1100 Traffic Signals

1100.1 General

Traffic signals are power-operated traffic control devices, other than a barricade warning light or steady burning electric lamp, that warn or direct road users to take a specific action. They are used to control the assignment of right-of-way at locations where conflicts between motorists, bicyclists, and pedestrians exist or where passive devices such as signs and markings do not provide the necessary flexibility of control to move motorists, bicyclists, and pedestrians in a safe and efficient manner.

The functions of properly located and operated traffic signals include but are not limited to the following:

- Provide for safer and more orderly road function for all road users.
- Increase the traffic-handling capacity of an intersection where proper physical layouts and control measures are used.
- Prevent or reduce the frequency of certain types of crashes, especially right-angle collisions and crashes involving pedestrians and bicyclists.
- Permit pedestrians, bicyclists, or traffic from minor streets to enter or cross continuous traffic on a major street.
- Provide for continuous, or nearly continuous, traffic movement for all road users along a given route, when coordinated under favorable conditions.

An unwarranted or improperly designed or maintained signal installation may:

- Cause excessive delay.
- Encourage disobedience of signal indications.
- Promote circuitous travel on alternate routes.
- Increase crash frequency, especially rear-end collisions.

Because of the potential downsides of an unwarranted or improperly designed signal, it is of the utmost importance that the consideration and design of a signal installation be preceded by a thorough study directed by someone experienced and trained in the field. Equally important is the need to make provisions for future maintenance and operation.

This chapter presents the New Mexico Department of Transportation's (NMDOT's) policy, procedures, and standard practice for the justification and design of traffic signals for its facilities.

1100.2 References

The following references are used in the planning, design, construction, and operation of traffic control signals installed on NMDOT facilities. Conformance with federal and state laws and codes is required.

1100.2.1 Federal/State Laws and Codes

- Americans with Disabilities Act (ADA) of 1990, 23 Code of Federal Regulations (CFR) Part 36, Appendix A, Standards for Accessible Design.
- 18.31.6 New Mexico Administrative Code (NMAC), State Highway Access Management Requirements (State Access Management Manual [SAMM]).
- New Mexico Statutes Annotated (NMSA) Section 66-7-301, Speed Regulations.
- NMSA Section 66-7-303, Establishment of Speed Zones.

1100.2.2 Design Guidance

- A Policy on the Geometric Design of Highways and Streets (Green Book), American Association of State Highway and Transportation Officials (AASHTO), current edition.
- Designing Walkable Urban Thoroughfares: A Context Sensitive Approach, Institute of Transportation Engineers (ITE), 2010.
- Guide for the Development of Bicycle Facilities, AASHTO, current edition.
- Guide for the Planning, Design, and Operation of Pedestrian Facilities, AASHTO, current edition.
- Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), United States Department of Transportation (USDOT), Federal Highway Administration (FHWA), current edition.
- National Cooperative Highway Research Program (NCHRP) Report 457, Engineering Study Guide for Evaluating Intersection Improvements, Transportation Research Board (TRB), 2001.
- NCHRP Report 672, Roundabouts: An Informational Guide, TRB, 2010.
- NCHRP Report 731, Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections, TRB, 2012.
- NMDOT Standard Drawings.
- NMDOT Standard Specifications for Highway and Bridge Construction, current edition.
- Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way, (PROWAG), SNPRM, 2013.
- Railroad-Highway Grade Crossing Handbook, FHWA.
- Traffic Detector Handbook, FHWA, 2006.
- Traffic Signal Timing Manual, FHWA.
- Urban Bikeway Design Guide, National Association of City Transportation Officials (NACTO), 2014.
- Urban Street Design Guide, NACTO, 2013.

1100.3 Definitions

Terms used in the discussion of the planning and design of traffic control signals are defined below.

- **Accessible pedestrian signal (APS)** - A device that communicates information about the WALK phase in audible and vibrotactile (vibrating surface that communicates information through touch, located on the accessible pedestrian signal button) formats. The NMDOT established specific guidelines for APSs in May 2017. These guidelines are provided as Attachment 1 to this chapter.
- **Battery backup system (BBS)** - A system of batteries that will provide power to a traffic signal in case of power failure, also called an uninterrupted power supply (UPS).
- **Beacon** - A traffic signal of one section face(s) providing flashing yellow or red signal indications, supplementing warning or regulatory signs, or intersection control.
- **Closed-loop system** - A signal coordination system comprised of local intersection controllers and a system master controller with links for both sending system commands and receiving status data.
- **Controller** - An electrical device controlling the sequence and duration of indications displayed by traffic signals.
- **Controller cabinet** - An outdoor housing unit that contains a traffic actuated controller and all other associated equipment to perform the necessary switching of illuminated signal indications.
- **Coordination** - The establishment of a definite timing relationship between adjacent traffic signals.
- **Cycle length** - The time required for one complete sequence of signal phases around an intersection.
- **Detector** - A device used to identify the presence of vehicles or pedestrians desiring the right-of-way.
- **Dual ring** - The arrangement of vehicle phases into two rings, permitting the concurrent timing of some vehicle phases.

- **Electrical service** - The connection to a supply facility of an electric utility providing the electrical energy necessary to operate the control device and signal indications.
- **Emergency vehicle detector system** - An electronic device installed in a controller cabinet and in an emergency vehicle that causes the controller to be manipulated upon recognition of the signal from the emergency vehicle.
- **Emergency vehicle signal** - A special adaptation of a conventional traffic signal installed to allow for the safe movement of authorized emergency vehicles.
- **Engineer** - A registered Professional Engineer in the State of New Mexico who is qualified by training and experience to perform traffic studies and to design and inspect the installation of traffic signals.
- **Extension interval** (gap) - A timing interval during the extendable portion of green that is resettable by each detector actuation. The green right-of-way of the phase may terminate on expiration of the unit extension time.
- **Flash mode** - When signal lens indications are illuminated with rapid intermittent flashes.
- **Flasher warning assembly** - Flashing beacons that are used only to supplement an appropriate warning or regulatory sign or marker. The displays consist of two alternating flashing yellow indications.
- **High-intensity activated crosswalk beacon (HAWK**) - A traffic control device used to stop road traffic and allow pedestrians to cross. It is also known as a pedestrian hybrid beacon (PHB).
- **High-speed roadway** - A roadway with a posted speed of 45 miles per hour (mph) or higher.
- **Indication** - The illumination of a signal lens whereby the movement of vehicle or pedestrian traffic is controlled.
- **Interval** - A discrete portion of the signal cycle during which the signal indications remain unchanged.
- **Interval sequence** - The order of appearance of signal indications during successive intervals of a cycle.

- **Interval timing** - The passage of time that occurs during an interval.
- **Intelligent Transportation System (ITS)** - Electronic technology used to monitor and manage traffic and transportation systems.
- **Light Emitting Diode (LED)** - Very small electronic lights that are very energy efficient, used together in groups or arrays.
- **Local public entity** - A city, county, or tribal government that has legal jurisdiction at a specific location and is responsible for the electrical energy, telephone costs, and maintenance of the approved and accepted signal and lighting system, also referred to as the maintaining agency.
- **Loop detector** - A device capable of sensing a change in induction caused by the passage or presence of a vehicle over a loop sensor embedded in the roadway.
- **Low-speed roadway** - A roadway with a posted speed of lower than 45 mph.
- **Maintaining agency** - The local public entity responsible for the electrical energy, telephone costs, and maintenance of the approved and accepted signal and lighting system-. Occasionally, the maintenance and operation of the traffic signal(s) may be contracted back to the NMDOT Signal Laboratory if the maintaining agency cannot support the effort.
- **Multi-lane approach** - An approach that has two or more lanes, regardless of the lane use designation.
- **Offset** - The time relationship, expressed in seconds or percent of cycle length, determined by the difference between a defined interval portion of the coordinated phase green and a system reference point.
- **Overlap** - A phase that operates concurrently with one or more other phases.
- **Pattern** - A unique set of traffic parameters (cycle, split, and offset) associated with each signalized intersection within a predefined group of intersections.

- **Pedestrian clearance** - The first clearance interval following the WALKING PERSON indication (symbolizing WALK), normally flashing an UPRAISED HAND (symbolizing DON'T WALK).
- **Pedestrian signal** - A traffic signal installed at an intersection that is used to provide a protected phase for pedestrians by terminating the conflicting vehicular movements to allow for pedestrian crossings.
- **Phase** - Those right-of-way change and clearance intervals in a cycle assigned to any independent traffic movement(s).
- **Phase sequence** - A predetermined order in which the phases of a cycle occur.
- **Portable traffic signal** - A type of conventional traffic signal used in work zones to control traffic. This signal is most commonly used on two-way two-lane highways where one lane has been closed for roadwork. This signal is most commonly operated in pairs, with one signal at each end of the work zone. This eliminates the need for 24-hour flagger control. The traffic signal provides alternating right-of-way assignments for conflicting traffic movements. The signal has an adjustable vertical support with two, three-section signal displays and is mounted on a mobile trailer with its own power source.
- **Preemption** - When the normal phase sequence at an intersection is interrupted and/or altered to a special signal control mode because of a special situation such as the passage of a train or the granting of the right-of-way to an emergency vehicle.
- **Presence detection** - The sensing by a vehicle detector that a vehicle, whether moving or stopped, has appeared in its field.
- **Progression** - Maintaining optimal traffic flow through a series of traffic signals by coordination of signal controller timing from intersection to intersection with time of day programs or a communication system.
- **Professional Traffic Operations Engineer (PTOE)** - A traffic engineer as certified by the Transportation Professionals Certification Board.

- **Queue cutter traffic signal** - A traffic signal used at highway-rail grade crossings where the queue from a downstream traffic signal is expected to extend within the minimum track clearance distance. It is used to keep vehicles from an adjacent signalized intersection from queuing on the railroad tracks.
- **Recall** - An operational mode for an actuated controller whereby a phase, either vehicle or pedestrian, is displayed for each cycle whether demand exists or not.
- **Rectangular Rapid Flashing Beacon (RRFB)** - A user-actuated yellow LED rapid-flashing assembly. It may reduce crashes between vehicles and pedestrians at uncontrolled pedestrian crossings by increasing driver awareness of potential pedestrian conflicts.
- **Red clearance interval** - A clearance interval, which may follow the yellow interval, when both the terminating phase and the next right-of-way phase display red (typically called "all red").
- **Road users** - Includes motor vehicles, transit riders, pedestrians, bicyclists, and other non-motorized modes of travel.
- **Signal** - An optical device that is electronically operated by a controller assembly and that communicates a prescribed action (or actions) to road users.
- **Signal priority list** - Priority listing of intersections meeting signal warrants and other criteria contained herein and in 18.31.6 NMAC and approved by the General Office Traffic Technical Support Bureau for installation of traffic signals. The list shall include two categories: 1) new signals and, 2) signal pole and mast arm upgrades.
- **Speed limit sign beacon** - A beacon installed with a fixed or variable speed limit sign. The preferred display is two flashing yellow indications.
- **Stop sign beacon** - A beacon installed above a stop sign. The display is a flashing red indication.
- **Temporary traffic control signal** - A traffic control signal that is installed for a limited time period. A portable traffic control signal shall be defined as a temporary traffic control signal that

is designed so that it can be easily transported and reused at different locations.

- **Through street bandwidth** - The percent of signal cycle length during which a vehicle may safely progress at or near the posted speed limit through a series of coordinated, signal controlled intersections.
- **Traffic signal** - The complete installation of a traffic control system at an intersection, including the illuminated signal indications, supports, electrical controls, and distribution system.
- **Traffic signal spacing** - The number of traffic signals per mile, determined by functional classification of facility and posted speed.
- **Traffic signal standard** - A pole-type structure that supports and positions signal and lighting devices, including arms, mounting hardware, and breakaway devices as required.
- **Traffic signal system** - A network of local intersection controllers interconnected by communication lines to a central, master permitting a network where timing control, database management, monitoring, and function diagnostics are coordinated from a central point.
- **Video detection system** - A system that tracks vehicles on a roadway by processing video images and provides detector outputs to a traffic controller, also called machine vision detection.
- **Warning beacon** - A beacon that supplements a warning or regulatory sign or marking. The display is a flashing yellow indication. These beacons are not used with STOP, YIELD, or DO NOT ENTER signs or at intersections that control two or more travel lanes. A warning identification beacon is energized only during those times when the warning or regulation is in effect.
- **Yellow change interval** - The first interval following the green right-of-way interval in which the signal indication for that phase is yellow.

1100.4 Procedures – Traffic Signals

The design of traffic signals should be accomplished in a logical sequence, outlined as follows:

1. Pre-design (Section 1100.4.1)
   a. Establish the need for signal and obtain approvals (Section 1100.4.1.1).
   b. Signal system analysis: determine if the signal is in an interconnected system, existing or future (Section 1100.4.1.2).
   c. Agreements: obtain a Letter of Intent to maintain from local governmental entity (Section 1100.4.1.3).
2. Design (Section 1100.4.2)
   a. Power: determine availability and location of electric service from local electrical service provider (Section 1100.4.2.1).
   b. Accessibility: determine any pedestrian access improvements identified in official local planning documents and/or necessary for compliance with the ADA and the PROWAG (Section 1100.4.2.2).
   c. Determine number and required sequence of signal phases (Section 1100.4.2.3).
   d. Determine any preemption requirements (Section 1100.4.2.4).
   e. Determine controller type and support equipment required (Section 1100.4.2.5).
   f. Determine, if applicable, the signal system control type (Section 1100.4.2.6).
   g. Determine the placement of signal equipment (Section 1100.4.2.7).
   h. Determine signal displays, face design, and placement (Section 1100.4.2.8).
   i. Determine the type and location of detectors (Section 1100.4.2.9).
   j. Determine the conduit and cable system required (Section 1100.4.2.10).

