following publications provide a wide range of guidance in the design of traffic signals and the needs of pedestrian and bicyclists at signalized intersections:

- Manual of Traffic Signal Design, Second Edition, ITE
- Traffic Control Devices Handbook, Second Edition, ITE
- [Signalized Intersections: Informational Guide, Second Edition, FHWA](#)
- Signal Timing Manual, NCHRP Report 812
- Achieving Multimodal Networks, FHWA
- Urban Street Design Guide, NACTO
- Walkable Urban Thoroughfares, ITE
- Don't Give Up at the Intersection, NACTO

Traffic signal designs should be based on project and intersection-specific design criteria ([Section 13A-3, D](#)). Key elements to consider and include in the design, as appropriate, include the following:

1. Signal Layout:

- a. Pole locations considering clear zone requirements, existing and proposed utilities, signal head locations, mast arm lengths, lighting needs, elevation differences, pedestrian pushbutton locations, and right-of-way constraints.
- b. Cabinet location considering proposed power service, signal interconnect, sight distance, and cabinet accessibility.
- c. Motor vehicle and pedestrian signal head locations and configurations considering visibility and proposed phasing. Where bicycle lanes are present, signals must be visible to bicyclists or provide a separate indication, see [Section 12B-3, L](#) for guidance.
- d. Handhole locations and conduit layout to minimize lengths of conduit runs. Consider providing a larger (Type III or IV) handhole near the signal cabinet and routing all signal conduits to the cabinet through this handhole.
- e. Signing needs.
- f. Stop line and advance detection.
- g. Miscellaneous equipment (EVP, traffic monitoring camera, etc.)

2. Conduit and Wiring:

- a. Conduit sizes considering conduit fill percentage.
- b. Wiring quantities and configurations based on equipment needs.
- c. Fiber optic cable configuration, terminations, and splicing.

3. Phasing and Timing:

- a. Type of left turn phasing (protected-only, protected-permissive, permissive-only) for each approach.
- b. Possible right turn overlap for right turn lanes or turn restrictions to reduce conflicts with pedestrians and bicyclists.
- c. Phasing sequence diagram.
- d. Recommended initial timings.

4. Miscellaneous Items:

- a. Traffic signal notes and supplemental specifications, as needed.
- b. Estimated traffic signal quantities.
- c. Specific equipment or materials requirements.
- d. Reference or include applicable [SUDAS Specifications Section 8010 figures](#) and/or special details needed.

E. Traffic Signal Operations

The following publications provide guidance regarding traffic signal timings and operations:

- Signal Timing Manual, NCHRP Report 812
- Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections, NCHRP Report 731
- [Section 4E.06 Pedestrian Intervals and Signal Phases](#), MUTCD
- Interim Approval for Optional Use of a Bicycle Signal Face, FHWA IA-16
- [Section 12B-3, L](#)

1. Left Turn Phasing Considerations: Traditionally, protected-only left turn phasing has been used for dual left turn lanes, due to safety concerns with permissive operation. However, protected-only left turn phasing can be inefficient, particularly during off-peak times. If protected-permissive or permissive-only left turn phasing is being considered, a traffic engineering study should be performed, including evaluation of the following:

- Operating speeds
- Possible sight distance obstructions (vehicles in opposing left turn lane(s), horizontal/vertical roadway geometry)
- Left turn and opposing through traffic volumes (vehicle mix - trucks)
- Left turn crossing distance
- Crash history
- Vehicle delays and queuing
- Potential pedestrian crossing conflicts
- Controller, cabinet and equipment flexibility and limitations

If protected-permissive or permissive-only operation is determined to be acceptable, flashing yellow arrow signal heads are required for separate signal faces per the MUTCD. Consideration should be given to providing this type of operation only during off-peak times.

2. **Automated and Adapted Traffic Signal Control:** To help jurisdictions better manage the variations in traffic volumes and operating speeds along signalized corridors, the use of automated traffic signal performance measures (ATSPMs) and/or adaptive traffic signal control (ATSC) could be considered.

The use of ATSPMs give agencies a better idea of how signal timing plans are performing throughout the day / week / month / year and provide the information needed to make adjustments to fine tune timing plans and coordination plans. New traffic signal controllers, or third party equipment added to existing traffic signal controllers, collect the real-time data needed to produce the performance reports. More information can be found on the [FHWA ATSPM Website](#).

The data produced through the ATSPMs can be used to determine the potential need for an ATSC system, which utilizes much of the same data collected for ATSPMs and adjusts traffic signal plans or coordination plans automatically. ATSC systems can be useful for corridors in which traffic is more variable or unpredictable than what could be addressed with specific time-of-day timing and coordination plans. More information can be found on the [FHWA ATSC Website](#).

3. **Signal Cycle Length:** The signal cycle length at an intersection can have a significant impact on pedestrian and bicyclist travel. Signal cycle lengths of 60 to 100 seconds are common in urban areas, as they allow frequent street crossings and encourage efficient use of a street network. In suburban areas where vehicle traffic is consolidated on a relatively small number of arterial and collector streets, signal cycle lengths are typically longer - between 100 and 120 seconds, sometimes even longer during peak periods. At intersections with a longer signal cycle length, all users approaching from a minor street can experience significant delays. This can result in reduced signal compliance for both pedestrians and bicyclists where gaps are present. Consideration should be given to providing shorter signal cycle lengths during peak and off-peak times, or operating in “free” or fully actuated mode during off-peak periods so the signal switches to the side street phase more quickly to minimize delays to side street users including bicyclists. However, signal cycle length reductions must not come at the cost of adequate pedestrian crossing intervals.
4. **Pedestrian and Bicyclist Signal Timing and Phasing for Reducing Delay and Managing Conflicts:** Frequent crossings accommodating walking and biking speeds for all ages and abilities are key to creating a safe, accessible, and connected pedestrian and bicycling network. Sections 13A-4, F and [12B-3, L](#) provide guidance on pedestrian and bicycle signal timing and detection, respectively. As motor vehicle speeds and volumes increase, separate signal phasing may be appropriate to improve safety for all users. Guidance for signal phase separation is also described in Sections 13A-4, F and [12B-3, L](#).

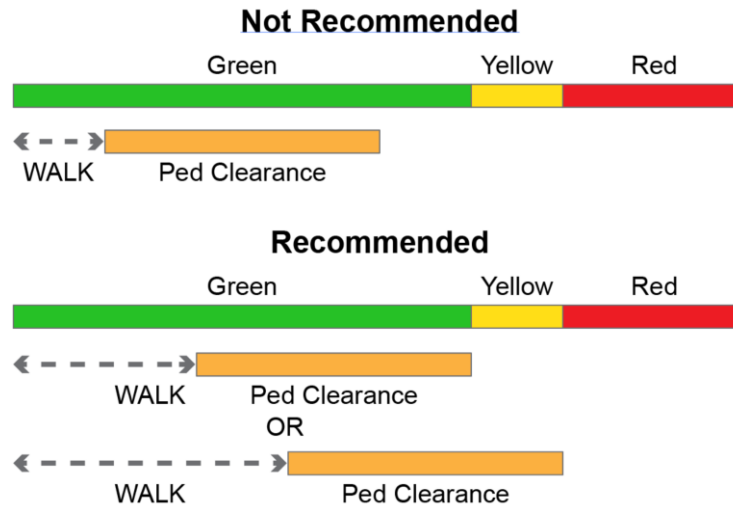
F. Pedestrian Signal Timing and Design

1. Signal Timing:

- a. **Signal Cycle Length:** In some instances, where pedestrians routinely experience long delays at signals, they may elect to cross away from the crosswalk at locations where conflicts are not controlled by a signal. Therefore, strategies to reduce overall cycle length can be particularly important for pedestrian safety. Where pedestrians are expected regularly, cycle lengths greater than 90 seconds should often be discouraged. In addition to reducing cycle lengths, designers may also consider using half-cycle lengths, particularly during off-peak hours. Adaptive signal control, where employed, should have limited variation in cycle length. Operations for adaptive signal control should be confined to suburban settings and event venues where traffic patterns can be highly variable.

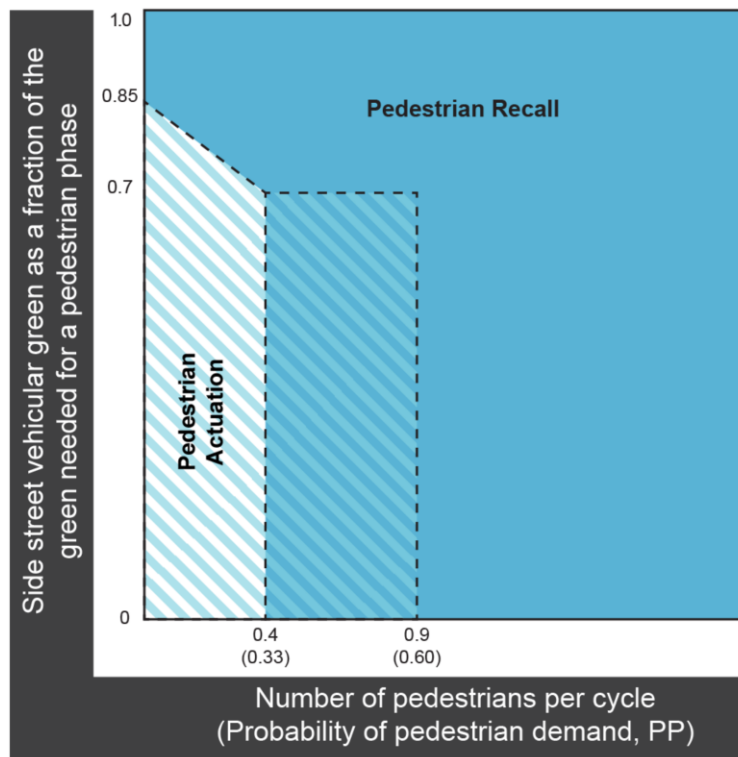
- b. **Pedestrian Signal Phase Timing:** Details for programming the walk and clearance interval are provided in MUTCD [Section 4E.06](#). Signal timing should strive to maximize the WALK + FLASHING DON'T WALK phase so total pedestrian time is equal to the total concurrent vehicle green and yellow timing; see Figure 13A-4.01. To address conflicts, designers should instead use one or a combination of treatments listed in Section 13A-4, F, 2.

Figure 13A-4.01: Maximizing the WALK Interval.



- c. **Recall and Actuation:** Pedestrians should not always be required to push a button to call the pedestrian phase at locations with high pedestrian volumes. This is particularly important in downtown corridors or business districts where there tends to be significant pedestrian volume and relatively short cycle lengths. In such environments, fixed time operation with time-of-day phase plans often functions more efficiently compared to actuated or semi-actuated signal timing. Fixed time operation allows for signal controllers to call pedestrian phases each cycle. In a fixed time grid, pedestrian WALK + FLASHING DON'T WALK intervals are often the maximizing factor for phase length, as the time necessary to accommodate pedestrian movements exceeds the time needed for motor vehicles. Designers may consider providing an automatic pedestrian phase according to Figure 13A-4.02. This could be accomplished based on different signal timing plans at certain times of day or day of the week.

If it is determined the pedestrian phase should switch from actuated to recall based on the time of day, designers can minimize confusion by ensuring the pushbutton includes a confirmation light. When the signal operations have switched to pedestrian recall, the detection indicator can be programmed to illuminate by default.

