CHAPTER 9 - HIGHWAY TRAFFIC SIGNALS

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9-1.00 INTRODUCTION

9-1.01 Purpose

The purpose of this chapter is to present uniform guidelines, procedures, and preferred practices used in the planning, construction, revisions, and maintenance of highway traffic signals on trunk highways in Minnesota.

9-1.02 Scope

This chapter applies to all highway traffic signals that are on state trunk highways. Highway traffic signals that are installed by agencies other than the State of Minnesota and that are not on state trunk highways may utilize the guidelines in this chapter, as appropriate. There is no legal requirement for using these guidelines by local agencies.

Highway traffic signals include all power-operated (manually, electrically, or mechanically operated) traffic control devices by which traffic is warned of conflicting movements or directed to take some specific action. Highway traffic signals assign right-of-way where conflicts exist or where passive devices, such as signs and markings, do not provide the necessary flexibility to properly move traffic safely and efficiently.

Traffic control signals, flashing beacons, pedestrian hybrid beacons, pedestrian signals, hybrid beacons, emergency vehicle signals, movable bridge signals, portable traffic signals, and temporary traffic control signals are covered in this chapter. The planning, design, and operation of highway traffic signals in Minnesota must conform to the standards, limits, and alternatives provided in the “Minnesota Manual on Uniform Traffic Control Devices” (MN MUTCD). Where the standards in the MN MUTCD are broad, this Traffic Engineering Manual describes preferred practices of design and operation of signals. The standards and guidelines of the MN MUTCD and this Manual are to be a basis for engineering judgment, not a substitute for it.

This chapter is intended as an overview of guidelines and procedures for the process of highway traffic signal design and operation in Minnesota. Please refer to “MnDOT Signal Design Manual” (Signal Design Manual) and “MnDOT Traffic Signal Timing and Coordination Manual” (Signal Timing Manual) when traffic control signal design and operations training and/or detailed description is needed. This chapter may reference chapters in the Signal Design Manual and Signal Timing Manual when appropriate.

This chapter should be used together with other documents to design and operate highway traffic signals on trunk highways in Minnesota. The MN MUTCD details minimum standards for the planning, design, and operation of highway traffic signals. The National Electrical Manufacturers Association (NEMA) Standards Publication No. TS 1-1989 or TS 2-Ver 2.06, 2003, “Traffic Control Systems”, latest revision, gives specifications for traffic signal control equipment. Detailed drawings for traffic control signal construction are in the MnDOT Standard Plates Manual. The MnDOT Standard Specifications for Construction book, latest revision, governs the construction of highway traffic signals. Other applicable documents include the latest version of the National Electrical Code by the National Fire Protection Association (NFPA), MnDOT Technical Memoranda from the Office of Traffic Engineering, the signal design details found on the MnDOT Traffic Engineering Signals web site, and Minnesota Statutes.

9-2.00 ACRONYMS

Acronym	Definition
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
AFMS	Automated Facilities Management System
APL	Approved Products List
APS	Accessible Pedestrian Signal
AWF	Advance Warning Flasher
CAES	Office of Computer-Aided Engineering Services

CESU	Central Electrical Service Unit
FHWA	Federal Highway Administration
FYA	Flashing Yellow Arrow
ICE	Intersection Control Evaluation
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
LED	Light-Emitting Diode
MESU	Metro Electrical Service Unit
MnDOT	Minnesota Department of Transportation
MN MUTCD	Minnesota Manual on Uniform Traffic Control Devices
MUTCD	Manual of Uniform Traffic Control Devices
NEMA	The National Electrical Manufacturers Association
NFPA	National Fire Protection Association
RESU	Regional Electrical Service Unit
TE Request	Traffic Engineering Request

9-3.00 LEGALITY

For highway traffic control signals to serve any useful purpose, their indications must be clearly understood and strictly observed. To achieve these objectives, highway traffic signals should be uniform, there should be valid justification for installation, and compliance with them must be legally enforceable. National standards have been developed for the installation and operation of traffic control signals. The actions required of motorists and pedestrians are specified by statute or by local ordinance or resolution consistent with national standards. Legislation establishing the authority for installation, the meanings of the signal indications, and the required compliance to these indications by the road user, are outlined in such documents as the Uniform Vehicle Code and Minnesota Statutes.

9-3.01 Legal Authority

Legal authority is established in Minnesota Statutes Section (Minn. Stat. Sec.) 169.06, Subdivisions (Subd.) 1-4) for the Department and local units of government to place and maintain highway traffic signals, require obedience to highway traffic signals, prohibit the use of unauthorized highway traffic signals, and prohibit interference with official highway traffic signals.

Minn. Stat. Sec. 169.06 refers to specific types of signals as follows: Subd. 5 - Traffic Control Signals, Subd. 6 - Pedestrian Control Signals, Subd. 7 - Flashing Signals and Subd. 8 - Lane Direction Control Signals.

9-3.02 Jurisdiction

All highway traffic signals to be installed on Minnesota trunk highways shall have approval by the MnDOT District Traffic Engineer prior to installation.

When a highway traffic signal is to be installed for which agencies in addition to the State of Minnesota have responsibility, an agreement shall detail the responsibility of each participating agency.

9-3.03 Meaning of Signal Indications

The legal meaning of traffic control signal indications in Minnesota is found in the MN MUTCD, Part 4 and in Minn. Stat. Sec. 169.06, Subd. 5.

9-3.04 Tort Claims

Chapter 12 of this Manual discusses tort claims as they relate to highway traffic signals.

9-4.00 GENERAL DESCRIPTION OF HIGHWAY TRAFFIC SIGNALS

A highway traffic signal is a device that contains one or more indications to warn of an impending hazard or right-of-way change. Traffic signals are commonly called stoplights, semaphores, or flashers. The largest percentage of highway traffic signals are intersection traffic control signals.

Most highway traffic signals are installed in response to high vehicle and/or pedestrian volumes, or a high number of correctable crashes. A justified highway traffic signal, properly designed, installed, operated, and maintained, is an asset to the traveling public. A highway traffic signal that is unjustified, poorly designed, installed, operated, or maintained may decrease the safety or the efficiency of an intersection.

9-4.01 Types of Highway Traffic Signals

The general category of highway traffic signals includes traffic control signals, pedestrian hybrid beacons, emergency vehicle signals, pedestrian signals, flashing beacons, railroad crossing signals, freeway ramp control signals (ramp meters), lane-use control signals, in-roadway lights, movable bridge signals, portable signals, and temporary traffic control signals. See MN MUTCD Part 4 for additional detailed descriptions of highway traffic signals.

9-4.01.01 Traffic Control Signals

Intersection traffic control signals (commonly called traffic signals) are the most common type of highway traffic signal. The primary function of an intersection traffic control signal is to assign the right-of-way to different movements at intersecting streets or highways. It does this by giving to each movement, in turn, a green indication or flashing yellow arrow indication, which allows drivers to proceed through the intersection. Intersection traffic control signals allow traffic and pedestrians to cross heavily traveled roadways safely, provide for the efficient operation of intersections, and reduce right angle crashes.

The decision to install a traffic control signal should be made after an Intersection Control Evaluation (ICE) is performed for the intersection. The purpose of the ICE is to document all of the analysis that went into determining the recommended alternative. The amount of analysis will depend on each project's location and scope. Intersections which are part of larger projects and/or have significant impact to adjacent intersections will require significant analysis and documentation. Stand-alone intersections will require a safety and capacity analyses and documentation of other factors such as cost and right-of-way information. The goal is to select the optimal control for an intersection based on an objective analysis of the existing conditions and future needs.

If, as a result of the ICE, a traffic control signal for the intersection is warranted, a design using the latest standards will result in a safe operation. The signal is to be installed according to the plans and special provisions. After a signal is installed, it must be maintained to ensure safe operation.

Traffic control signals can operate under two types of control, pretimed or traffic actuated (see MnDOT Signal Timing and Coordination Manual).

1. **Pretimed**
   Under pretimed control, the intersection is operated using predetermined, fixed cycle lengths, splits, and offsets.

2. **Traffic Actuated**
   Under traffic actuated control, the intersection is operated according to traffic demands. Cycle lengths, splits, and offsets change according to traffic demands.

Two or more traffic control signals that are operated as a system are said to be coordinated. These coordinated traffic control signals are operated to permit continuous movement or minimize delay along an arterial highway or throughout a network of major streets.

Pedestrian or Mid-block Signal

A pedestrian signal is a traffic control signal installed, usually at mid-block, to allow pedestrians to cross a road. It uses a red, yellow, and green ball indication. Pedestrians can push a button to give them the right-of-way to cross the road. These signals are installed to benefit a nearby school for example or other pedestrian traffic generator.

Emergency Vehicle Hybrid Beacon

An emergency vehicle hybrid beacon is a special type of highway traffic signal system used to warn and control traffic and to assist emergency vehicles to access the roadway in a safe and efficient manner. In most cases, the beacon should be placed mid-block. Since the indications are displayed dark when in rest, it is not considered a traffic control signal.

Emergency Traffic Control Signal

An emergency traffic control signal is a traffic control signal in front of or near a building housing emergency vehicle equipment where a signal is not otherwise warranted, but is needed to allow emergency vehicles to safely enter the roadway. At mid-block locations, the traffic control signal stays green for the mainline traffic until preempted in the station. This permits the emergency vehicle to receive the right-of-way and enter the roadway immediately.

One-Lane, Two-Way Signal

A one-lane, two-way signal (commonly referred to as a portable signal system) is a traffic control signal used at a location that is not wide enough to allow traffic to flow in both directions simultaneously (for example a one lane bridge or a construction area). These signals essentially operate as a two-directional control.

Pedestrian Hybrid Beacon

A pedestrian hybrid beacon (often referred to as a High-Intensity Activated Crosswalk Beacon or HAWK) is a special type of hybrid beacon used to warn and control traffic at an un-signalized location to assist pedestrians in crossing a street or highway at a marked cross walk. The pedestrian hybrid beacon must be ADA compliant and in most cases the pedestrian hybrid beacon should be placed mid-block. It should meet the warrants found in the MN MUTCD, Part 4. Since the indications are displayed dark when in rest, it is not considered a traffic control signal.

9-4.01.02 Flashing Beacons

Advance Warning Flashers (AWF) are highway traffic signals that alert vehicles approaching a traffic control signal that the green indication is about to terminate. This highway traffic signal uses two 12-inch yellow indications above the “PREPARE TO STOP WHEN FLASHING” sign that flashes alternatively in a wig wag operation. AWF’s are part of the intersection traffic control signal, located typically 700’ to 800’ ahead of the intersection.

Flashing beacons are highway traffic signals that draw attention to signs, pedestrian crossings, and intersections. A flashing beacon is either a red or yellow circular indication.

Warning Beacon

This type of yellow flashing beacon is used to identify obstructions in or immediately adjacent to the roadway, to supplement warning and regulatory signs, except the “STOP”, “YIELD”, and “DO NOT ENTER” signs, and to identify pedestrian crosswalks.

Speed Limit Sign Beacon

This type of yellow flashing beacon is used with fixed or variable speed limit signs. Where applicable, a flashing speed limit beacon (with an appropriate accompanying sign) may be used to indicate that the speed limit is in effect. The use with a “SCHOOL SPEED LIMIT” sign is an example.