3. Complete plans, specifications, and estimates (Section 1100.4.3)
4. Obtain final approval and complete maintenance agreement with local governmental entity (Section 1100.4.1.3)
5. As requested, provide timing recommendations for the signal (Section 1100.4.4)

The following sections describe the procedures to be followed prior to installing a signal on a New Mexico state highway.

1100.4.1 Pre-Design

1100.4.1.1 Establish Need for Signal and Obtain Approvals

Traffic Signal Evaluation

The installation of a traffic signal shall be preceded by a traffic engineering evaluation. The engineering evaluation shall be conducted in accordance with the MUTCD, as clarified in sections of the SAMM.

Because traffic signals could cause or increase delay for at least one leg of an intersection when serving the needs of another, a signal shall not be installed unless a study demonstrates that a traffic signal will:

- Meet or exceed one or more MUTCD signal warrants.
- Provide benefits that cannot be achieved by less-restrictive or less-costly means, especially with regard to safety.
- Have an acceptable impact on the major street traffic flow, including appropriate signal spacing and progression.

The objective of the traffic signal evaluation is to document the request and need for the signal, justify the installation of the signal with a warrant analysis, and provide an assessment of its impact on the state highway. All studies must be comprehensive and consistent with NMDOT procedures to ensure that the benefits of a traffic signal will outweigh its disadvantages.

Signal Request and Documenting Need

Requests for traffic signal and/or signal system installation are typically submitted to the Traffic Technical Support Section of the NMDOT General Office in Santa Fe from the NMDOT District

Traffic Engineers. These requests are typically submitted to the NMDOT District offices from the public, developers, NMDOT Project Managers, local governmental entities (cities and counties), or political inquiries. Occasionally, requests may come directly to the Traffic Technical Support Section of the General Office; in this case, they are referred back to the NMDOT District offices for their review and evaluation.

Usually there is a perceived need for the installation of traffic signals, signal systems, and/or lighting. Typically, these perceived needs are for signals at:

- Intersections with congestion, long delays, and large traffic volumes.
- Intersections with crash histories or one serious crash.
- Imminent large scale development, usually predicated by a traffic impact study. Typically these could include new subdivisions, large department stores, or retail centers.
- Major highway projects including realignments, new connector links, interchanges, or remodeling of existing routes.

Justify Signal with MUTCD Warrant Evaluation

Signal warrant studies of candidate intersections shall be conducted in accordance with MUTCD standards and NMDOT procedures from the SAMM. Studies shall be performed by a professional engineer licensed in New Mexico or under the auspices of the respective District Traffic Engineer in the area of the state where the proposed project is located. Any signal warrant study performed by a local entity shall be reviewed by the respective District Traffic Engineer. The study shall be conducted within two years of the proposed construction date for the signal installation.

The following data should be obtained for an engineering study of traffic signal justification:

- The number of vehicles entering each approach to the intersection for each hour for a minimum of 12 hours of a representative day. These 12 hours should represent the 12 highest hours of a typical 24-hour period as determined by experience and historic data.

- Eight hours (preferably the eight highest hours) of the above required counts should be made by manual counts providing turning movement counts for each of the eight hours. The eight-hour manual counts should include pedestrian movement counts as well as vehicular counts; however, low pedestrian volumes should not be construed as justification to not include pedestrian signals or other accommodations for pedestrians if traffic signals are to be installed. Pedestrian counts shall separately identify school crossing volumes.
- The 85th percentile speed of all vehicles on the uncontrolled approaches to the intersection and the posted speeds for all controlled approaches.
- Crash data by type, location, direction of movement, severity, time of day, date, and day of week for at least three years. It may be necessary for the District Traffic Engineer to request this data from the local governmental entity.
- A conditions diagram showing physical layout including intersection geometrics, channelization, grade, sight distance restrictions, crosswalks, sidewalks, parking, pavement marking and signing, street lighting, driveways, location of nearby railroad crossings, utility poles, adjacent land use, and distance to nearest signals.

A vehicle-seconds of delay study should be conducted for each controlled approach during the peak hours when warrant studies are borderline, or when they are needed for priority-ranking evaluations.

Traffic signal studies will be based on current traffic counts; however, the traffic signal study shall be based on projected (five-year) traffic volumes if it involves either:

- An intersection planned for reconstruction and the construction project is projected to significantly alter future traffic volumes from normal background growth.
- An existing intersection that is projected to be impacted by a significant new traffic generator.

Normally, design year (20th year) and construction year (year the project is expected to be completed) volumes should be used in the evaluation. The design year (20th year) projected volumes are not used to warrant signals but should be used to determine future geometric requirements. If construction-year volumes exceed minimum warrant requirements, the new traffic signal may be included in the initial project. If the 20-year projection shows signals would be warranted but construction-year volumes do not warrant a signal, a 10-year volume projection may be requested to determine if provisions should be made for future signal installations in the design plans and for future planning and budgeting.

At an intersection where minor-road drivers are primarily turning right, signalization may produce fewer benefits to operations. Accordingly, it may be prudent to subtract a portion of the minor street right-turning volume when evaluating volume-based signal warrants. The methods provided in NCHRP Report 457, in particular Figure 2-11, "Minor-road right-turn volume reduction for warrant check," should be used to determine if the right-turn volume on the minor road is influencing the warrant.

The methods provided in NCHRP Report 457 should be used to determine the appropriate right-turn volume reduction to use when evaluating volume-based signal warrants.

All new and existing signals shall meet the criteria of at least one of the warrants set forth in the MUTCD. The Engineer must be aware that traffic signal warrant analyses are based upon criteria that can be interpreted differently depending on assumptions. Warrants can be influenced by factors such as interpretation of speed (posted or actual), population (in fringe areas), intersection geometry, delay calculations, and latent demand for pedestrian accommodations based on adjacent or nearby land uses. The engineer shall receive concurrence on warrant assumptions from the NMDOT Traffic Engineer. The signal warrant analysis should be documented in a format agreed upon by the NMDOT.

Consider Alternatives to Signalization

If warrant studies are conducted on existing configurations, geometric modifications to intersections shall be considered to eliminate the need for traffic signals. This includes the consideration of converting the intersection to a roundabout. NCHRP Report 672, Roundabouts: An Informational Guide, offers

generalized information on comparing the operations of various intersection control modes at a planning level.

The engineer shall review existing and proposed lane geometry and existing and adjusted traffic volumes. This information will allow the engineer to prepare final traffic signal warrant determinations and intersection capacity studies for the forecasted count and proposed geometry scenario. At this point, the engineer shall recommend modifications to the existing or proposed intersection configurations using a traffic operations analysis program that uses methodologies from the Highway Capacity Manual (HCM). The engineer shall also determine proposed traffic signal phasing based upon the finalized geometry and HCM optimized level of service.

The engineer may be able to eliminate the need for signalization by:

- Building right-turn or left-turn lanes
- Adding through lanes
- Widening the mainline median
- Distributing traffic to alternate routes
- Converting the intersection to a roundabout

Even when one or more of the MUTCD warrants for signalization is met, the installation of a traffic signal may not be the most prudent choice. Along with the MUTCD warrant evaluation, the following should also be considered:

- **Minimums** - The intent of the MUTCD thresholds is to establish a minimum boundary below which a traffic signal should not be installed. Meeting or exceeding these thresholds does not automatically mean that a traffic signal will provide improved operations of the whole intersection. Crash rates and/or overall delay may still be increased with the installation of a signal.
- **Crashes** - Traffic signals may be installed to reduce certain types of crashes (e.g., right-angle or pedestrian collisions). However, the installation of a traffic signal may actually increase the number of rear-end collisions and may fail to reduce turning conflicts between vehicles and pedestrians. Crash data should be analyzed for contributing factors other than right-of-way assignment to determine probable benefits from signalization.

- **Geometrics** - The geometric design of an intersection can affect the efficiency and safety of a traffic signal. Installation of traffic signals at poorly aligned intersections may, in some cases, increase driver confusion and thereby reduce the overall efficiency of the intersection. The installation of a signal may require geometric improvements including realignment and/or provision of adequate turning lanes. In such cases, where practical, the geometric improvements should be made prior to installing a signal.
- **Spacing** - The installation of traffic signals at closely-spaced intersections may have a detrimental effect on traffic movements on the major street. Additionally, a traffic signal should provide some gapping in the major street traffic flow to nearby intersections or accesses. The SAMM shall be consulted to determine acceptable signal spacing. Additionally, closely spaced signals (those spaced within a half mile of each other) should be coordinated as a progressive system.
- **Benefit factors** - In addition to the MUTCD warrant requirements, the signal warrant analysis should consider other factors to demonstrate that benefits of a traffic signal outweigh its disadvantages. For example, it is appropriate to consider the extent to which a traffic signal could be more effective than a STOP sign in improving problems such as delay, congestion, approach conditions, and driver confusion. Future land use or other evidence of the need for additional right-of-way assignment should also be considered.

Approval

If the subject intersection satisfies at least one signal warrant contained in the MUTCD, it will be forwarded to the Traffic Technical Support Section for review to determine if both a need exists for a signal at an intersection and a signal is appropriate at the given location.

Prioritization

The Traffic Technical Support Section will prepare and maintain a Signal Priority List. The Signal Priority List annually ranks approved intersections on state and federal routes in New Mexico according to the rating system. The criteria used in weighting and

determining priority are based on the number and types of warrants that are satisfied. Higher ranking intersections are expected to have a greater likelihood that a signal will provide an overall benefit to the public.

Because of funding limitations, all intersections included on the priority list may not be programmed. Consequently, the priority list is used to determine the order in which new signal installations will be placed on the NMDOT program. Other governmental agencies can fund the design and construction of a traffic signal that is not high enough on the list to receive funding.

Letting and construction schedules may vary according to the complexity and impact of the project. Where possible, intersections warranting signalization should be included in highway improvement projects for an existing route. If a signal installation is delayed, a temporary signal may be considered. Temporary signals may provide for a limited scope of improvements with the intent of providing signalization and addressing the most immediate transportation needs.

Design, development and construction of signal projects that are 100 percent funded by others and meet NMDOT requirements will automatically be considered part of the NMDOT's Signal Priority List, with no ranking, and may be completed on an accelerated schedule.

An approved project shall be assigned a control and project number. Signals may be assigned control numbers for design prior to programming for construction.

Preliminary Scoping Report

After inclusion in the Signal Priority List, a preliminary project scoping report shall be prepared, outlining the extent of improvement and cost. Input from the District Traffic Engineer and the local entity will be sought.

For projects submitted by a local entity, a scoping report shall be prepared by the local entity with approval by the General Office Traffic Technical Support Bureau, District Traffic Engineer and Engineering Support Division. If the intersection continues to

satisfy signal warrant criteria upon analysis of the project scope and geometric conditions, the project will be approved and included on the Signal Priority List.

A local entity must have NMDOT approval for the installation of a traffic signal or signal system on any state route even if the local entity funds the entire cost of a project. For any contemplated work that involves a signalized intersection on the state highway system, the local government agency shall coordinate the proposed work through the appropriate District Office. This signal work shall conform to the MUTCD, including warrants, and to NMDOT policy and practices for traffic signal design. On projects submitted by a local entity, the local entity shall prepare a scoping report and obtain approval by the Traffic Technical Support Engineer, District Traffic Engineer, and Preliminary Design Bureau Chief.

1100.4.1.2 Signal System Analysis

The number of traffic signals per mile has a significant influence on roadway travel speed and vehicular delay. Acceptable travel speeds and minimal delay occur when sufficient distance and relatively uniform spacing is provided between signals. Traffic signal spacing requirements shall be defined according to the functional classification of the highway where the intersection is located and shall be more restrictive for roadways with higher functional classifications.

All traffic signals installed less than one-half mile apart on state highways should be coordinated as a progressive system. Standards for the spacing of signalized intersections and through-street bandwidths (for progressive systems) are provided in the SAMM.

In the planning of new signalized intersections, including rural and urban fringe areas that may become urbanized in the future, attention to the location of intersections is critical if major roadways are to maintain their mobility function in the long-term. Selection of the appropriate signal spacing interval must be based upon the desired progression speed and the longest cycle length that is anticipated. The SAMM provides guidance on progression analysis. Once a spacing interval is selected, arterial-to-arterial intersections must be located at the selected interval or at even multipliers of the interval.

In urbanized areas or other unique situations where signal spacing may be less than the standard required signal spacing in the SAMM, a signal progression analysis must be performed as part of a signal warrant analysis. The analysis should explore options and demonstrate that with signal installation(s) efficient traffic progression can be maintained on the major street.

