Section 12

Traffic Signal Design

12.1 General

This section of the manual is intended for use as a guide in the planning and design of the Traffic Signal Plan and Electrical Plan of a traffic signal installation that conforms to Department policy. It will provide a means of developing uniformity in the design and plan preparation of traffic signals.

The term "traffic signals" can include many types of control signals: pedestrian signals, lane-use control signals, hazard identification beacons, school sign flashing beacons, moveable bridge signals, priority control signals, and railroad pre-emption. However, certain general design criteria can be applied to all traffic signals.

Complying with all of the design criteria is sometimes difficult. It will require some judgment on the part of the designer to draw the necessary balance. However, it is necessary that the criteria be followed as closely as possible in order to achieve uniformity of traffic signal design. It is recognized that situations will occur where good engineering judgment dictates deviation from this Department policy. Any such deviation shall be detailed in writing and submitted for approval to the Manager of Traffic Signal and Safety Engineering (TSSE).

It is not the intent of this section to reproduce all the information that is adequately covered by textbooks and other publications that are readily available to the designer. This section, when used in conjunction with engineering knowledge of traffic signal design and good judgment, should enable the designer to perform their job more efficiently.

The terminology used in this section, unless stated otherwise, is as defined in the current addition of National Electrical Manufacturers Association (NEMA) Standard Publication No. TS-1, Part 1, entitled "Traffic Control Systems".

All traffic signal plans shall be produced in CADD utilizing Microstation to NJDOT and TSSE CADD standards. Non-compliance to CADD standards will result in plan rejection.

12.2 Reference Publications

- FHWA - *Manual on Uniform Traffic Control Devices* (MUTCD)
- ITE - *Transportation and Traffic Engineering Handbook*
- FHWA - *Traffic Control Device Handbook*
- ITE - *Manual of Traffic Engineering Studies*
- ITE - *Manual of Traffic Signal Design*
- SPECIFICATIONS:

  NJDOT - *Standard Specifications for Road and Bridge Construction*

  NJDOT - *Special Provisions*

  NJDOT - *Electrical Material Specifications*

  AASHTO - *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals*
- NFPA - *National Electrical Code* (NEC)

- NJDOT - *Standard Electrical Details*
- NJDOT - *Sample Plans*
- NJDOT - *CADD Manual*
- OSHA - *Code of Federal Regulations Title 29*, Part 1926

All publications shall be the latest edition.

12.3 General Design Criteria

12.3.1 Warrants for Traffic Signals

The NJDOT has adopted the MUTCD as the guideline for the design and application of traffic control devices on all state highway and all decisions with regard to traffic control devices shall be based on the MUTCD as provided by N.J.S.A. 39:4-120. All traffic signal installations must be warranted in accordance with the MUTCD and as noted in the MUTCD meeting a warrant does not constitute approval for signalization. A traffic signal warrant study must include sufficient vehicular and pedestrian counts, the latest three year detailed crash analysis at the intersection and a detailed plan or condition diagram of the intersection identifying the geometric features including intersection sight distance, existing traffic control devices and markings, spacing to existing signals and speed limits. In addition the engineer is required to provide a recommendation that if warranted the signalization is based on his analysis and investigation and that signalization is in the best interest of safety and the expeditious movement of traffic. TSSE is responsible for review and approval of the traffic signal warranting analysis. The designer shall obtain TSSE's approval that a traffic signal is warranted prior to starting the actual design of the traffic signal.

12.3.2 Traffic Signal Design –"TS" Plan - General

The NJDOT meets at least the minimum standards set forth in the MUTCD. However, in most cases a higher level design, that exceeds these minimum standards with respect to number and placement of signal heads and timing and operation of the signal, should be achieved.

The following section is intended to provide guidance to the designer in the development of the Traffic Signal (TS) Plan.

- All plans are to be prepared using CADD Microstation, NJDOT and TSSE CADD standards. All plans are to be scaled at 1 inch = 30 feet.
- All traffic signals on the state highway system are to be designed as semi-actuated signals with areas of presence detection, unless otherwise approved by TSSE.
- All actuated traffic signals are to be designed utilizing pedestrian push-buttons that provide the pedestrian the ability to cross the State highway.
- The traffic signal timing and operation shall be shown on a separate plan sheet. In addition, the designer shall provide the timing and operation in WORD format on a computer diskette or CD and submit to TSSE.

A. Typical Signal Layout Considerations – General

NJDOT has adopted the near side left overhead – far side right overhead signal head placement as its basic design for each approach of a signalized intersection. The near side left signal head over the roadway typically provides stop bar definition and it is to be located as close as possible to the stopline.

B. Signal Head Placement

The signal head placement is to conform as close as possible to the following:

- One Lane Approach;

  The far side signal head is to be placed as close as possible over the center of the lane on the far side of the intersection. The near side signal head is to be placed as close as possible over the center of the opposing lane.

- Two Lane Approach;

  The far side mast arm is to have one, preferably two, overhead signal heads. If only one signal head is used, it should be placed over the white line separating the two lanes on the far side of the intersection. If the approach has an exclusive turning lane(s), two signal heads are to be used. If the exclusive turn lane(s) has a protected phasing operation, an additional overhead signal head is to be provided for this purpose and be placed as close as possible over the center of this exclusive lane. The near side signal head is to be located over the opposing lane closest to the centerline.