Intersection Control Beacon

Intersection control beacons are used at intersections where traffic or physical conditions exist that do not justify the installation of a traffic signal, but where high crash rates indicate a special hazard. The installation of intersection control beacons overhead above the intersection is limited to red on all approaches (where an all-way stop is warranted). It is only used in conjunction with 4-way stop signs.

Stop Beacon

This type of red flashing beacon is located above a stop sign to emphasize and draw attention to the stop sign.

9-4.01.03 Railroad Crossing Signals

Railroad approach signals are used at highway-railroad grade crossings to give warning of the approach or presence of a train. When indicating the approach or presence of a train, the signal displays to the approaching highway traffic two red lights in a horizontal line flashing alternately. The signals may be supplemented by gates that extend across the roadway lanes and keep vehicles off the tracks while trains are present or approaching. A detailed explanation of railroad signals can be found in the MN MUTCD Part 8.

Railroad approach signals are designed and installed by the railroad companies, and reviewed and approved by MnDOT's Office of Freight and Commercial Vehicle Operations (OFCVO).

If a signalized intersection is near a railroad crossing, the traffic control signals may have a preemption system connected with the railway approach signal system that allows vehicles to safely clear the railroad tracks, and modifies the operation of the signal to allow traffic movements that do not conflict with the train while it is present. If gates are not in place and the railroad is interconnected to a traffic control signal, contact the MnDOT Office of Freight and Rail as soon as possible to determine if gates are needed and what funding options are available. Detailed descriptions and the approved interface are discussed in the MnDOT Signal Design Manual. Traffic signals that are interconnected to railroad crossings should be equipped with battery backup systems.

9-4.01.04 Freeway Entrance Ramp Control Signals (Ramp Meters)

Freeway entrance ramp control signals, commonly referred to as ramp meters, are described in Chapter 3 of this manual, Freeway Corridor Traffic Management.

9-4.01.05 Lane-Use Control Signals

Lane-use control signals are special overhead indications that permit or prohibit the use of specific lanes of a street or highway. They are placed directly over the lane they control and have distinctive shapes and symbols. Lane-use control signals are described in this Chapter 3 of this manual, Freeway Corridor Traffic Management, and in the MN MUTCD Part 4, Highway Traffic Signals.

9-4.01.06 Movable Bridge Signals

On roadway approaches to a movable (draw, swing, or lift) bridge, traffic control signals are generally used to stop vehicular traffic when the bridge is opened. Signal heads are installed at both approaches to the bridge, often in conjunction with warning gates or other forms of protection. The traffic control signal is coordinated with the bridge control and arranged so that adequate warning time is provided in advance of the bridge opening to ensure that the bridge will be clear of all traffic.

9-4.01.07 Temporary Traffic Control Signals

A temporary traffic control signal differs from a permanent traffic control signal in that it uses wood poles and span wires to place the signal indications in the driver's line of sight. A temporary traffic control signal may also use a non-intrusive means of vehicle detection, such as microwave or video detection. In all other ways, a temporary traffic control signal is just like a permanent signal.

Temporary signals are meant to be in place for only a short time, from a few months up to a few years. Most are used as intersection traffic control signals during construction projects.

9-4.01.08 Portable Traffic Control Signals

Another type of temporary highway traffic signal is the portable traffic control signal. Portable traffic control signals have limited use in conjunction with construction and maintenance projects and should normally not operate longer than 30 days. A portable traffic control signal must meet the physical display and operation requirements of conventional traffic control signals.

9-4.02 Elements of Traffic Control Signals

9-4.02.01 Signal Indications

A traffic control signal must be seen in order for the driver to react and make the required action. The most basic part of a traffic control signal is the signal indication. This is how the traffic control signal transmits information to the driver. This information or message is portrayed by selective illumination of one or more colored indications.

A signal indication is made up of a Light-Emitting Diode (LED) array, and housing with a visor. Signal indications are 12 inches in diameter, are red, yellow, or green, and can be circular or arrows. They can be found on the MnDOT approved products list. When three to five signal indications are mounted together vertically or in a cluster, they form a signal head. In five section signal head cluster mount situations, bi-modal indications can be used with a total of six indications. Each signal head is outlined with a black background shield. Traffic signal indications and heads are covered in more detail in the MN MUTCD, Part 4. LED signal indication modules should be replaced on a cycle of every seven years not to exceed 10 years, or earlier if visual observation warrants replacement.

Signal heads for vehicular traffic are often accompanied by signal heads for pedestrian control. Pedestrian signal indication symbols are LED, are white for WALKING PERSON (WALK) and orange for HAND (DON'T WALK), with orange countdown timers. Part 4 of the MN MUTCD provides more detail regarding the design and application of countdown pedestrian signals.

Vehicle and pedestrian signal heads are attached to poles and pedestals by mounting assemblies that support the signal heads and serve as a wire way for the electrical conductors. There are two primary mounting assemblies: angle and straight mounts, as found on the MnDOT approved products list for signals. There are other possible bracketing arrangements on older existing traffic signals; shown on MnDOT Standard Plates 8110 and 8111.

9-4.02.02 Flashing Yellow Arrow for Left Turns

The installation of the flashing yellow arrow (FYA) left turn indication is required on all new traffic signal dedicated left turn lane approaches on the Minnesota trunk highway system. This includes both mainline and cross street dedicated left turn lanes. A four section head using a red arrow, yellow arrow, flashing yellow arrow, and green arrow shall be used. Any agency doing work on the trunk highway system shall install the flashing yellow arrow. The FYA can be omitted from the design for the following reasons:

1. If the left turner has limited intersection sight distance (as defined in AASHTO's "A Policy on Geometric Design of Highways and Streets").

2. If conflicting (i.e. overlapping) left turn paths are present such that split phase operation is the only option.
3. If it has been determined that the signal will always operate protected-only, based on engineering judgment related to multiple turn lanes, high volumes, and high speeds (all three present).

If a flashing yellow arrow is not installed based on the above criteria, the system shall be designed to easily accommodate a change to a flashing yellow arrow in the future, including length of mast arm, wiring, cabinet, and controller.

If the flashing yellow arrow is not installed at a location because it has conflicting left turn lanes or a sight distance deficiency, or if there is other information that is important for the signal operator or future signal designer to be aware of, this information shall be provided by the signal designer on the signal plan.

When operated properly by time of day, the flashing yellow arrow can be used in many situations where protected-only phasing had been the only operational option.

Sign R10-X12 (LEFT TURN YIELD ON FLASHING YELLOW ARROW) must be installed for a flashing yellow arrow on the trunk highway for a minimum of six months after installation of the indication.

Additional guidelines for the operation can be found in the MnDOT Traffic Signal Timing and Coordination Manual. FYA design guidelines can be found in the MnDOT Signal Design Manual.

9-4.02.03 Poles, Mast Arms, and Pedestals

Poles, mast arms, and pedestals are the structures that support signal heads. They are made of galvanized steel for structural strength and for protecting the wiring to the signal heads.

Mast Arm

A mast arm is a structure that is extended over the roadway. Mast arm lengths are between 15’ and 80’. There are two designs series to the mast arms, the PA series (15’ to 55’) and the BA series (60’ to 80’). The BA series poles and mast arms have significantly higher costs.

Typical PA Pole and Mast Arm

The typical PA pole and mast arm, shown on Standard Plate 8123, (15’ to 55’ mast arms), consists of a tapered octagonal shaft positioned on a cubical transformer base. A mast arm is attached near the top of the shaft, which is actually two arms braced together to form a truss. The mast arm extends horizontally from the top of the pole shaft in 5’ incremental lengths between 15’ and 55’. Extending vertically from the top of the pole shaft is the luminaire arm extension, on which the street light (luminaire) is placed.

Typical BA Pole and Mast Arm

The typical BA pole and mast arm, detailed on Standard Plates 8133 and 8134, consists of a tapered round shaft positioned on a cubical transformer base. A mast arm is attached near the top of the shaft, which is actually two arms braced together to form a truss. The mast arm extends horizontally from the top of the pole shaft in 5’ incremental lengths between 60’ and 80’. Extending vertically from the top of the pole shaft is the luminaire arm extension, on which the street light (luminaire) is placed.

Traffic control signals on arterial highways typically use four mast arm poles per intersection.

Signal Pedestals

Signal pedestals are used on divided highways or in places where PA and BA type signal poles are not practical. Signal pedestals are shorter, do not have mast arms, and are not used for overhead signal placement. They are designed to break away from the foundation on impact in order to minimize damage to a striking vehicle. A typical signal pedestal and its base are shown on Standard Plate 8122.

Temporary Traffic Control Signal Systems

Temporary traffic control signal systems may be mounted on wood poles or suspended from span wire that is stretched over the roadway. These systems should only be installed as temporary traffic control signals and are built with the intent to remove them after road work construction is complete or after a permanent traffic control signal has been installed.

9-4.02.04 Cabinet and Control Equipment

The control equipment for the traffic control signal at an intersection is housed in an aluminum cabinet at the intersection. The cabinets are placed close enough to the intersection so that the maintenance and or operation technicians can observe the intersection while they are working on the cabinet, but far enough away so that the cabinet is not likely to be struck by an out of control vehicle.

Signal Cabinet

The typical signal cabinet sits on a concrete foundation. It has a power venting fan to reduce heat buildup on warm days. The wiring between the signal cabinet and the poles or pedestals is placed in underground conduit.

Controller

The controller is a specialized solid-state microcomputer that is programmed to control the signal indications, and give the right-of-way to various approaches, based on a timing plan.

MnDOT uses a NEMA fully actuated traffic controller. This traffic actuated controller varies the timing for all controlled conflicting movements based on vehicular or pedestrian demand as determined by detectors placed in the roadway or near the pedestrian crossing.

The typical controller is a 16, 8-phase, traffic actuated, NEMA TS2 Type 1 controller. This means it can control many separate traffic movements, including protected left turn movements, for all approaches to an intersection. A NEMA controller is built to the specifications of the National Electrical Manufacturers' Association. The controller includes a time-clock to control events by time of day and a coordinator to synchronize the operation of the intersection controller with that of other controllers in a coordinated system of controllers or intersections.

Solid State Load Switches

Solid state load switches are devices that when activated by the cabinet's low voltage control circuitry, turn on and off the 120 VAC (RMS) electric power that goes to the signal heads and powers the indications.

Malfunction Monitor Unit

The malfunction monitor unit, also called a failsafe or MMU, is a device that monitors cabinet output and internal cabinet voltages. If the MMU senses an improper signal output or internal voltage, it will put the intersection into the all red flashing mode of operation.

Vehicle Detector Units

Vehicle detector units sense very small inductance changes as vehicles pass over coils of wire, also known as loops, imbedded in the roadway. This change in inductance is converted to an on/off signal connected to a controller input so that the controller can take appropriate action. Other detector technology used less frequently by MnDOT includes video detection and microwave.

Flasher

The solid state flasher is a two circuit device that controls the signal indications when the intersection drops out of normal operation into the all red flashing mode. It provides a backup flashing operation. When a traffic control signal is in the flashing mode the signal indications should be flashed red for all approaches.