1100.4.1.3 Agreements

In accordance with NMDOT policy, all traffic signals on state highways, including those partially or fully funded by federal or state dollars, are to be maintained by the appropriate municipality or county entity. Prior to initiation of project design, a Memorandum of Understanding (MOU) between the NMDOT and the local governmental entity shall be prepared and executed to formalize the parties' agreement for signal construction and maintenance. Local entities may be asked to complete the MOU document during the signal priority application process. The MOU shall generally define the project scope and the responsibilities of each party for providing future maintenance, electrical energy cost, and operation supervisions for the signal equipment.

A Signalization Agreement shall be executed prior to completion of design and letting of permanent and temporary traffic signals and traffic signal systems for installation on state highways. The Signalization Agreement shall be consistent with the MOU, but shall set forth the responsibilities of the parties in specific detail. MOUs and Signalization Agreements shall be prepared by the General Office Traffic Technical Support Bureau with assistance from the Project Development Engineer.

In some cases where participatory funding by different agencies is involved, a Cooperative Agreement or Joint Powers Agreement may be required. These agreements will be prepared by the Local Government Agreement Unit with assistance from the General Office Traffic Technical Support Bureau and shall be prepared and executed prior to advertisement for construction letting. MOUs shall still be prepared for these projects before beginning final design.

When signal projects are to be constructed by local entities, contractors working for local entities, or private developers, an agreement defining the construction management, control, insurance, maintenance and inspection responsibilities shall be prepared and submitted to the appropriate District for review and approval prior to advertising for construction.

1100.4.2 Design

In general, the NMDOT uses the MUTCD criteria for the design and placement of traffic signals, including pedestrian signals. This includes, but is not limited to, signal indications, color requirements, the number of lenses per signal face, and the number and location of signal supports.

In additional to the MUTCD, the sections below provide additional details and information on traffic signal design. Special details or requirements may be used for signal installations within some local maintenance jurisdictions (such as the City of Albuquerque) when these details or requirements are part of their standard practice.

All traffic signal projects shall be designed, constructed and maintained in accordance with the MUTCD, applicable AASHTO policies, the SAMM and other NMDOT standards unless a documented variance is approved in writing by the Chief Engineer.

1100.4.2.1 Electrical Service

Preliminary design activities shall include contacting the appropriate electric service provider to determine the most feasible location for service, identifying any excess costs in extending electrical service lines, and determining any local standards to be followed for the service connection. It is important that the location of the service connection, controller, and signal feeds be coordinated for efficient design. Prior to the completion of the design, approval of the availability, exact location, and any excess charges for providing electrical service (120/240 Vac) must be obtained from the local electrical energy provider.

1100.4.2.2 Pedestrian Accessibility

All new traffic signal installations are subject to ADA regulations; furthermore, pedestrian access with the intersection and circulation controlled by or impacted by the traffic signal must be designed in accordance with the NMDOT Standard Drawings for Pedestrian Facilities, which were developed in accordance with the PROWAG. Important elements include sidewalk and curb ramp design and the placement of signal equipment. Necessary access improvements will be included with a new signal installation, even when sidewalk/roadway reconstruction or improvements were not contemplated with the installation activity. When modifications are made to an existing traffic signal and such alterations involve a change to existing pedestrian sidewalks or passageways, then all pedestrian accesses within the intersection shall comply with ADA provisions for new construction. Chapter 1200 of this Design Manual provides additional guidance on pedestrian accessibility.

1100.4.2.3 Signal Phasing

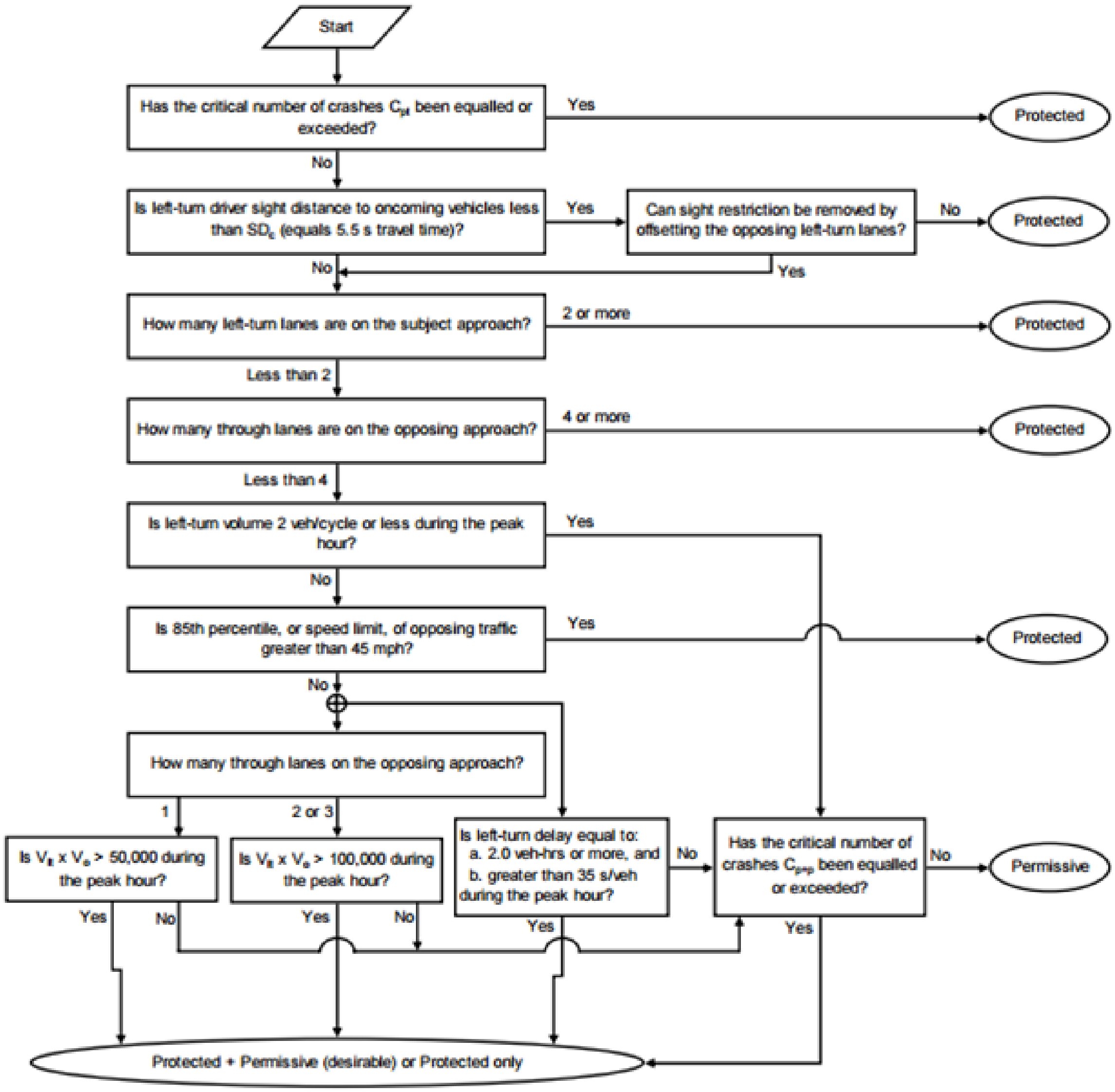
The engineer designing the traffic signal should conduct a study of traffic movements to determine permitted and controlled movements. Once the number and sequence of traffic phases is determined, the engineer can identify the interval, color sequence, and types of signal indications that will be required.

In general, the most efficient operation is obtained with the fewest possible sequential phases; however, each signal installation should be designed to provide safe and efficient control of conflicting traffic movements, including bicyclists and pedestrians.

A protected left-turn movement can improve the ease with which a driver can turn left against an opposing traffic stream; however, the additional time required for right-of-way, change, and clearance intervals can appreciably increase the required cycle length and overall delay. Therefore, the need for a protected left-turn phase should be carefully considered. The FHWA has published guidelines that may be used to determine the appropriate left-turn phasing at an intersection (Exhibit 1100-1). When designing for a coordinated system, left-turn phasing impacts on the available through-band timing must be considered.

Exhibit 1100-1

Guidelines for Determining the Potential Need for a Left-Turn Phase



Number of Left-turn Movements on Subject Road	Period During Which Crashes are Considered (years)	Critical Left-Turn-Related Crash Count When Considering Protected-only, C_{pt} (crashes/period)	When Considering Prot.+Perm, C_{p+p} (crashes/period)
One	1	6	4
One	2	11	6
One	3	14	7
Both	1	11	6
Both	2	18	9
Both	3	26	13

Oncoming Traffic Speed Limit (mph)	Minimum Sight Distance to Oncoming Vehicles, SD_c (ft)
25	200
30	240
35	280
40	320
45	360
50	400
55	440
60	480

Variables

V_ℓ = left-turn volume on the subject approach, veh/h

V_o = through plus right-turn volume on the approach opposing the subject left-turn movement, veh/h

Source: Adapted from (Kell and Fullerton, 1998; Orcutt, 1993; Traffic Engineering Manual, 1999).

Signal phasing for an intersection normally consists of two to eight phases per cycle. Signal phases should be identified as shown in Exhibit 1100-2. Phases 1, 2, 5, and 6 are used for the major street and phases 3, 4, 7, and 8 are used for the minor street. Phases 2 and 6 are normally designated the coordinated through movement phases for a coordinated signal system; however, if a local agency is using a different convention for phase numbering, the NMDOT will match that phasing scheme.

Exhibit 1100-2
Phase Identification by Directional Movement

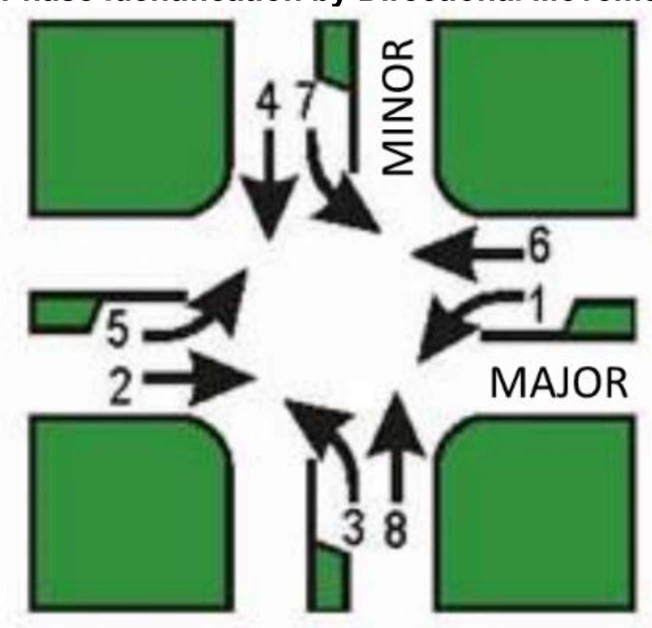
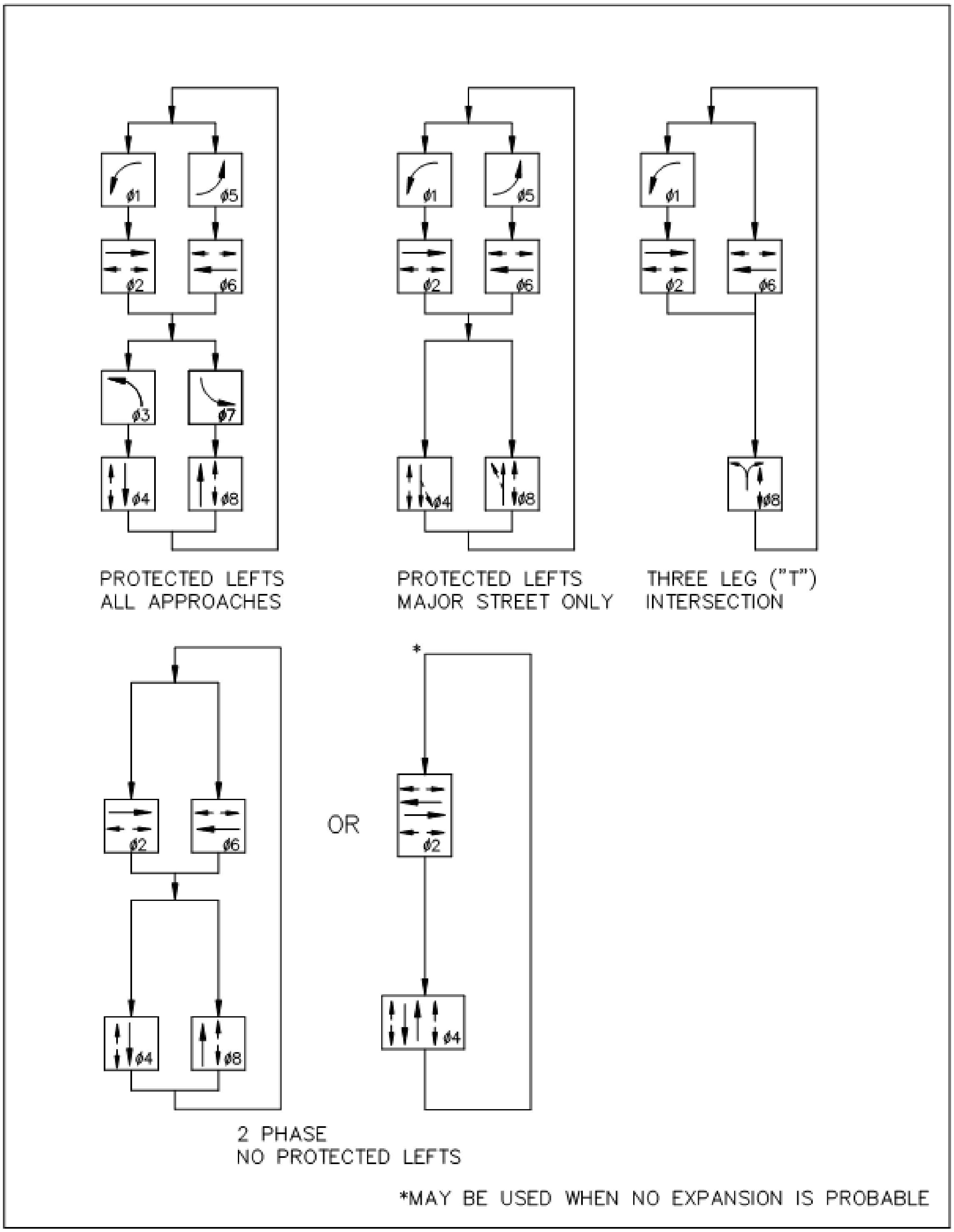


Exhibit 1100-3 illustrates common phasing configurations used on state highway signal installations. The dual ring (quad left) phase configuration provides the following:

- Allows the use of two to eight phases. Unused phases remain in the traffic controller logic and may be implemented at a future time as traffic conditions change. Non-exclusive turning movements may be permissive with the through movement.
- A barrier requires that phases in both rings for that street must be terminated before moving to a cross-street phase(s).