Figure 13A-4.02: Recall versus Actuated Pedestrian Phase for Coordinate-Actuated Arterials

Source: Cesme, Furth, Cashman, and Lee, 2021

2. **Signal Phasing for Managing or Reducing Conflicts:** There are a variety of alternative signal phasing options for reducing or eliminating conflicts between motorist and pedestrians. Designers should consider both the operational and safety impacts of signal phasing changes at an intersection. Designers should also be aware a phasing scenario may necessitate a separate motor vehicle turn lane and an additional signal phase, which may increase delay for some users, including pedestrians. Fully separated crossings may require longer cycle lengths, which may result in reduced user compliance with signal indications and increased potential for conflict. The four major phasing scenarios, criteria, and considerations are described below. There may not be one solution but a combination of treatments for specific periods or scenarios to address pedestrian safety.
 - a. **Leading Intervals:** Leading pedestrian intervals (LPIs) or leading through intervals (LTIs) may be used to give pedestrians a head start (typically a minimum of 3 seconds) when crossing the street. LPIs are a proven safety countermeasure to reduce vehicle-pedestrian crashes at intersections. Implementation allows waiting pedestrians to enter the crosswalk where they become more visible to conflicting motorists. Both LPIs and LTIs accomplish the same goal through different strategies.
 - **Leading Pedestrian Intervals:** With traditional signal phasing, parallel pedestrian WALK and motor-vehicle circular green indications start at the same time, immediately after the conclusion of the red clearance interval. With LPIs, the walk phase begins as usual and parallel motor vehicle circular green indications start after a brief period. Designers should include APS units where LPIs are provided; without APS units, pedestrians with low or no vision may not be able to maximize the advantage of LPIs, as they otherwise use the noise of concurrent vehicles to determine when to begin walking.

- **Delayed Turn or Leading Through Intervals:** A delayed left (or right) turn or LTI provides a green signal to through movements while delaying permissive left (or right) turns for a specific period. This delay time may vary based on site specific conditions, but (similar to an LPI) is usually between 3 and 6 seconds. This option minimizes intersection capacity impacts while providing a partially protected pedestrian phase, allowing those on foot a head start in order to establish themselves in the intersection before turning movements are allowed after the protected left (or right) turn phase.

The following equation is used for calculating the LPI interval (rounded to the nearest second).

$$LPI(sec.) = \frac{W_1 + W_2}{S_w} \quad \text{Equation 13A-4.01}$$

where:

LPI = Leading pedestrian interval, sec

W1 = Width of first lane of moving vehicles, ft

W2 = Width of shoulder, bicycle lane, and/or parking lane, ft

S_w = Walking speed, typically 3.5 ft/sec

Source: Lin, 2017

An approach meeting any one of the following criteria may be a good candidate for the installation of an LPI:

- Reported crash history finds one or more crashes per year have occurred over the last 3 years between vehicles turning on green and pedestrians crossing the street on the associated crosswalk with the pedestrian WALK signal;
- A visibility issue exists between the driver's view of pedestrians on the crosswalk due to obstructions or poor sight distance at an intersection approach that can be improved through an LPI. LPIs by themselves don't resolve sight distance limitations, as they don't protect pedestrians who arrive at the end of the WALK phase. Physical measures to remove corner sight obstructions should be given primary consideration;
- Intersection observations reveal conflicts between crossing pedestrians and turning vehicles in which there is a risk of collision should their movements and speeds remain unchanged;
- One of the two movement volumes (turning vehicle volume (A), or pedestrian volume (B), identified in Equation 13A-4.01) meet at least one the thresholds identified in the table for a given warrant.

Table 13A-4.01: LPI Volume Warrant Thresholds

Warrant	Turning Vehicles Volume (A)	Pedestrian Volume (B)
Vehicle Peak Hour	≥ 130 per hour	≥ 25 per hour
Pedestrian Peak Hour	≥ 100 per hour	≥ 50 per hour
4 Hour Vehicular and Pedestrian Volume	≥ 105 per hour	≥ 30 per hour
8 Hour Vehicular and Pedestrian Volume	≥ 100 per hour	≥ 25 per hour
School Crossing	≥ 50 per hour	

Source: Modified Lin, 2017

When a protected left turn phase is provided, it should occur as a lag to prevent left turning vehicles from continuing to cross during the LPI. Designers must avoid the “yellow trap” (see NCHRP Report 812 Section 4.3.1.3) when providing a lagging turn phase.

b. Protected Pedestrian Phase and Turn Restrictions: Protected pedestrian phases or protected-only signal phasing for turn movements can significantly reduce conflicts between pedestrians and motorists. This process eliminates specific motor vehicle phases (e.g. left turns) that cross concurrent pedestrian phases. For example, if the permissive left turns (either green ball or flashing yellow arrow), the cross pedestrian WALK/FLASHING DON'T WALK phase is eliminated and there is no longer a turning conflict for the crossing during that phase. In these cases, pedestrian phases may occur before (lead) or after (lag) conflicting vehicular movements.

Turn restrictions or protected pedestrian phases may be considered when one or more of the following criteria are met:

- There are high conflicting turning vehicles volumes. High turning volumes are defined as equal to or exceeding:
 - 200 total right and left turning vehicles per hour;
 - 50 left turning vehicles per hour when crossing one lane of through traffic; or
 - 100 right turning vehicles per hour.
- There is a high volume of total approaching traffic (greater than 2,000 vehicles per hour for all approaches);
- There are high pedestrian volumes (pedestrians are 30% of vehicle volumes or 300 pedestrians per hour);
- Crash patterns at the study location or nearby locations with similar geometry support the use of separating motor vehicle and pedestrian phasing. Typically, this encompasses three or more left turn or right turn collisions where pedestrians had the right-of-way over a 3 year period;
- The available sight distance is less than the minimum stopping sight distance criteria;
- The intersection geometry is unusual (streets intersect at acute/obtuse angles or streets have significant curvature approaching the intersection), which may result in unexpected conflicts and/or visibility issues;
- The intersection is in close proximity to senior housing, elementary schools, recreational areas, playgrounds, and/or health facilities.

Protected pedestrian phases or protected-only turn phases may be implemented on a permanent basis, during specific hours, or “on-demand” when a pedestrian is present and activates the pushbutton. When used for a specific time of day (school arrival and departure, e.g.), blank out NO TURN ON RED signs or red arrows should be used for conflicting motorist movements when the protected pedestrian phase is in operation. If only one movement or street meets the criteria above, consider a treatment to address those specific issues before implementing an intersection-wide approach (i.e., provide protected-only turns for the major roadway and allow for permissive turns on the minor roadway, if turning volumes are low on the minor roadway).

- c. Concurrent Pedestrian Phase with Permissive Vehicle Turns:** At most signals, the WALK indication for pedestrians is displayed concurrent with the green indication for parallel through vehicular movements. Concurrent timing often allows vehicles to turn left or right across the crosswalk during the WALK and FLASHING DON'T WALK phases with change interval countdown indication (pedestrian clearance interval), provided the motorists yield to pedestrians. To mitigate conflicts and improve motorist yielding, designers may consider the following treatments:
- Regulatory signs, such as the R10-15a series “TURNING VEHICLES YIELD TO [PEDESTRIANS]”
 - Flashing yellow arrows (see below)
 - Geometric treatments to reduce vehicle speeds and increase sight distances such as raised pedestrian crossings and curb extensions (see [Sections 12A-5](#) and [5M-1](#))

Flashing yellow arrows (FYAs) may be used for left or right turning motor vehicles to emphasize drivers may proceed after yielding to oncoming traffic and/or pedestrians in a crosswalk. FYAs allow flexibility in providing permissive turns while warning drivers of potential conflicts. Refer to the Interim Approval (IA-10) and MUTCD for additional guidance.

- d. Exclusive Pedestrian Phases:** An exclusive pedestrian phase (EPP), sometimes referred to as a “Barnes Dance”, stops vehicular traffic in all directions, allowing pedestrians to cross the intersection in all directions, including diagonally. This treatment can produce a safer operation over conventional phasing, but delays for both pedestrians and motorists can be higher than conventional signal timing. A protected pedestrian phase, specific turn restrictions, or LPIs are more appropriate solutions. An EPP may be preferred over a protected pedestrian crossing for the following scenarios.
- A combination of the criteria listed in Section 13A-4, F, 1, a, is met and 15% of pedestrians desire to cross diagonally
 - During special events occupying a substantial portion of the public right-of-way (street fairs, parades, etc.)
 - The start and end of school days for major school crossings
 - Intersections where certain motor vehicle turning movements are either not allowed or not in conflict with designated pedestrian crossings

Signs may be attached to signal poles or pedestrian pushbuttons to inform people the intersection has an EPP and they may cross diagonally; to inform where an EPP must be actuated by a person waiting to cross; or to deter crossing against the pedestrian signal concurrently with vehicle traffic. Signals including EPP should time pedestrian phases to accommodate the longest possible crossing.

If a diagonal crossing is employed, designers may need to consider how a person with a visual disability would know they could cross diagonally. Such determinations need to be carefully considered along with pushbutton placement and pedestrian ramp design for accessibility. Pavement markings should be designed according to MUTCD [Figure 3B-20](#).

3. Geometrics:

- a. Geometrics have a significant impact on pedestrian operations and safety at signalized intersections as alluded to in the previous section. Intersection skew, number of lanes, lane width, medians, islands, and curb returns all impact the distance pedestrians must travel to cross an intersection. As the distance to traverse an intersection approach increases, so does the signal timing that must be allocated to the pedestrian clearance interval. Long pedestrian clearance intervals can have a negative impact on traffic capacity and operations including increased delays to pedestrians, therefore designers minimize overall crossing distance to improve safety and reduce delay for all. Pedestrian actuation will disrupt traffic signal coordination and it may take several cycles to bring a corridor back into coordination; but it can improve safety and have minimal impact to operations during motor vehicle off-peak hours. A traffic engineer must balance the priorities and safety of vehicles and pedestrians at signalized intersections.
- b. Right turns present challenges for pedestrians. A driver of a vehicle turning right on red will be looking left for a gap in traffic. A pedestrian approaching from the right may have a walk indication. If the driver sees a gap but does not look back to the right, the pedestrian may not be seen by the driver resulting in a collision. As a result, a traffic engineer must decide whether to allow right turns on red. Right turn on red restrictions may be used to reduce this conflict, though such signs may not be effective if sight distance is not limited by geometry or other roadway features (landscaping, business signs, etc.) without significant enforcement efforts. A NO TURN ON RED (R10-11) sign may be used to always prohibit this movement, or a dynamic NO TURN ON RED sign may be installed to limit turns at specific times or conditions. Where left turns on red are legal on one-way streets, such restrictions may be appropriate for similar reasons.
- c. Pedestrian volume and safety are important considerations when designing right turn lanes. Right turn lanes can present additional challenges for pedestrians, especially if the returns are large and channelize traffic with an island and are therefore discouraged where pedestrians are expected. Designers should work to reduce the curb radius and may use elements such as truck aprons to keep speeds low. Where intersections are skewed, channelizing islands can mitigate larger corner radii. Channelizing islands should be designed to slow speeds and maintain visibility between pedestrians and motorists through geometric design; see Exhibit 5-7 of NCHRP Report 834. For retrofits, a raised crossing may be considered to reduce speeds of right turning vehicles and encourage yielding.
- d. An additional geometric consideration as it relates to pedestrians is the pedestrian refuge. Right turn islands and medians often double as pedestrian refuges. If islands and medians are intended to be used as pedestrian refuges, they must be large enough to hold pedestrians and be ADA compliant. A traffic engineer must consider the likelihood that pedestrians will stop and get stranded in an island or median. On large approaches, it may be intended that pedestrians only cross a portion of the approach and stop in a median or island. As a result, a traffic engineer must decide whether to install supplemental pushbuttons in the right turn island or median. If islands and medians are not intended to function as pedestrian refuges, they must be located so they do not obstruct the path of pedestrians. See [Section 12A-5](#) for refuge island design guidance.