Other Equipment

Other equipment to be found in the cabinet includes accessible pedestrian signal (APS) control units, flash transfer relays, and other miscellaneous equipment and wiring.

Preemption

Preemption overrides the normal operation of the traffic signal controller. When a preemption call is placed into the controller, the preemption program will allow preference to buses, emergency vehicles, light rail, and trains. There are three levels of preemption:

1. **Railroad Preemption** – This is the highest priority of preemption. Railroad preemption is

used only on trains and will override normal intersection sequencing, transit preemption, and emergency vehicle preemption. Railroad preemption will first clear the track phase, and then bring up only phases that do not conflict with the railroad crossing.

2. **Emergency Vehicle Preemption** – This preemption is used on fire trucks, police cars, and ambulances. This preemption will override all normal intersection sequencing and transit preemption and bring up greens immediately or hold a green for the approaching emergency vehicle until the preemption call is gone.
3. **Transit Preemption** – This preemption is used for buses and sometimes light rail. This preemption needs special programming beyond preemption programming and does not override operations as emergency vehicle or railroad preemptions do. Transit preemption will hold a green longer or bring up a green sooner than normal operation allowing additional green time for transit vehicles. The transit emitter call is on a lower frequency than emergency vehicle call frequency.

9-4.02.05 Detection

All new traffic signal systems on trunk highways today are traffic-actuated, which means that the intersection approaches are given right-of-way in response to actual traffic demand, rather than according to a fixed time pattern.

Detector Types

Detectors enable the controller to “know” which approaches to an intersection have traffic demand that must be served.

The most common type of vehicle detection device in use by MnDOT is the inductive loop. The loop is a coil of wire embedded in the pavement that carries a very low level, high frequency signal. When a conductive mass passes over the loop it creates an inductance change causing the resonant frequency to change. The frequency change is sensed by the detector and it signals the controller that a vehicle is present.

Other types of vehicle detectors include magnetic coil, microwave, radar, sonic, and video. Descriptions can be found in technical literature.

Detector Functions

Vehicle detectors perform a variety of functions. They can place a call to the controller to change the right-of-way at the intersection, extend the amount of time the phase is given, and can be used to count traffic.

Detector placement for most efficient operation of a traffic-actuated intersection is a complex subject and is discussed in the MnDOT Signal Design Manual and the MnDOT Traffic Signal Timing and Coordination Manual.

Pedestrian Pushbutton

A pedestrian pushbutton, is a pushbutton switch mounted near a crosswalk. When the button is pushed, it indicates to the controller that a pedestrian is present and wishes to cross the street.

All new traffic control signals are required to be ADA compliant. Accessible pedestrian signals (APS) are placed at all new traffic control signals that have a pedestrian indication. Accessible pedestrian signals use a button that includes a locating tone along with sound, LED confirmation light, and tactile (vibrating) information to assist users in crossing the street. When a major revision of a traffic control signal is being done, an APS must also be installed. Major reconstruction is considered work affecting poles on 3 of the 4 corners at the intersection. When other work is being done at the intersection such as a mill and overlay, the signal should be at a minimum made “APS ready”. APS ready means wires, conduit, and pedestrian stations have been placed in the intersection corner so that only the APS buttons need to be installed in the future. More information can be found in the MnDOT Signal Design Manual and the MnDOT ADA Guide.

Installation

The installation of saw cut inductive loop detectors is shown on Standard Plate 8130; the installation of the Rigid PVC inductive loop detectors is shown on Standard Plate 8132; the installation of Accessible Pedestrian Signals (APS) is shown on a detail sheet included in the plan set.

9-4.02.06 Source of Power and Service Equipment

Signal controller cabinets are powered by 120 volts alternating current (VAC) electricity from the local electric utility company. The cabinet is wired to a signal service cabinet. The electric utility company brings power to the meter. On the load side of the meter, the wiring and circuit breakers or fuses belong to the agency that owns the signal. The combination of meter and circuit breakers is called service equipment. The location of the service equipment is called the source of power.

Service equipment is mounted on the equipment pad along with the controller cabinet. In rare cases it can be mounted on a wood pole. MnDOT signal service cabinets are designed to accommodate a battery backup system. In the design process, a decision to use a battery backup system must be made. The cabinet can use up to four batteries and a power inverter. The cabinet can be used without a backup system and can accommodate the inverter and batteries anytime in the future, if desired.

Service equipment and the equipment pad are detailed within the plans. Signal Controller cabinets are state furnished and service equipment must be purchased off the MnDOT approved products list for signal equipment.

9-4.02.07 Conduit and Handholes

The electrical wiring between the signal cabinet and the poles or pedestals usually travels in underground conduit. Conduit can be either rigid steel conduit or non-metallic conduit whose size is determined by the application and the number of cables that it must accommodate. A grounding wire is needed if there are 120 VAC power conductors in the conduit.

Handholes must be listed on the MnDOT approved products list. They are placed in conduit runs to provide junctions for conduit, to facilitate the pulling of cables, and to provide water drainage for the conduits.

9-4.03 Timing and Coordination of Traffic Control Signals

Details for timing and coordination of traffic control signals are in the MnDOT Traffic Signal Timing and Coordination Manual.

It is often necessary to consider the movement of traffic through a system of consecutive intersections or through an entire network, rather than through a single intersection. In this case, each traffic control signal is considered a dependent part of a system. The goal is to maximize the efficiency of the whole system rather than any one intersection in the system.

A system of traffic control signals can be made up of a number of fixed-time controllers, a number of actuated controllers, or a combination of both kinds. A group of intersection controllers is usually interconnected by twisted pair copper wire or fiber optic interconnect, though sometimes time-based coordination or wireless interconnect is used.

In coordinated master or central controller systems, the entire system and all individual controllers can be controlled by a computer that receives information from detectors and adjusts the traffic control signal system according to traffic demand.

In general, two or more signalized intersections can be coordinated if they are less than one-half mile apart, or if the travel time between them is less than a cycle length. Coordination software may suggest coordination between signals that are more than one-half mile apart. Coordination between signals can be considered at any distance as long as an analysis can prove beneficial. A timing mismatch of even a few seconds between two intersections can result in considerable delay to traffic.

Software should be used to show and to help coordinate traffic signal timing at adjacent intersections.

The selection and use of specific coordination equipment should take into account the nature of the area, the traffic characteristics of the roadway, and the available capital and operating budget.

9-4.04 MnDOT Enforcement Light

An enforcement light is an additional light (blue) that is added to the back of the signal pole or indication. Proper positioning of this light allows a single police officer to see the enforcement light, the approach stop line, and the offending vehicle at the same time. The light is wired to be in sync with the red indication and therefore permits an officer to enforce violations of the red light from a strategically accommodating position near the intersection. In many cases, given conditions at the intersection, the light may not be beneficial to red light enforcement and a decision to install should be made between the signal agency and the local police department. The light should not be installed without consideration from all agencies involved. The light is only intended to be seen by the enforcement officer and should only be installed selectively on one or two of the intersection approaches to avoid confusion.

9-4.05 Standard Design/Operation for MnDOT Signals with Railroad Preemption

The circuits detailed below should be installed when railroad preemption at a traffic control signal is required. MnDOT will need to notify the railroad of the preferred design circuits. Optional circuits may depend on existing conditions such as number of tracks or traffic controller type.

Railroad Interconnection

Railroad Interconnection is the electrical connection between the railroad active warning system and the traffic signal controller assembly for the purpose of railroad preemption.

Railroad Advance Preemption and Advance Preemption Time

This is when notification of an approaching train is forwarded to the highway traffic signal controller unit or assembly by railroad equipment for a period of time prior to activating the railroad active warning devices. This period of time is the difference in the Maximum Preemption Time required for highway traffic signal operation and the Minimum Warning Time needed for railroad operation and is called the Advance Preemption Time.

Railroad Simultaneous Preemption

This is notification of an approaching train that is forwarded to the highway traffic signal controller unit or assembly and railroad active warning devices are activated at the same time.

Railroad Maximum Preemption Time

This is the maximum amount of time needed following initiation of the preemption sequence for the highway traffic signals to complete the timing of the Right-of-Way Transfer Time, Queue Clearance Time, and Separation Time.

Railroad Single Break Interconnect Circuit

This is a 7 - 2 wire circuit interconnection between the signal controller cabinet and the railroad bungalow equipment.

Interconnect cable from the traffic control signal cabinet to the railroad bungalow should be a 2-12/c #14 signal control cable in accordance with 3815.2C.3. The following two-wire circuits should be established within these cables:

1. Energy - 24VAC RMS
2. Advanced Preemption - Begins the railroad preemption sequence when the railroad equipment first notifies the traffic controller of an approaching train.
3. Supervisor - Additional circuit providing additional verification of the integrity of the interconnect cable between the signal cabinet and the railroad cabinet. If the circuit is broken the traffic control signal will go into all red flash.
4. Simultaneous Preemption - Activates when lights on the railroad begin to flash. Should be used to turn on blank out signs if present. Can also be used for train restart if train stops with detection area for switching.

5. Gate Down - Activates when the highway-rail grade crossing gate arms are lowered to near horizontal. Prevents track clearance green from terminating before the railroad crossing gates are down.

6. Traffic Health Circuit (new 2019)

   The Traffic Health Circuit is provided by the traffic signal control cabinet unit to the railroad crossing warning system. It is connected to the controller cabinet signal flash transfer relay control circuit so that the health circuit will de-energize any time the traffic control signals are flashing or dark. If the railroad detects a signal health fault the railroad crossing gate arms will begin their decent as soon as an approaching train is detected.

7. Advanced Pedestrian Preemption Circuit (new 2019)

   The Advanced Pedestrian Preemption Circuit begins a sequence to terminate any active pedestrian (not vehicle) movement when the railroad equipment first notifies the traffic signal controller of the approaching train. This circuit is ideal for long pedestrian clearance times. The circuit is activated by the equipment response railroad equipment and some traffic controllers do not accommodate this preemption input.

The railroad preempt circuit should be a single break interconnect circuit with supervision and gate down logic (gate horizontal control).

A battery backup system should be installed and utilized on all new traffic signals that have railroad preemption.

Turning movements toward a highway-rail grade crossing where the intersection traffic control signals are preempted by the approach of a train and are located within 200 feet of the highway-rail grade crossing should be prohibited during the preemption sequence based on criteria in Chapter 8 of the MN MUTCD. If the left turn is prohibited, new and reconstructed signals with left turns with an exclusive left turn lane should install a 4-section flashing yellow arrow signal head and utilize the RED arrow to prohibit this move. A blank-out sign may be needed to prohibit the left turn if there is a shared through-left turn lane. If the right turn is prohibited, blank-out signs prohibiting right turns should be used at all new and reconstructed signals to prohibit turning movements toward the highway-rail grade crossing during preemption. The approved blank-out signs are shown below in Figure 9-1.

Figure 9-1 Blank-Out Signs

An engineering study may be conducted to analyze whether or not to prohibit the turns based on a diagnostic team review. The team should consist of representatives from the MnDOT Signal Design Team, MnDOT's Office of Freight and Commercial Vehicle Operations, and any local authorities affected. This decision must be documented and kept in the signal design file. Some factors to be considered during this review include: geometrics of the intersection, turn lane capacity, design vehicle, volumes, and the speed limit of the tracks.