Exhibit 1100-3
Typical Phasing Schemes



- Allows the unused portion of any left-turn phase to be transferred to the opposing through movement, independent of the opposite left-turn phase.

Other special phasing such as that required for a five-leg intersection or where one controller may operate two or more road intersections (such as at a diamond interchange) should be developed on a case-by-case basis. It may be possible to develop the special phasing with the standard dual ring, or it may require reprogramming a standard controller.

Overlapped displays allow a traffic movement to operate with one or more non-conflicting phases. Most commonly, a minor street's exclusive right-turn phase is overlapped with the non-conflicting major street's left-turn phase. An overlapped display can be terminated after the parent phase (the main phase the overlap is associated with) terminates. An overlapped display programmed for two or more parent phases continues to display until all of the parent phases have terminated. An overlap is made up of two or more phases—not one phase controlling two movements.

Left-Turn Phasing

The need for an exclusive left-turn phase should be carefully considered. One way to justify an exclusive left-turn phase is through an evaluation of turning and opposing traffic (see Exhibit 1100-1). For intersections with a left-turn phase(s), the following criteria shall govern their operation:

- **Protected-permissive** - A protected left-turn movement is typically not necessary during much of a signal's operation because variations in traffic volumes may provide sufficient gaps for conflicting traffic movements. On state highways, the preferred operational sequence is to provide an actuated left-turn movement followed by a through movement in which a vehicle may turn left permissively. The advantage of the protected-permissive operation is that the time of the left-turn interval may be reduced (or in some periods skipped), thereby reducing overall intersection delay, and better utilizing the potential capacity of the through movement green time.

- **Protected only** - Protected-only left turns are extremely limiting; therefore, they should be used only when tight control is absolutely necessary for a specific approach at an intersection. Protected-only left-turns should also be considered for dual (two-lane) left-turn movements.
- **Lead-lag lefts** - On state highways, the preferred phase sequence is for the protected-left phase to precede the through movement for that approach (leading left). The advantage of leading left-turns is that any unused time reserved for the left-turn phase will be added to the opposing through movement, thereby improving through movement capacity, reducing delay, and improving the through movement green band for signal systems. Also, a leading left turn may clear a left-turn queue that would interfere with the through movement.

  Disadvantages of a leading left turn are that the beginning of the through movements may not start simultaneously or be precisely controlled in the phase sequence, which is of concern in operating a coordinated signal system. Also, leading left-turns can violate pedestrians' expectations of when to begin crossing the street upon termination of the cross-street green.

  Lagging left turns may be considered when a signal system progression analysis shows that this sequence will benefit the through green bands. This includes the possibility of lead-lag phasing where the left turns may lead the through movement in one direction and lag the through movement in the other direction.

  For intersections where the side approaches are offset (e.g., diamond interchange ramp terminals), lagging left turns should be used to provide a phase sequence that will prevent vehicles from queuing between the intersecting roads.

- **Left-turn storage** - Protected left phases require dedicated lanes to permit independent right-of-way assignment to the turning and through movements. It is important that the turn-holding lane be evaluated with the signal operation to assure proper storage for the anticipated left-turn movement queues. The SAMM provides guidance on the storage length for left-turn lanes.

- **Right-turn overlap movement** - During a protected left-turn phase, traffic flow for the reverse movement (e.g., southbound-to-westbound right for the eastbound-to-northbound left) may be expedited with a right-turn arrow displayed concurrently with the left-turn indication, when a right-turn lane is available.

Pedestrian Movements

Provisions for pedestrian crossings shall be provided across every leg of a signalized intersection unless a corner may be physically restricted from potential pedestrian access. Provisions include pedestrian signals and pushbuttons and a pedestrian-actuated phase.

A leading pedestrian interval may be considered at intersections where heavy turning traffic comes into conflict with crossing pedestrians during the permissive phase of the signal cycle. Leading Pedestrian Interval's (LPI), sometimes called Pedestrian Head start or Life Preserving Interval, typically gives pedestrians a 3–7 second head start when entering an intersection with a corresponding green signal in the same direction of travel. LPIs enhance the visibility of pedestrians in the intersection and reinforce their right-of-way over turning vehicles, especially in locations with a history of conflict. With this head start, pedestrians can better establish their presence in the crosswalk before vehicles have priority to turn left. LPI's provide the following benefits:

- Increased visibility of crossing pedestrians.
- Reduced conflicts between pedestrians and vehicles.
- Increased likelihood of motorists yielding to pedestrians.
- Enhanced safety for pedestrians who may be slower to start into the intersection.

FHWA's Handbook for Designing Roadways for the Aging Population https://safety.fhwa.dot.gov/older_users/handbook/ recommends the use of the LPI at intersections with high turning vehicle volumes. Refer to the Manual on Uniform Traffic Control Devices for guidance on LPI timing. Costs for implementing LPIs

are very low, since only signal timing alteration is required. This makes it an easy and inexpensive countermeasure that can be incorporated into pedestrian safety action plans or policies and can become routine agency practice.

1100.4.2.4 Preemption

Provisions shall be made for interrupting the normal sequence of a traffic signal when it is determined to be necessary for the priority movement of a train or emergency vehicle. Transit preemption is usually handled in a metropolitan area where agreements allow the municipality to implement and maintain it. Preemption shall be a special signal sequence that will provide the required clearances and prohibit vehicle-pedestrian conflicts with the priority movement. Vehicular and pedestrian movements conflicting with the priority movement will not be permitted for the duration of the preemption period.

At a traffic signal equipped with both emergency-vehicle preemption and railroad preemption, railroad preemption shall have priority. In instances when emergency-vehicle preemption is needed during the time that the intersection is operating on railroad preemption, the railroad preemption sequence shall continue unaffected until it is completed. When railroad preemption is needed during emergency-vehicle preemption, railroad preemption shall immediately assume control of the intersection.

Railroad Preemption

Railroad preemption shall be provided for every traffic signal located within 200 feet of a railroad-highway grade crossing or where vehicle queues may reach the track based on a queue analysis. Design elements that should be considered when evaluating railroad preemption include intersection geometrics, vehicular volume, queue lengths, distance from the crossing to the intersection, approach speeds for the train and motor vehicles, and the presence of public transportation vehicles or trucks carrying large or hazardous cargoes. A primary criterion is to avoid trapping vehicles on the track by conflicting operations of the highway traffic signal and the railroad grade crossing signal.

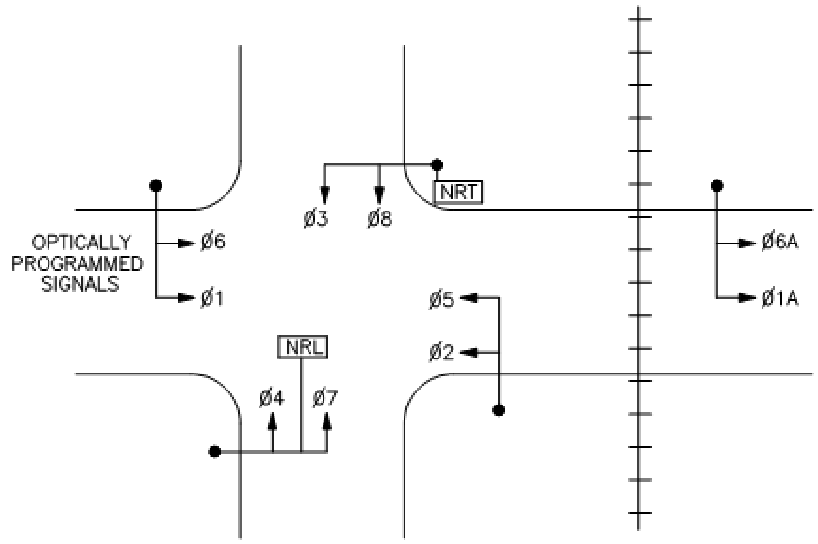
Railroad preemption requires that an electrical circuit be installed between the grade crossing signals and the traffic signal. This is to establish and maintain the preempted condition during the time that the railroad grade crossing signals are in operation. This connection must be requested from the railroad company at the time of preliminary design to ensure proper design coordination. The electrical connection must be installed in the railroad signal cabinet as determined by the railroad authority. The final connection to the railroad signal is normally performed by the railroad. Exhibit 1100-4 provides an example of an eight-phase railroad preemption.

The special vehicle signal sequence is handled by traffic signal control equipment. Railroad preemption for signals on state highways shall conform to the following:

- When preempted by train movements, the traffic control signal will immediately provide a short green interval for the approach crossing the track. This is done to clear any vehicles that may be on the track, or so close to the track as to be in danger, or in a position to interfere with the operation of crossing gates. The traffic signal will subsequently display an indication to prevent vehicles from entering the track area; traffic movements that do not conflict with the railroad movement may be permitted. If at the time of preemption, the green interval is on an approach that does not cross the track, the green interval will be immediately terminated with a standard yellow phase change interval in order that green time may be given to the approach crossing the track.

Exhibit 1100-4

Typical Railroad Preemption, 8-Phase



PHASE/ INDICATIONS	R/W	PREEMPT CL	TRACK CLEARANCE		PREEMPTION HOLD INTERVALS
Ø1	← G	← G	← G	← Y	
Ø1A	← G	Y	R	R	
Ø2	G	Y	R	R	
Ø3	← G	← Y	R	R	
Ø4	G	Y	R	R	PHASES
Ø5	← G	← Y	R	R	Ø2, Ø5
Ø6	G	G	G	Y	Ø3, Ø4, Ø8
Ø6A	G	Y	R	R	
Ø7	← G	← Y	R	R	
Ø8	G	Y	R	R	
NRT – NLT SIGNS	OFF	ON	ON	ON	ON

- Following preemption, proper yellow change and red clearance interval signal phases must change from green or yellow, respectively. The length of yellow change and red clearance intervals shall not be altered by preemption.
- Any walk or pedestrian clearance intervals in effect following preemption that must change shall be immediately terminated with a DON'T WALK (upraised hand symbol).
- Optically programmable signal faces shall be used for the far side of the intersection for the track approach. The view of these signal faces shall be limited to the portion of the approach from the tracks to the intersection. Standard signal faces shall be installed on the near side of the intersection approach. The supplemental heads should operate in unison with the primary signal during normal operation. With preemption sequencing, the programmable signal face shall display the green indication to clear the tracks, while the near side signal displays red.
- Vehicle phases that do not conflict with the railroad crossing may be permitted to sequence during the preemption period.
- Blank-out signs that display NO RIGHT TURN or NO LEFT TURN should be used as appropriate.
- The layout of the preemption sequences should state specifically what phase change interval is to occur regardless of when the preemption begins in relation to the normal phase sequence. Also, the warning time provided by the train detection circuit must be obtained from the railroad authority to ensure that the preemption sequence will be able to clear the tracks during this time.

Chapter 1110 of the Design Manual provides additional guidance on railroad-highway grade crossings.

Emergency Vehicle Preemption

Traffic signals on state highways may be preempted by authorized emergency vehicles. The purpose of such preemption is to provide the right-of-way to an emergency vehicle as soon as practical. This preemption may be controlled by one of the following means:

- By direct wire, modulated light, or radio from a remote location such as a firehouse.
- By modulated light, radio, or global positioning system (GPS) technology from the emergency vehicle itself.

Designers are referred to the standards and guidelines for preemption provided in the MUTCD.

When emergency-vehicle preemption control is by means of a modulated light source, radio, or GPS, the following shall apply:

- The transmitter shall be permanently mounted on the emergency vehicle or building and shall operate at a range sufficient to permit normal yellow change and red clearance intervals to take place prior to the arrival of the emergency vehicle. (The normal pedestrian clearance interval may be abbreviated.)
- The system shall be designed to prevent simultaneous preemption by two or more emergency vehicles on separate approaches.