- Three Lane Approach;

  The far side mast arm is to have two to three overhead signal heads based on the number of receiving lanes and exclusive turn lanes. Generally, the number of heads corresponds to the number of receiving lanes for through movements, in addition to a head(s) used to control an exclusive turn lane. Placement of these heads should be located as close to the center of the lanes as possible. The near side signal head is to be located over the opposing lane closest to the centerline.

- Four Lane Approach;

  The far side mast arm is to have three to four overhead signal heads based on the number of receiving lanes and exclusive turn lanes. Placement should be as described above in the 3 Lane Approach.

- Approaches with median or curbed barrier separating opposing traffic;

  Signal heads shall be aligned over the roadway as noted above, except that in this case, the near side signal head will be placed to the left of the median or barrier curb , typically back to back with the far left through signal head for opposing traffic.

C. Supplemental Signal Heads

Supplemental signal heads may be used in the design when justifiable by engineering judgment. The following is a brief description of the justifications for installing supplemental heads:

- Signal Heads for Stop line Definition;

  For example, the near side signal head does not appear to provide adequate stop line definition due to geometric features. In the case of a right horizontal curve, a pole mounted signal head may be added to the left of the approach. It should be as close as possible to the stop line of that approach.

- Signal Heads for Pedestrians;

For some intersections, pedestrian activity is minimal and does not warrant the installation of pedestrian "WALK/DON'T WALK" signals. In such cases, a supplemental 3 section head may be installed, if a condition exists where a pedestrian could not fully view any other signal head in the intersection. This supplemental signal head will be pole mounted and aligned so that the pedestrian can view the signal face in the direction that the pedestrian wishes to cross.

- Signal Heads for Increased Advance Visibility;

  The MUTCD provides the minimum sight distance required for viewing traffic signal heads. If the specified minimum distance is not met for continuous view of at least two signal faces, a warning sign is required and possibly an active (electrified) warning sign may be justified. In some cases the installation of a supplemental signal head in the appropriate location may provide adequate sight distance and negate the need for such warning devices.

D. Signal Heads for Protected Turning Movements

- Protected Left Turns

  Protected left turn phasing is normally provided only at locations that have a dedicated left turn lane. This movement is to be controlled by a signal head consisting of red, yellow and green left arrows. Two signal heads are to be provided for this movement, one of which should be overhead. This overhead signal is normally designed as part of the far right signals on a mast arm. The left turn signal head is to be located a minimum of 1/3 of the way into the left lane, measured from the right edgeline marking that separates the left turn lane and the adjacent through lane.

- Protected Right Turns

  For a non-channelized protected right turn movement, the signal head located on the far right side of the intersection on the mast arm is to consist of a standard three section signal head plus a bi-modal green/yellow right turn arrow in the fourth section. If a supplemental signal head is needed for pedestrians, then it also is to be a four section head in order for the pedestrian to not be in conflict with the protected vehicular phase.

  For a channelized protected right turn movement, a pole mounted three section head consisting of red, yellow and green right turn arrows should be located on the right side of the approach. Where feasible, a far side pole mounted three section head consisting of red, yellow and green right turn arrows should be installed.

E. Detection

Detection is required for all traffic signals on the state highway system unless otherwise approved by TSSE. The primary form of detection to be integrated into a signal design is image detection. Image detection shall be operated in the presence mode. The location of the image detection device should either be on the far side signal standard itself or mast arm, in accordance with the manufacturers' recommendations. The area of detection is 40 feet as measured back from the painted stopline.

If approved, the alternative type of detection is a loop detector that is operated in the presence mode. Specific details of the type and layout of loop

detectors will be discussed in the subsequent electrical section of this chapter.

Under special circumstances TSSE will approve the use of a force off detector. A typical situation is where the vehicle queue on a signalized approach, usually an off-ramp, could queue back and affect through traffic on the main highway. In the interest of safety, a special pre-emption sequence can be implemented to give a priority green phase to this approach to clear the queue. This sequence is initiated by recognition of a constant vehicle call (typically a minimum 5 seconds) on the strategically placed force-off detector. The location of the force-off detector is determined by the designer and is based on engineering judgment, geometry, peak hour traffic volumes and site observations.

12.3.3 Traffic Signal Timing and Operation - General

The foremost objective in the installation of a traffic signal is to assign sequential right of way to conflicting vehicular and pedestrian movements ina manner that is safe and efficient. In order to achieve signal efficiency, the most critical factor is the traffic signal timing and operation. In general, the first considerations for preparing a timing directive are as follows:

1. Cycle length
2. Clearance times
3. Pedestrian indications within a multi-phase operation
4. Protected versus protected - permissive left turn phases.
5. Emergency vehicle and railroad pre-emption sequences.

A. Coordination - Cycle Length

The designer shall investigate and provide a report of a total system design concept in each project. The Department currently utilizes several types of traffic signal systems as follows:

1. Time Base - Time base coordination, when installed at a group of intersections, provides a coordinated system without the use of interconnecting cables.
2. Closed Loop - continually monitoring a minimum of 30 local intersection operations and system performance. The system is also capable of traffic responsive operation and providing maintenance reports. When the design of a project includes the installation or modification of a computerized closed loop traffic signal system, the ITS Engineering Unit shall be contacted for the proper system design criteria.
3. Isolated Intersection Control - Isolated intersection control is only utilized when coordination is not required, typically referred to as variable or free float operation.

The existing cycle used within a system of coordinated signals, in which a new signal is to be incorporated, dictates what cycle length is to be used. The most common cycle lengths used are 90 and 120 seconds. In order to determine the offset to the reference (master) signal, a time–space diagram of the entire system must be plotted. This type of signal operation will only service the side street call or pedestrian call at a point in the cycle where the offset is measured, thereby keeping the signal system in synchronization.