Additional guidelines for the railroad preemption can be found in the MnDOT Traffic Signal Timing and Coordination Manual and the MnDOT Signal Design Manual.

9-5.00 TRAFFIC SIGNAL JUSTIFICATION PROCESS

9-5.01 Engineering Studies for Traffic Signals

Intersection Control Evaluation (ICE) reports must be completed to document the process of selecting the optimal control for an intersection based on an objective analysis for existing conditions and future needs.

If traffic control signals are proposed for an intersection, enough study should be done and documented to demonstrate the need for a traffic control signal.

Studies that will be helpful in assessing and demonstrating the need for a traffic control signal include the following:

- 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 doing various traffic studies are found in the Institute of Transportation Engineers, Manual of Transportation Engineering Studies.

Intersection Control Evaluations are discussed in Section 9-5.02.04 of this chapter.

9-5.02 Warrants and Justification for Traffic Control Signals and Flashing Beacons

9-5.02.01 Traffic Control Signal Warrants

Warrants have been developed to determine if an intersection needs some type of traffic control. Justification for a signalized intersection should be based on meeting one or more of the established warrants as stated in the Minnesota Manual on Uniform Traffic Control devices (MN MUTCD). Traffic control signals should not be installed unless one or more of the signal warrants in the MN MUTCD are met, but the meeting of a warrant or warrants does not alone justify the installation of a traffic control signal.

The data collected as part of the engineering studies should be used in combination with the warrants to justify the need to install the traffic control device. The ICE should show that the intersection will benefit in improved safety and/or operation.

The traffic signal warrants are stated in Part 4 of the MN MUTCD. There are 9 warrants for traffic signals. Refer to Part 4 of the MN MUTCD for definitions of each of these warrants.

The statements that follow give intents and interpretations of the warrants. Only the warrants that need clarifications are listed here.

WARRANT 1: Eight-Hour Vehicular Volume

Warrant 1 is the warrant that pertains to volume and is the most common warrant for justifying intersection control.

The same eight hour period must be used for both the Major and the Minor Streets. Either Condition A (Minimum Vehicular Volume) must be met for 8 hours or Condition B (Interruption of Continuous Traffic) must be met for 8 hours. It does not need to be the same 8 hours for Condition A and Condition B.

MnDOT policy on the use of the speed reduction factor is that if a mainline roadway has a posted speed limit of 45 mph or above, that is sufficient evidence that the 85th percentile speed is above 40 mph, and a speed study is not required.

The population reduction factor (70%) mentioned in Warrants 1-3 states that an intersection lying “within the built-up area of an isolated community having a population of less than 10,000...”. In the seven-county metropolitan area, it is often a judgment call whether a community is isolated or not. There is no strict criteria on this. Geometrics play an important part in determining the volume requirements.

WARRANT 2: Four-Hour Vehicular Volume and WARRANT 3: Peak Hour

These warrants may not be addressed by projected or hypothetical volumes, or for currently nonexistent intersections. Actual on-site studies are required.

WARRANT 4: Pedestrian Volume

This warrant allows the installation of a traffic signal if there are a considerable number of pedestrians. If a signal is warranted, the signal should be traffic actuated with pedestrian indications.

WARRANT 6: Coordinated Signal System

An ICE report addressing Warrant 6 should contain a time-space diagram of the proposed intersection and nearby signals, helping to demonstrate that a progressive system will help maintain platooning and group speed.

Signals are installed under Warrant 6 on the basis of the 85th percentile speed, so a speed study is necessary for this warrant. It is expected that any signal installed under Warrant 6 would include interconnect.

WARRANT 7: Crash Experience

For Warrant 7, the requirement is the 80% columns of Warrant 1, Condition A or Condition B, or 80% of the pedestrian volumes of Warrant 4.

ICE reports that address Warrant 7 are to include a collision diagram. A time-space diagram showing that the proposed signal system will not seriously disrupt progressive traffic flow should be included. Discussion of the failure of less restrictive remedies is also required by the MN MUTCD.

Current MnDOT policy is that, in general, Warrant 7 is not applicable to an intersection that is already signalized.

WARRANT 8: Roadway Network

Current MnDOT interpretation of Warrant 8 is that its intent is the use of a signal to pull traffic away from other intersections, "to encourage concentration and organization of traffic flow networks." Therefore, MnDOT policy is that Warrant 8 does not apply to isolated intersections, but rather to intersections in urban grid systems.

WARRANT 9: Intersection Near a Grade Crossing

Warrant 9 is intended for use on an intersection approach with a STOP or YIELD sign where the proximity of a grade crossing is the main reason to consider installing a traffic control signal. This warrant should be used only where the conditions described in the previous traffic signal warrants are not met.

9-5.02.02 Warrants for Flashing Beacons at Intersections

Flashing beacons at intersections include intersection control beacons mounted on span wire directly over an intersection (all-way stop only), stop beacons mounted on a pedestal above stop signs (red), and warning beacons mounted on a pedestal above intersection ahead symbols signs (yellow). Both overhead and pedestal mounted beacons have advantages and disadvantages. Overhead beacons may distract the motorist from roadway signing, but they aid the motorist in locating the intersection. Pedestal mounted beacons help draw attention to stop and intersection ahead signing, but do not help locate the intersection for the mainline driver who sees only flashing yellow mounted on an intersection ahead sign, somewhere in advance of the intersection itself. In any case, any flashing beacon must be justified under one or more of the following warrants.

WARRANT 1: Limited Visibility

Where sight distance is limited, a flashing beacon may be installed if the sight distance is less than that shown in the table below for any approach to the intersection. Locations qualifying under limited visibility must have previously had adequate warning signs and pavement markings installed.

Design Speed (mph)	**Stopping Sight Distance** (feet)
15	80
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645
70	730
75	820
80	910

NOTE: The distances here are to ensure the driver (3.5 ft. height-of-eye) who can not see an oncoming vehicle (3.5 ft. height-of -object) has enough time to react and make a stop. The numbers above are based on the 2011 AASHTO, "A Policy on Geometric Design of Highways and Streets", Table 3-1: Stopping Sight Distance on Level Roadways, page 3-4.

WARRANT 2: Crash Rate

A flashing beacon may be installed where high-hazard safety improvement criteria are met or where in one year where there have been four or more crashes of the right-angle or left-turn type or of the type deemed preventable by a flashing beacon.

WARRANT 3: School Crossing

A flashing beacon may be installed at an established school crossing where, during the heavy crosswalk usage periods, there are more than 500 vehicles per hour (actual or effective rate) crossing the crosswalk, AND, insufficient usable gaps for pedestrians using the crosswalk.

WARRANT 4: Rural Trunk Highway Junctions

At or near some rural junctions of two or more high speed trunk highways, a flashing beacon may be installed to warn drivers of an unexpected crossing of another highway.

9-5.02.03 Advance Warning Flashers (AWF) Consideration

An Advance Warning Flasher (AWF) is a device that MnDOT uses to convey to the motorist information about the operation of a traffic signal. An AWF is typically found at certain high speed locations where it may be necessary to get the motorists attention through a visual indication about a pending change in the indication of a traffic control signal. The AWF assists motorists in making safer and more efficient driving decisions by informing them that they must prepare to stop. The AWF configuration, placement, and timing details can be found in Part 4 of the MN MUTCD.

An AWF should only be installed in response to a specifically correctable problem, not in anticipation of a future problem. Generally, AWF implementation is appropriate only at high speed locations. Before an AWF is installed, other remedial action should be considered.

Refer to the MnDOT Signal Design Manual and MnDOT Traffic Signal Timing and Coordination Manual for guidelines for consideration and timing of AWF's.

9-5.02.04 Intersection Control Evaluation (ICE)

Why an ICE Report

Selecting the appropriate traffic control for an intersection is an important aspect of intersection design and should be initiated early in the design process. Previously, engineers mainly considered the installation of a traffic signal or stop signs to mitigate traffic delay and safety problems for at-grade intersections. This rationale has changed over the years and now there are many different options for intersection control including the installation of a traffic signal, all-way stop, roundabout, reduced conflict intersection, higher capacity intersections, and grade separation. To select the optimal design, an Intersection Control Evaluation (ICE) may need to be completed. The ICE process will compare the viable intersection control alternatives on an equal basis and help identify the best alternative.

Definition and Purpose

The goal of an ICE is to identify the optimal control for an intersection based on an objective analysis for existing conditions and future needs. The overall design of the intersection and multi-modal uses (pedestrian, bicycle, and transit) should also be considered. In some instances, a corridor analysis will be required depending on the intersection in relation to adjacent intersections and their respective traffic control.

There are several areas of analysis that should be evaluated through the ICE process:

- Intersection/roadway safety,
- Traffic operations,
- Intersection geometry design, and
- Identification of the appropriate traffic control device.

Based on the results of the preliminary analysis, further considerations may be needed on a case-by-case basis to investigate other factors such as an economic analysis, environmental considerations, right-of-way, and political issues. The purpose of the ICE report is to document the analysis and design considerations, and to document how these determined the study recommendations.

The scope of an ICE report can vary widely and should be determined case-by-case and be specific to address the intersection or project needs. Preliminary discussions with the governing agency should always be completed when considering the scope of the ICE. These discussions will assist in refining the scope and context of the analysis and what should be documented within the ICE.

The following provides general guidelines to help determine when an ICE should be completed:

- When any intersection or traffic control improvements are being considered on a trunk highway or NHS roadway.
- When a trunk highway intersection with a county or municipality cross-street is being considered for intersection improvements or a traffic control change.
- When existing safety or traffic operational issues exist or are expected in the future, and there is a need to identify improvements.
- As part of a state or local agency roadway reconstruction project where intersections are impacted; and there is a need to identify the appropriate lane geometrics and intersection control devices.

General Information

All intersection treatments must be considered as early in the project as possible. An ICE is not required for intersections that are determined to need minimal control such as two-way stop, yield, or no control. However, a traffic operation or safety analysis may be necessary to ensure an appropriate design. The contents of an ICE can support these traffic control decisions.

An ICE must be written under the supervision of a licensed Professional Engineer in the State of Minnesota and approved by the District Traffic Engineer before the preliminary plan is finalized. Each district can require additional review and approvals, if desired.

See the MnDOT Traffic Engineering's Intersection Control Evaluation Guidelines for Implementation website for more information.

Intersection Control Alternatives

There are many alternatives for intersection control, each with advantages and disadvantages. Each type of control considered for an intersection design alternative should be acceptable to the public, the local governmental unit, and the local road authority. A list of common traffic control options follows. It may not always be necessary to review all options. As an example, some intersections may require more emphasis on intersection design characteristics and only require a review of one or two different traffic control options. This list is not all-inclusive and it is possible that an entirely different or unique solution may be preferred or justified at a certain location. See the MnDOT Traffic Engineering's Intersection Control Evaluation Guidelines for Implementation website for more information.

- Traffic Signal
- Two-Way Stop Control
- All-Way Stop Control
- Roundabout
- Non-Traditional Intersections
- Access Management Treatments
- Grade Separation

The ICE Process

The process needed to complete an ICE is highly dependent on several factors: project origination and size, type of project, and the magnitude of traffic operation or safety issues to address. These factors influence the complexity and extent of the study.