The NMDOT typically installs emergency-vehicle preemption equipment at all traffic signal approaches where emergency vehicles require the right-of-way regularly.

Normally, emergency-vehicle preemption equipment is installed, operated, and maintained by the local governmental entity, but the installation at any signal on a state highway must have NMDOT approval.

1100.4.2.5 Traffic Signal Controllers

Traffic signal controllers installed on state roads shall meet the specifications of the latest National Electrical Manufacturer's Association (NEMA) Standards for Traffic Control Systems. These microprocessor-type controllers shall:

- Provide versatility for all intersection control applications.
- Be capable of being programmed for a two to eight phase, pre-timed fully actuated operation or a special combination of sequential and/or concurrent phase timing for unique intersections.

Using standardized controllers allows for enhanced interchangeability and upgradeability, reduced maintenance inventories, and simplifies programming and timing processes. In

addition, the microprocessor-type controllers are normally specified with internal preemption and coordination capabilities (for current or future use).

Controller Phasing

Controller phasing shall be specified as determined in Section 1100.4.2.3. The signal plan (phase sequence, inactive phases, any overlaps, and/or preempt sequences) as established in the design will be held in the controller's non-volatile memory and is normally pre-programmed by the vendor. However, the controller remains capable of being reprogrammed for functional data and operational timing through a keyboard.

Phase Actuation

All traffic signal controllers used for isolated intersections (not coordinated with one or more additional traffic signals) should be operated with every phase vehicle-actuated. Actuation will permit phase skipping (omitting a phase with no demand) and time extensions based on demand. The operation has no fixed cycle length and permits maximum reduction in delay for all movements. The major street or highway phase(s) may be programmed for recall to ensure that the signal will rest in major street green during light traffic periods.

Coordinated traffic signals must operate under a fixed background cycle, and the coordinated phases (normally the major street) will operate under system control and will not respond to vehicle demand (semi-actuated control). Vehicle detection provisions should be provided for the coordinated phases only when the traffic signal may be operated free (or non-coordinated) during portions of a day. All non-coordinated phases should be actuated.

All pedestrian movements and timing for full- and semi-actuated operations should be actuated by pedestrian demand.

Pre-timed signal operation (fixed cycle and phase lengths) should be considered only in urban locations such as downtowns, activity nodes, and small town or rural main streets with cross-coordinated (grid) type coordination, close spacing (< 500 feet), slow speeds (<40 mph), and relatively high pedestrian volumes. Pedestrian timing would be incorporated into the phase timing.

Traffic Controller Equipment

Traffic signal controllers are in an environmentally protective cabinet installed at the site. This cabinet includes protective devices and wiring connections. The following components are included in the controller cabinet:

- Controller unit including any special functions
- Conflict monitor
- Detector for units and field wire terminals
- Field (signal) wiring terminals and load switches
- Power service panel with load/lightning protection
- Interconnect connections and telemetry (when applicable)
- System master (when applicable)
- Video processor (when applicable)

1100.4.2.6 Signal System Control

A signal system should be provided (or expanded) with signalized intersection installation(s) as determined in Section 1100.4.1.2. The availability and capabilities of signal systems has been expanding due to recent advancements made in computer technology. Signal system design should attempt to take full advantage of these advancements, within the limits of the capabilities of the local maintaining agency. For some systems, training may be considered a necessary component. All signal system designs shall be coordinated with the traffic design engineer and the local governmental entity.

Time-Based Coordination

This type of coordination can be used without any physical interconnect between intersection controllers. Time-based coordination is usually an internal function of the controller. An accurate clock is provided in the controller. The controller software uses this clock as a reference to activate the appropriate timing plan and keep the controller in step with the rest of the signals in the interconnected system.

Time-based coordination is the most economical type of signal interconnect since interconnect conduit and cables are not needed between intersections. A drawback to time-based coordination is that the clocks must be periodically synchronized since they will drift over time. A drift of a few seconds can impact the traffic progression. Also, all timing revisions and reviews must be made at the individual intersection site location. Time-based coordination does not offer the upload, download, and monitoring capabilities of a closed-loop system.

Closed-Loop System

With a closed-loop system, local signal controllers are linked to subsystem masters that coordinate traffic signal patterns by the time of day or traffic conditions. A closed-loop system can monitor and update progression data at the local controller and obtain notification of local failures or status. The entire network is constantly monitored by the central office computer. Complete updates of the system status, traffic flow, and controller diagnostic reports are available via displays and printouts.

Closed-loop systems may be composed of one arterial master, or a number of arterial subsystem masters, tied to a central office computer. The architecture of a closed-loop system lends itself to the possible phasing of subsystem installations. The initial planning of a closed-loop system for an urban-area arterial should include determining the ultimate system needs and scope for the areas.

The major components of a closed-loop system are:

- **Local controller interconnect hardware** - This provides the interface between the controller located at each intersection, system detectors, and the on-street master. The local interconnect hardware will transmit the traffic volume data to the field masters, which can be accessed and monitored by the central office computer. A variety of system timing patterns such as traffic responsive, time of day, manual pattern selection, and free operation will be stored in the local interconnect hardware.

- **On-street system master** - This component supervises the operation of the signals in its subsystem to provide optimum control patterns based on prevailing traffic conditions. It will perform numerous tasks such as:
  - Storing signal timing and offset patterns.
  - Receiving and analyzing data from the system and its detectors.
  - Automatically selecting the best timing pattern in the traffic-responsive mode.
  - Directing the local interconnect hardware to implement the chosen responsible patterns at the intersections.
  - Receiving status and failure messages and sending them to the central office computer for review and response.
- **Communication system** - The communication between the intersection controllers and the on-street master is normally carried by communication cable (fiber optic cable) installed in a dedicated conduit system.

  The communication between the street masters and central computers is normally a link using auto-dial modems that communicate over standard telephone lines. Where possible, it is preferred to connect field masters and the central computer by dedicated hardwire.
- **System detectors** - The system detectors are normally inductive loops installed to monitor individual lanes at selected points. To properly monitor traffic (volumes, occupancy, and speeds) the detectors should be placed at the far side of intersections or at mid-block locations.
- **Central office computer** - This is the principal operator interface for a closed-loop system. This system allows a traffic engineer to monitor the system operation for optimum performance, appropriate adjustments, and troubleshooting. The system is driven by software supplied by the vendor. Remote computers, such as computers located in a signal maintenance office, can also be used.

The advantages of a closed-loop system are the convenience of revising timing, immediate detection of malfunctions, ongoing data collection for future revisions, and quick response to traffic volume functions. However, proper maintenance and supervision is essential to fully utilizing its capabilities. Future maintenance and operational responsibility is, therefore, a major component in the planning, justification, and design of a closed-loop system. Training and initial installation setup should be included with its installation.

Adaptive Traffic Control Systems

An adaptive traffic control system (ATCS) adjusts, in real time, signal timing plans based on the current traffic conditions, demand, and system capacity. An ATCS usually includes algorithms that adjust a signal's split, offset, phase length, and phase sequences to minimize delays and reduce the number of stops. Some ATCSs are not constrained by the traditional ring-and-barrier structure, allowing more flexibility to best serve actual traffic conditions. ATCSs require extensive surveillance, usually in the form of video and/or pavement loop detectors, and a communications infrastructure that allows for communication with the central and/or local controllers.

The NMDOT is currently evaluating the best way to implement ATCS technology along heavily traveled corridors.

1100.4.2.7 Placing Signal Equipment

For the most part, the design engineer has limited options available for determining acceptable placement locations for signal pedestals, mast arm signal poles, pedestrian pedestals, pedestrian detectors, and controllers. From a roadside safety aspect, these elements should be placed as far back from the roadway as possible. However, due to visibility requirements, mast arm length limitations, and right-of-way limitations, traffic signal equipment often must be placed relatively close to the travel way. Additionally, design engineers must consider the encroachment of this traffic signal equipment into the normal pedestrian way and make provisions to ensure intuitive and comfortable pedestrian movement, including compliance with ADA standards.

The design engineer should consider the following when determining where traffic signal equipment will be placed:

1. Controller
   - The controller cabinet should be located as far from the travel way as practical, normally near the right-of-way line.
   - The controller cabinet should be placed in a position that will minimize the chance of being struck by an errant vehicle. Generally, a controller cabinet is less vulnerable being placed next to an approach side of a roadway than on the departure side.
   - The controller cabinet should be located where it can be easily accessed by maintenance personnel. The location should provide adjacent standing room with the door open and clear access to a place where a maintenance vehicle can be parked.
   - The controller cabinet should be located so that a technician working in the cabinet can see the intersection without obstruction. Normally, the cabinet is placed with the door facing away from the intersection.
   - The controller cabinet should be located on the same intersection corner as the electrical power source.
2. Signal Poles
   - On urban curbed facilities, the centerline of a signal pole shall be no closer than three feet from the face of the curb, but preferably five to six feet. It is preferable to place signal poles on the back side of the sidewalk or adjacent to the right-of-way line. Additional factors that should be considered include the constructability of the pole foundation and placing the pole(s) in locations that minimize interference and inconvenience for pedestrians.
   - On non-curbed facilities, the signal pole should be placed at least two feet outside of the shoulder and at least 10 feet from a travel lane. The cross-section of the road at this point needs to be used to establish the exact location of the pole foundation. The foundation should not be placed in the bottom of the ditch section. No parts of the sides of the

foundation should be exposed which may, in many cases, cause the need to backfill around the foundation, creating a pole platform. The top of the foundation elevation should be determined to assure minimum required clearance of the mast arm over the driving lanes.

- Pedestrians. If a signal pole or cabinet must be located in the sidewalk, maintain at least four feet of clear passage width (exclusive of the curb) from the furthest edge of sidewalk or other above-ground obstruction and the installed pole. Required ADA clearances must be maintained from any curb ramps. Portions of the signal pole foundation extending beyond the installed pole must be flush with the sidewalk.

Mast Arm and Pole Installation

Under most circumstances, traffic signal displays are installed on mast arms that are placed on the far side of the intersection. This allows the signal heads to be placed directly over the through lanes. In addition, the rigid mounting also allows for better control of the signal heads when it is windy.

Pedestal traffic signal poles are used for the placement of a left-turn signal in a median or as an auxiliary corner signal support for mounting a near-side or far-left signal. Pedestals may also be used as an auxiliary support for mounting pedestrian signals and push buttons when the mast arm pole is too far from a crosswalk terminal. This typically occurs at intersections with large corner radii.

Placing signal poles in a median should be considered on a case-by-case basis. Mast arms may be designed up to 65 feet long, which permits placing signal displays over the median of most roadways. However, mast arms that are more than 30 feet long are much more expensive and should be justified by analyzing factors such as median width, speeds over 40 mph, curb type (barrier, mountable), and local maintenance policy.

Traffic signal standards (including poles and supports) required in NMDOT project plans and standard specifications are identified as follows:

1. Type I - A pedestal-type support for traffic signal displays, small controller cabinets, or splice cabinets.
2. Type II - A mast arm type support for overhead and side-of-pole traffic signal displays.
3. Type III - A combination mast arm traffic signal support and luminaire pole with an upper separate luminaire arm. Luminaire mounting heights of 30 feet to 42 feet may be specified. This type of standard may also be used to mount the camera for video detection systems.

All traffic signal supports installed on state highways shall be in conformance to the NMDOT Standard Drawings.

Span-Wire Installation

Signal heads may be placed on span-wires under some temporary situations in construction zones. Advantages to span-wire include the following:

- Foundations are not required; therefore, it is easier to determine pole locations.
- Electrical wiring can cross roadways on the span-wire, eliminating the need for crossing under a roadway.

Disadvantages to span-wire include the following:

- Span-wire does not provide enough rigidity under windy conditions.
- Signal faces are harder to see on narrow roads.
- Pedestrians have a more difficult time seeing signal faces.
- Installations are often considered to be aesthetically unpleasing.
- Poles may require down guys.

When a span-wire system is installed, at least one (but preferably both) signal displays for each approach shall be 40 feet or more from the stop line. To accomplish proper signal display positioning, boxing an intersection (spans across each leg of the intersection,

permitting far-side signal mounting) is preferred over a diagonal span. When designing a span, it is important that the span length and the required sag be identified so the required pole height can be determined.

1100.4.2.8 Signal Displays

A traffic signal display consists of many parts including the signal head, signal face, lenses, optical unit, and visors. The criteria set forth in Part IV, Section B of the MUTCD are to be followed in determining appropriate signal display arrangement, placement, and equipment. In addition, the following guidelines and policies shall be followed when designing signal displays on state highways.