Traffic signals not in a coordinated system are typically designed with a variable cycle or a free float operation and are characterized by setting a minimum green to the main arterial. Once the minimum green time is met, any call on the side street or a pedestrian call will immediately terminate the main arterial green. The variable cycle is used in isolated rural areas where signal spacing is usually greater than 1 mile and signal coordination is not practical. It can also be used during late night and early morning hours to reduce vehicular delay on side streets in a coordinated system, when coordination is no longer critical.

B. Minimum Green–Yellow - Red Times

The minimum times allocated in traffic signal timing and operation shall be as follows:

	Minimum
Actuated through movements -	7 second green
Lead left turn movements -	5 second green arrow
Yellow clearance -	3 seconds
Yellow arrow clearance -	3 seconds
All red clearance -	2 seconds
All red arrow clearance -	2 seconds

The above outlines the minimum times to be used when developing a signal timing plan. It is the responsibility of the designer to determine the total clearance time for the intersection, based on the speed of vehicles and the width of the intersection traversed.

C. NJDOT uses the following formula

Total clearance time= $T + V/2a + (W + L)/V$

Where T= Perception time (1 second)

a= Deceleration (10 ft/sec)

L= Length of vehicle (20ft.)

W= Crossing width

V= Velocity in ft/sec

By inserting the variables of W and V in the equation, the designer is able to calculate the total clearance time (yellow + all red).

The NJDOT rule for calculating the yellow change interval is:

One second for every 10 miles per hour (minimum of 3 seconds).

For speeds above 30 mph, the yellow time must be rounded upward.

EXAMPLES: 35MPH = 4 seconds yellow

45MPH = 5 seconds yellow

55MPH = 6 seconds yellow

After establishing the yellow time, it is then subtracted from the total clearance time calculated above to obtain the all red clearance time. As with the yellow time, the all red clearance time is always rounded upward. The phasing pattern must be known in order to determine the worst case

(farthest) point of vehicle-vehicle or vehicle-pedestrian conflict. Actuated phases may or may not be skipped and therefore, the greatest travel length for "W" must be used to determine the total clearance.

12.3.4 Pedestrian Timing Considerations - General

Traffic signal designs for signals on the state highway system must consider the needs of pedestrians, based on factors such as signal standard location, operation and phasing complexity.

In some cases where the traffic signal is operating in the fixed–time mode, the minimum green time set for the minor cross street must satisfy the minimum pedestrian crossing time requirements. The designer should evaluate each signalized intersection for special considerations and meet the requirements of the MUTCD, such as designated school crossings that justify the installation of Walk / Don't Walk pedestrian signals.

Pedestrian Timings

The NJDOT standard pedestrian signal is the countdown Walk / Don't Walk signal. The minimum walk time allocated should be 7 seconds. The pedestrian clearance time is calculated using the longest crosswalk length, curb to curb, and dividing this by the MUTCD walking rate. Lower walking speeds may be used where justified by an engineering study. When developing a signal timing and operation plan, it is important to begin with the fixed parameters such as yellow change, all red clearance and the pedestrian clearance phase. The walk time for the actuated phases is then determined, according to the capacity constraints of each individual intersection. It should be noted that the sum of pedestrian actuated Walk and Flashing Don't Walk times do not have to equal the vehicle actuated maximum green time for the same approach. If higher, a vehicle extension line should be incorporated into the timing plan to account for green time in excess of the side street maximum green.

12.3.5 Pre-Emption

Pre-emption of traffic signals on the State highway system include:

Emergency Fire and Rescue, Railroad and Moveable Bridge pre-emption.

A. Emergency Fire and Rescue

   If an emergency traffic signal is found to be justified or if an existing traffic signal is identified as needing a pre-emption sequence, the State will only install a hard wire connection within State right of way up to the fire/rescue house, if it is within one thousand feet of the traffic signal. Any installation and maintenance of equipment, needed beyond State right of way and within the fire/rescue house, to operate the traffic signal pre-emption will be the responsibility of the party having jurisdiction of the fire/rescue house.

   In no case will the State participate in the purchase, installation and maintenance of any "Optical" system or other system used to remotely initiate a pre-emption sequence.

   If pre-emption is approved, a timing sequence needs to be developed that provides adequate time to allow for safe egress of the fire/rescue vehicles. Care should be taken to ensure that all timing plans have a sufficient guaranteed minimum green time to the main street to avoid the display of a "flash" green. All vehicular and pedestrian clearances times must be guaranteed.

B. Railroad

Railroad pre-emption follows a similar timing sequence pattern, but may not assign the right of way to any approach, i.e. red to all approaches, because the train has the right of way at all times. When designing a railroad pre-emption, special care should be taken in locations that have channelized free flow right turns that direct traffic toward the grade crossing. Blank-out turn prohibition signs should be considered and designed to initiate and terminate with the traffic signal pre-emption.

Railroad pre-emption is to be incorporated at all locations where an active track is within 200 feet of an existing or proposed traffic signal or where vehicle queues could reach the tracks from a traffic signal any distance away. In most cases, the Department will typically conduct a Diagnostic Team meeting. A formal Docket is prepared delineating the equipment and traffic control devices to be constructed at the grade crossing and directs the installation of a traffic signal pre-emption, if warranted.