The ICE process is conducted in two phases:

Phase 1

Phase 1 is completed very early in the project development process with the purpose of scoping and recommending one or more traffic control options for further development. In Phase 1, data is collected, warrant analyses are completed, and operational and safety analyses of the alternatives are performed for existing and future conditions. A decision may be reached after Phase 1 if there is only one viable alternative, but it still may be necessary to develop preliminary layouts, cost estimates, and other project development tasks to complete the ICE report.

Phase 2

The second phase, if needed, is alternative selection and development of an approved preliminary layout. In Phase 2, a more rigorous design process is needed using MnDOT's typical design process for developing preliminary layouts. In some instances, multiple intersection alternatives will need to go through the entire design process for equal comparison. Once a preferred alternative is selected, the formal ICE report can be written documenting the design process.

Depending on the scope and size of the project, a Public Involvement Process may be needed where local stakeholders and the general public can provide input and comment on the alternatives.

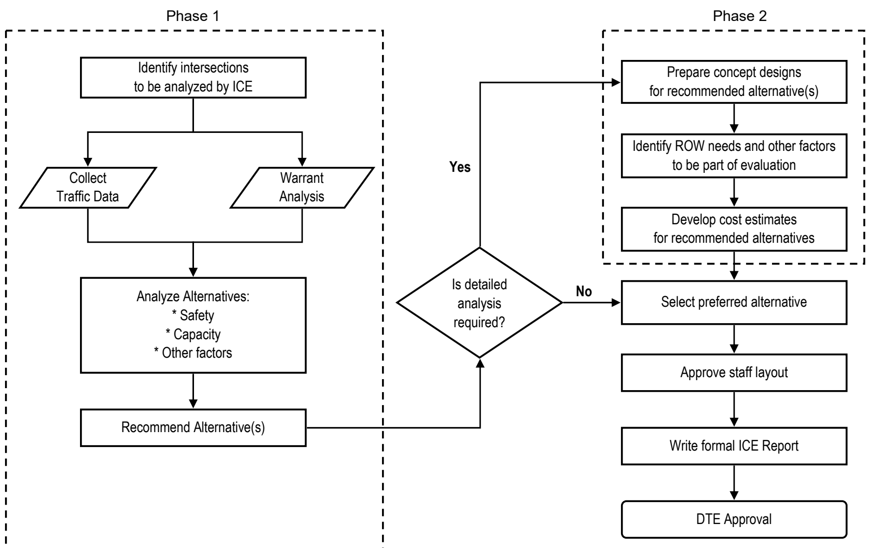

Figure 9-2 ICE Development Process

Depending on the complexity of the project and scope determined with the local agency, the necessary steps to complete an ICE are as follows:

- Warrants and Justification - There are 9 warrants for traffic signals. Refer to Part 4 of the MN MUTCD for definitions of each of these warrants.
- Crash Evaluation
- Intersection Capacity Evaluation
- Intersection Design and Engineering Considerations
- Right-of-Way Impacts and Project Cost
- Political Considerations and Public Involvement
- Multi-Modal Considerations
- Other Considerations

The steps are described in detail in the ICE Manual found on the MnDOT Traffic Engineering's Intersection Control Evaluation Guidelines for Implementation website.

ICE Report/Memorandum

Depending on the amount of the analysis, a full report may not be necessary and a memorandum will be acceptable. The ICE manual provides a detailed outline, data requirements, and a sample of a typical ICE report.

9-5.02.05 Traffic Control Signal Removal Justification Criteria

Signalized intersections that meet 80 percent of the volume requirements of MN MUTCD Part 4, Warrant 1 should be considered justified and should not be removed. Signalized intersections that do not meet 80 percent of the volume requirements of MN MUTCD Part 4, Warrant 1, but meet 60 percent of the volume requirements of Warrant 1 are in the gray area and may be considered for traffic control signal removal. Additional studies, findings, engineering judgment and documentation beyond the volume requirements will be needed to justify retaining the signal.

Signalized intersections that do not meet 60 percent of the volume requirements of MN MUTCD Part 4, Warrant 1 and meet no other Warrant are unjustified traffic control signals and should be removed. The traffic signal removal decision process should be followed as set forth in the "User Guide for Removal of Not Needed Traffic Signals", FHWA-IP-80-12, November 1980.

In the traffic control signal removal process, the District Traffic Engineer considers all the findings and the decision is made whether or not to remove the traffic signal. The final decision concerning signal removal is a blend of analytical procedures and political considerations coupled with professional judgment. However, the technical findings from the analysis should provide a strong factual basis for reaching, supporting, and defending the final decision or recommendation. The most important factor in success for removing the traffic control signal is early and frequent contact with the community in question to outline why the traffic control signal removal is being considered (safety, delay, and cost (refurbishing and maintenance)) and to obtain the community's feedback and concerns.

All findings of the decision process shall be summarized by the District Traffic Engineer in a signal removal justification report. As part of the traffic control signal removal justification report, a review of all-way and two-way stop warrants to determine which control solution would be the best replacement should be completed.

Convincing the community of what type of traffic control should replace the signal can be a challenge. Communities are often concerned about the speed of traffic through town, and pedestrian safety due to the absence of the traffic signal. The public perception is often that a traffic signal is a safety and traffic calming device, when in fact the signal's sole purpose is to indicate the right-of-way.

All traffic control signals that are determined to be retained should be revised to meet current standards. These traffic control signals should be prioritized along with other traffic control signal projects and scheduled for revision as permitted.

9-6.00 TRAFFIC CONTROL SIGNAL PROJECT PROCEDURES

9-6.01 Traffic Control Signal Project Management Flowchart

Chart 9-1 below illustrates a typical state-let traffic control signal project management flowchart based on the deliverables and important milestones.

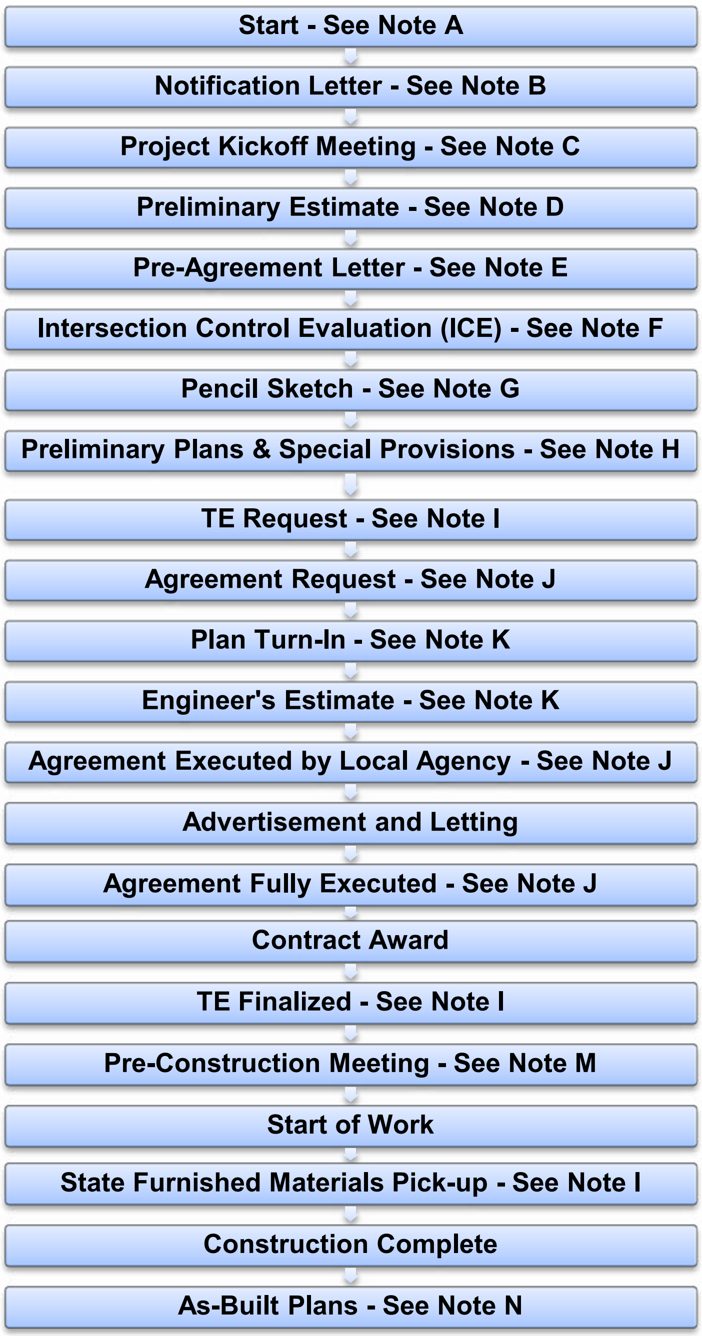

Chart 9-1 Typical State Let Traffic Signal Project Management Flowchart

9-6.02 Notes on Traffic Control Signal Project Management Flowchart

A. START PROJECT

The Statewide Transportation Improvement Plan (STIP) and the Program and Project Management System (PPMS) identify the project and project manager. This is the beginning of tracking of the project.

Signal design projects can be characterized based upon the following parameters:

1. Contracting agency - MnDOT let versus local agency let, or force account (work by MnDOT or local maintenance forces).
2. Funding source - state federal funds, local federal funds, state funds, state funds through a cooperative agreement, state aid funds, and local funds.
3. Designer - MnDOT, consultant, design build contractor, county and city.
4. Scope - Stand alone signal project or part of larger construction project.

B. PROJECT NOTIFICATION LETTER

Early project coordination is the key to a successful review process. For MnDOT designed projects, the Project Notification Letter is sent from the MnDOT district to the affected local agencies of an upcoming project. The letter describes the project need and justification, scope, proposed letting date, expected construction duration, contact personnel (name, title, mailing address, phone, and e-mail), funding source(s), and any need for inplace plans and mapping.

For externally designed projects, the designer should send the Project Notification Letter to the MnDOT District Traffic Engineering office with similar information.

C. PROJECT KICKOFF MEETING

The designer should schedule a Project Kickoff Meeting to discuss the project scope, data collection findings and goals, and MnDOT and local agency issues and goals. The meeting's purpose is to make all project participants fully aware of all issues so that the project management, scope, funding, and technical issues are resolved prior to the beginning of signal design activities. This meeting should include the signal designer, local agency project manager (city, county, etc.), agencies affected by the project (cost, operation, maintenance), and MnDOT District Traffic Engineering office personnel.

In preparation for the Project Kickoff Meeting, the designer will begin data collection. The data to be collected (as needed) should include: obtaining inplace signal plans (or CADD files if available), obtaining mapping if available, identifying any current problems with signal operations and/or maintenance, identifying signal design standard or geometric deficiencies, checking for other proposed projects in the vicinity including project time lines, checking crash rates, checking existing cabinet/controller condition and compatibility, and obtaining a preliminary cost estimate for state furnished materials and labor.