4. **Visibility:** Visibility is important to the safe operation of the pedestrian indications. Pedestrian indications as well as the pushbuttons should be easily located by pedestrians. Consider where vehicles, especially large trucks, may stop so they do not obstruct the view of the pedestrian indications. This will require careful location of median noses, stop bars, crosswalks, and the pedestrian heads. Finally, make sure there are no obstructions in the returns that may prevent drivers and pedestrians from seeing one another such as the signal cabinet or vegetation.
5. **Countdown Pedestrian Heads:** Pedestrian signals with countdown displays show the number of seconds remaining in the clearance interval and their use has been shown to reduce both pedestrian and vehicular crashes at signals. MUTCD requires countdown pedestrian heads where the pedestrian change interval (the flashing upraised hand signal) is more than 7 seconds; see MUTCD [Section 4E.07](#). Traffic engineers should consider using countdown pedestrian heads for crosswalks where the pedestrian change interval is 7 seconds or less because they are easier to understand for all users.
6. **Americans with Disabilities Act:** The Americans with Disabilities Act (ADA) addresses several design requirements relating to pedestrians. ADA addresses design requirements for items such as sidewalk ramps, truncated domes, and pedestrian pushbuttons. These topics are addressed in detail in [Chapter 12](#) and other design guides such as the MUTCD and the AASHTO Policy on Geometric Design of Highways and Streets.
 - a. **Accessible Pedestrian Signals (APS):** Evaluate each traffic signal project location to determine the need for accessible pedestrian signals, especially if the project location presents difficulties for individuals with visual disabilities. The MUTCD contains standards for APS and pedestrian pushbuttons but does not require them. PROWAG requires APS and pedestrian pushbuttons when new signals are installed. For existing pedestrian signals, PROWAG requires APS and pedestrian pushbuttons when the signal controller and software are altered, or the signal head is replaced. An engineering study should be completed that determines the needs for pedestrians with visual disabilities to safely cross the street. The study should consider the following factors:
 - Potential demand for accessible pedestrian signals
 - Requests for accessible pedestrian signals by individuals with visual disabilities
 - Traffic volumes when pedestrians are present, including low volumes or high right turn on red volumes
 - The complexity of the signal phasing, such as split phasing, protected turn phases, leading pedestrian intervals, and exclusive pedestrian phases
 - The complexity of the intersection geometry

One tool that is available for evaluation of the need for APS and also prioritizing the order for installing APS equipment on crosswalks can be found at www.apsguide.org developed by the National Cooperative Highway Research Program (NCHRP).

If APS are warranted, it is necessary to provide information to the pedestrian in non-visual formats. This will include audible tones and vibrotactile surfaces. Pedestrian pushbuttons should have locator tones for the visually impaired individual to be able to access the signal. Consistency throughout the pedestrian system is very important. Contact the Jurisdictional Engineer regarding the standards and equipment types that should be incorporated into the design of the accessible pedestrian signal system. New tones such as clicks, ticks, and other electronic sounds have replaced the cuckoos and chirping tones of past systems.

- b. **APS Design Elements:** Refer to MUTCD [Sections 4E.08](#) through [4E.13](#) and the following information.
- 1) **Pushbutton Stations:** An APS pushbutton station is a weather-tight housing with a 2 inch diameter pushbutton, a speaker, and a pedestrian sign. Braille signing, raised print or a tactile map of the crosswalk may also be provided. The pushbutton has a vibrotactile arrow pointing in the direction of the crossing.
 - 2) **Location of Pedestrian Pushbuttons:** Pushbuttons (APS and non-APS) should be located adjacent to the sidewalk, between 1.5 and 6 feet from the edge of curb, shoulder, or pavement and no more than 5 feet from the outside crosswalk line (extended). Where physical constraints make the 6 feet maximum impractical, pushbuttons should be located no more than 10 feet from the edge of curb, shoulder, or pavement. Where two pushbuttons are provided on the same corner of the intersection, they should be separated by at least 10 feet. If the 10 feet separation is not feasible, audible speech walk messages are required for APS. Supplemental pushbutton poles or posts will typically be needed to meet the above criteria. The MUTCD requires a pedestrian pushbutton mounting height of approximately 3.5 feet above the sidewalk; keep in mind that the 3.5 feet is above the grade where the pedestrian would be when accessing the button. The pushbutton should be located so pedestrians using the audible or vibrotactile indication can align themselves and prepare for the crossing while waiting close to the pushbutton station and the crossing departure point.
It is common to see a narrow grass strip between the sidewalk and pole used to mount the pushbuttons or to only see sidewalk on one side of a pole containing multiple pushbuttons. It is difficult to impossible for a person in a wheelchair to reach the pushbutton in cases like these since it often requires the person to struggle with one wheel in the grass and one on the sidewalk. As a result, sidewalks must be paved up to the pole used to mount the pushbuttons and be at a reasonable slope. There should also be sidewalk on each side of a pole that has a pushbutton.
 - 3) **Locator Tone:** APS pushbuttons have a locator tone to allow visually impaired individuals to access the signal. The locator tone should be audible 6 to 12 feet from the pushbutton. The locator tone is active during the pedestrian clearance and “DON’T WALK” intervals.
 - 4) **Walk Indications:**
 - In addition to visual indications, APS include audible and vibrotactile walk indications. When at least 10 feet separation is provided between pedestrian pushbutton stations, the audible walk indication is a percussive tone. If 10 feet separation is not provided, speech messages are required. The speech message should name the street to be crossed and indicate that the walk sign is on. For example: “Main. Walk sign is on to cross Main.” Designations such as “Street” or “Avenue” should not be used unless necessary to avoid ambiguity at a particular location. If the traffic signal rests in WALK, the tone/message should be limited to 7 seconds and be recalled by a button press during the WALK interval, provided that the crossing time remaining is greater than the pedestrian change interval.
 - The vibrotactile walk indication is provided by a high visual contrast tactile arrow on the pushbutton that vibrates during the walk interval. The vibrotactile indication is particularly useful to individuals who have both visual and hearing impairments. The pedestrian must be able to place a hand on the device while being aligned and waiting to begin the crossing. The arrow should be aligned parallel to the direction of travel on the associated crosswalk.

c. APS System Options:

- Products currently in the marketplace involve use of 2 wire or 4 wire systems, indicating the number of wires between the pushbutton station and the control unit (CU). The 2 wire system uses a central CU mounted in the controller cabinet, and may provide Ethernet connectivity. Advantages of this system include minimal field wiring required on retrofit applications and central control of multiple crossings.
- The 4 wire system requires a separate CU mounted in the applicable pedestrian signal head for each pushbutton station. In addition to the typical two wires between the pushbutton and the controller cabinet, a 4 wire cable must be provided between the pushbutton station and the CU. This system may be more cost effective for installations with only one or two crossings.

G. Motorists, Bicyclists, and Pedestrian Expectations

Other traffic signal design considerations involve driver and pedestrian expectancy. A traffic engineer must look beyond the traffic signal being designed and consider the characteristics of the corridor and the attributes of the existing traffic signals along the corridor. For example, left turn phasing should be applied consistently and not switch between protected only and protected/ permissive without legitimate reasons. Pedestrian signal heads and audible pedestrian signals should be provided at signalized intersections in urban and suburban contexts that have sidewalks and curb ramps on the approaches in order to establish consistent expectations and safety for pedestrians. In places lacking sidewalks, other criteria may also be used to determine when pedestrian signal devices should be provided. These other criteria can be considered as part of engineering studies and could include pedestrian activity; expected or anticipated land use; transit stops; or the presence of schools, parks, or employment. If pedestrian signal heads are used, they should be used consistently and not sporadically where one intersection uses the heads and the next intersection relies on vehicular signal heads to guide pedestrians. Similarly, where separated bicycle lanes are present, the type of signal used for bicyclists should be consistent throughout; see [Section 12B-3, L](#). Traffic signal head style, placement, and orientation for both general purpose lanes and separated bicycle lanes should be consistent along a corridor as well as sign type, size, and location. Intersections should not randomly switch between doghouse and vertical five section heads, center of lane and lane line placement, or vertical and horizontal signal head orientation. Consistently applied design criteria improve motorist, bicyclist, and pedestrian expectations, which typically promote improved safety and operations. However, circumstances exist that may, at times, require changes to design criteria to increase vehicle and pedestrian safety and operations.

H. Future Development and Improvements

One of the biggest traffic signal design challenges is designing a traffic signal in an area that is under development or being redeveloped. Under these circumstances, much of the data needed for design is either unknown or unstable. Land uses are often modified and business prospects continually change often having significant impacts on existing and future traffic volumes. In addition, the rate at which traffic volumes will increase is difficult to determine. In such cases, the traffic signal designer must work closely with adjacent area land use planning agencies to work towards reasonable expectations for future travel demands and overall operations. It may be possible for anticipated future intersection improvements to be accommodated for within the design to significantly reduce the need to replace signal poles, mast arms, and foundations or add additional functionality to the traffic signal. These simple steps can build credibility with the public and add considerable efficiency to the traffic signal design and overall engineering process.

I. References

Cesme, B., P.G. Furth, R. Cashman, and K. Lee. [*Development of Pedestrian Recall versus Actuation Guidelines for Pedestrian Crossings at Signalized Intersections*](#). 2021.

Lin, Pei-Sung, et al. "Development of Statewide Guidelines for Implementing Leading Pedestrian Intervals in Florida." Florida Department of Transportation. 2017.

[*Signalized Intersections: Informational Guide*](#), Second Edition, FHWA-SA-13-027, July 2013

Traffic Signal Specifications Information

This section provides design information that complements and is organized similar to [SUDAS Specifications Section 8010](#).

The information below provides selective guidance on the specifications.

A. Part 1 - General

1. **Submittals:** There are several key submittals required of the contractor following award of the project. These are described below.
 - a. **Schedule of Unit Prices:**
 - 1) **Document:** Prepared by the traffic signal designer and included within the contract documents or provided to the contractor prior to construction.
 - 2) **Purpose:** Establish unit pricing for change order work if needed. Used to estimate partial payments.
 - 3) **Includes:** Identification of major traffic signal items along with an estimate of quantity and units of measurement. Two additional blank columns are provided (unit price, and unit extension).
 - 4) **Contractor Action:** Within 30 days after award, the contractor is required to submit a completed schedule of unit prices to the contracting authority.
 - 5) **Engineer Action:** Review the schedule in a timely manner. Check the appropriateness of each unit price, the accuracy of each unit extension calculation, and ensure that the grand total for all unit extensions matches the lump sum bid item for traffic signalization.
 - b. **Material and Equipment List:**
 - 1) **Document:** Prepared by the traffic signal designer or contractor.
 - 2) **Purpose:** Contracting authority approval of materials and equipment for all major traffic signal items.
 - 3) **Includes:** Identification of major traffic signal items along with an estimate of quantity and units of measurement. Two additional blank columns are provided (manufacturers name and each item's model number).
 - 4) **Contractor Action:** Within 30 days after award, the contractor is required to submit a completed list of materials and equipment to the contracting authority for approval.
 - 5) **Engineer Action:** Review the list in a timely manner. Check the appropriateness of each identified manufacturer and model number. Upon acceptance, sign and date the list and provide a copy to the contractor.
 - c. **Contractor Certification:**
 - 1) **Document:** Prepared by the contractor on company letterhead.
 - 2) **Purpose:** Contracting authority verification of contractor qualifications.
 - 3) **Includes:** Name, contact information, and certification of the Level II International Municipal Signal Association (IMSA) Certified Traffic Signal Technician(s) working on the project, along with a copy of their IMSA certificate.
 - 4) **Contractor Action:** Within 30 days after award, the contractor is required to submit the contractor certification to the contracting authority.
 - 5) **Engineer Action:** Review the appropriateness of the information provided.

d. Shop Drawings:

- 1) **Document:** Prepared by the traffic signal pole supplier for the contractor.
- 2) **Purpose:** Contracting authority review of traffic signal poles, supports, and related hardware.
- 3) **Includes:** Shop drawing information detailing each traffic signal pole, accompanying parts, and necessary hardware.
- 4) **Contractor Action:** Within 30 days after award, submit shop drawings to the contracting authority for engineer review.
- 5) **Engineer Action:** Review the shop drawings in a timely manner. Check the appropriateness of each detail. Upon completion of the review, sign/initial and date the shop drawings and provide a copy to the contractor.

e. Catalog Cuts:

- 1) **Document:** Prepared by the traffic signal equipment supplier for the contractor.
- 2) **Purpose:** Contracting authority review of all items within the equipment and materials list as well as for supporting components.
- 3) **Includes:** Catalog cut information detailing the make, model number, manufacturer, and specific details for all traffic signal equipment.
- 4) **Contractor Action:** Within 30 days after award, submit catalog cuts to the contracting authority for engineer review.
- 5) **Engineer Action:** Review the catalog cuts in a timely manner. Check the appropriateness of each item. Upon completion of the review, sign/initial and date the catalog cut documents and provide a copy to the contractor.

