

CHAPTER 9

TRAFFIC SIGNAL DESIGN – POST-INSTALLATION

9.1 Traffic Signal Maintenance Guidelines

The primary goal of this section is to provide effective maintenance guidelines to transportation agencies responsible for the operation of traffic signals in Tennessee. After activation, it is recommended that signalized intersections be routinely inspected by trained personnel in order to reduce agency exposure to liability and to provide safe operations to the public. Preventive Maintenance and Response Maintenance guidelines are detailed in the following sections. The ITE/IMSA Traffic Signal Maintenance Handbook was used as a Standard Reference in the development of these guidelines.

9.1.1 Reducing Agency Exposure to Liability

Most tort liability claims originate from negligent traffic signal installation and maintenance. In regards to maintenance, negligence is the failure to comply with the duty to maintain traffic signal equipment in a reasonably safe condition, through some act or omission on the part of the agency or its employees. Therefore, an agency should observe the following to reduce its exposure to liability:

- **Temporary Traffic Control Plans:** Agencies should conform to the specifications of the MUTCD when performing traffic signal maintenance tasks. Agencies should also inform local law enforcement and emergency services agencies of all lane closures, detours, and other changes in traffic control. Appropriate training should be provided for agency employees. Appendix C provides a table with recommended MUTCD temporary traffic control plans for typical maintenance tasks.
- **Routine Inspection:** Agencies should perform preventive maintenance and signal timing maintenance as described in these guidelines. In addition, maintenance records should be regularly reviewed to identify recurring problems with the signal equipment and appropriate actions should be taken. Crash records should also be reviewed to identify potential defects or hazards. Furthermore, it is recommended that all agency employees, such as police, roadway maintenance, utility, sanitation, etc. who regularly work on the street system be trained to look for and properly report any damaged or apparently defective traffic signal equipment to a pre-determined notification system.
- **Maintenance Practices:** Maintenance personnel should be trained in the proper actions to take in the case of traffic control system malfunction or loss of control. Temporary control by police should be sought in potentially dangerous situations until repairs can be completed or until adequate

interim warning measures can be implemented. Maintenance work should be performed by qualified personnel. Agencies should perform response maintenance as described in these guidelines.

- **Maintenance Records:** Adequate maintenance records are essential. Records may be in hardcopy or electronic format. Duplicate records should be stored at an offsite location.

9.1.2 Preventive Maintenance

The objective of preventive maintenance is to prevent the failure of traffic signal equipment before it actually occurs. Replacing worn components before they fail has the potential to preserve and enhance equipment reliability. Furthermore, a good preventive maintenance program can reduce agency liability, extend the life of the installation, reduce the frequency and severity of malfunctions, and make better use of manpower and resources. TDOT recommends that signal timing directives be checked during preventive maintenance for safe and efficient traffic signal operations.

- **Recommended Documentation:** The following documents should be available at each signalized intersection for reference by the technician (typically kept in the cabinet):
 - **Actual drawings:** A set of traffic signal plans with a record of necessary changes approved during construction.
 - **Approved timing directives:** Timing directives should contain the address of the intersection, date the directive was approved, name and signature of the person approving the directive, and all the parameter settings necessary for the designed operation. The parameters include, but are not limited to, phasing sequence, timing, signals displayed during each interval, signal head numbering, coordinated and non-coordinated phases, splits, cycles, offsets, pedestrian timings, preemption, volume density, detector plans, TOD operation, etc.
 - **Logbooks:** The logbook should contain the address of the intersection, make, model, and serial number of the controller components and the communication equipment. Technicians should, at a minimum, include their name, date, and time of the visit to the intersection, work performed (including parts that were replaced), condition on arrival, and condition when the technician left.

A copy of actual drawings, approved timing directives, and logbooks should be stored in the agency office in a safe location. It is also recommended that user manuals for all of the equipment used at signalized intersections be available to technicians.