The following is the project Kick-off Meeting check list for each intersection affected by a project:

<u>Project Management</u>

- MnDOT Traffic Engineering project manager
- Project sponsor/lead (MnDOT, city, county)
- Designer (MnDOT, city, county, consultant)
- Project location (TH/Intersection)
- Project process (Permit, State Aid, local initiative/AM funding, MnDOT Programmed)
- Proposed project time line

<u>Project Scope</u>

- Work proposed (new signal, major/minor revision, EVP, phasing change, standard, accessible pedestrian signals, flashing yellow arrow)
- Project proposer's specific goals (lanes, phasing, heads, EVP, etc.)

- MnDOT's specific goals (lanes, phasing, heads, EVP, etc.)
- Effect/coordination with RTMC systems
- Effect/coordination with lighting systems
- ICE/project memo required
- Operation issues
- Operation issues not addressed by proposed project
- Maintenance issues
- Safety/crash issues
- Traffic engineering construction liaison scope of responsibilities

System Operation/Management

- Use Cost Participation, Operations, and Maintenance Responsibilities Worksheet

Funding/Costs

- State, City, or County furnished materials and labor estimate for proposed work
- Need for an agreement (signals/lighting) for this proposed work (Pre-agreement letter to follow, if necessary)
- Need for a permit for this work
- Funding sources and cost participation of proposed work

Technical Issues (Use Field Walk Checklist to Identify all Issues)

- Field walk
- Effect on inplace source of power
- Battery backup system must be installed if the traffic control signal will have railroad preemption
- SOP meeting and notification letter needed
- Equipment pad revisions needed
- EVP sight lines adequate (vertical and horizontal)
- Effect on inplace interconnect - need for interconnect
- Effect on inplace HH's - need to be moved or receive replacement covers
- Standards upgrades proposed/needed (LED, EVP, pedestrian indication, etc.)
- Phasing review needed
- Detection needs/changes
- Striping/signing affected
- Approach signing affected (review conflicts)/needed (coordinate)
- Utility information and process/needs - notification letter and time line
- Specification requirements (design, operations, CESU for EVP card delivery, etc.)
- Accessible pedestrian amenities status including Americans with Disabilities Act (ADA) compliance (ramps, sidewalk, indications, PB placement, markings)

Further Contacts

- Since the project scope can change as result of data review and this meeting, define what actions will be taken to inform all attendees and stakeholders of project scope changes.

References

- Refer to www.dot.state.mn.us/trafficeng for checklists, details, standards, sample special provisions, and other significant information.
- Refer to signal design manuals for processes and technical information.

D. PRELIMINARY ESTIMATE

A Preliminary Estimate will be the basis for the costs in the Pre-Agreement Letter. The Preliminary Estimate will include the preliminary construction contract cost and will additionally identify costs for state furnished materials and labor, and costs for design and construction engineering. As the project costs become better defined, the designer should update the Preliminary Estimate.

E. PRE-AGREEMENT LETTER

The District Traffic Engineering project manager will send a Pre-Agreement letter to affected local agencies and MnDOT offices identifying the following:

1. Preliminary Estimate with breakdown.
2. Project scope.
3. Funding and cost participation.
4. Time line.
5. Major/minor maintenance responsibilities.
6. Source of power supply costs and ongoing responsibilities.
7. Signal and coordination operation responsibilities.
8. State, County, or City furnished material/labor.
9. Construction engineering costs.

See details of cost sharing in the MnDOT Signal Design Manual and MnDOT Policy and Procedures for Cooperative Construction Projects with Local Units of Government.

F. Intersection Control Evaluation (ICE) Report

An ICE Report shall be approved by the MnDOT District Traffic Engineer. This report should be completed prior to traffic control signal plan development, but only after the project scope is clearly defined. See Section 9-5.02.04 of this chapter for details of the ICE.

PENCIL SKETCH

A "pencil sketch" or preliminary CADD drawing (usually graphics and charts - no pole or construction notes) of the new signal should be provided to the MnDOT District Traffic Engineering office for review. This will allow MnDOT to comment on important design elements (head placement, detection, phasing) prior to signal plan development. This will eliminate significant design changes once the signal design has begun.

Signal designers should meet and confer to agree on preliminary signal design. The design topics to be discussed should include, but not be limited to the following:

1. General nature of the signal project: new installation, minor, or major revisions.
2. Phasing of the intersection, relation of proposed phasing to the traffic volumes and turning movements; use of flashing yellow arrow left-turn phasing rather than protected-only; use of overlaps.
3. Presence of railroad near intersection.
4. Restricted movements at the intersection.
5. Lack of sight distance.
6. Determine design standards based on who will operate the system.
7. Use of 4-section heads and non-standard bracketing.
8. Head type.
9. Appropriateness of poles and pedestals for the site.
10. Placement of signal standards to ensure legal placement of all vehicle and pedestrian signal indications. See the MnDOT Signal Design Manual, for signal head placement diagrams.
11. Placement of accessible pedestrian signals relative to signal poles and inplace sidewalks and crosswalks.
12. Need for EVP and placement of components.
13. Need for battery backup.
14. Enforcement lights and placement.
15. Detector placement and functions. See the MnDOT Signal Design Manual for loop detector placement diagrams.
16. Placement and type of handholes.
17. Design of equipment pad.
18. Type of service equipment.
19. Discuss needs for combined pad with lighting and/or TMC.
20. Need for intersection geometric improvements.
21. For revised systems, the wording of the signal pole notes for the revision.
22. Need for AWF's, supplemental heads, etc.
23. House moving route needs.
24. Painting of signal if required by the local agency. The cost of painting is solely the responsibility of the local agency.
25. Luminaires metered or unmetered.

26. Source of power (to determine cabinet location).

27. Interconnect (determine need and type, location of master).

G. PRELIMINARY PLANS AND SPECIAL PROVISIONS

For in house designs, the MnDOT District Traffic Engineering office project manager distributes the preliminary signal design package (as distinct from a roadway design package) for review to the MnDOT District Traffic Engineering office, District State Aid office, Cooperative Agreements, Consultant Agreements, Permits, Metro or Regional Electrical Service Unit, and other district functional offices as appropriate. The preliminary signal design package should consist of the appropriate number of copies of signal plans (hard copies), signal special provisions, Microstation CADD file, preliminary estimate, source of power letter, and power application form (if applicable). The preliminary signal design package is required for all projects. The District Traffic Engineering office project manager works directly with the designer on format and technical comments, keeping other project managers informed.

The plan should identify the Traffic Engineering (TE) number, the system ID number, the master ID number (if applicable), and the electric utility meter address.

NOTE: To expedite the signal plan review process, the signal plan should be checked by the signal designer prior to submittal. A checklist for plan reviews is available in the MnDOT Signal Design Manual.

H. TRAFFIC ENGINEERING REQUEST

A Traffic Engineering (TE) Request is a work order requesting state furnished materials and/or labor from the Central Electrical Services Unit. Signal projects let by MnDOT will utilize a state furnished traffic signal controller and cabinet. Other state furnished materials, especially for temporary traffic signal systems, may include microwave or video detection systems. In addition to the state furnished materials, a TE Request may also include a request for labor, such as modifying wiring within an existing signal controller cabinet in the field and APS installation. The District Traffic Engineering office prepares and submits the TE Request in the AFMS system and the Central Electrical Services Unit approves it.

The project special provisions should require the Contractor to contact the Central Electrical Services Unit to request the state furnished materials at least 30 days before the materials are needed. The Central Electrical Services Unit will finalize the TE Request, which ensures that the materials are correctly charged to the signal construction project.

The project special provisions should require the Contractor to again contact the Central Electrical Services Unit three days before picking up the state furnished materials.

I. SIGNAL AGREEMENT

MnDOT shall prepare a signal agreement as needed. Items typically covered within the agreement are:

1. Construction cost participation.
2. Responsibility for power cost.
3. Responsibility for major maintenance.
4. Responsibility for minor maintenance.
5. Responsibility for maintenance costs.
6. Responsibility for battery backup.
7. LED indication replacement schedule.
8. Responsibility for enforcement lights.
9. Responsibility for signal timing and operation.
10. Costs and responsibility for Emergency Vehicle Preemption (EVP) systems.

11. Reimbursement for State, County, or City furnished materials/labor.
12. Construction engineering costs.

The signal agreement request is often part of the final Plan Turn-In.

Projects requiring signal agreements should not be let without the agreement signed by the local unit of government. The construction project should not be awarded without a fully executed agreement (signed by all parties).

J. PLAN TURN-IN

The MnDOT District Traffic Engineering office project manager ensures that all of the comments to the preliminary submittal have been appropriately addressed. Upon completion of the final review, MnDOT (either the District Traffic Engineering office project manager or the larger roadway project manager) will begin final processing of the project package. Once all the district and local signatures are obtained, the project will be submitted to the Pre-Letting Section of the Office of Technical Support for final processing.

Traffic control signal plan approvals handled by MnDOT for other agencies, with or without the state aid process, are handled differently depending on whether the project has federal funding participation, and whether or not the intersection involved is on or off the trunk highway system.

If a traffic control signal at a trunk highway intersection is being built or revised by any other agency, the District Traffic Engineer shall approve the final plans before bids are opened on the project. If a proposed signal is not at a trunk highway location, the District Traffic Engineer will indicate concurrence with the design by means of a memorandum to the State Aid office.

The project submittal package should include:

1. Hard copy and Microstation CADD files of the signal plans.
2. Hard copy and Microsoft Word files of the signal special provisions.
3. Tabulation of Quantities for the signal project.
4. Sight distance calculations.
5. ADA decisions.
6. SOP letter and checklists.
7. Project correspondence.
8. Major design decisions.

K. ENGINEER’S ESTIMATE

The Office of Technical Support prepares the final Engineer’s Estimate based upon the tabulation of quantities provided by the signal designer.

L. PRE-CONSTRUCTION MEETING

For the Pre-Construction Meeting the District Traffic Engineering office project manager should invite the MnDOT District Traffic Engineering office operations personnel as appropriate.

M. AS-BUILT PLANS

As-built signal plans should be forwarded to the MnDOT District Traffic Engineering office upon completion of projects administered by local agencies.

N. Global Positioning System (GPS) Component and Utility Location Data

GPS coordinates should be collected for each traffic signal pole or pedestal including pedestrian push button stations, SSB service and traffic signal cabinets, handholes, source of power, and underground cable that is either direct buried or in conduits installed. This information should be forwarded to the MnDOT Traffic Engineer to be used with the MnDOT Geographic Information System (GIS).

9-7.00 TRAFFIC CONTROL SIGNAL DESIGN

9-7.01 General Considerations

The design of a traffic control signal system is a process of balancing, among other things, the requirements of the MN MUTCD, intersection geometrics, operational characteristics of the intersection vehicle and pedestrian traffic, the nature and volume of arterial traffic, and the constraints of the construction process. Please see the MnDOT Signal Design Manual for more information.

9-7.02 Intersection Geometry

Intersection geometry is an important element of traffic control signal design. The design of traffic control signal system hardware and operation of the traffic control signal system should be preceded by a thorough evaluation and, if necessary, geometric improvement of the existing intersection.