2. **Measurement and Payment:** Traffic signal work is typically bid as a lump sum item of which no measurements are made. However, partial payments to the contractor are established through measuring or estimating installed quantities and applying these quantities to the appropriate unit price (see Schedule of Unit Prices above).

B. Part 2 - Products**1. Underground:**

- a. **Handhole:** Handholes are a critical component to traffic signal design. The designer should verify with the jurisdiction how handhole lids are to be labeled and whether cable hooks should be included in handholes (sometimes not included in fiber optic handholes).

Handholes can come in all shapes and sizes (see [SUDAS Specifications Figure 8010.103](#)) and must be specified by the Engineer.

The designer should ensure that the contract documents clearly distinguish between handhole types, sizes, and desired locations. Handholes are typically uniquely numbered on the contract documents.

- b. **Conduit:** The SUDAS Specifications allow both steel and flexible conduit. Steel conduit is typically used on all service risers and plastic PVC or HDPE is used at all other locations. A typical signal installation will use a variety of conduit sizes. Some jurisdictions may request a specific color for fiber optic conduit. When connecting HDPE conduit to PVC conduit, the designer should work with the Contractor to clarify the method or materials to be used.

The following is a conduit checklist to consider during signal design:

- Conduit size and cables listed.
- Correct symbol for in-place conduit.
- Correct symbol for proposed conduit.
- Check for conflict with in place underground utilities.
- Check if conduit fill is less than 40%.
- 3 inch minimum typical size conduit under all public traveled roadways.
- Possible spare conduit stub out of controller cabinet for future use, threaded and capped.
- Conduit runs for interconnect should be as straight as possible.
- No PVC above ground (for example: bridge crossings and wood pole systems).
- Size of bends and elbows in conduit according to National Electrical Code or UL guidelines.
- If conduit is suspended under a bridge, does the distance between supports conform to code, is a hanger detail given in plan, and are expansion fittings called for?

An online resource can be found through MnDOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for considering conduit installation and features.

- c. **Wiring and Cable:** Signalized intersections require a variety of standard wires and cables; however, the number, size, and quantity of extra conductors pulled can vary by agency. The designer should include sufficient details to ensure the clear identification of cable runs by conduit. The inspector should make sure all wires are terminated neatly and in an organized fashion. Cables for vehicle and pedestrian signal heads should be continuous from the pole base to the controller cabinet without splices in underground handholes. Video and emergency vehicle preemption cables should be continuous without splices from the unit to the controller cabinet. All plan terminology should be consistent for example:
- Cable callouts/symbols identifying the number of cables and the number and size of conductors (for example 1-12C#14, 2-5C#14, 2-2C#14, 1-1C#6 Ground, 1-1C#10 Tracer, etc.).
 - Ped indications with separate 5/C #14 cables.
 - Separate 2/C #14 detector lead-in cable for each group of loop detectors.
 - Provide spares for future expansion of system, if necessary, and label them.
- d. **Foundations:** Signalized intersections require footings or foundations for all poles, pad-mounted controller cabinets, and other service cabinets such as fiber optic hubs or electrical service panels. Cabinet footing details are shown on [SUDAS Specifications Figure 8010.101](#). The designer should ensure that the plans reflect any desired future use spare conduit stubs out of the foundation.

Foundation size and depths vary according to pole style, mast-arm length, and pole loadings. The SUDAS Specifications provide figures for both pedestal poles and for mast-arm poles ([SUDAS Specifications Figure 8010.102](#)). SUDAS standard Type A mast arm pole foundation in soil designs ([SUDAS Specifications Figure 8010.102](#) and Table 13A-5.01) are based on the following guidelines, parameters, and assumptions:

- Broms' method for lateral resistance (moment/shear design) per AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals*, 6th Edition, 2013 (AASHTO LTS-6), with a safety factor of 2.86, which accounts for the possible under capacity of the soil strength (0.7) and the overload factor for the loadings (2.0).
- Alpha method for torsion design per FHWA-NHI-10-016 *Drilled Shafts: Construction Procedures and LRFD Design Methods*, May 2010, with a safety factor of 1.0.

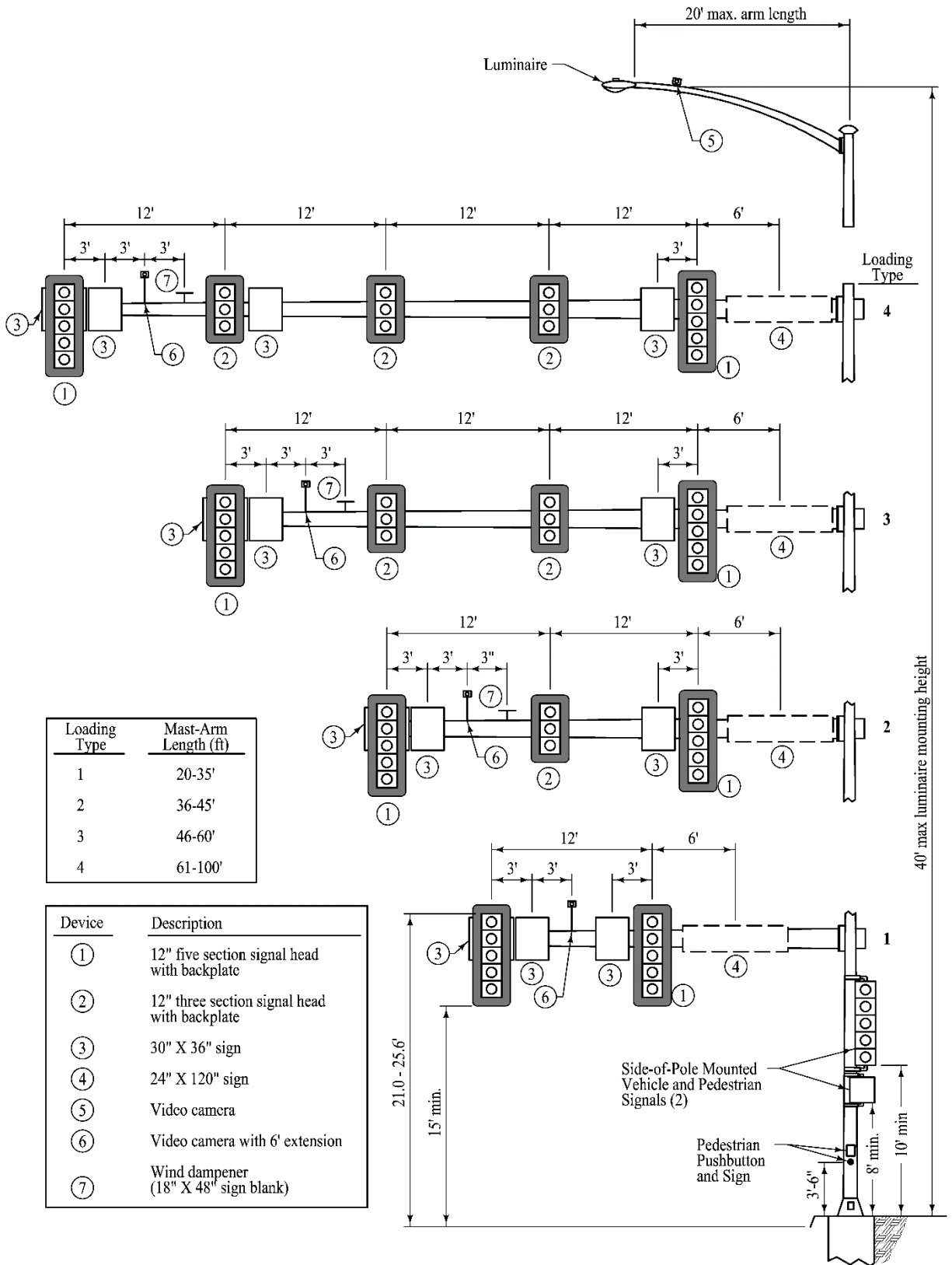
- Disturbed soil due to frost: 2.5 feet for moment/shear design, 5.0 feet for torsion design. Broms' method as presented in AASHTO LTS-6 includes an additional 1.5 diameters of foundation length to be added to the minimum foundation length required. The maximum value of 1.5 diameters or 2.5 feet shall be used when determining the disturbed soil for moment/shear design.
- Groundwater is present for moment/shear and torsion designs.
- Pole loadings as shown in Figure 13A-5.01, with poles designed per AASHTO LTS-6 specifications. Basic wind speed equals 90 mph with a 50 year mean recurrence interval and gust effect factor of 1.14 for strength design. Use Category II for fatigue design. Apply only natural wind gust loads (i.e. do not apply galloping loads, vortex shedding loads, or truck-induced gust loads) for fatigue design. Install vibration mitigation devices on all traffic signal pole mast arms over 60 feet in length as shown in the figures.
- Cohesive soils along the length of the foundation with an average blow count (N60) greater than or equal to 8, which equates to an average unconfined compressive strength (Qu) greater than or equal to 2.0 kips per square foot.
- Reinforced concrete design per AASHTO LTS-6 specifications.

For pole loading conditions greater than shown in Figure 13A-5.01, granular soils, or lower strength soils, special foundation designs will be required. Soil boring testing should be performed prior to construction to verify soil types and strengths if non-typical soils are suspected. If rock is anticipated at the project site and the designer intends to utilize the Type C mast arm pole foundation in rock or a Type B foundation (see [SUDAS Specifications Figure 8010.102](#)), determine rock quality through a subsurface investigation completed by a geotechnical engineer licensed in Iowa. If rock is encountered unexpectedly, the contractor may undertake a subsurface evaluation conducted by a geotechnical engineer licensed in Iowa to determine the quality of the rocks encountered. Based on that investigation, the Engineer may approve the use of a Type B or Type C foundation in rock if requested by the contractor.

Table 13A-5.01: Standard Mast Arm Pole Foundation Designs

Loading Type (Figure 13A-5.01)	Maximum Mast Arm Length (feet)
1	35
2	45
3	55
3	60
4	70
4	80
4	90
4	100

Figure 13A-5.01: Mast Arm Pole Loadings for Standard Foundation Designs



The designer should ensure that foundations:

- Are located in compliance with applicable clear zone requirements (unless breakaway pedestal poles)
- Do not conflict with pedestrian walkways or ramps
- Are at the proper finish grade elevation
- Avoid or minimize conflicts with existing or proposed utilities
- Provide acceptable pedestrian pushbutton locations per MUTCD guidance
- Are located to provide adequate visibility of signal heads

An online resource can be found in MnDOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for foundation types and installation details.