C. Moveable Bridge

Typically separate traffic control signals are already included on the bridge approaches to specifically stop inbound traffic, upon preemptive actuation. When a signalized intersection is located on either or both sides of a moveable bridge, the outbound movements off of the bridge are subject to pre-emption, since the potential exists for vehicles to queue on the bridge. The preemptive sequence shall address the required clearance interval, based on vehicle start up delays. To avoid gridlock of the intersections during long bridge openings, the traffic signal design(s) is to include blank-out signs and a rest phase for the non-conflicting adjacent street movements.

12.3.6 Temporary Traffic Signals

When an existing traffic signal is affected by the construction, they shall be revised as follows:

A. Where possible, all existing equipment should be left in place while the proposed signal is constructed. The designer shall provide a scheme of the construction to verify that the equipment can be left in place. A scheme shall be provided for each stage of construction, which includes detailed temporary wiring and any safety protection, if required.

B. A temporary signal shall be included in the contract whenever an existing signal must be removed prior to the completion of the new signal.

C. If a signal is being removed as part of the design and not replaced, the designer shall indicate the stage of construction that the signal will be removed.

D. When an existing signal is part of a "system", the ITS Engineering Unit shall also be notified and the system aspect of the signal shall be their responsibility.

NJDOT uses temporary traffic signals exclusively during construction projects, when it is deemed necessary to control traffic by a traffic signal for a stage or stages of a project and it is not possible to install or maintain a permanent traffic signal. The typical temporary signal consists of a two pole span wire arrangement that spans the intersection diagonally. Standards are typically placed on the near left and far right corners of the major street approaches to facilitate meeting the MUTCD cone

of vision requirements. A four pole box span is also an option to minimize span length.

Because all signal heads are typically located on one span wire, the dead load is maximized on the cable and poles. Since temporary traffic signals are used exclusively on construction projects, each two pole and cable system must be structurally designed individually and certified by a Professional Engineer, licensed in the State of New Jersey, usually the project designer. The certified plans and calculations must be submitted to the Bureau of Structural Engineering for approval. The designer shall provide plans, timing, details and certified structural calculations supporting the design and the material to be used.

With the diagonal placement of the span wire, the designer must give consideration to the lateral placement of signal head and possible spillover of illumination to a conflicting movement. Tunnel visors, louvers or other methods may be required to control spillover.

The temporary signal must be designed specific to each stage and, whenever possible, incorporate the maximum number of signal heads for all stages to minimize over-roadway signal head shifts in the field. Image detection and pedestrian push-buttons are to be included. The use of image detection will permit the signal to operate in the semi-actuated mode and therefore be more efficient. The image detection is then available for repositioning to accommodate multiple stages at the signal. Like permanent traffic signals, highway lighting shall be provided in the temporary traffic signal design.

12.3.7 Traffic Signal Controller

The current Department standard is an eight phase fully actuated traffic signal controller. The controller is a microprocessor based digital unit with a minimum of dual ring quad left or sequential operation, as specified in the current NJDOT Specification Nos. EB-TSC-ITB-8 and EB-TSC-8CL.

The designer shall review the timing sequence to insure that an eight phase traffic signal controller can perform it. The controller shall not require external timers or timing relays to perform the timing sequence. The designer, in all cases, must consider and utilize the overlapping pedestrian movement or concurrent traffic movements. The timing schedule is placed on a separate plan sheet.

The controller is the most important component of the traffic signal; therefore, the designer must use extreme care in choosing a location for the controller at the intersection. As a minimum, the following criteria shall be adhered to:

- Offset the controller as far as possible from the traveled roadway within the right-of-way, allowing adequate work area for maintenance.
- Provide the maintainer the best possible visibility of the signal indications when working on the cabinet.
- The controller location shall be the least vulnerable to vehicular accidents and not restrict sidewalk areas.

12.3.8 Traffic Signal Standards

Types, designs and certain typical installation details for traffic signal standards and their foundations are included in the NJDOT Standard Electrical Details.

Aluminum traffic signal standards and transformer bases shall be of aluminum alloy to support traffic signal mast arms with a length of 25 feet or less. When the mast arm exceeds 25 feet, the traffic signal standard shall be steel.

The Traffic Signal Standard "C" is used when required to obtain the minimum roadway overhead clearance for signal heads mounted over the roadway.

The roadway overhead clearance of the signal head must be examined and calculated when a traffic signal standard, particularly "T", is installed at the low side of a banked section of roadway.

Traffic Signal Standard "K" is the preferred standard to be used for 25 foot mast arms.

The designer is responsible for loading calculations necessary to verify that the standard and arms will support the signal indications and signs. All mast arm signs are free swinging in accordance with the standard details.

Locate traffic signal standards as follows:

A. The minimum offset is 32" from face of curb or edge of pavement to center of the standard.

B. Steel traffic signal standards are located 10 feet from the face of the curb when possible. A minimum of 5 feet from the face of the curb to the center of the steel traffic signal standard should be maintained.

C. Traffic signal standards shall not be located in areas of handicap ramps nor shall they obstruct the crosswalks.

D. Use traffic signal standards, where feasible, to support pedestrian signals and push buttons.

E. Traffic signal standards shall not be located on the traffic side of (in front of) the guiderail or any natural or manmade deflecting barrier. The location must provide the distance necessary for rail deflection when struck and a reachable distance for pedestrians to push the pedestrian push button. Exceptions on a case by case basis may be made only with approval of Traffic Signal and Safety Engineering.