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- **Frequency:** TDOT recommends that preventive maintenance be performed every six months, with a minimum of once a year. Agencies should review maintenance records and service calls, determine trends, and determine its appropriate preventive maintenance scheduling. TDOT also recommends that agencies inspect signals after severe weather to determine potential damage and ensure proper operation.
- **Recommended Tools, Equipment, and Supplies:** Agencies performing traffic signal maintenance should have the means of testing its traffic signal equipment routinely, using its own testing equipment or contracting it out. Typically, the following equipment is used for testing:
 - A certified CMU or MMU tester (printouts of system timing tests, voltage tests, power conflict, red fail conflict, short yellow indicator, AC power failure transfer, restore, power fluctuation, etc);
 - Loop detector analyzer and tester for testing loops and detector amplifiers (signal strength, inductance and change of inductance, resistance);
 - Video monitor to observe video detection operation;
 - Suitcase tester or test box for controller;
 - Load switch tester (verify current outputs);
 - BIU tester;
 - Earth ground clamp;
 - Power quality meter;
 - Digital multi-meter;
 - Test kits for communication.

It is also recommended for agencies to have readily available spare parts for the proper maintenance of traffic signals. Examples of commonly used spare parts are the following:

- Pushbuttons and accompanying signs;
- Spare cabinet fans and thermostats;
- Spare controller;
- Signal and flash load switches;
- Flash transfer relays;
- Replacement air filters;
- Spare controller cabinet bulbs;
- Spare circuit breakers;
- Spare ground fault circuit interrupter (GFCI) receptacles;
- Spare detector panel relay sockets and relays;

- Spare preemption relay sockets and relays;
 - Spare communication equipment;
 - Spare gasket material for cabinets;
 - Replacement LED modules;
 - Spare UPS batteries;
 - Spare loop detector amplifiers;
 - Spare video detection card and camera interface panel;
 - Spare power supply for detector cards.
- **Deficiencies Requiring Immediate Action:** Once a deficiency is found during an inspection of a traffic signal, agencies should take appropriate actions to preserve the safe and efficient operation of the intersection. The documentation of the problem and proper servicing action or communication to a supervisor is necessary. The following are examples of deficiencies requiring immediate action:
- A CMU or MMU that fails any of the tests performed by the tester;
 - Bad load switches;
 - Damaged signal heads;
 - Damaged or missing traffic signal hardware;
 - Broken or damaged doors for pole base or handhole access;
 - Nonfunctioning pushbuttons;
 - Missing ground wire, bushings or connectors;
 - Damaged, frayed, or faulty cables;
 - Non-functioning preemption;
 - Faulty circuit breakers, GFCIs, or mercury switches;
 - Missing junction or splice box covers;
 - Bad controller.
- **Preventive Maintenance Checklists:** Appendix C contains recommended TDOT Traffic Signal Preventive Maintenance Checklist Forms. Technicians should initial all pages of the form once a job is finished.

9.1.3 Response Maintenance

Response maintenance is the type of maintenance required when one or more components of a traffic signal system fails, causing the traffic signal to malfunction or operate in a way that is not intended. Response maintenance will be required, for example, during knockdowns, when the signal is operating in flash mode due to faulty equipment, when wrong indications or multiple indications are displayed, when indications are dark, when signal heads are out of proper alignment, when the intersection is not resetting after a power loss, etc. Agencies with good preventive maintenance programs will significantly reduce the number of response calls.

- **Standard Operating Procedure:** Agencies should have a SOP to notify personnel when traffic signal response maintenance is required. A clear understanding of the actions to properly respond to service calls is necessary. Response maintenance may be performed by in-house staff or may be outsourced to a contractor. Response times may be established to different tasks, based on the urgency of the service to be performed. A two-hour response time is a widely accepted standard, but agencies should consider the geographic area that needs to be covered (larger cities may need additional time), traffic conditions (peak and off-peak periods), and weather-related conditions. Agencies should develop a plan to determine how the initial call will be serviced. First, a list of intersections that the agency will be servicing needs to be determined. The list should then be shared with authorities (police, 911 dispatchers, etc), signal technicians, and contractors (if necessary). Next, determine the number to be called in case a traffic signal needs to be serviced. It is important to recognize the potential need for a call tree (in-house and contractors) and also plan for off-hours, holidays, and weekends.
- **Recommended Documentation:** The following information should be included in the service call by the person receiving the complaint:
 - Name of caller;
 - Date and time the complaint was received;
 - Location and apparent problem as reported;
 - Name of receiver.

The following information should be added to the initial service call by the person sent to the field:

- Maintenance personnel, time dispatched, and time of arrival;
- Trouble found (as reported by the maintenance crew), action taken, and time cleared.