- e. **Bonding and Grounding:** All traffic signal installations must be bonded and grounded according to the National Electrical Code.

Bonding is defined in the Code as the permanent joining of metallic parts required to be electrically connected. In a traffic signal, the term is used to describe the electrical and mechanical connection of conduit, metal poles, cabinets, and service equipment.

Grounding is defined in the Code as a conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conductive body that serves in place of earth.

The designer should ensure that the contract documents include sufficient notation for the traffic signalized intersection to be properly bonded and grounded. This includes placing ground rods at each traffic signal pole and at the controller as well as through use of bonding and grounding jumpers within the handholes.

An online resource can be found in MnDOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for bonding and grounding details.

2. **Detection:** Detectors provide vehicle and pedestrian inputs to the traffic signal controller. Proper detector installation, operation, and maintenance is critical to the safe and efficient operation of any signalized intersection. An online resource to learn more about detection styles, modes, and typical layouts can be found within MnDOT's [Traffic Engineering Manual](#). Since this document is a PDF, some of the information from this source is provided below.

Detector sizes and locations vary by agency and by location. SUDAS provides standard drawings for typical modified diamond and rectangular detector loops ([SUDAS Specifications Figure 8010.104](#)).

An online resource can be found in MnDOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for installation and mounting details.

- a. **Inductive Loop Vehicle Detector:** A common type of vehicle detection device in use today is the inductive loop. This is a loop of wire imbedded in the pavement (saw cut in existing concrete or NMC loop in new concrete) carrying a small electrical current. When a large mass of ferrous metal passes over the loop, the magnetic field is disturbed and generates, or induces, a change in resonant frequency in the wire. This change in frequency is then recognized by the detector amplifier and signals the controller that a vehicle is present.

- b. Pedestrian Push Button Detector:** There are a number of ways to provide pedestrian actuation at a signalized intersection. The most common equipment used by far is the pedestrian pushbutton detector. Pressing the button provides a contact closure that actuates the call. There are plenty of examples of good and bad pedestrian pushbutton placement; however, part of the problem is getting the pedestrian to use the button. Specific information regarding pedestrian detectors can be found in the MUTCD [Section 4E.08 Pedestrian Detectors](#).

An online resource can be found in MnDOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for style, installation, and mounting details.

- c. Video Detection Camera System:** Vehicle detection by video cameras is a popular form of vehicle detection within Iowa. The rapid processing of video images provides the detection outputs to the controller. The designer should carefully consider the type of equipment necessary to provide video detection, the maintenance needs of this equipment, and the specific installation and mounting requirements necessary.

Designers should consider relevant manufacturer recommendations and other online resources.

- d. Microwave/Radar Vehicle Detector:** Microwave/radar detection is often used within Iowa during temporary signal control to provide simple, non-intrusive vehicle detection.

- 3. Communications:** The designer may be required to provide supplemental specifications for these items given the highly proprietary nature of this equipment and the needs of the contracting agency. Generic specifications have been provided in the SUDAS Specifications.
- 4. Cabinet and Controller:** The designer may be required to provide supplemental specifications for the controller, cabinet, and emergency vehicle pre-emption system given the highly proprietary nature of this equipment. Cabinet and controller options include TS1, TS2, ATC, and 2070. The need for controllers to collect high definition data should be considered. Generic specifications have been provided in the SUDAS Specifications; this section also includes references to UPS battery backup system and emergency vehicle preemption system. The designer should carefully consider the cabinet and mounting requirements of the battery back-up system.

An online resource can be found in MnDOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for style, installation, and mounting details.

5. Poles, Heads, and Signs:

- a. Vehicle Traffic Signal Head Assembly:** Vehicle signal heads must comply with MUTCD [Chapter 4D](#).

An online resource can be found in MnDOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for style, installation, and mounting details.

- b. Pedestrian Signal Head Assembly:** Pedestrian vehicle signal heads must comply with Chapter 4E of the MUTCD.

- c. Traffic Signal Poles and Mast Arms:** Signalized intersections require poles and mast arms to achieve proper traffic signal and pedestrian head placement. The default is for the contractor to furnish one-piece poles and mast arms. The designer should include plan note information if two-piece poles and mast arms will be allowed. Mast arm details and typical loadings are shown on Figure 13A-5.01; additional mast arm details are shown [SUDAS Specifications Figure 8010.105](#). The designer should ensure that the plan locations comply with all clear zone, sight restriction, and pedestrian criteria. Vertical clearance to overhead utility lines is a constant issue that designers should take note of during design. Although the minimum height from the pavement to the bottom of the signal housing is 15 feet, the designer should consider the street classification and the volume of large trucks in establishing the signal height above the pavement. However, the top of the signal housing cannot exceed 25.6 feet above the pavement. If the project being designed has specific requirements relative to the elevation of the end of the mast arm in relation to the connecting point on the vertical pole, include those requirements in the plans or special provisions of the contract documents.

An online resource can be found in MnDOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for style, installation, and mounting details.

- d. Traffic Signal Pedestal Poles:** Pedestal poles are often used for pedestrian signals and pushbuttons, and are much easier to locate within a tight right-of-way. Pedestal pole details and typical head mounting information are shown on [SUDAS Specifications Figure 8010.106](#).
- e. Traffic Signs:** The designer must ensure that all signs comply with Iowa DOT standards and the MUTCD.

C. Supplemental Requirements

A summary listing of items within [SUDAS Specifications Section 8010](#) requiring supplemental requirements to be provided by the designer includes, but is not limited to, the following:

- Handholes - specify types, sizes, and lettering.
- Foundations - specify dimensions and any conduit stubs needed for future use.
- Communications - specify all traffic monitoring equipment along with any fiber optic equipment and materials.
- Cabinet, controller, battery backup, vehicle detection, pedestrian detection, PTZ camera, and emergency vehicle preemption - specify all relevant equipment.
- Traffic signal poles and mast arms - specify finish for pole.
- Traffic signs - specify sheeting, sign dimensions, street name sign letter series and sizes, and mounting requirements.

D. Temporary Traffic Signals

When a temporary traffic signal ([SUDAS Specifications Figure 8010.107](#)) is included in the work, the designer must address the following items:

- Type of vehicle detection equipment to include, if any.
- Type of emergency pre-emption equipment, if any.
- Number of signal heads for each direction.
- Signal control equipment, including pedestrian equipment if to be included.
- Basic signal timing and any modifications based on construction staging.
- Points for relocation of temporary traffic signal if a trailer mounted unit is specified.



Work Zone General Information

A. Introduction

This section provides information on establishing temporary traffic control in work zones, addressing the safe and efficient accommodation of all road users: motorists, bicyclists, pedestrians, and those with special needs. The information presented is based on standards and guidance in the 2009 Edition of the Manual on Uniform Traffic Control Devices (MUTCD). References to the MUTCD sign designations in this chapter are shown in parentheses, e.g. (W20-1).

Not all the recommendations in this chapter will apply to every circumstance faced by local agencies, and each unique situation may not be addressed. Modifications of the typical applications may be required to adapt to specific field conditions. Therefore, use engineering judgment, seeking the advice of experienced professionals and supervisors in difficult and complex interpretations. This information can be used as a reference for temporary traffic control in work zones on all city or county roadways. However, always check contract documents and local agency requirements for any pertinent modifications.

B. Importance of Quality Traffic Control

The value of proper traffic control through work zones cannot be overemphasized. Three major reasons for providing quality temporary traffic control can be identified:

- 1. Safety:** Many crashes occur each year in Iowa work zones, resulting in death and injuries to motorists and workers. Appropriate levels of traffic control will help lessen the occurrence of work zone crashes.
- 2. Liability:** Improper use of temporary traffic control, deficiency of devices, or negligence may result in legal claims against a contractor, agency, or even individual workers. Complying with accepted standards and guidance could help avoid and reduce possible legal actions.
- 3. Responsibility:** Providing temporary traffic control in compliance with established practices is a requirement of the public trust; it's simply the right thing to do!

The MUTCD is incorporated into the Code of Federal Regulations and is recognized as the national standard for traffic control devices on all roads open to public travel in the nation. In addition, Iowa has adopted the MUTCD as the state standard (Iowa Code section 321.252 and Administrative Rule 761 - Chapter 130). Local agencies are required to adhere to the MUTCD requirements in Iowa Code Section 321.255. Always remember the MUTCD standard statements, "The responsibility for the design, placement, operation, maintenance, and uniformity of traffic control devices shall rest with the public agency or the official having jurisdiction," and "temporary traffic control plans and devices shall be the responsibility of the authority of a public body or official having jurisdiction for guiding road users." Even though the authority for placing temporary traffic control is sometimes granted to others (contractors, utilities, etc.), the responsibility for requiring properly signed work zones remains with the agency that has jurisdiction over that road or street.

C. Applicable Standards and References

The MUTCD presents minimum standards only. Iowa has adopted the MUTCD as the official standard for traffic control, but many applications and practices in Iowa exceed national standards. The user should check for recent revisions of the MUTCD and state and local policies before selecting an appropriate application.

- 1. National Requirements:** Other important federal requirements and guidance are available in Federal Highway Administration's (FHWA) *Standard Highway Signs* manual and the National Committee on Uniform Traffic Laws and Ordinances' *Uniform Vehicle Code*. Worker and flagger apparel recommendations and requirements from the American National Standards Institute (ANSI) have been adopted into the MUTCD. Information about worker and flagger apparel can be found through the International Safety Equipment Association (ISEA). Complying with the *Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way*, also known as the Public Right-of-Way Accessibility Guidelines or PROWAG, is especially important when accommodating pedestrians. The US Access Board is an excellent source for background and supplemental accessibility information (www.access-board.gov). The Institute of Transportation Engineers' *Traffic Control Devices Handbook* also provides valuable supplemental guidance.
- 2. State Requirements:** When working on or near any road or street right-of-way where Iowa Department of Transportation (Iowa DOT) has jurisdiction, Iowa DOT requirements take precedence over this chapter.
- 3. Local Requirements:** Cities and counties may adopt ordinances and policies that apply to temporary traffic control - provided these meet or exceed the standards presented in the MUTCD. Verify local requirements before establishing any temporary traffic control on local roads and streets.

D. Work Duration

Work duration is a major factor in determining the number and types of devices used in TTC zones. The duration of a TTC zone is defined relative to the length of time a work operation occupies a spot location. The five categories of work duration and their time at a location are:

- Long-term stationary is work that occupies a location more than 3 days.
- Intermediate-term stationary is work that occupies a location more than one daylight period up to 3 days, or nighttime work lasting more than 1 hour.
- Short-term stationary is daytime work that occupies a location for more than 1 hour within a single daylight period.
- Short duration is work that occupies a location up to 1 hour.
- Mobile is work that moves intermittently or continuously.