F. Traffic signal standards shall not be located near the curve of:

- A corner with a radius of less than 15 feet, or;
- A corner with a radius of less than 30 feet provided where trucks and buses turn right occasionally, or;
- A corner with a radius of less than 50 feet provided where large truck combinations and buses frequently turn right.

G. The designer is responsible for locating and identifying the horizontal and vertical clearances of the utility company's primary (750 volts or more) and secondary power lines and assure that the minimum clearances are in accordance with the NEW JERSEY ADMINSTRATIVE CODE CHAPTER 25 UTILITY ACCOMMODATION, Section 16:25-5.3 (b). The designer coordinates the electrical design work with the present and future plans of the utility companies. All overhead and underground utilities must be shown on the plans. There shall be no conflicts with the lighting and traffic signal installation.

12.3.9 Traffic Signal Indications

The location and type of indications shall be approved and/or determined by the Bureau of Traffic Signal and Safety Engineering.

12.3.10 Intersection Lighting

Intersection lighting is included as part of the traffic signal design at all signalized intersections and conform to Section 11 subsection , "Lighting At Intersections". The intersection lighting shall be installed on Traffic Signal Standards, "C", "SC", or "K" with a "KE" extension.

12.3.11 Conduits

Rigid metallic conduits (RMC) 3" in diameter, is used throughout for all traffic signal cables. Conduit size for loop detector cables is 1-1/2" in diameter. Conduit size for overhead electrical services and telephone services is 2" in diameter or as required by the utility company. Typical details regarding conduit installations are included in the standard electrical details.

Rigid nonmetallic conduits (RNMC) may be used for interconnect conduits between intersections or for conduits to control "Red Signal Ahead" signs. Install a ground wire if nonmetallic is installed.

12.3.12 Cables and Wires

All cables and wires, including neutrals, to be used for traffic signal circuits and incoming secondary service shall conform to the specifications and shall be fully color coded. The designer provides a block wiring diagram as shown on NJDOT Sample Plans. The block wiring diagram indicates the cable letter for each cable extending from the controller to the base of the traffic signal standard. The letters are to be assigned sequentially to cables terminating at the far corner first, then to cables terminating at the next corner as the first group passes through (east corner then north corner; south corner then west corner, as shown in the NJDOT Sample Plans. The designer calculates the wire fill of all conduits to insure conformance to the National Electrical Code. The following cable areas are used for wire fill:

Cable	Cross Sectional Area
10/C #14	0.322 sq. in.
5/C #14	0.166 sq. in.
2/C #14	0.105 sq. in.

The designer provides sufficient wire from each traffic signal standard to the controller; however, in order to avoid a redundancy in the wiring system, the following traffic signal faces may be wired in parallel in the base of an individual traffic signal standard:

- Traffic signal faces of a main street or side street on the same phase, provided there is exclusive left turn signal phase.
- Traffic signal faces of a minor side street, provided they are on the same phase and most likely they will not be on separate phases or will not have an exclusive left turn phase in the future.

The signal cables are brought directly to the controller. The designer shall observe the following criteria:

- All vehicular indications are wired on a 10/C #14 cable. A 5/C #14 may be used when only one indication is on the pole.
- All pedestrian indications are wired on a 5/C #14 cable.
- All push buttons are individually wired on a 2/C #14 cable.

- All loop detectors are wired with a 2/C (twisted pair) #14 cable. Each loop detector has its own twisted pair of detector lead-in wires and are connected separately to a channel of the detector unit.
- Each traffic signal circuit of a load switch must be less than 10 amperes; provide calculations for the circuits of more than 7 amperes.
- Lighting circuits installed as part of the traffic signal installation will utilize the same conduit system as the traffic signal circuits and conform to Section 11, "Roadway Lighting Systems". The wire size is #8 AWG or as required.

12.3.13 Vehicular Detection

A. Image Detection

1. On all new traffic signal designs, Image Vehicle Detection will be used. The area of detection will be the same as when designing inductive loops. The Plan will be labeled "AREA OF DETECTION".
2. On all revisions to traffic signal designs that involve vehicle detection changes, Image Vehicle Detection will be used. The area of detection will be the same as when designing inductive loops. The Plan will be labeled "AREA OF DETECTION".
3. The Image Detection unit (camera) must be placed aiming the camera as straight as possible to the area of detection, trying not to view the area of detection on an angle.

B. Inductive Loop Detection

The Department also installs inductive loop detectors for vehicular detection. A series of short loops shall be installed to cover the area of detection determined by the traffic engineer. Other types of detectors are used only in areas where the loops could not be installed, such as a steel bridge deck.

Installation of inductive loop detectors conforms to the following guidelines:

1. Under normal conditions a diamond shaped loop, which is approximately 6' x 6' in the direction of travel, is utilized to cover the area of detection. The largest loop is 6' x 18'.
2. Loops directly behind the stop line are designed as small as possible to guarantee the detection of motorcycles stopped directly behind the stop line. See Figure 12-B.
3. The designer should first try to use a series of four short loops. Where the area of detection cannot be covered with a four-loop layout, additional loop(s) should then be considered as shown in Figures 12-A through 12-D.
4. The longitudinal spacing between two loops shall be in the range of 5 feet to 16 feet. The spacing shall decrease gradually as a vehicle approaching the intersection reduces its speed.
5. Except in areas of parking, the side edge of a loop shall have a lateral spacing of 3 feet from a curb or pavement edge and 3 feet from a painted double yellow line or a white line.
6. Under normal conditions the front edge of the loop immediately behind the stop line is no more than 2 feet from the top of the stop line. The maximum spacing between loops adjacent to the stop line shall be 5

feet. A spacing of less than 5 feet for these loops may be used to meet the requirements set forth in the next item (7).