Once on location, the technician should assess the site conditions and confirm that the trouble reported represents what is being observed. A determination should be done if additional staff or equipment will be

necessary to address the problem. It is highly recommended to take photos to document the time and date, site conditions upon arrival (include street name signs), temporary traffic control implemented, and conditions once service is restored to the traffic signal. It is also recommended for technicians not to direct traffic, asking for law enforcement assistance if necessary. Lastly, technicians should complete the traffic signal service call report immediately after the work is finished. Appendix C provides a recommended Traffic Signal Service Call Report.

9.2 Automated Traffic Signal Performance Measures

TDOT encourages maintaining agencies to collect performance measures, or MOE, to enhance traffic signal system operations. ATSPMs can easily be used to manage and optimize all modes of traffic signal operations. They can be monitored and/or reported via email alerts, and can be reported independent of central system software. The basic performance measures are proactive in monitoring traffic signals for impacts to the traffic signal operations, such as malfunctioning detection and troubleshooting complaints. Performance measures also allow a maintaining agency to be more efficient when creating work orders, such as:

- Diagnosing a problem and describing it to the technicians;
- Making sure the right technician is dispatched to the field;
- Correcting the problem remotely without having to dispatch a technician;
- Making sure the complaint is observed at the right time of day, if applicable.

Travel time, delay, and average speeds are also commonly used performance measures to evaluate the quality of traffic movements along a corridor. Current traffic signal technology provides the opportunity for practitioners to collect detailed information that could be used to fine-tune traffic signal timings and improve operational efficiency. In order to collect ATSPMs, traffic signal controllers must be able to meet the following requirements:

- Be able to collect high-resolution traffic data that is recording events at a rate of 0.1 seconds;
- Be compatible with the Indiana Traffic Signal Hi-Resolution Data Logger Enumeration software capabilities;
- The ATSPM source codes are free and available from the Utah DOT.
- Be able transfer data remotely to a server. This data transfer can be achieved using a variety of means, including wireless modems, Internet Protocol (IP) over radio, and fiber optic cable. One connection is needed at each isolated intersection or interconnected corridor.

The Indiana Traffic Signal Hi-Resolution Data Logger Enumeration software is free and is provided at no cost to maintaining agencies. Information Technology (IT) support will also be needed to set up the ATSPMs since they involve the transfer of data. Most ATCs are capable of reporting ATSPMs, but it is important for the designer to verify

traffic signal controller requirements to ensure its compatibility for reporting these types of performance measures. There are currently more than 30 types of ATSPMs that can be reported from the traffic signal controllers: Table 12.1 shows some ATSPMs with the controller and detection requirements needed for each ATSPM.

Table 9.1 – Types of ATSPMs and Controller/Detection Requirements

Automated Traffic Signal Performance Metric	Controller with High-Resolution Data Capability	Type of Detection Needed ⁽¹⁾				
		Advanced Count Detection	Advanced Speed Detection (Radar Only)	Lane-by-Lane Count Detection	Lane-by-Lane Presence Detection	Probe Travel Time (GPS or Bluetooth)
Purdue Phase Termination	X					
Split Monitor	X					
Pedestrian Delay	X					
Preemption Details	X					
Transit Signal Priority Details ⁽²⁾	X					
Purdue Coordination Diagram	X	X				
Approach Volume	X	X				
Platoon Ratio	X	X				
Arrivals on Red	X	X				
Approach Delay	X	X				
Approach Speed	X		X			
Turning Movement Counts	X			X		
Yellow and Red Actuations	X			X		
Purdue Split Failure	X				X	
Purdue Travel Time Diagram	X					X

- Any type of detectors (loops, radar, video, pucks, etc.) can be used to collect traffic data except for the Approach Speed metric which requires radar detection.
- The Transit Signal Priority Details ATSPM is currently under development.