Work Zone Set Up

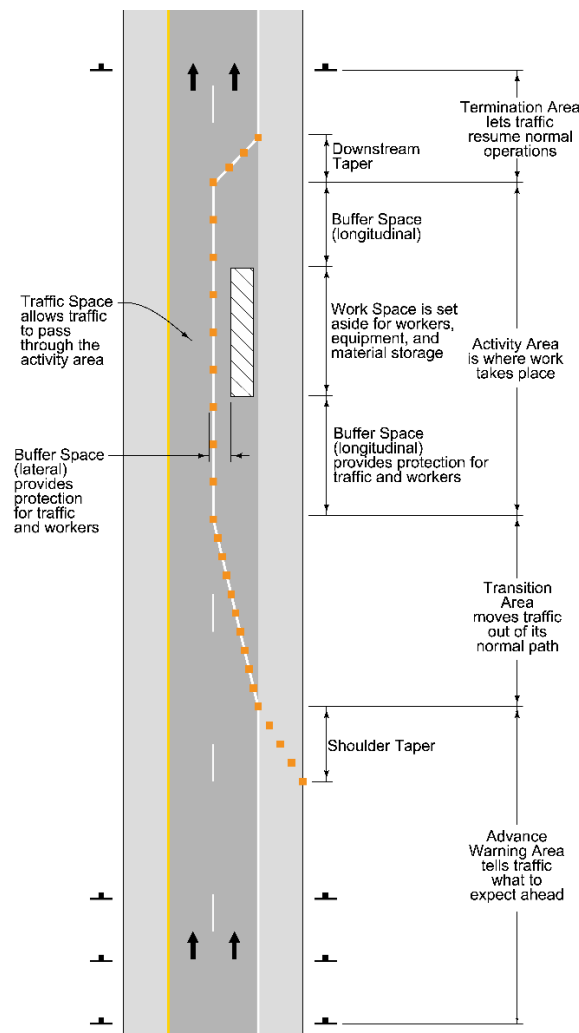
A. Major Elements

A typical work zone, designated with signs and various other traffic control devices, is defined as extending from the first advance warning sign or vehicle with amber, high-intensity, rotating, flashing, oscillating, or strobe light to an END ROAD WORK (G20-2) sign or other device beyond which traffic returns to normal paths.

Most work zones involving major traffic obstructions can be divided into four major areas:

- advance warning
- transition
- activity
- termination

Figure 13B-2.01: Work Zone Temporary Traffic Control - Major Elements



1. **Advance Warning Area:** Advance warning is crucial to safety, and every work zone should include this important feature. Without effective warning, road users cannot be expected to react properly. The advance warning area is that section of roadway where road users are informed about the activity ahead. Depending on the type of road, traffic volumes and speeds, and degree of obstruction, advance warning might consist of a
 - vehicle with amber, high-intensity, rotating, flashing, oscillating, or strobe light,
 - single sign, or
 - series of signs.

Vehicle hazard lights may be used to supplement amber, high-intensity, rotating, flashing, oscillating, or strobe lights (hereinafter called vehicle warning lights), but they shall not be used alone. Flags may be used to call attention to the advanced warning signs

When a series of signs is required, information is presented in this order:

- a. General information, such as ROAD WORK AHEAD (W20-1)
 - b. Description of activity or obstruction, such as RIGHT LANE CLOSED AHEAD (W20-5R) or ONE LANE ROAD AHEAD (W20-4)
 - c. Specific action, such as BE PREPARED TO STOP (W20-7b) or FLAGGER AHEAD (W20-7a)
2. **Transition Area:** In a transition area, traffic is directed from the normal, intended path to a new course, such as from one lane to another. To accomplish this, the MUTCD requires channelizing. Channelization, or redirection of traffic, is usually accomplished with tapers.
 3. **Tapers:** Part 6 of the MUTCD discusses tapers in detail. Several types of tapers are available for work zones, depending on circumstances:
 - Merging tapers are used for lane closures on multi-lane roadways.
 - Shifting tapers divert traffic to alternate paths without closing lanes.
 - Shoulder tapers can be used to delineate shoulder closures.

The recommended minimum length of all these taper types depends on the speed of approaching traffic and the width of the lane being closed. Lengths of merging tapers for various speeds are shown in Table 13B-2.01. Speed limit refers to the legally established and signed speed limit.

Two other taper types do not depend on traffic speed or lane width:

- one lane, two-way taper (used mostly for flagging or self-regulating)
- downstream (termination) taper

One hundred feet is the maximum recommended length for a one-lane, two-way taper, but a length of 50 feet can benefit flagging operations. Refer to the [Iowa DOT's Flagger's Handbook](#) for more details. At least 100 feet for each closed lane is recommended for a termination taper length. For merging taper lengths on multi-lane roadways, see Table 13B-2.01.

Speed Limit (mph)	Taper Length (L) (ft)	Number of Devices	Spacing of Devices (ft)
20	80	5	20
25	125	6	25
30	180	7	30
35	245	8	35
40	320	9	40
45	540	13	45
50	600	13	50
55	660	13	55

* This table does not apply to one lane, two-way (flagger) tapers.

4. **Channelizing Devices:** Several channelizing devices are available for use in tapers, including cones, verticals panels, drums, and barricades.
5. **Activity Area:** The activity area of many work zones can be divided into three main parts:
 - a. **Buffer Space:** Buffer spaces are recommended wherever workers are exposed to high-speed moving traffic. Neither work activity nor storage of equipment, vehicles, or material should occur within a buffer space.
 - 1) **Longitudinal buffer spaces** are a safety protection for workers and road users. They give drivers space to recover in emergency situations. Like many other work zone dimensions, longitudinal buffer space is based largely on the traffic speed. Table 13B-2.02 includes buffer lengths for various traffic speeds and are applicable to all temporary traffic control situations. The length of the longitudinal buffer space used may need to be modified based on site conditions.

Table 13B-2.02: Longitudinal Buffer Space

Speed (mph)	Length (ft)
20-35	0-200
40	0-300
45	0-400
50	400
55	600

- 2) **Lateral buffer spaces** are especially effective in high-speed and heavy traffic situations where maximum possible separation of workers from moving vehicles is desired. Flaggers are often beneficial in these circumstances as well.
- b. **Work Space:** The work space is that area closed to traffic where maintenance and construction activities are accomplished. This area can be occupied by equipment, materials, and workers and should be made as secure and safe as possible.
- c. **Traffic Space:** Motor vehicles and other road users occupy the traffic space, also known as the open lane. Workers and equipment should respect this area and not intrude or otherwise hamper free movement of traffic in the open lane.
4. **Termination Area:** The termination area begins at the end of the work space and extends to the END ROAD WORK (G20-2) sign, if posted. This sign is optional, but is recommended by the MUTCD. A downstream or termination taper (50 to 100 feet) may be installed in this area for traffic guidance.

Temporary Traffic Control Devices

Traffic control devices are any signs, signals, markings, or other items used to guide, warn, and regulate traffic. Traffic control devices are the major means of communication for road users; thus it is most important that design, condition, and placement be proper at all times. All devices used in work zones shall comply with the provisions of the MUTCD. In addition, sign design must comply with the *Standard Highway Signs* manual. Do not install temporary traffic control devices until work is ready to begin. The MUTCD requires all temporary traffic control devices to be promptly removed or covered when no longer needed. Signs are the most common type of work zone traffic control device, categorized into three types:

- regulatory
- warning
- guide

The MUTCD requires all signs to be retroreflective or illuminated when used at night. Roadway lights are not sufficient as illumination sources. Supplemental nighttime warning lights may be required in pedestrian or recreational areas.

A. Regulatory Signs

Regulatory signs inform users about traffic laws and regulations. Because these signs impose legal obligations, they must be used properly and only with prior official authorization by the local agency. Regulatory signs are generally rectangular with a black legend and border on a white background. Exceptions include the STOP, YIELD, DO NOT ENTER, WRONG WAY, and ONE WAY signs. STOP (R1-1), ROAD CLOSED (R11-2), and SPEED LIMIT (R2-1) are all regulatory signs. Specific requirements for road closures are discussed in detail later in this chapter.



B. Warning Signs

Warning signs draw attention to conditions on or near the roadway that may not be readily apparent. These signs are generally diamond-shaped with an orange background and black lettering or symbols; although other colors are allowed for a few specific signs. Examples of common warning signs are the FLAGGER (W20-7a) and the ROAD WORK AHEAD (W20-1) sign. Advisory speeds on warning plaques are not enforceable; use for guidance only.



C. Guide Signs

Guide signs advise drivers and pedestrians about navigating through the work zone. These signs are normally orange with black lettering. An example of a guide sign is END ROAD WORK (G20-2).



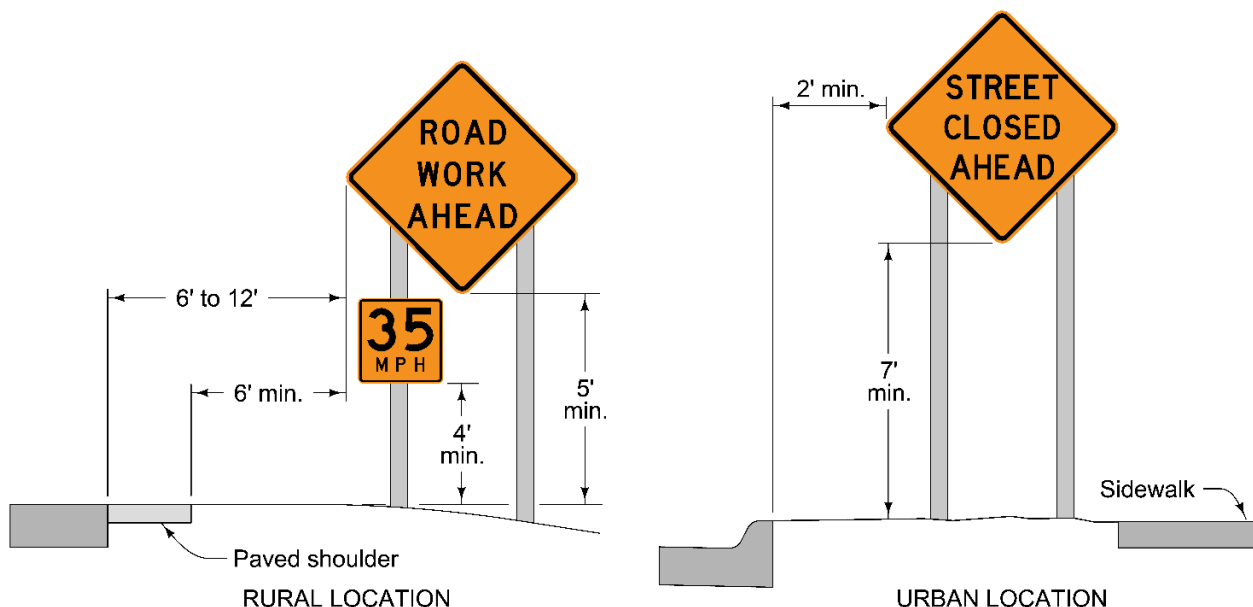
D. Sign Dimensions

Sign size and legend are critical for road user recognition and understanding. Based on traffic speed, use the following guidelines when deciding sign dimensions. For best performance, use larger signs, even in low-speed areas.

- **High speed roadway (35 mph and above):** Advance warning signs shall be at least 48 inches by 48 inches. In general, uppercase lettering should be at least 7 inches high.
- **Moderately low traffic volumes and speeds (25 to 35 mph):** The MUTCD allows 36 inches by 36 inches, with an uppercase lettering size of 5 inches.
- **Low speed local roads and streets (25 mph or below):** Smaller advance warning signs, 30 inches by 30 inches, may be allowed, with sign messages short and symbols clear in meaning.

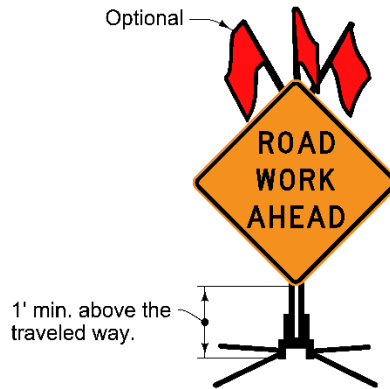
E. Sign Installation

Consider the position of signs relative to the roadway and the spacing between the signs when installing temporary traffic control. The MUTCD requires that long-term stationary work zones (more than three consecutive days in one location) use post-mounted advance warning signs. Minimum dimensions for post-mounted signs are shown on the figure below.