Signal Face Design

The lenses (sections) of all traffic signal faces shall be arranged in a straight line, typically having either three or five sections. Overhead signals should be arranged for horizontal mounting, while side-of-pole and pedestal-mounted signals are to be arranged vertically. Temporary signals installed overhead on a span-wire support may be vertical. NMDOT's policy is to use only 12-inch lenses on state highways. To enhance visibility, the entire visible signal face (except lenses) and visors are to be colored black. In addition, black back plates should be used on all overhead signals. Where protected/permissive left-turn phasing is used, a third signal face is typically used in addition to the minimum two signal faces required for through traffic. Protected left-turn-only movements shall be controlled by three-section signal displays composed of arrow indications, supplemented by an adjacent Left on Green Arrow Only sign. Pedestrian signals shall be of a single section and shall use a symbolized WALK/DON'T WALK (walking person/upraised hand) message in conformance to Part IV, Section D of the MUTCD. When upgrading traffic signals, all pedestrian signals with word messages should be upgraded to symbol messages with countdown indications.

Signal Display Placement

The positions of signal indications shall be designed in accordance with the MUTCD, latest edition. Per the MUTCD, when conditions prevent drivers from having a continuous view of the signal faces, a

warning sign shall be installed. If the approach speed meets or exceeds 40 mph, the sign should be supplemented by a warning beacon.

Pedestrian signal displays are normally mounted on the same pole as vehicular displays; however, all pedestrian signals shall be positioned to provide maximum visibility at the beginning and continuously through a controlled crosswalk.

Optically Programmed Signals

Optically programmed signal displays have special lenses that can be let up (masked) to provide a sharp optical cut-off of the indication both vertically and horizontally. These signal displays are typically used to distance-limit the visibility of signal indications by horizontal cut-off. These signal displays shall be used in the far-side displays for a railroad crossing approach (see Chapter 1110 of the Design Manual) or other closely spaced intersections.

With a vertical cut-off, these signal displays may be used to direct the signal indication to specific approach lanes, not allowing visibility to adjacent lanes. Typical applications include complex intersection geometry such as a five-leg intersection or skew intersections. To be effective, the programmable signal display should be positioned as close as possible to the projection of the desired cut-off line as physically practical. A programmable signal display placed 12 feet or greater transversely from this cut-off line cannot be programmed to provide an effective cut-off.

Optically programmed signal displays shall not be used unless designed for a specific purpose as described above. Programmed signals are much more expensive than standard displays and when uncontrolled (unmasked) still provide a smaller visible cone than a standard signal display with visors.

1100.4.2.9 Detectors

A detector determines the presence of a vehicle or pedestrian, or the passage of a moving vehicle. This presence or passage detection is sent back to the controller (or system master), which will adjust signal operation accordingly. The NMDOT does not specify the type of detection to be used in its design, as long as the product is listed on the NMDOT's approved product list. Inductive loop detectors

and video detection are used most often; radar and infrared detection may also be used. Other types of detection that have been used or are available are pressure, magnetometer, and sonic, but they are not used on state highways because they have greater operational problems and are less versatile compared to other choices.

Inductive Loop Detector

The inductive loop detector can be used to detect vehicle presence or passing vehicles; determine vehicular counts; determine speed; detect shapes; and is generally accurate and easy to maintain. An inductive loop detector (loop detector) consists of two or more loops of wire embedded in the pavement surface. The wire loop is connected to an electrical oscillator. When a metallic mass is within the loop area, the loop's magnetic field is disturbed, affecting the frequency of the electrical current. This effect is amplified and transmitted to a controller as a detection signal.

Inductive loops should be installed in paved areas in conformance with the details and dimensions shown on the latest NMDOT standard sheets. The following are key items of concern for loop installation:

- Saw cutting must be uniform and at proper depth; the loop wire must be covered with a minimum of two inches and the cover must be maintained.
- Loop wire must be sealed with an approved material and in accordance with manufacturer's recommendations, finished flush with the pavement surface.
- Corners should be cut at 45 degree angles or cored so that the loop wire is not turned around a sharp 90 degree corner.
- All embedded loop wire must be a continuous, unspliced wire.
- Preformed loops should be used when installing new concrete paving.
- When loops are placed in adjacent positions, a separate slot for each detector's head wire to the pull box must be provided for maintenance.

- Lead-in cable, running from a pull box near the loop to the signal controller, must be a continuous, unspliced cable.
- The pavement surface must be in good condition for the loop to be properly installed. The exact position of the loop may have to be adjusted to avoid surfacing problem areas, or resurfacing may be required.

The two basic types of loops are long loops (six feet x 35 feet or six feet x 40 feet) and short loops (six feet x six feet). A long loop or series of long loops in each lane (including turning lanes) are normally placed at the intersection to detect the presence of vehicles stopped at the traffic signal. These loops should be centered in each lane, located no closer than 1.5 feet to a lane line. Turn-lane loops adjacent to through lanes should be of the quadrupole type (loops with center saw cut forming two three-foot-wide loop windings with a common wire slot down the middle). This type of loop has a smaller electrical field, which reduces the chance of false calls from vehicles in adjacent lanes. The through lanes should use the normal rectangular loops. Typical loops are shown in Exhibit 1100-5.

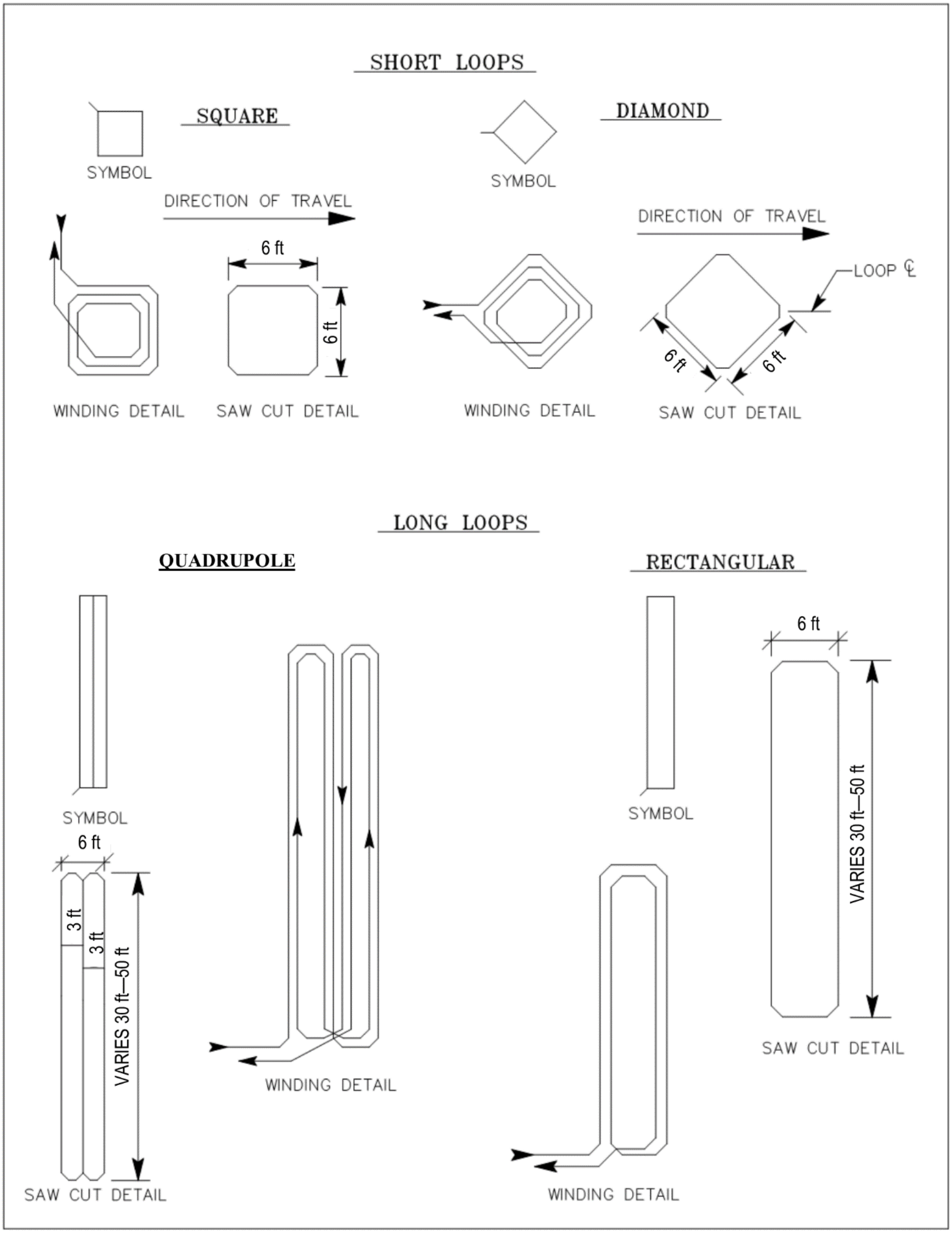
Detectors for dilemma zone protection are discussed in Section 1100.4.4.4.

When the major street approach is under coordinated system coordinated operation or will be operated in a recall mode, the stop line long loops may be eliminated for thru traffic lanes. In this case, however, the initial phase timing must be set to accommodate the possible queue between the stop line and the advance detector.

Inductive detectors may be operated in the presence mode or pulse mode. In pulse mode a vehicle is seen only once upon entering the detection zone, whereas in presence mode the signal is continuous as long as a vehicle remains within the detection zone. All detectors (long or short) used for normal signal operation (call or extension) should operate in the presence mode. The pulse mode should be used only when a detector loop is used for counting purposes.

Exhibit 1100-5

Typical Detector Loops



Special small-loop designs have been developed for detecting bicycles; however, careful design and placement must be used for them to be effective. Where bicycle facilities are present, including on paved shoulders or along a designated bicycle route, loops must be designed to detect bicyclists. Failure to detect bicyclists can lead to decreased signal compliance by bicyclists, creating safety concerns. MUTCD (2009) Sections 9B.13 and 9C.05 provide information on appropriate signage and pavement markings to optimally position bicyclists on detection equipment.

Short loops in different lanes tied to the same detector unit channel are normally connected in parallel to allow one loop to operate given the chance of loss of the other lane loop. However, the designer needs to be aware that a series connection of loops increase the circuit inductance while parallel connection decreases circuit inductance, which reduces overall loop sensitivity. For this reason, long loops detecting the same phase should be connected to individual detector channels.

Loops installed for system detection should be placed on the departure side of a signal controlled intersection to avoid any signal-caused queues. These loops should be short (six feet x six feet), placed normal to the traffic flow, and operated in the pulse mode.

Video Detection Systems

A typical video detection installation consists of small video cameras mounted on the top of the corner-positioned mast arms and a video processor unit installed in the cabinet. Standard laptop computers can be used for detection zone setup and viewing detector actuations within the traffic scene. Remote monitoring for both setup and traffic surveillance may be provided with the appropriate video transmission interconnect. Advantages to video detection in lieu of pavement loop detectors includes the following:

- No loops or devices need be placed within the roadway pavement. The traffic control impacts normally associated with detector loop construction and maintenance can be avoided. Also, pavement conditions do not become a major factor in the detector system reliability.
- Video detectors allow the detection zones to be any size and placed anywhere within the video image. These zones may be

easily adjusted. Additional capabilities of some systems include determining volume counts, lane occupancy, speed, density, headways, vehicle lengths, and average delays. This information may be brought back to a remote signal management center for use in signal system evaluation and optimization.

- When provided with remote monitoring capabilities at a signal/traffic management center, it may be used for incident detection.
- It may be used with temporary traffic signal installations in construction areas where detection loops cannot feasibly be placed in the pavement and where detection zone adjustment will be required.

Disadvantages or concerns with video detection systems, which must be evaluated before a decision is made to incorporate some within a design, include the following:

- The relative cost of video detection is higher. It is more cost effective at multi-phase high-speed intersections where complex multi-loops would be required.
- Video detection represents new technology in the traffic field, and is subject to developmental flux. Care must be taken in specifying the equipment to be used. The equipment evaluation should include experience with existing installed systems, probable vendor technical support, and training.
- Video detection systems require a higher and more complex level of operational supervision than loop systems. The local government maintaining entity must have the personnel available to perform these functions.
- Video detection requires the placement of higher and more costly (Type III) signal poles to provide mountings for the video cameras. With the higher poles, proper clearance must be maintained with overhead utility lines. Because of the requirement for the Type III poles, upgrading existing signals to video detection may be difficult and expensive.
- To fully use the capabilities of a video detection system and to provide proper operational supervision, remote monitoring should be included. This additional complexity and cost may be

more appropriate with the installation of an interconnected signal system.

The decision to use video detection in a design should be made on a case-by-case basis. The decision to use video detection requires both the approval of the NMDOT and the maintaining government entity. It is recommended that the design of video detection systems be reviewed with manufacturers' technical representatives to ensure that the choice of camera locations, optics, and data/video interconnect are appropriate for the application.

Radar Presence Detection

A radar presence detector is a frequency-modulated continuous wave radar device that provides accurate vehicle detection. For presence detection at the stop bar it is normally mounted on the back of the opposing approach's mast arm, and reports real-time presence of both moving and stopped vehicles. Radar detectors may also be mounted on roadside poles to track a variety of upstream inputs such as vehicular speed, vehicle headways, and the estimated time of arrival to the stop bar, as a method of dilemma zone protection. Radar is sometimes used in conjunction with video to increase detection accuracy.

Infrared Detection

Active and passive infrared sensors are manufactured for traffic applications. The sensors are mounted overhead to view approaching or departing traffic or traffic from a side-looking configuration. Infrared sensors are used for signal control; volume, speed, and class measurement; and for detecting pedestrians in crosswalks. With infrared sensors, the word detector is also used to refer to the light-sensitive element that converts the reflected or emitted energy into electrical signals. Real-time signal processing is used to analyze the received signals for the presence of a vehicle.