The following geometric elements should be considered:

1. Pavement width should be adequate for anticipated traffic movements and future capacity requirements. Highway capacity analysis should be performed to get a better understanding of the capacity of the intersection.
2. If appropriate islands should be designed and constructed so that the driver has adequate reaction distance to them and they are large enough to install a standard signal foundation. Existing shoulders should always be carried through the intersection; this will usually provide enough reaction distance to the island. However, turning radii should be checked to ensure enough setback for comfortable turns.
3. Turn lanes must provide adequate storage in order to prevent turning traffic from interfering with other traffic movements and thus causing capacity breakdown.
4. When a median width is more than 30 feet between opposing through lanes, special signal design considerations are necessary (See MN MUTCD Section 4P). Extremely wide medians confuse drivers on the crossing street, prevent them from being comfortable with opposing traffic, and cause them to lose track of their path. Wide medians also cause capacity restrictions because more time is needed for vehicle movements and clearances through the intersection.
5. Sidewalks should be constructed as close to the center of the corner as possible. Pedestrian crosswalks should be in line with the sidewalk and as close to the intersection as practical. ADA guidelines must be followed for proper ramps, pedestrian access routes, and push button locations.
6. Alignment changes within the intersection should be avoided. Vehicles approaching the intersection should be directed through the intersection. Vertical alignments approaching signals must allow for proper signal visibility.
7. Driveways within an intersection should be signalized and accommodated by the intersection geometrics. Whenever feasible, the driveways should be located or relocated outside the limits of the intersection.
8. The size of corner radii is an important consideration. Excessively large corner radii may obscure intersection limits and create a hazard for bicycles and pedestrians, while very small radii may create a hazard for motorists. Corner radii at signalized intersections should not be less than 20 feet nor more than 60 feet. A turning radius guide for 58-foot vehicles should be used to determine proper corner radii. At intersections where bus routes are located, corner radii should be analyzed giving due consideration to bus maneuvers.

9. It may be necessary to relocate utilities such as manholes, catch basins, fire hydrants, overhead power and telephone lines, and power poles to obtain adequate geometrics for signalization. The existence of these utilities must not get in the way of adequate geometrics.

10. Pedestrian curb ramps are typically required at all corners. An evaluation can be done if there is question whether the curb ramp must be put in. See the MnDOT ADA website for more detailed information.

9-7.03 Operational Characteristics

The behavior of the traffic at an intersection is another highly important element of signal design. The following elements should be considered:

1. Existing 15-minute vehicle volumes, by vehicle class, and pedestrian volumes are the most basic operational consideration. Data used should represent intersection operation in peak periods.
2. Intersection capacity should be determined based on the Highway Capacity Manual and other sources.
3. The vehicle approach posted speeds should be determined for the location of advance detection.
4. Adjacent land uses should be evaluated to identify activities that may conflict with intersection operation. Items that should be considered include entrances, advertising devices, and areas of high pedestrian activity (schools, manufacturing plants, shopping centers, etc.).
5. Crashes within the intersection should be studied to determine causes and possible design solutions.
6. Pedestrian volumes and school-crossing activities should be studied to determine pedestrian routes and necessary design treatments. Pedestrian movements in and around signals should be routed into the intersection crosswalks in front of vehicles stopped for the signal.

9-7.04 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. System considerations in signal design should include, but are not limited to the following:

1. Adjacent signals should be interconnected and coordinated whenever they are less than one-half mile apart, when the travel time between adjacent signals is less than the cycle length at each signal, or when platoons leaving one intersection remain intact to the next signal.
2. Properly spaced signalized intersections greatly simplify coordination in planning new signals. Minimum spacing of one-quarter mile is recommended. Irregular signal spacing reduces the overall operational efficiency of the mainline movements and greatly complicates signal coordination.
3. Whenever possible, platoons should be kept intact to allow easier mainline coordination and minimize cross-street delay.
4. New street or roadway construction should anticipate the need for future signals and the need for handholes and conduit, particularly under the roadway.
5. Pre-timed controllers may be used in built-up urban environments, particularly central business districts. The streets are not excessively wide and the traffic patterns are quite

predictable. In this environment, a signal cycle should contain pedestrian movements. 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 the volumes are usually quite high on these arterials. There are not usually many pedestrians crossing such an arterial, so an actuated controller tends to operate much more efficiently, as it is not necessary to time pedestrian intervals except when an actual demand exists. MnDOT traffic control signals are now exclusively fully actuated.

6. Splits and offsets should be carefully estimated to determine their impact on arterial flow. A split is the relative percentage of green time allocated to each of the various phases at a single intersection. An offset is the travel time between signals, usually expressed in seconds but sometimes in percent of cycle length.
7. Minimum pedestrian walk and clearance timings should be anticipated when designing coordinated signal systems.

9-7.05 Signal Design Elements

1. The most efficient operation of a traffic control signal system is with the fewest phases that are sufficient to move traffic without hazardous conflicts. Procedures exist to determine the optimum number of phases for an intersection. See the MnDOT Signal Design Manual for a discussion of phasing considerations.
2. The primary consideration in signal head placement is clear visibility. Drivers approaching an intersection shall be given a clear and unmistakable indication of their right-of-way assignment. The number and placement of signal faces shall conform to the requirements of Sections 4D.10 through 4D.25 of the MN MUTCD. Overheads should be located as near as practicable to the line of the driver's normal view. It is recommended that an overhead indication should be used over each lane. The size of lenses shall be as stated in section 4D.7 of the MN MUTCD. See the signal head placement charts in the MnDOT Signal Design Manual. In general, vehicle signal faces should be placed and aimed to have maximum effectiveness for an approaching driver located a distance from the stop line equal to the distance traveled while reacting to the signal and bringing the vehicle to a stop at an average approach speed. Visors, shields, or visual delimiting should be used to help in directing the signal indication to the approaching traffic, and to reduce sun phantom resulting from external light entering a signal indication lens. The Horizontal Location of Signal Faces diagram shown in MN MUTCD Section 4D.7 should be used as an aid in placing vehicle signal faces.
3. Vehicle detectors should be placed according to the detector spacing chart and the loop placement diagrams shown in the MnDOT Signal Design Manual.
4. At locations where pedestrians are expected, provisions must be made to control pedestrian activity in and around the signalized intersection. Pedestrian indications and Accessible Pedestrian Signals (APS) shall be provided if minimum pedestrian crossing time exceeds minimum vehicular green time, or if any of the conditions set out in section 4E.3 of the MN MUTCD are met. Pedestrian push buttons should be installed at locations with pedestrian activity where it is not operationally efficient to provide pedestrian timing on every cycle. Pedestrian signal indications shall be mounted, positioned, and aimed so as to be in the line of pedestrians vision, and to provide maximum visibility at the beginning of the controlled crossing. Locations of the pushbuttons in an accessible pedestrian signal are subject to placement criteria. See the MN MUTCD Part 4 and the Americans with Disabilities Act (ADA) guidelines for more details.
5. If it is determined to prohibit pedestrian movement across any approach, that prohibition must be clearly visible to pedestrians by use of Standard Sign R9-3a on each side of the prohibited crosswalk. See Part 4 and Part 2B of the MN MUTCD for further information.

6. Luminaires for roadway lighting should be installed with traffic control signals and flashing beacons. Luminaires are generally LED luminaires for use at a 40 foot mounting height, mounted in the far-right quadrants of the major street. Installing luminaires at all four quadrants should be considered to meet adequate light levels, larger intersections will require additional luminaires. Forty foot mounting heights provide even light distribution. Street lights installed on Type A signal mast-arm poles should be mounted at approximately 350 degrees clockwise from the mast arm in order to provide frontal illumination of any signs mounted on the mast arm.

Signal design must take into account the existing adjacent lighting systems and the equipment available to provide access to the luminaires for maintenance. The presence of overhead power lines must also be taken into account. These must be designed around or moved.

Use the Signal Design Review Check List that is in the MnDOT Signal Design Manual.

9-8.00 TRAFFIC SIGNAL PLANS AND SPECIFICATIONS

9-8.01 General

The end products of the pre-construction activities in signal design are the Plan, Special Provisions, and the Engineer's Estimate. Supporting the Plans and Special Provisions are the standard design practices, the MnDOT Standard Plates Manual, MnDOT Standard Specifications for Construction, other applicable national and local standards, and any necessary agreements. Detailed information is shown in the MnDOT Signal Design Manual.

9-8.02 Traffic Signal Control Plans

The Districts are responsible for developing traffic control signal plans. If the districts desire, they may request review of the plans by MnDOT's Office of Traffic Engineering (OTE).

9-8.03 Special Provisions

The Special Provisions for traffic control signal projects include complete detailed specifications of the traffic control signal system(s) and maintenance of traffic section which details the contract time schedule and provisions for traffic during construction. The Special Provisions are project specific specifications that supplement the MnDOT Standard Specifications for Construction book. A sample signal special provision is located on the OTE web site.

Responsibilities related to the Special Provisions are as follows:

1. District Traffic Engineer
    a. Submits to the Special Provisions Engineer of the Office of Technical Support, the Special Provisions for MnDOT designed signal system projects. The Special Provisions should be submitted in accordance with the pre-determined "Project Pre-Letting Date" deadlines.
    b. Submits to the Special Provisions Engineer in the Office of Technical Support, a completed copy of Form 21184, Contract Time Schedule Recommendations and Misc. Data, and Form 21185, Provisions for Traffic During Construction. This information should be submitted in accordance with the pre-determined "Project Pre-Letting Date" deadlines.
2. Office of Traffic Engineering Signal Unit
    a. Upon request of the District, the OTE Signal Unit reviews Special Provisions for signal system projects let by the State or other agencies involving the trunk highway system. The Office of Traffic Engineering website will maintain sample Special Provisions for district, consultant, and other agencies to access.

9-8.04 Tabulation of Quantities

The Detailed Construction Estimate (Engineer's Estimate) for all signal system projects let by the State is prepared by MnDOT's Office of Project Management and Technical Support. The District is responsible for providing a detailed tabulation of quantities to the Office of Technical Support as a basis for the Engineer's estimate. The MN MUTCD provides a sample tabulation of quantities. Districts may also provide a designer estimate.

9-8.05 Standard Plates Manual

The MnDOT Standard Plates Manual contains standard drawings of traffic signal equipment referred to in signal plans and Special Provisions.

9-8.06 Standard Plan Manual

MnDOT's Standard Plans contains a set of drawings developed by MnDOT, detailing standard construction and materials. These standards are incorporated, where applicable, into a set of road construction plans. Pedestrian curb ramp details can be found here.

9-8.07 MnDOT Standard Specifications for Construction

MnDOT Standard Specifications for Construction ("Spec Book") contains the standard provisions to be used and referred to in signal plans and special provisions.

9-8.08 Other Standards

Other national and local standards that are applicable to traffic signal plans and specifications are as follows:

1. National Electrical Code
2. National Electrical Safety Code
3. ICEA-NEMA Standards for Electrical Wire and Cable
4. ITE Standards
5. State and Local Statutes and Ordinances
6. Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD)
7. MnDOT Signal Design Manual

9-9.00 TRAFFIC CONTROL SIGNAL CONSTRUCTION

9-9.01 State Furnished Material

It is in the public interest for MnDOT to supply both new and refurbished traffic signal equipment and to assemble and modify this equipment for federal-aid projects because of the uniformity and ability to maintain. The purchase of large quantities of materials occurs using the low bid process and then the material is supplied to the contractor for each contract. The state purchasing of material shall conform to FHWA PPM 21-6.3, Paragraph 14 and a Public Interest Finding will be completed.