7. The distance from the front edge of the area of detection to the intersection shall be as shown on Figures 12-A through 12-D. In the case of a skewed intersection, the dimension shall be measured perpendicular from the extension of the curbline to the front loop. In no case shall any portion of the loop extend beyond the extended curbline into the intersection area. In some cases, depending upon the skew angle, a supplemental loop should be required to insure that vehicles overriding the stop line will not leave the area of detection.
8. When a loop is used mainly as a system loop or a dual function loop (local intersection detection and system detection), it shall be a 6' x 6' rectangular shaped loop and installed in the center of the traveling lane in which volume counts are to be taken.
9. A force-off loop and motion loop shall be of rectangular shape and installed at locations determined by the traffic engineer.
10. All loops shall be identified alphabetically and in sequence as a vehicle approaches the intersection.

The designer will field check each intersection to select proper loop locations. This field check must consider driveway locations, pavement conditions, manhole locations, width and skew of the roadway, power sources and other electrical equipment that will interfere with proper loop operation.

In summary, the final decision concerning the size, shape, spacing and location of loop detectors for proper traffic control is a combination of analytical procedures and application of good engineering judgment.

When detection is needed on bridges, the use of probes, preformed loops, microwave, video and infrared detectors shall be investigated.

12.3.14 Junction Boxes

Use 18" x 36" junction boxes for the traffic signals.

Use 17" x 30" junction boxes only for loop wires and loop detector lead.

Junction boxes shall not be installed in handicap ramp areas. The placement of junction boxes should also avoid sidewalk areas whenever possible.

In order to facilitate cable pulling and splicing, install a junction box adjacent to traffic signal standard(s), the controller, loop detectors and at each end of conduit crossings under roadways.

The location of conduit crossings should be so arranged that the junction boxes at terminals of such conduits could also be used as service points to the above noted facilities. Junction boxes are designed to accept a maximum of six conduits. In cases where the number of conduits and cables are in excess of the junction box capacity, except in front of the controller where two junction boxes may be installed, the design should be re-examined.

12.3.15 Incoming Service

The secondary service, obtainable from the local utility company's pole or manhole, shall be used to service the complete installation at each intersection. Standard services shall be single phase, 3-wire, 120/240-volt, utilizing #6 AWG. When service is obtained from a manhole, the designer shall consult the utility company

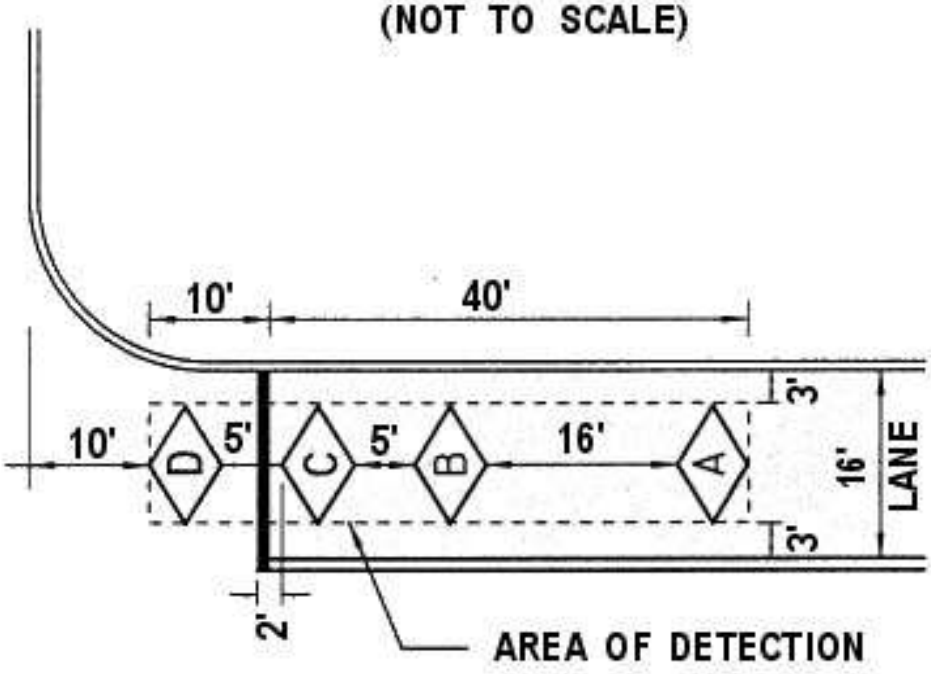
for the size, location, material and termination of the service conduit, and the installation of the service wire.

The designer shall prepare a written preliminary request for service to the local utility company indicating the required service and obtain their written approval including any utility company assigned request number. Information on the continuous load and payee of the energy charge shall also be provided in the letter.