Supplemental plaques may be mounted 1 foot lower than the primary sign. If installed within the clear zone, sign supports shall be crashworthy or shielded. Signs should not be positioned on sidewalks or bicycle facilities in urban areas, and any signs with less than a 7 foot mounting height should not project more than 4 inches into pedestrian facilities.

Portable sign mounting is used for work zone applications lasting less than 3 days. The supports shall be crashworthy.



Several designs have been approved, but any used in the clear zone shall be crashworthy per the test and evaluation criteria of National Cooperative Highway Research Program (NCHRP) Report 350 or Manual on Assessing Safety Hardware (MASH). Fabric, roll-up, portable signs are popular because they are lightweight and easy to install. However, some designs are too flexible in windy conditions, degrading visibility. Flexible base portable signs that do not provide necessary stability in windy situations shall be adequately supported, or work activities must be terminated. Both the requirements for crashworthiness and adequate visibility shall be met with all work zone signs. Other installation methods for work zone signs include vehicle and barricade mounting. Do not allow post-mounted signs to encroach on sidewalks, shared use paths, or bike lanes or place portable signs on them unless those facilities are officially closed.

Vehicle-mounted signs should be high enough for adequate visibility for approaching vehicles, suggested at least 4 feet above the ground surface.



Barricade mounted signs shall be at least 1 foot above the traveled way. In addition, signs on Type III barricades should not cover more than 50% of the top two rails and not more than 33% of all three rails.

F. Spacing of Signs

Appropriate spacing is crucial for road users' reaction to work zone signs. Spacing depends on several factors, including speed of traffic, type of roadway, locations of intersections or major driveways, vertical and horizontal roadway alignment, and physical obstructions in the work area. If road users don't seem to be recognizing the signs, consider increasing the sign spacing and/or size and adding flags or warning lights.

The MUTCD contains guidance for minimum spacing of signs in Section 6C.04. A basic "rule of thumb" for warning sign placement is 4 to 8 times the speed limit in urban areas and 8 to 12 times the speed limit in rural locations. Table 3 illustrates these minimum guidelines. The positions of the signs should be adjusted for available sight distance.

Table 13B-2.01: Distance Between Signs

Speed Limit (mph)	Spacing (ft)
25	100
35	250
45	350
55	500

G. Channelizing Devices

Channelizing devices warn about work zone conditions and guide road users through or around the work area. Several types of channelizing devices are available, including cones, vertical panels, channelizers, tubular markers, drums, and barricades - with new types continually being developed and approved. Promptly repair, clean, or replace any devices that are damaged, dirty, or deficient in retroreflectivity.

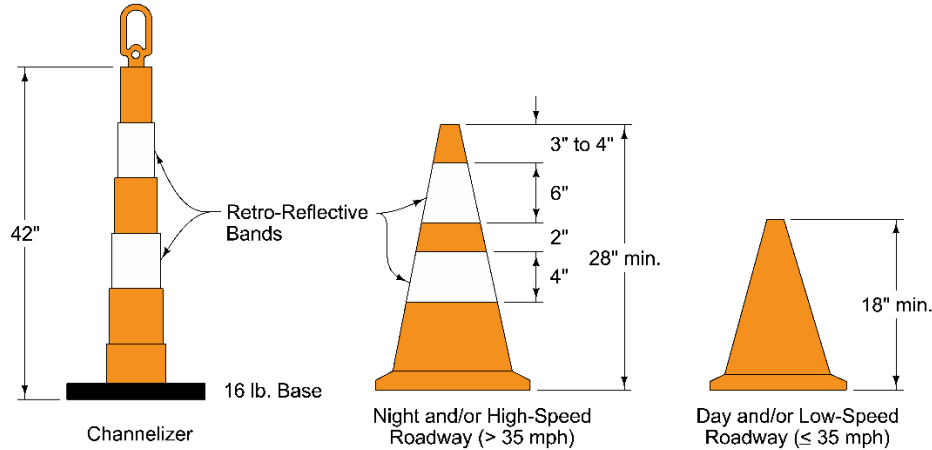
- Ballast:** Ballast is often required to maintain position and stability of channelizing devices, and proper placement and type of ballast is important. Follow these guidelines:
 - Never place ballast on top of channelizing devices; keep ballast on the lower part of the device.
 - Use sandbags or weighted bases, and do not use items such as rocks, broken concrete, etc., for ballasting.
- Spacing of Devices:** Like signs, spacing of channelizing devices in work zone applications depends primarily on traffic speed. A rule of thumb suggested by the MUTCD for maximum spacing is the speed limit when used in merging or shifting taper applications and twice the speed limit for tangent applications. Closer spacing should be considered where drivers might need more guidance, such as in horizontal curves or in low-speed applications.

Table 13B-2.02: Channelizing Device Spacing

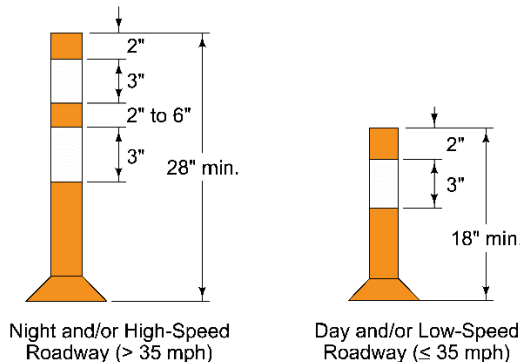
Speed Limit (mph)	Taper (ft)	Buffer (ft)	Work Space (ft)
25	25	50	50
30	30	60	60
35	35	70	70
40	40	80	80
45	45	90	90
50	50	100	100
55	55	110	110

3. Types of Devices:

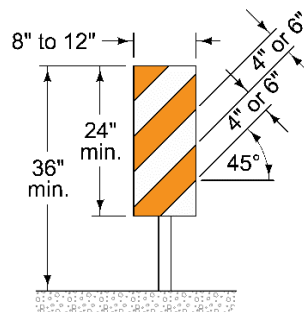
- a. **Cones:** Cones are required to be predominantly orange in color. Retroreflective striping is required for night use. To maintain proper position, ballasting as described earlier may be employed, or cones can be nested to increase weight and stability.



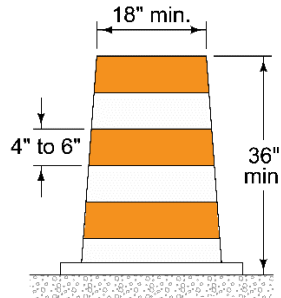
- b. **Tubular Markers:** Tubular markers have similar requirements as cones - predominantly orange, crashworthy, and retroreflective if used at night. Because of the narrow width (2 inch minimum), tubular markers are especially useful in restricted work areas. These devices must be securely ballasted or attached to the road surface to prevent movement.



- c. **Vertical Panels:** Vertical panels provide greater visibility for road users than some other channelizing devices and can still be used in narrow work zone applications. Panels shall also have alternating retroreflective orange and white stripes, 4 or 6 inches wide, sloping downward at an angle of 45 degrees in the direction vehicular traffic is to pass. If warning lights are used with vertical panels, they must be securely fastened to prevent dislodging if struck by an errant vehicle. Proper ballasting should be used to maintain stability.

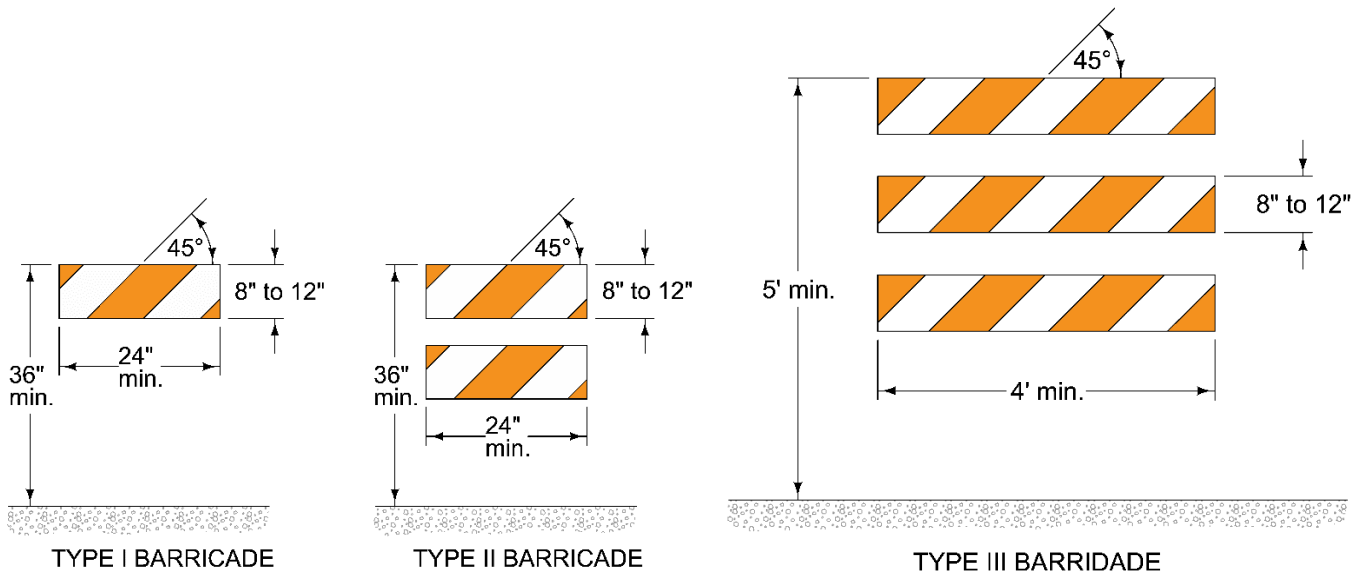


- d. Drums:** Drums are very effective traffic control devices, especially for long-term applications. These devices shall be made with lightweight, deformable materials and alternating 4 to 6 inch wide orange and white retroreflective stripes. Drums made of metal are not allowed, and tops shall be securely fastened to prevent accumulation of debris. Using ballast on top of drums is not acceptable.



- e. Barricades:** Barricades for work zone applications are available in three types: I, II, and III, differentiated primarily by the number of boards used. Barricades may be used individually or in groups to mark a specific condition. They may also be used in a channelization series, in either taper or tangent applications.

Type I barricades are generally used on conventional roads or city streets. Type I or Type II barricades are intended for work areas where traffic flow is maintained. Type II or Type III barricades are recommended on higher volume roadways. Type III barricades should be used to close or partially close a street or road. For complete closures, Type III barricades can be extended across the entire roadway or street or supplemented with fencing.



Using ballast, rocks, or broken concrete on top of barricades for stabilization is not allowed. Barricade rails shall feature alternating retroreflective orange and white stripes, 4 to 6 inches wide, sloping downward at a 45 degree angle in the direction traffic is expected to pass. As with vertical panels, properly placing the barricades is very important. If traffic is allowed to pass Type III barricades, retroreflective striping at the appropriate slope is required on both sides.

f. **Miscellaneous Devices for Channelizing:** The MUTCD describes several other devices that can be used in channelization of vehicular and pedestrian traffic in work zones.