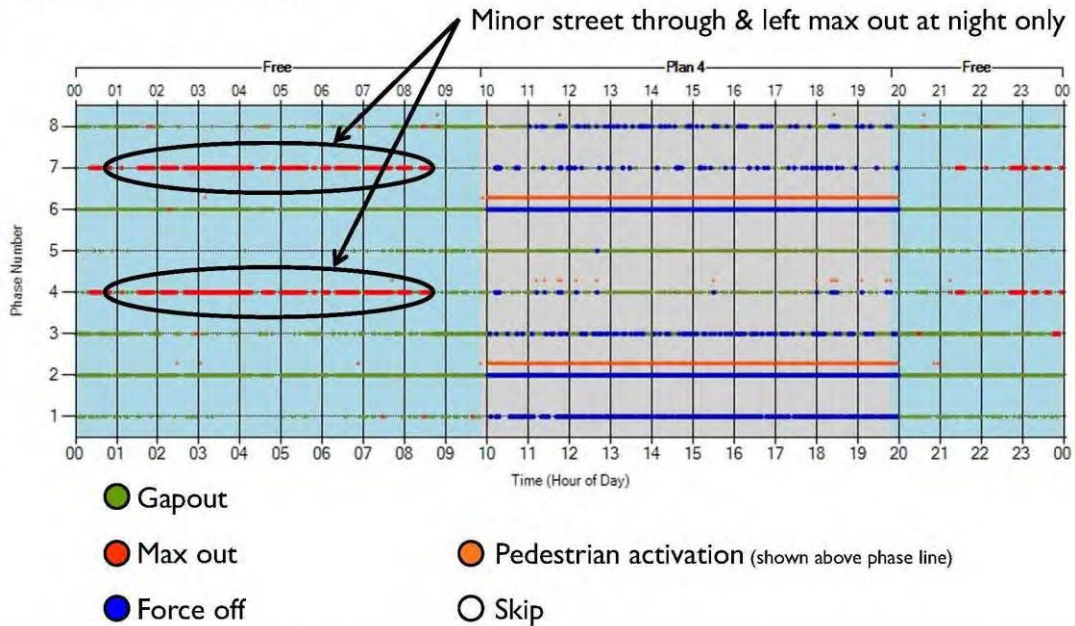
The ATSPM reports are dependent upon adequate vehicle detection in the field. As shown in Table 9.1, many different types of detectors and configurations can be used. A couple of before and after examples using ATSPMs are shown in Figures 9.1 and 9.2, respectively. For additional information on ATSPM's, the designer should reference the Traffic Signal Timing Manual, the FHWA Traffic Analysis Toolbox, the Performance Measurement Fundamentals, and the Indiana Joint Research Program Performance Measures for Traffic Signal Systems.

Figure 9.1 – Automated Traffic Signal Performance Measure Before Example (Purdue Phase Termination and Split Monitor)

Source: Utah DOT

Complaints: Light is Red Too Long – Before

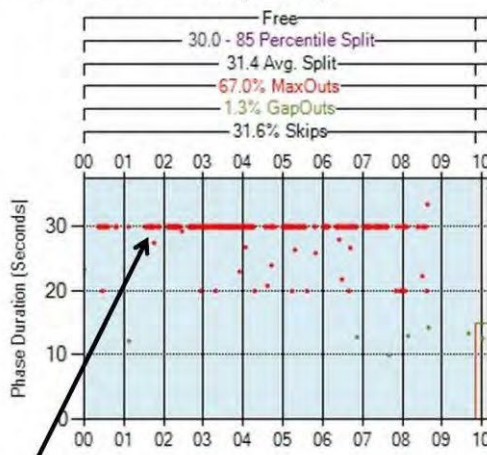
Metric: Phase Termination



Complaints: Light is Red Too Long – Before

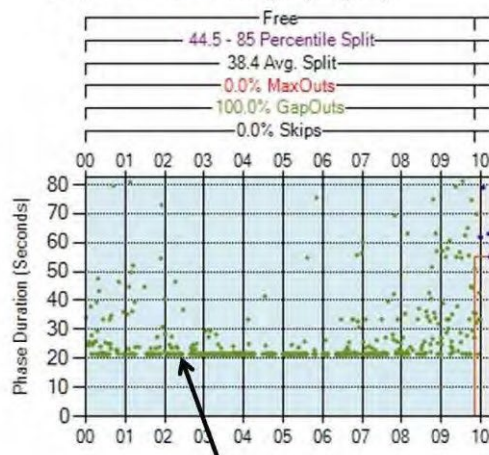
Metric: Split Monitor

Northbound Left (Minor)



Minor side street left turn maxes out during the middle of the night. Green for about 30 seconds.