When it is determined that there will be State furnished materials to be provided by the Central Electrical Services Unit (CESU):

1. The District Traffic Office shall write a Traffic Engineering (TE) Request on the Automated Facilities Management System (AFMS).

2. The AFMS System ID and TE Request number shall be on the Traffic Signal plan.
3. One or two weeks prior to the letting of the contract, the District Traffic Office approves the TE Request on the AFMS.
4. CESU reviews the TE Request and enters the Electronic Concurrence in the AFMS.
5. The work is then assigned and completed by CESU personnel.

9-9.02 Signal Turn-On Procedure

Advance notice should be given to the public when a signal is to be activated. Those who should be present when the signal is activated include: (1) Project Engineer, (2) Contractor, (3) District Traffic Engineer (4) Regional Electrical Services Unit (RESU)/Metro Electrical Services Unit (MESU), and (5) City Police, if appropriate. The MN MUTCD describes the considerations for bringing the new signal out of flashing operation into normal stop and go operation.

9-9.03 Post Turn-On Procedures

After a signal has been activated, a copy of a memorandum of notification should be sent to the:

1. City
2. County
3. Affected power company
4. State Patrol
5. CESU & RESU/MESU
6. Office of Traffic Engineering (OTE - Central Office).

This notice should include the location, date and time of turn-on, maintenance responsibilities (including dates of warranties affecting the project), and the vertical clearances of any objects suspended over the roadways.

A sample signal turn on letter can be found on the OTE website.

9-10.00 TRAFFIC SIGNAL OPERATIONS

9-10.01 General

It is the responsibility of the District Traffic Engineer to observe the operation of all traffic signals in the district. Any timing or operation that is not correct should be corrected. Personnel in the Central Office Signal Unit can assist in the determination of the timing. Unusual hardware implementations may require the assistance of personnel from the Central Electrical Services Unit. The District Traffic Engineer shall maintain a complete timing record, including all preemption timing, in the controller cabinet and in the District Traffic Office. In the event the District Traffic Engineer determines a traffic signal is to be revised by state maintenance forces, a TE Request is to be written. The TE Request should outline the work that is to be done. Normally, the District Traffic Office will be contacted by the Central, Metro, or Regional Electrical Services Unit, as appropriate, after concurrence and before the work is done.

Each district should budget for payment of electrical power usage where the State has that responsibility.

The District Traffic Office shall keep a current maintenance log in each controller cabinet and any timing change performed to that signal shall be duly recorded on that log.

The District Traffic Office should perform an “operations check” of all district traffic control signals every 6 to 12 months. The operations check will review the operation of the traffic signal including checking all vehicle indications, pedestrian pushbuttons, detection, and other items critical for efficient operation of the traffic control signal. The cabinet filter should also be replaced once every 12 months.

A sample signal maintenance log sheet can be found on the OTE website.

9-10.02 Operational Timing Practices

Detailed information is shown in the MnDOT Signal Design Manual. It should be noted that those guidelines, procedures and practices are general and should only be used as a guide. Many other factors at each individual intersection must be considered along with engineering judgment when applying the guidelines.

9-11.00 TRAFFIC CONTROL SIGNAL MAINTENANCE

9-11.01 General

Maintenance work on traffic signal systems that is the responsibility of the State is performed by the Electrical Services Unit (ESU). ESU has three electrical service units within it as follows:

1. **Metro Electrical Services Unit (MESU)**
   The MESU performs repairs within the seven county Metro Area. MESU works primarily on high voltage type repairs and equipment including traffic control signals, street lighting, and other electrical traffic control systems. MESU only works in the Metro District and is part of the Metro District Traffic Office.

2. **Regional Electrical Services Unit (RESU)**
   The RESU performs repairs in greater MnDOT districts outside of the Metro area. RESU works primarily with high voltage type repairs and equipment including traffic control signals, highway lighting, Intelligent Transportation Systems (ITS), Variable Message Signs (VMS), and other electrical traffic systems in greater Minnesota. This group also works on control equipment and other related electronic systems when needed. They are located throughout the state and are part of the Office of Traffic Engineering.

3. **Central Electrical Service Unit (CESU)**
   The CESU performs shop and field repairs of traffic signal control equipment and other traffic related electronic systems, receives Gopher State One Call location requests, updates cabinets and prints, prepares state-furnished equipment for installation by contractors on traffic control signal projects, and provides technical field assistance. CESU works primarily with low voltage type repairs and equipment, providing service in all districts. CESU is part of the Office of Traffic Engineering.

   CESU will perform a preventative maintenance (PM) checks of all MnDOT traffic control signals every 12 to 24 months. This PM will place the signal in flash to perform a Malfunction Management Unit test. The PM will also check indications, pedestrian pushbuttons, detection, and any other items critical to efficient operation of the traffic control signal.

A municipality or county may, by resolution, request that the State, with its own forces, perform certain maintenance work assigned to the municipality or county using a separate reimbursable maintenance and operation agreement. The State is reimbursed for work through this agreement. The District and the Metro or Regional Electrical Services Unit should evaluate such requests for feasibility for the State to do this additional work. The signal agreement will define responsibilities for maintenance and monthly power cost.

9-11.02 Malfunction Repair

In the event of an equipment malfunction, the District Traffic Engineer, State Patrol, or other authorities call the Metro, Central, or Regional Electrical Services Unit to dispatch a repair crew. The District Traffic Engineer assigns each intersection a Signal Maintenance Priority that indicates the order that traffic signal malfunctions should be serviced when malfunctions are known to exist at more than one intersection. The Signal Maintenance Priorities are as follows:

1. Repair as soon as possible.
2. Repair before next peak hour.
3. Repair next scheduled workday.

4. Repair as schedule permits.
5. No State maintenance responsibility.

After hours, the call typically comes into the District Maintenance or State Patrol Dispatcher. In the Metro area the dispatcher will contact the appropriate Metro or Central Electrical Services Unit “on call” person. In greater Minnesota the dispatcher will call the appropriate district person or the Regional Electrical Services Unit person. After the dispatcher makes contact with the Metro, Central, or Regional Electrical Services Unit or the appropriate district contact, it is the responsibility of this person to follow-up on the problem.

When a traffic control signal malfunction has been reported to the District, and the local authority is responsible for the maintenance of that traffic control signal, the responsible jurisdiction should be contacted immediately to arrange for prompt repair.

9-11.03 Signal Indication Failures

All indication failures that are the responsibility of MnDOT shall be reported to the Metro or Regional Electrical Services Unit personnel. Indication failures that are the responsibility of other agencies shall be reported to them for correction. Any indication failure report received by the Metro or Regional Electrical Services Unit that is not the responsibility of MnDOT will be referred to the responsible agency for correction. All such reports shall be documented by the Metro or Regional Electrical Services Unit.

LED signal indications fail by gradually dimming until they no longer provide adequate output. The Institute of Transportation Engineers (ITE) provides specification for required light output of the indications. To ensure LEDs meet light output requirements, LED indications shall be replaced every 7 to 10 years. This should be considered when budgeting for maintenance.

9-11.04 Signal Maintenance Log

A paper signal maintenance log is present in each traffic control signal cabinet. Anyone who does any repair work, changes to controller programming, and/or modifications in the cabinet or at the intersection shall record the action in the signal maintenance log. The signal maintenance log provides a historical record of work done in the cabinet to assist personnel in diagnosing problems in the cabinet and in making operational adjustments. A copy of the signal log sheet can be found on the OTE website.

9-11.05 Automated Facilities Management System

In addition to the signal maintenance log contained in the intersection controller cabinets, the Automated Facilities Management System (AFMS) maintains a record of signal maintenance for each intersection for which the State has maintenance responsibility. Whenever a maintenance call is made to an intersection, the work that is done is recorded and entered into the AFMS. The AFMS provides data for analysis of such factors as maintenance time apportionment and equipment reliability. It also provides tracking for legal issues.

The AFMS contains computer records for all traffic signals and flashing beacon systems on trunk highways in Minnesota and for any additional traffic control signals or other devices for which the State has any responsibility.

9-12.00 TRAFFIC SIGNAL COMPUTER AIDS

9-12.01 General

District Traffic Offices, traffic engineers and technicians in the State of Minnesota have access to a number of computer programs that assist with the intersection or network geometry setup and/or modification, traffic signal warrant analysis and justification, design, timing and coordination plan development, operations, and management of traffic signal systems. Computer programs can also help with signal inventory and maintenance management. More information can be found in the MnDOT Signal Timing and Coordination Manual.

9-12.02 Computer Software

There are many software programs available to the traffic signal designer or operations analyst.

The Highway Capacity Manual software was developed for the Federal Highway Administration and follows the capacity analysis procedures found in the latest edition of the Highway Capacity Manual.

Signal warrant analysis software, given volume, speed, and geometric data for an intersection, will produce tables and graphs, and will analyze the volume counts against traffic signal warrants defined in the Minnesota Manual of Uniform Traffic Control Devices (MN MUTCD).

There are many computer tools that users can choose from for signal timing and coordination analysis applications. A detailed introduction of the MnDOT most used software, Synchro, and a brief description of three other widely utilized programs, including, TRANSYT-7F, PASSER-II, and CORSIM are provided in the MnDOT Signal Timing and Coordination Manual. It is important to know that one cannot (or should not) simply implement the computer-generated timing and offset settings. Engineers must carefully fine-tune settings in the field based on observations of actual traffic flows.

9-12.03 Computer-Aided Drafting

MicroStation is an extremely powerful computer-aided drafting software. Training is available through the Office of Computer-Aided Engineering Services (CAES) in Central Office.

9-13.00 REFERENCES

1. Institute of Transportation Engineers (ITE). Manual of Traffic Engineering Studies, by Paul C. Box and Joseph C. Oppenlander, 4th ed. Arlington, VA.; Institute of Transportation Engineers, 1976.

2. Institute of Transportation Engineers (ITE). Traffic Engineering Handbook, Wolfgang S. Hoamburger, P.E., James L. Pline, P.E., ed. 6th ed. Englewood Cliffs, NJ: Prentice-Hall, Inc., 2009.

3. Capacity Analysis Techniques for Signalized Intersections, by Jack F. Leisch Arlington, VA; Institute of Transportation Engineers, 1986.

4. Minnesota Department of Transportation Standard Plates Manual.

5. Minnesota Department of Transportation, Standard Specifications for Construction.

6. Minnesota Department of Transportation, Technical Manual.

7. Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD)

8. National Electrical Manufacturers Association NEMA Traffic Control Systems, Standards Publication TS 1-1989 Washington, DC.

9. National Electrical Manufacturers Association NEMA Traffic Control Systems, Standards Publication TS 2- 2003 Washington, DC.

10. National Fire Protection Association (NFPA) National Electrical Code.
11. National Research Council, Transportation Research Board (TRB) Highway Capacity Manual.
12. United States Department of Transportation, Federal Highway Administration Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD).
13. United States Department of Transportation, Federal Highway Administration, User Guide for Removal of Not Needed Traffic Signals.
14. MnDOT Signal Design Manual.
15. MnDOT Traffic Signal Timing and Coordination Manual