1) **Arrow Boards:** As described in MUTCD Section 6F.61, arrow boards are signs with lighted elements capable of flashing or sequential displays. They are intended to be used with signs or other traffic control devices. The panels are rectangular and non-reflective black with yellow lights. The types of arrow boards used for temporary traffic control are:

- Type A: Suitable for low-speed urban streets
- Type B: Used on intermediate speed roadways or for maintenance and mobile operations
- Type C: Used for high-speed and high-volume applications

Table 13B-2.03: Minimum Requirements by Board Type

Board Type	Board Size	Legibility Distance	Number of Elements
A	48 x 24 inches	1/2 mile	12
B	60 x 30 inches	3/4 mile	13
C	96 x 48 inches	1 mile	15

Arrow boards can be mounted in various ways, but they should be mounted at least 7 feet above the ground, except on vehicle-mounted arrow boards, which should be as high as practical. Amber, high-intensity, rotating, flashing, oscillating, or strobe lights are required when panels are mounted on vehicles. Boards shall be able to dim 50% for night operations.

A caution mode is only allowed for two-lane or shoulder applications. The MUTCD does not allow a single arrow board to close more than one lane at a time.

Examples of the advance warning arrow board displays are below. Note right arrow is shown; left is similar.



Flashing Arrow (Merge Right)



Sequential Arrow (Merge Right)



Sequential Chevron (Merge Right)



Flashing Double Arrow (Merge Right or Left)



Flashing Caution

Flashing Caution

Alternating Diamond Caution

- 2) **Portable Changeable Message Sign (PCMS):** These devices have become more common in work zones on high-volume and high-speed roadways. A PCMS has a message panel, control system, power source, and transporting unit. Requirements and guidance for using these devices is presented in MUTCD Section 6F.60, and these provisions should be closely reviewed before using a PCMS. Effectiveness of a PCMS depends on how well drivers perceive and react to this device. Therefore, message visibility, length, clarity, and location to work activities are all critical for getting the most benefit from these devices. Current PCMS designs are not crashworthy, so place the devices off the roadway or behind a barrier.
- 3) **Shadow Vehicles:** Shadow vehicles, equipped with two amber, high-intensity, rotating, flashing, oscillating, or strobe lights mounted on the rear of the vehicle, can be used to warn traffic of the operation ahead. The distance between the work vehicle and the shadow vehicle may vary according to terrain, type of work, or other factors. Whenever adequate stopping sight distance exists, the shadow vehicle should maintain the minimum distance to the work vehicle and proceed at the same speed. The shadow vehicle should slow down in advance of vertical or horizontal curves that restrict sight distance. The work and shadow vehicle should pull over periodically to allow traffic to pass. When an adequate shoulder is present, the shadow vehicle should use it for travel. If the work and shadow vehicle cannot pull over to allow traffic to pass, a DO NOT PASS (R4-1) sign may be placed on the shadow vehicle.



Inspection and Documentation of Temporary Traffic Control

A. Documenting Inspections

Monitoring work zone traffic control should be a priority for all transportation agencies. Observations cannot be substantiated unless properly recorded. Inspections and documentation should always be current and accurate. Entries should be brief and factual (no opinions). Never erase mistakes; always cross out errors and make corrections (eraser marks in a diary may raise credibility concerns). Consider taking a video or photographs of the traffic control immediately after it's installed. The TTC Zone Checklist below can be used to help with this documentation process.

Temporary Traffic Control (TTC) Zone Checklist

Project: _____ Inspector's Name: _____
Date: _____ Time of Day: _____

Overall appearance of TTC Zone: _____

A. DRIVE THRU

- Maneuvers easy to follow?
• Adequate warnings of hazards?
• Signing clear?
• Traffic control devices sufficiently visible?
• Consistent with traffic control plan?
• Comments: _____

D. ARROW BOARDS

- All elements burning?
• Placement?
• Alignment?
• Capable of dimming?
• Consistent with traffic control plan?
• Comments: _____

B. SIGNS

- Need to be removed/repositioned/covered?
• Need to be cleaned/replaced?
• Need additional signs?
• Existing signs need to be covered?
• Sign supports crashworthy?
• Adequate retroreflectivity?
• Correct size?
• Correct spacing?
• Consistent with traffic control plan?
• Comments: _____

E. PAVEMENT MARKINGS

- Conflicting markings?
• Retroreflective?
• Proper width and length?
• Comments: _____

C. CHANNELIZING DEVICES

- Adequate taper length?
• Device spacing?
• Need for additional devices?
• In need of repair/cleaning/replacement?
• Adequate retroreflectivity?
• Consistent with traffic control plan?
• Comments: _____

F. FLAGGING

- High visibility clothing?
• Positioned appropriately?
• Proper equipment?
• Professional behavior?
• Comments: _____
• Corrective action required? _____
• Urgent? _____
• Within 3 days? _____
• Within _____ days?

Comments: _____

Signed: _____

B. Documenting Crashes in the Work Zone

When establishing any documentation procedure for work zone crashes, ensure supervisory and legal staff are aware of these records. Special documentation for work zone crashes should consider using this guidance:

- Develop and follow standard procedures.
- Establish and maintain a relationship with local law enforcement.
- Record all pertinent information, but only facts - not opinions.
- Use standard forms, if available.
- Supplement with photos and police reports.
- Describe any resultant revisions in temporary traffic control.
- Analyze any crash data at the completion of the project.

Other Work Zone Considerations

A. Flagging in Work Zones

Flagging is commonly considered one of the most dangerous jobs in temporary traffic control. Visibility and recognition by drivers are very important for safe and efficient flagger operations. Iowa has adopted even more stringent standards for flagging activities; these are described in the [Iowa DOT's *Flagger's Handbook*](#) and should be carefully reviewed before beginning any flagging activities.

B. High-Visibility Safety Apparel

All workers within the right-of-way who are exposed either to traffic (vehicles using the road/street for purposes of travel) or to work vehicles and construction equipment within the TTC zone shall wear high-visibility safety apparel that meets the Performance Class 2 or 3 requirements of the ANSI/ISEA 107 publication entitled "American National Standards for High-Visibility Safety Apparel and Headwear" or equivalent revisions.

C. Nighttime Operations

MUTCD Section 6G.19 offers guidance and advice for temporary traffic control measures for nighttime operations. Traffic volumes are reduced at night, but the number of impaired drivers may increase. Impaired drivers and reduced visibility mean that additional steps need to be taken to ensure safe and efficient working conditions. Work areas should be lighted to provide adequate visibility for work tasks and road users. Lighting shall not produce a disabling glare condition for approaching road users, flaggers, or workers. MUTCD Section 6F.82 describes specific requirements for lighting during night hours. Size and type of luminaries, mounting height, pole location, and positioning are all specified. The performance of the lighting should be observed immediately after implementation and then periodically during use. For flagging at night, comply with the [Iowa DOT's *Flagger's Handbook*](#).

D. Accommodation of Pedestrians and Bicyclists

The MUTCD requires all road users to be controlled throughout work zones, including motorists, bicyclists, and pedestrians. When urban streets are being improved, needs of pedestrians and bicyclists should receive as much attention as the needs of motorists.

- 1. Pedestrians:** The Americans with Disabilities Act of 1990 requires suitable access for persons with disabilities, even in work areas. Temporary traffic control for pedestrians should consider the special needs of disabled pedestrians, including those with visual disabilities. MUTCD Sections 6D.01 and 6D.02 provides guidance for planning temporary traffic control for pedestrians:
 - Pedestrians should not be led into conflicts with vehicles or work zone equipment.
 - A safe and convenient path should be provided for pedestrians, closely replicating existing sidewalks.

Pedestrians shall be notified in advance if sidewalks will be closed. The MUTCD requires standard signs to be supplemented with alternative warnings such as audible messages or instructions to aid visually impaired pedestrians, if such a need is identified. In addition, a firm, stable, and slip resistant surface should be provided throughout the entire length of any temporary pedestrian facility. There should be no curbs or abrupt changes in grade or terrain that could cause tripping or be an obstacle to wheelchair use.

To avoid conflicts with work zone activities, pedestrian travel may need to be diverted. Moving work equipment across designated pedestrian paths should be avoided or at least minimized. Temporary traffic barriers should be considered for safe separation when vehicular and pedestrian paths are relocated close together in long-term work areas. Mesh fencing, caution tape, rope, or chain strung between traffic control devices will not comply with standards in PROWAG and should not be used.

For additional guidance, refer to MUTCD Chapter 6D, [SUDAS Design Manual Chapter 12](#), and the Field Guide for Pedestrian Accommodation in Work Zones (FHWA Grant DTFH61-13-H-00025).

- 2. Bicyclists:** Proper planning for bicyclists through and along work zones is as important as planning for motor vehicle traffic, especially in urban and suburban areas. According to the MUTCD, if the TTC zone affects the movement of bicyclists, adequate access to the roadway or shared use path shall be provided. On low volume roads or short work zones, standard traffic control practices are usually adequate. It is important to remove temporary signing, debris, and other obstructions from the edge of the roadway, bike lane, or shared use path after each day's work.

If a bike facility detour involves significant out of direction or distance travel, bicyclists will prefer to ride through the work zone. It is preferable to allow bicyclists to proceed as close to their original route as possible. On longer projects, a temporary bike lane or a wide travel lane may be needed. Advance work zone signs should not obstruct the bicyclist's path. Signs should be placed on the shoulder or planting strip rather than in the bike lane or on the shared use path. For additional guidance, refer to the AASHTO Guide for the Development of Bicycle Facilities, 4th Edition.

E. Road and Street Closures

Roadway improvements can generally be accomplished more efficiently and safely when vehicular traffic is detoured from the work area. However, access for local property owners and commercial interests must be maintained in many situations. Even though a street or road section is closed by official action, the agency must still consider appropriate temporary traffic control measures in that area even if only for local public traffic. Properly using specific regulatory signs is required.

Traffic control for closures can be considered in two different applications: outside the work area and inside the actual closed street or road section. MUTCD Part 6 includes specific requirements and guidance for temporary traffic control associated with closures.

When safety fence is needed, provide orange plastic mesh containing ultraviolet stabilizers with a height of 48 inches \pm 2 inches. Maximum aperture opening of a nominal 4.5 square inches. Connect to posts or drums to keep the safety fence upright and tight. In lieu of safety fence, Type III barricades may be placed continuously across the pavement, including shoulders if present.

While the messages on the following signs may seem similar, each must be used appropriately:

- ROAD (STREET) CLOSED (R11-2),
- LOCAL TRAFFIC ONLY signs (R11-3a), and
- ROAD CLOSED TO THRU TRAFFIC (R11-4).

MUTCD Section 6F.08 states that the ROAD (STREET) CLOSED (R11-2) sign shall not be used where road users are allowed to pass. When local access (vehicular or pedestrian) is allowed in closed street or road sections, be sure to maintain an appropriate level of temporary traffic control, including

- warning signs
- barricades and other channelizing devices at drop-offs, and
- fencing of excavations

F. Business Access

Providing clearly defined, continuous access to businesses along the construction area is critical to the success of a long duration traffic control setup. The only time a business access should be closed is when it falls within the activity area. When that situation occurs, consideration should be given to cross easements between properties and temporary access connecting adjacent properties. Signage indicating alternate business access points should be added to the temporary traffic control setup.



Work Zone Traffic Control References

American Road and Transportation Builders Association. *Pedestrian Accommodation in Work Zones: A Field Guide*. Based on FHWA Grant Agreement DTFH61-13-H-00025. February 2018.

International Safety Equipment Association. American National Standard for High-Visibility Safety Apparel and Accessories.

Iowa Department of Transportation. *Flagger's Handbook*. October 2015.

U.S. Access Board. *Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way*. Also known as the public Right-of-Way Accessibility Guidelines or PROWAG.

U.S. Department of Transportation. Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition.

U.S. Department of Transportation. Federal Highway Administration. *Standard Highway Signs (Including Pavement Markings and Standard Alphabets)*. 2004 Edition.

Wiegand, P., Richards, B. *Temporary Traffic Control Handbook*. 2016 Edition.

