
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.

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.
- 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
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

- 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
 - 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 AWF
- 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. 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.

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. At intersections with low volumes of pedestrians crossing such as an arterial, an actuated controller tends to operate much more efficiently, as it is not necessary to time pedestrian intervals except when an actual demand exists.

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:

- 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

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. Signal head locations and configurations considering visibility and proposed phasing.
- 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.
- 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

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.

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](#).

F. Pedestrian Considerations

1. 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 have a negative impact on traffic capacity and operations. A pedestrian actuation will disrupt traffic signal coordination and require several cycles to bring a corridor back into coordination. However, large pedestrian volumes may dictate signal timing resulting in less than optimal conditions for vehicles. 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.
- c. Right turn lanes can present additional challenges for pedestrians, especially if the returns are large and channelize traffic with an island. The islands can channelize right turning vehicles away from the traffic signal indications creating difficulties signaling the right turn movement. Pedestrian volume and safety are important considerations when considering and designing right turn lanes.
- 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 push buttons 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.

2. **Visibility:** Visibility is important to the safe operation of the pedestrian indications. Pedestrian indications as well as the push buttons 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.
3. **Special Considerations:** Circumstances often arise that require special considerations. For example, children may have difficulty understanding the meaning of pedestrian indications. Count down pedestrian heads may be easier for children to understand; therefore, have increased value in school zones. Count down pedestrian heads may also have added value on wide approaches. The flashing numbers can attract a person's eye and the numbers tell a pedestrian how much time they have to cross which has added value on very wide approaches. There may be a particular area within a city that has a high concentration of visually impaired. In this case, audible pedestrian indications may have added benefit. In many cases, some extra thought and minimal dollars can change a design from adequate to desirable.
4. **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 push buttons. These topics are addressed in detail in [Chapter 12 - Sidewalks and Bicycle Facilities](#) 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. Some jurisdictions elect to provide APS for all new or modified signal installations. 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 push buttons 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) **Push Button Stations:** An APS push button station is a weather-tight housing with a 2 inch diameter push button, a speaker, and a pedestrian sign. Braille signing, raised print or a tactile map of the crosswalk may also be provided. The push button has a vibrotactile arrow pointing in the direction of the crossing.
- 2) **Location of Pedestrian Push Buttons:** Push buttons (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, push buttons should be located no more than 10 feet from the edge of curb, shoulder, or pavement. Where two push buttons 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 push button poles or posts will typically be needed to meet the above criteria. The MUTCD requires a pedestrian push button 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 push button should be located so pedestrians using the audible or vibrotactile indication can align themselves and prepare for the crossing while waiting close to the push button station and the crossing departure point.

It is common to see a narrow grass strip between the sidewalk and pole used to mount the push buttons or to only see sidewalk on one side of a pole containing multiple push buttons. It is difficult to impossible for a person in a wheelchair to reach the push button 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 push buttons and be at a reasonable slope. There should also be sidewalk on each side of a pole that has a push button.

- 3) **Locator Tone:** APS push buttons 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 push button. 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 push button 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 push button 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 push button 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 push button station. In addition to the typical two wires between the push button and the controller cabinet, a 4-wire cable must be provided between the push button station and the CU. This system may be more cost effective for installations with only one or two crossings.

G. Driver 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. 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. Traffic signal head style, placement, and orientation 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 driver 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.

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 ~~PVC~~ 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 [Chapter 11 - Conduits and Fittings](#) from 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

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 through [Chapter 10 - Foundations and Equipment Pads](#) from 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 through [Chapter 13 - Grounding and Bonding](#) from 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 [Chapter 9 - Traffic Signals](#) from 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 through [Chapter 15 - Vehicle Detection](#) from [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 through [Chapter 18 - Accessible Pedestrian Signal Push Buttons](#) from 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 through [Chapter 21 - Traffic Control Signal Cabinets](#) from 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 through [Chapter 17 - Signal Heads and Luminaires](#) from 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 through [Chapter 16 - Signal and Light Poles](#) from 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.