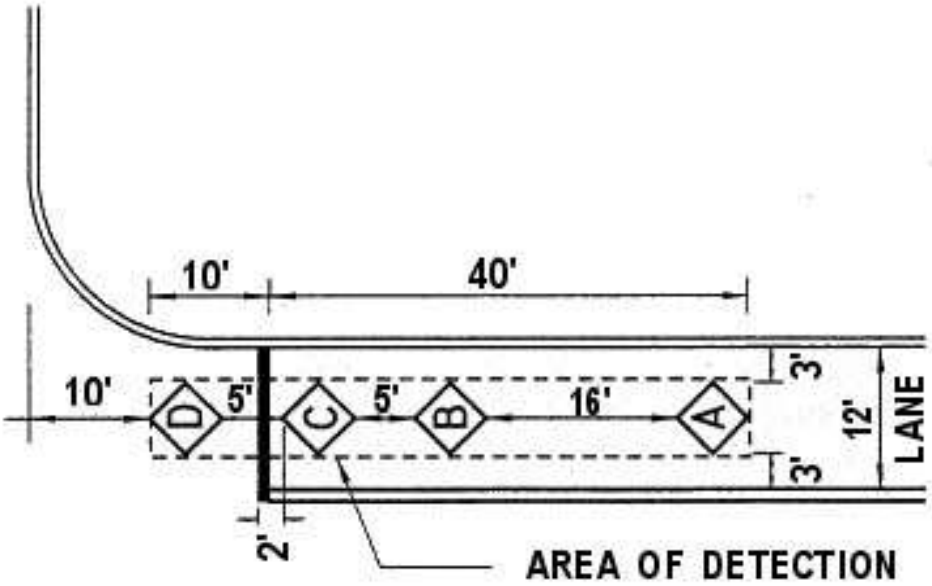
LOOP LAYOUT SINGLE LANES - 12' & 16'

FIGURE 12-A
BDC09MR-02

(NOT TO SCALE)



A - 6' x 10'
B - 6' x 10'
C - 6' x 10'
D - 6' x 10'



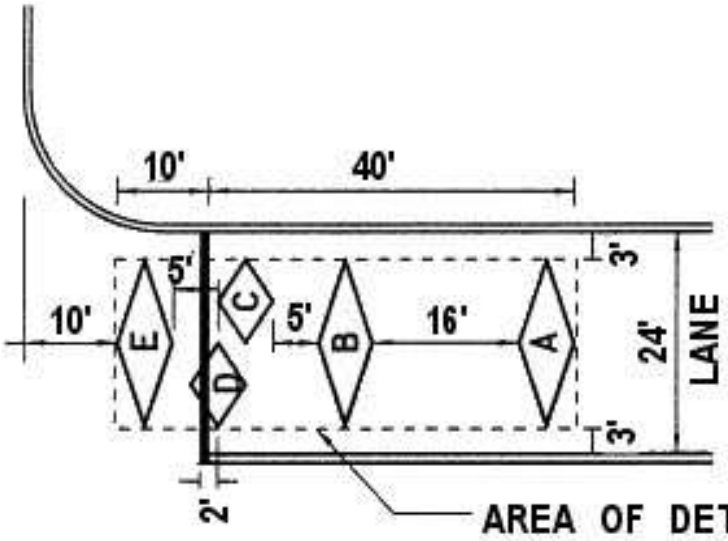
A - 6' x 6'
B - 6' x 6'
C - 6' x 6'
D - 6' x 6'

NOTE: ALL LOOP DIMENSIONS ARE NOMINAL.

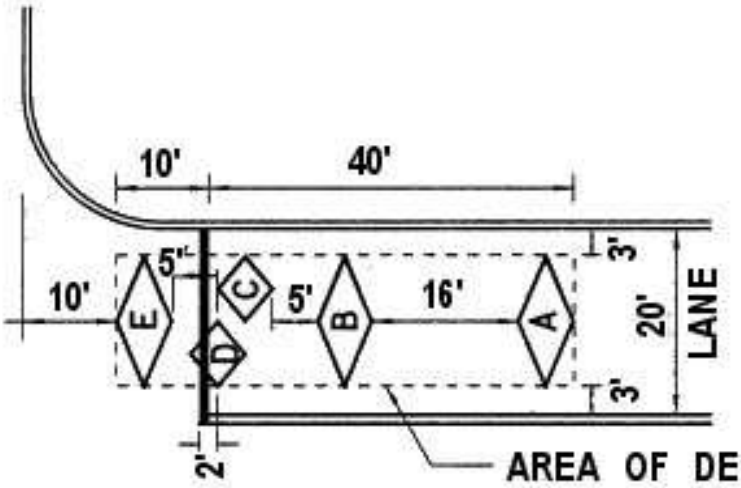
LOOP LAYOUT SINGLE LANES - 20' & 24'

FIGURE 12-B
BDC09MR-02

(NOT TO SCALE)



A - 6' x 18'
B - 6' x 18'
C - 6' x 9'
D - 6' x 9'
E - 6' x 18'



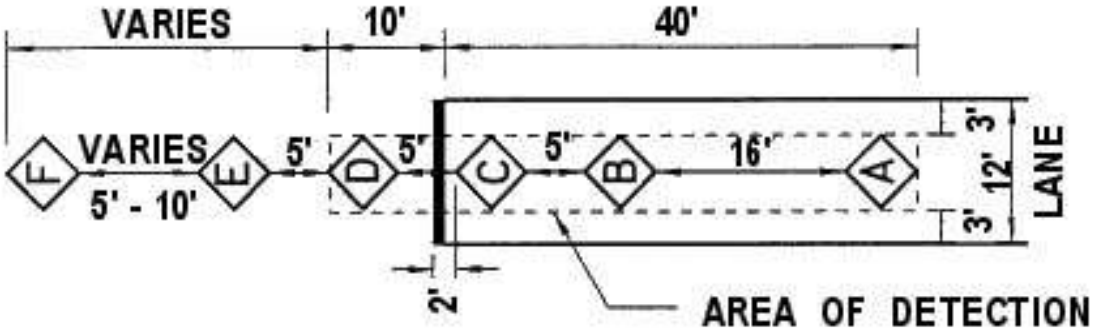
A - 6' x 14'
B - 6' x 14'
C - 6' x 7'
D - 6' x 7'
E - 6' x 14'