Pedestrian Detection

Push buttons shall be provided so that a pedestrian may request the pedestrian phase to cross each leg of a signalized intersection, unless a corner may be physically restricted from potential pedestrian access. New push buttons shall be accessible and placed in accordance with the MUTCD and PROWAG.

Pedestrian push buttons may be used to provide detection for bicyclists. These push buttons are placed on a short pole at the curb line adjacent to a bicycle lane and are separate from those provided for pedestrians. This design is only feasible when the bicycle lane is directly adjacent to the curb line, and is not feasible if there is a right-turn lane present, for example.

1100.4.2.10 Conduit and Cable System

Electrical connections between the power supply, controller, detectors, and signal displays are to be carried in a closed underground conduit system.

The conduit system consists of electrical cables consisting of a single or multiple conductors (wires), connectors, conduit, and pull boxes. The design engineer should consider the following when developing the traffic signal wiring plan:

- **Service connections** - Service connections from the local utility lines and service meter should go directly to the controller and be as short as possible. It is important that the design engineer establish with the local electrical utility the exact service connection point to the electrical distribution lines at the time of preparing preliminary plans. This permits the proper coordination of the utility service with the design of the controller location and electrical signal distribution cables.

  The electric service meter/shut-off may be located on the side of the utility pole or within a meter pedestal placed between the service drop and the controller. Meter placement shall be determined by local maintenance preference and should consider ease of access and aesthetic appearance. The electric service conduit system shall be underground from the meter to the controller and shall be exclusive for the service cable, normally three - # 6 American wire gauge (AWG) conductors. No electric service cable shall be run within any part of the signal conduit system.

  If the electrical service line is longer than 150 feet, a special design with larger conductors may be required. The voltage drop should be checked, and the voltage drop in the service line should not exceed six volts (five percent) based on the

maximum load (including maximum number of energized indications at one time, auxiliary flashers, equipment and outlets, and any lighting luminaires) times a 1.3 safety factor. Service conductors shall be sized to provide a voltage drop less than six volts.

- **Signal distribution cables** - All electrical cable between the controller, signal displays, and push buttons shall be within an underground conduit system (or run within a support pole). All electric cable and connections must meet national, state, and local electrical codes in addition to NEMA criteria.

  Electrical signal cables shall be color coded based on function. Cable size and color code shall be used as prescribed by the maintaining entity. All electric cable runs shall be continuous between the controller, signal displays, and pole bases.

- **Detector cables** - Detector cables shall be two-pair, shielded communication cable. Detector lead-in cable runs shall be continuous between the controller and the pull box where the cable is spliced to detector loop leads.
- **Pull boxes** - Pull boxes are provided to accommodate conduit run junctures to facilitate cable pulling and to permit splicing detector leads. The placement of pull boxes in the sidewalk should be avoided; Chapter 1200 of the Design Manual provides more information on the acceptable placement of pull boxes in relation to the pedestrian access route.
- **Underground conduit** - Underground conduit is used to connect the controller, traffic signals, and loop detectors. A conduit system provides ease of installation, maintenance, and protection from accidentally cutting the electrical signal cables. With a new traffic signal installation, conduit crossings should be established under all roadway legs, boxing the intersection with a closed conduit loop joined by pull boxes on each intersection corner. Empty conduit should be filled with a pull string to facilitate future use. This provides future access to each intersection and its related signal equipment in the event one crossing is cut or broken. Conduits used for carrying signal cable runs are typically 3 inches in diameter or larger. For runs carrying only detector cable, 2-inch conduit may be used.

Plastic conduit (PVC) is normally preferred except for locations where the conduit is exposed above ground or where conduit is installed in a poured concrete slab or deck then metallic conduit such as galvanized rigid steel is used.

1100.4.3 Preparation of Plans

The plan layout of the intersection to be signalized should be drawn at a scale of one inch = 20 feet. The layout should include the entire intersection area and design features of approaches that influence the traffic signal design. Normally one sheet is used per intersection; however, additional sheets with match lines may be used, if necessary. If drainage or pavement detail design plans are prepared at this scale, reproductions of these plans may be used for the signal layout, provided reproduction is made before details not pertinent to the traffic signal installation are added to the plans.

Features shown on the signal layout should include:

- Pavement outlines (existing and proposed), with lane widths and curbs.
- Sidewalk, accessible curb ramps (existing and proposed), crosswalks, stop lines, and lane lines.
- Parking conditions and bus stops.
- Driveways and drainage structures.
- Utilities and street lighting.
- Railroad or fire station locations.
- Arrows showing pavement lane use.
- Proposed phasing.
- Location of signal poles, controller, electrical service, and signal faces and their indications.
- Foundation type - the designer shall verify that the standard foundation drawings are appropriate for the particular situation; i.e., the conditions are within the design parameters shown in the NMDOT Standard Drawings. Where conditions require a custom foundation design it shall be submitted to the State Bridge Engineer for approval.
- Type, size, and location of detectors.

The designer shall verify that the standard foundation drawings are appropriate for the particular situation; i.e., the conditions are within the design parameters shown in the NMDOT Standard Drawings. Where conditions require a custom foundation design it shall be submitted to the State Bridge Engineer for approval

- Pull box locations.
- Conduit and cable runs.
- Function chart.
- Title block stating location.
- Sign location and type.
- Existing signals and removals.
- Interconnect runs (if any).
- Right-of-way limits and type.
- North arrow.
- All streets.
- Number of signal faces, poles, detectors, and pull boxes.

Design plans for traffic control signals on the state highway system shall be submitted to the General Office Traffic Technical Support Bureau and State Maintenance Bureau for review and approval prior to advertising for construction. Approval shall be obtained from the General Office Traffic Technical Support Bureau of design plans for traffic control signals.

1100.4.3.1 NMDOT Standard Drawings and Specifications

The latest versions of NMDOT Standard Drawings shall be included with the signal plan. Verification for the latest version of signal standards and specifications should be made with the Traffic Engineering Technical Support Section. Modifications or deviations from these standards should be detailed on the plans and/or by job special provisions after obtaining approval from the Design Division. Some local standards (such as City of Albuquerque pole standards) may be used when approved by the NMDOT and the maintaining entity.

Appropriate public notice shall be given prior to installing or removing a signal. Public notice may take the form of signing or placing the signal in flash mode in advance of implementing signal operations.

1100.4.4 Signal Timing

Consistent with the Signalization Agreement, signals shall be properly timed. Adjacent traffic signals shall be coordinated to insure safe and efficient traffic flow. The NMDOT, at its discretion, shall select an appropriate signal timing program for this purpose. In the timing of traffic signals, the needs of all transportation users shall be considered.

The sections below are the NMDOT's policy for the deployment of traffic signals change intervals and dilemma zone protection options for use throughout the state. Engineering judgment should be applied to the special cases and situations when the guidance provided here could not be readily applied. In these cases, an engineering investigation should be completed and the methodology should be approved by a NMDOT Traffic Technical Support Engineer.

1100.4.4.1 Yellow Change Interval

The yellow change interval for traffic signals maintained by the NMDOT and traffic signals located within NMDOT jurisdiction shall be determined using guidelines established in NCHRP Report 731, Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections.

1100.4.4.2 Red Clearance Interval

The red clearance interval for traffic signals maintained by the NMDOT and traffic signals located within NMDOT jurisdiction shall be determined using guidelines established in NCHRP Report 731, Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections.

1100.4.4.3 Pedestrian Intervals

NMDOT policy on calculation of pedestrian intervals is based on the 2009 Edition of the MUTCD. NMDOT uses countdown pedestrian signals as standard (discussed in Section 4E.07 of the 2009 MUTCD). The recommended pedestrian interval is the sum of the pedestrian walk interval and the pedestrian change interval.

Pedestrian Walk Interval

Pedestrian walk interval is the time for which a steady WALKING PERSON (symbolizing WALK) is displayed on a pedestrian signal head. A seven-second walk interval is recommended so that pedestrians will have adequate opportunity to leave the curb or wheelchair ramp before the pedestrian change interval begins. A walk interval of four seconds may be sufficient when fewer than 10 pedestrians per cycle are expected or where it is desired to favor the length of an opposing phase. A walk interval of seven seconds or more may be used for moderate to heavy pedestrian volumes.

Pedestrian Change Interval

The pedestrian change interval is the time for which a flashing UPRAISED HAND (symbolizing DON'T WALK) signal indication and countdown time are displayed on the pedestrian signal head. Following the pedestrian change interval, a buffer interval consisting of a steady UPRAISED HAND (symbolizing DON'T WALK) signal indication shall be displayed for at least 3 seconds prior to release of any conflicting vehicular movement. The pedestrian change interval is calculated based on the pedestrian clearance time less the buffer interval. The pedestrian clearance time is the estimated time it takes to walk across the street at a normal walking speed (typically 3.5 to 4.0 feet per second). The buffer interval should be equal to the yellow change interval of the vehicular signal phase provided for vehicles travelling parallel to the pedestrian crosswalk direction.

The following equation shall be used to calculate the pedestrian change interval:

Pedestrian Change Interval =

Pedestrian Clearance Time (P/w) - Buffer Interval (Y)
(rounded up to nearest whole second), where:

- P = distance from curb to curb or center of wheelchair ramp to center of wheelchair ramp along center of crosswalk (feet).
- w = normal walking speed (typically 3.5 to 4.0 feet per second).
- Y = the yellow change interval of the vehicular signal phase parallel to the crosswalk direction.

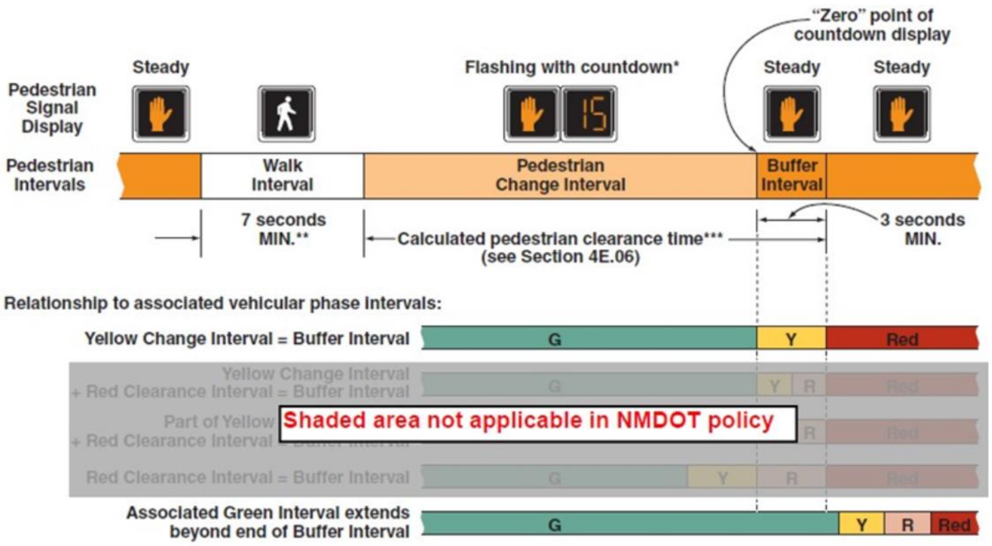
For new signal installations and modified signal installations the NMDOT policy recommends the use of extended pedestrian phase pushbutton functionality. A standard pedestrian pushbutton activation will prompt a pedestrian clearance time based on the above equation and 4.0 feet per second walking speed. An extended pedestrian pushbutton activation will prompt a pedestrian clearance time based on the above equation and 3.5 feet per second walking speed. This policy will require an additional setting configuration in the controller to allow for extended pedestrian phase pushbutton functionality and a MUTCD R10-32p sign denoting this functionality is in use.

Existing signal locations may remain as-is or be upgraded at the discretion of the NMDOT Traffic Engineering Technical Support Section. Recommended walking speed for installations without extended pushbutton functionality is 3.5 feet per second.

Additional consideration should be given to pedestrian signal indications near facilities that serve segments of the population with slower walking speeds. In this case walking speeds should be calculated based on a lower walking speed. Such populations should be anticipated near shopping centers, convalescent or rest homes, therapy centers, elementary schools, etc. A walking speed of 3.1 feet per second should be considered if senior citizens or school children are in the majority at a specific crosswalk. Walking speeds slower than 3.5 feet per second shall be approved by a NMDOT Traffic Technical Support Engineer.

Exhibit 1100-6 presents pedestrian intervals and Exhibit 1100-7 presents recommended values of pedestrian clearance time for various walking speeds and pedestrian crossing distances. The buffer interval should be subtracted from the pedestrian clearance time to determine the pedestrian change interval. Figure 4E-2 in the 2009 MUTCD shows pedestrian intervals in relation to the vehicular signal intervals.

Exhibit 1100-6
Pedestrian Intervals



* The countdown display is optional for Pedestrian Change Intervals of 7 seconds or less.
** The Walk Interval may be reduced under some conditions (see Section 4E.06).
*** The Buffer Interval, which shall always be provided and displayed, may be used to help satisfy the calculated pedestrian clearance time, or may begin after the calculated pedestrian clearance time has ended.