Westbound Through (Major)



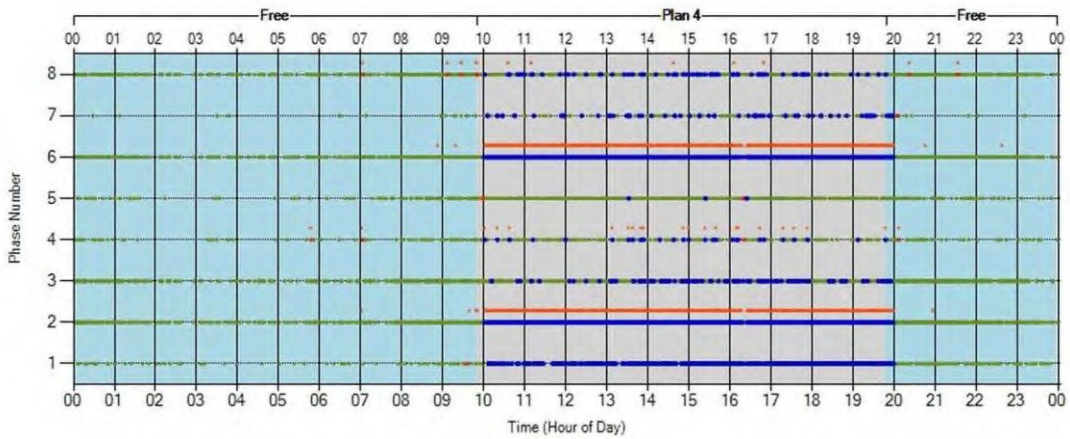
Major movement only green for 20 seconds.

Figure 9.2 – Automated Traffic Signal Performance Measure After Example (Purdue Phase Termination and Split Monitor)

Source: Utah DOT

Complaints: Light is Red Too Long – After

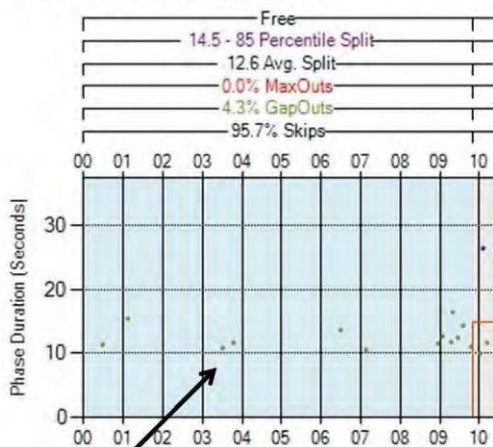
Metric: Phase Termination



Complaints: Light is Red Too Long – After

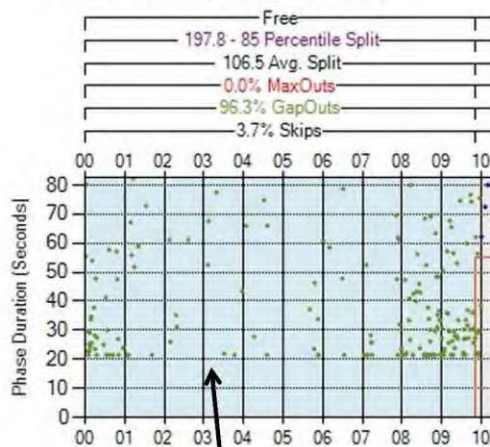
Metric: Split Monitor

Northbound Left (Minor)



Phase 7 rarely comes up.

Westbound Through (Major)



Phase 2 rests in green.

9.3 Removal of Traffic Signals

Although the original installation of a traffic signal may be based on the satisfaction of one or more traffic signal warrants and other factors, changes in traffic flow over time may reduce the effectiveness of traffic signal control. When this occurs, it may be appropriate to remove a traffic signal. The *MUTCD* does not contain specific traffic signal warrants for the removal of traffic signals. A general rule of thumb is that if a traffic signal does not meet at least 50% of the values of any of the traffic signal warrants, the traffic signal should be analyzed for removal. Even though traffic volumes may have decreased, the removal of a traffic signal requires engineering judgment, because removal of the traffic signal may or may not be appropriate. If the engineering study indicates that the traffic control signal is no longer justified, removal should be accomplished using the following steps:

- Determine the appropriate traffic control to be used after removal of the traffic signal;
- Remove any sight-distance restrictions as necessary;
- Flash or cover the traffic signal heads for a minimum of 90 days, and install the appropriate stop control or other traffic control devices;
- Remove the signal if the engineering data collected during the removal study period confirms that the traffic signal is no longer needed.

As a step down, replace the traffic signal with an all-way stop. If an all-way stop is not warranted, then remove the stop signs on the major approaches. Instead of total removal of the traffic control signal, the poles and cables may remain in place after removal of the signal heads for continued analysis. Remove all traffic signal equipment if the continued analysis finds that the traffic signal is no longer needed. See Appendix B for an example traffic signal removal form.