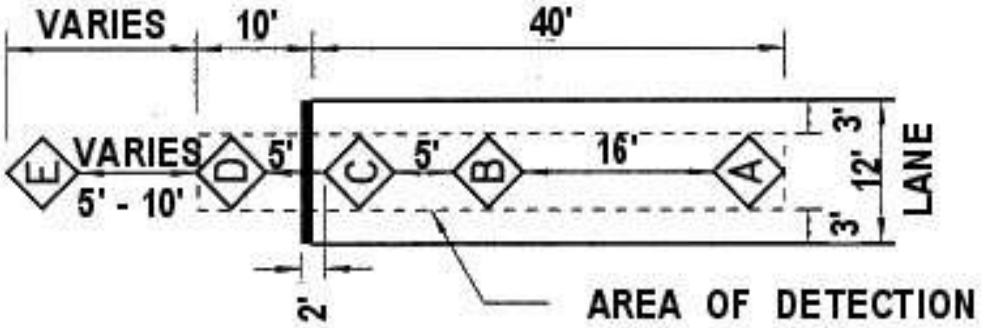
NOTES:
1. ALL LOOP DIMENSIONS ARE NOMINAL.
2. THE DIMENSION FROM THE TOP OF LOOP D TO THE BOTTOM OF LOOP E IS 2'.

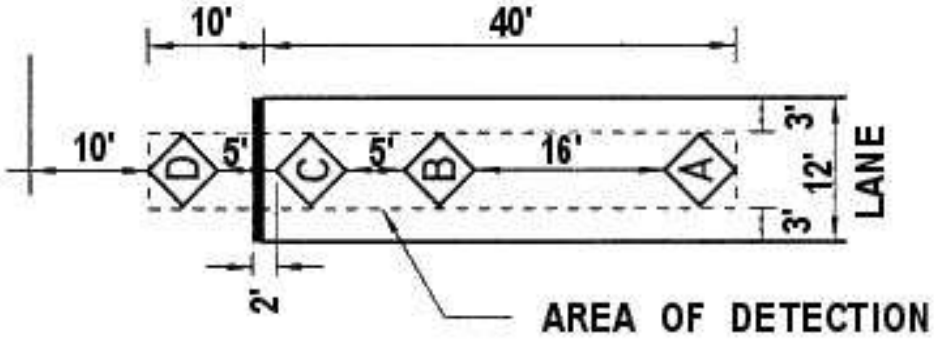
LOOP LAYOUT LEFT TURN LANE

FIGURE 12-C
BDC09MR-02

(NOT TO SCALE)





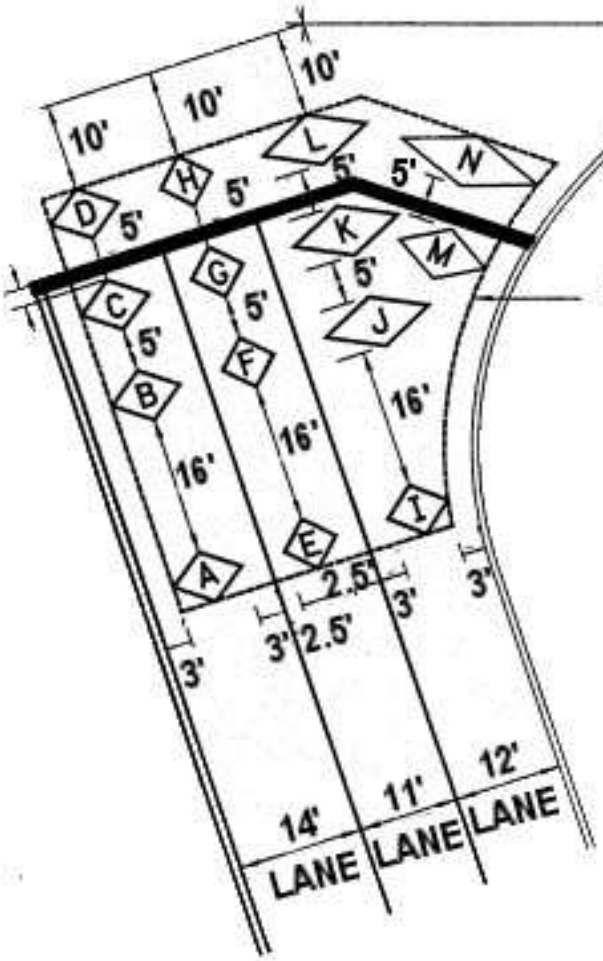


NOTE: ALL LOOP DIMENSIONS ARE NOMINAL.

LOOP LAYOUT

FIGURE 12-D
BDC09MR-02

(NOT TO SCALE)



AREA OF DETECTION

A - 6' x 8'
B - 6' x 8'
C - 6' x 8'
D - 6' x 8'
E - 6' x 6'
F - 6' x 6'
G - 6' x 6'
H - 6' x 6'
I - 6' x 6'
J - 6' x 12'
K - 6' x 12'
L - 6' x 12'
M - 6' x 7'
N - 6' x 16'

NOTE: ALL LOOP DIMENSIONS ARE NOMINAL