Legend
- G = Green Interval
- Y = Yellow Change Interval (of at least 3 seconds)
- R = Red Clearance Interval
- Red = Red because conflicting traffic has been released

Exhibit 1100-7
Recommended Pedestrian Clearance Times

Pedestrian Crossing Distance, P (feet)	Walking Speed		
	3.0 feet per second	3.5 feet per second	4.0 feet per second
	Pedestrian Clearance Interval (seconds)		
20	7	6	5
25	8	7	6
30	10	9	8
35	12	10	9
40	13	11	10
45	15	13	11
50	17	14	13
55	20	17	15
60	23	20	18
65	27	23	20
70	30	26	23
75	33	29	25
80	37	31	28
90	30	26	23
100	33	29	25
110	37	31	28
120	40	34	30
130	43	37	33

On a street with a median refuge width of six feet or greater, the pedestrian clearance time may be computed to provide only enough time to clear the crossing from the curb to the median; in such cases, an additional detector shall be provided on the median. This option, however, is not ideal for pedestrians and should only be considered when all other options for that intersection's operations have been exhausted.

During the transition into preemption, the walk interval and the pedestrian change interval may be shortened or omitted as described in Section 4D.27 of 2009 MUTCD.

APSs should be considered if a leading pedestrian interval is used (refer to Sections 4E.09 through 4E.13 of 2009 MUTCD). Additional

information on NMDOT guidelines for APSs are contained in Attachment 1 to this chapter.

Further information on pedestrian intervals is referenced in the Section 4E.06 of 2009 MUTCD.

1100.4.4.4 Dilemma Zone Protection

Signalized intersection approaches with highly variable approach speeds greater than or equal to 45 mph can exhibit safety issues in the form of what is known as a dilemma zone or indecision zone. A dilemma zone is the space where drivers approaching the intersection are confronted with a choice of whether to stop or continue through the intersection upon the onset of a yellow change interval. The dilemma can occur at a point, depending on the approach speed, where the approaching vehicle can neither stop safely at the stop bar nor clear the intersection before the start of a conflicting green phase. A more detailed discussion of the dilemma zone can be found on pages 4-25 to 4-32 in the FHWA Traffic Detector Handbook.

The dilemma zone effect at high speed signalized approaches can be reduced by incorporating advanced detection to prompt the traffic signal controller to find an acceptable gap to terminate the active phase by extending the green phase to allow an approaching vehicle through the dilemma zone or by extending the all red clearance interval. When considering extending the all red phase, further traffic analysis of the intersection and consultation with a NMDOT Traffic Technical Support Engineer is recommended.

Candidate locations have an approach speed of 45 mph or greater and are typically on non-coordinated signal phases. It should be noted, since dilemma zone protection uses green phase extensions and vehicle gap identification as a means of reducing dilemma zone impacts, dilemma zone protection has limited effectiveness when applied to signal phases in a coordinated system. In a coordinated system, these phases are typically set to run their maximum allotted time for the greatest coordinated throughput. Coordinated phases also encourage the formation of platoons which reduce speed variability; therefore reducing the likelihood of finding vehicles within the dilemma zone. Dilemma zone protection can be effective

on a coordinated system during off-peak (uncoordinated) hours and possibly during coordinated hours with advanced controllers and controller logic programming. The advanced programming allows the traffic signals to run in coordination, with a window at the yield point of the coordinated phases where the traffic signal detectors on the main line become actuated.

Two suggested infrastructure deployment options are recommended to provide dilemma zone detection; traditional advance loop detection or Continuous Tracking Advance Detectors (CTADs).

Deployment Option 1: Advance Loop Detection

Exhibit 1100-8 and Exhibit 1100-9 provide advance loop layouts for given 85th percentile speeds and are comparable with current practice of other DOTs. These exhibits apply advance loop detection concepts derived from the FHWA Traffic Detector Handbook, Traffic Signal Operations Handbook (published by the Institute of Transportation Engineers [ITE]), and Traffic Signal Timing Manual (published by ITE), The 85th percentile speeds should be determined based on speed data collected on the approach in question and confirmed with a NMDOT Traffic Technical Support Engineer.

The recommended detector placements assume the following:

- Braking reaction time is 1.5 seconds. This is more conservative than the one second used by many entities.
- Advanced detectors are six feet by six feet.
- Per AASHTO, a comfortable deceleration rate of 11.2 feet per seconds squared is applied.
- Passage time is two seconds.
- Detection mode is presence non-locking mode.
- Stop bar detection can remain in place. For stop bar detection standards, please reference NMDOT Standard Drawings.
- The AASHTO Green Book equation for braking distance (Equation 3-2).

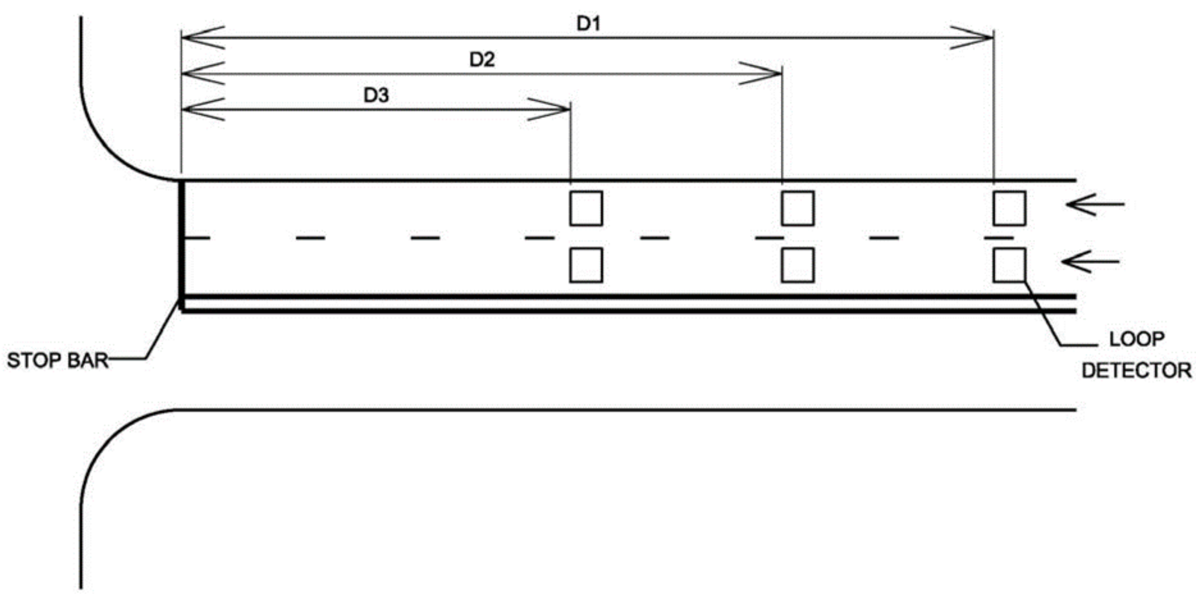
Exhibit 1100-8

Advanced Loop Detector Placement for High Speed Approaches

85th Percentile Speed (mph)	Speed Range (mph)	Advanced Detector Setback (feet from stop bar)		
		D_1	D_2	D_3
70	50 to 70	625	480	350
65	45 to 65	550	415	295
60	40 to 60	480	350	240
55	35 to 55	415	295	195
50	40 to 50	-	350	240
45	35 to 45	-	295	195

Exhibit 1100-9

Advance Loop Detector Placement Dimensions



Deployment Option 2: Continuous Tracking Advance Detectors (CTADs)

CTADs are radar detectors mounted on road side poles that track a variety of upstream inputs such as vehicular speed, vehicle headways, and the estimated time of arrival to the stop bar. These data inputs are used to determine if additional green time is needed to get vehicles through the dilemma zone and when to activate the yellow phase.

The detection range at current NMDOT installations for CTADs are 500 feet longitudinally and 400 feet laterally. However, depending on the product manufacturer, this detection range can vary and should be verified for design. Recommended CTAD placements should cover the dilemma zone ranges for the various 85th percentile speeds provided in Exhibit 1100-10.

Exhibit 1100-10

CTAD Dilemma Zone Coverage Requirement

85th Percentile Speed (mph)	Dilemma Zone Coverage (feet from stop bar)
70	195 to 625
65	195 to 550
60	195 to 480
55	195 to 415
50	195 to 350
45	195 to 295

Optional Advance Warning and Dilemma Zone Protection with CTADs

Flashing beacons can be deployed in conjunction with CTADs as mitigation for intersections experiencing drivers running red lights and can be beneficial for traffic with longer braking distances like truck trailers. The beacons provide additional warning and thus more time for drivers to safely stop at a red light. If this type of installation is desired, the CTAD with warning beacon is recommended to be placed three seconds in advance of the beginning of the 85th percentile speed dilemma zone. Exhibit 1100-11 indicates CTAD with warning beacon placement locations in feet from the beginning of the 85th percentile speed dilemma zone.

Exhibit 1100-11

CTAD with Warning Beacon Placement

85th Percentile Speed (mph)	CTAD and Warning Beacon Placement (feet upstream of dilemma zone)
70	310
65	290
60	265
55	245
50	220
45	200

It should be noted that the passage time setting on the controller should be set at three seconds. The warning flasher will be set to activate three seconds prior to the yellow phase, which is designed to occur simultaneously as the detected vehicle enters the dilemma zone.

1100.4.5 Removing Existing Signals

Changes in traffic patterns may cause a situation where a traffic signal is no longer justified. A signal on the state system may be removed with the mutual agreement of the District Engineer and Traffic Technical Support Engineer if a traffic engineering study indicates a signal no longer satisfies traffic signal warrants. In all cases, the local governmental entity shall be consulted.

The MUTCD provides guidance on the removal of a signal.

Prior to removing a signal, appropriate public notice shall be given. This may be in the form of signing or placing the signal in flash mode in advance of implementing signal control.

1100.5 Procedures – School Zone Flashing Beacons

The following describes the procedure to be followed prior to installing a school zone flashing beacon on a New Mexico state highway.

1100.5.1 Establish Need for Beacons and Obtain Approvals

School zone flashing beacons are usually requested because of a perception that drivers at a certain location need additional warning of an existing school speed zone. The purpose of the flashing beacons is to draw motorist attention to the reduced speed limit school zone sign.

Requests for the installation of school zone flashing beacons on state highways shall be submitted to the Traffic Technical Support Section of the NMDOT General Office in Santa Fe through the NMDOT District Traffic Engineers. Requests that come directly to the Traffic Technical Support Section of the General Office will be referred back to the NMDOT District offices for their review and evaluation.

Per state law, the speed limit is 15 miles per hour on all highways when passing a school while children are going to or leaving school and when the school zone is properly posted. When a school speed zone is established on a state highway, the school speed limit signs may be supplemented with a flashing yellow warning beacon. Although some school zones may have both signs and speed limit sign beacons, as long as there is a regulatory sign containing printed information warning drivers of the existence of the school zones, speed limit sign beacons are not a requirement.

Although some school zones may have both signs and speed limit sign beacons, as long as there is a regulatory sign containing printed information warning drivers of the existence of the school zones, flashing beacons are *not* a requirement.

A recommendation to supplement school speed zone signs with beacons will be made by the NMDOT District Traffic Engineer. Due to limited resources, not all school speed zone signs can be supplemented with flashing beacons. In order to make the best use of available funding, the decision to install flashing beacons will be based on objective engineering factors such as the cross section, traffic volume, and normal operating speed on the street, as well as the age of the school children using the crossing. The study documenting the decision whether or not to install flashing beacons at a certain school speed zone will be forwarded to the Traffic Technical Support section at the General Office. The State Traffic Engineer will approve or reject the recommendation. The study and signed letter of decision will be placed in the project file.

Once the installation of the flashing beacons has been approved, the local maintaining agency must provide a Letter of Intent for operation and maintenance of the beacons. The Letter of Intent should define the extents of the school speed zone and intervals of operation for the beacons.

1100.5.2 School Zone Flashing Beacon Design

The NMDOT Standard Drawings provide design details for both mast arm-mounted and pedestal-mounted school zone flashing beacons. School zone flashing beacons may be powered using either direct power or solar panels. These details should be coordinated with the District Traffic Engineer and included in the appropriate agreements.

Where the NMDOT is responsible for signing school speed zones and the decision is made to install associated flashing beacons, the S5-1 sign, SCHOOL SPEED LIMIT 15 WHEN FLASHING, shall be used. The signs and, when used, speed limit sign beacons, shall be placed at the most advantageous point to be conspicuous to approaching vehicular traffic. This may be off the shoulder of the road, in the median, or overhead to face traffic entering the school speed zone.

1100.6 Documentation

Required documentation for a traffic signal design project may include:

- Signal warrant study
- NMDOT approval to install signal
- Placement on the signalization priority list
- Preliminary scoping report
- Memorandum of Understanding (MOU)
- State Bridge Engineer approval of custom-designed mast arm foundation (if applicable)
- Signalization Agreement
- Cooperative Agreement or Joint Powers Agreement
- Recommended signal timing program (if requested)
- Study and letter of decision to install school zone flashing beacons
- Letter of Intent from the local agency to operate and maintain the school zone flashing beacons