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PREVENTIVE MAINTENANCE AND INSPECTION FOR TRAFFIC SIGNALS, ROADWAY LIGHTING AND OVERHEAD SIGN STRUCTURES

Prepared by CTC & Associates LLC

The MnDOT Asset Management Program and Office of Traffic Engineering are seeking information about the state of the practice in preventive maintenance and inspection strategies designed to extend the service life of traffic signals, roadway lighting and overhead sign structures. MnDOT is particularly interested in the expected service lives of these roadway assets, preventive maintenance and inspection activities and schedules, cost–benefits associated with preventive maintenance and inspection strategies, and the criteria used to determine asset replacement.

This Transportation Research Synthesis presents findings from a survey of select transportation agencies and a literature search of relevant national and state practices, research and guidance.

Technical Advisory Panel

Ray Starr, Technical Liaison
MnDOT Office of Traffic Engineering

Matt Mullins, Principal Investigator
CTC & Associates LLC

Mark Linsenmayer, Principal Investigator
CTC & Associates LLC

Leif Halverson, Project Coordinator
MnDOT Office of Research & Innovation

Brent Rusco, Project Advisor
MnDOT Office of Research & Innovation

Michael Cremin, Panelist
MnDOT Division of Modal Planning & Program Management

Steven Misgen, Panelist
MnDOT Metro District

Michael Schweyen, Panelist
MnDOT District 6

Trisha Stefanski, Panelist
MnDOT Division of Modal Planning & Program Management

Susan Zarling, Panelist
MnDOT Office of Traffic Engineering

The purpose of this TRS is to serve as a synthesis of pertinent completed research to be used for further study and evaluation by MnDOT. This TRS does not represent the conclusions of either the authors or MnDOT.

Preventive Maintenance and Inspection for Traffic Signals, Roadway Lighting and Overhead Sign Structures

Introduction

The MnDOT Asset Management Program and Office of Traffic Engineering are seeking information about the state of the practice in preventive maintenance and inspection strategies designed to extend the service life of traffic signal, roadway lighting and overhead sign support structures. MnDOT is particularly interested in the expected service lives of these roadway assets, preventive maintenance and inspection activities and schedules, cost–benefits associated with preventive maintenance strategies, and criteria used to determine asset replacement.

This investigation surveyed state departments of transportation (DOTs) and other transportation agencies that share similar climatic and environmental challenges that are faced in Minnesota, and transportation agencies that emerged as leaders during a preliminary literature review. This Transportation Research Synthesis presents the results from the survey and review of documents shared by survey participants. Results from the limited literature review of state and national research on these practices and the quantification of the benefits of such practices have augmented some of the information gleaned from survey respondents.

Summary of Findings

Survey of Practice

An online survey was distributed to selected members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Maintenance and of a Federal Highway Administration (FHWA) Asset Management group, recommendations from the Technical Advisory Panel and findings from a limited literature search. Of the 21 transportation agencies that received the survey, nine agencies responded:

- City of Columbus, Ohio.
- Illinois DOT.
- Indiana DOT.
- MnDOT.
- Ohio DOT.
- Ontario (Canada) Ministry of Transportation.
- Pennsylvania DOT.
- Quebec (Canada) Ministry of Transportation.
- Utah DOT.

Six of the nine agencies (Illinois, Minnesota, Ohio, and Pennsylvania DOTs; Ontario Ministry of Transportation; and Quebec Ministry of Transportation) included details on preventive maintenance and inspection for traffic signals structures, roadway lighting structures and overhead sign support structures; Utah DOT and Columbus, Ohio, provided details on traffic signals and overhead sign supports; and Indiana DOT provided information on traffic signals. Results are summarized in four topic categories:

- Service life.
- Traffic signals.
- Roadway lighting.
- Overhead sign supports.

Service Life

MnDOT expects traffic signals to serve effectively for 30 years, as do Illinois and Ohio DOTs, Ontario and Columbus, Ohio (Table 1). Pennsylvania and Indiana DOTs expect shorter lives of 25 years, Quebec expects a slightly longer service life of 35 years, and Utah DOT did not indicate an expected service life for traffic signals.

Table 1. Asset Expected Service Life (in Years)

Agency	Traffic Signal	Roadway Lighting	Overhead Sign Supports
Minnesota	30	30 / 50 for high mast	60
Columbus, Ohio	30	N/R	30
Illinois	30	30-40	30-40
Indiana	25*	N/R	N/R
Ohio	30	50	50
Ontario	30*	30-40	N/R
Pennsylvania	25	25	50
Quebec	35	35	35
Utah	Not determined	N/R	30**

N/R No response

*Indiana DOT expects poles to serve for 25 years, cabinets for 15 and controllers for five to 10 years. Ontario expects poles, mast arms and underground components to last for 30 years; cabinets, distribution equipment, hangars and support structures for 20 years; signal heads for 10 years; electronics and communications equipment for seven years; and LED signal units for five years.

**Utah DOT expects 30 years of its galvanization, not necessarily of the structure itself

For roadway lighting, MnDOT expects 30 year of service from standard structures and 50 years from high mast light poles. Illinois DOT and Ontario expect 30 to 40 years of service, while Quebec expects 35. Ohio DOT expects 50 years of service from its lighting structures, matching MnDOT expectation for high mast structures. Only Pennsylvania DOT, with a life expectancy for roadway lighting structures of 25 years, holds lower expectations for service durability.

MnDOT expectations for overhead sign support structure service exceed all other agencies that responded to the survey, with a 60-year service expectation. Columbus, Ohio, expects 30 years of service from the support structures, Illinois DOT expects 30 to 40 years, Quebec expects 35, and Ohio and Pennsylvania DOTs expect 50 years. Utah DOT expects 30 years of its galvanization, not necessarily of the structure itself; after 30 years, the agency regalvanizes or repaints structures.

Traffic Signals

Every survey respondent provided details about preventive maintenance and inspection of traffic signal structures. Two agencies shared knowledge about or interest in cost–benefits data on traffic signal inspections,

and seven shared information on their standards for replacing traffic signal structures. Tables 2 through 5 show comparisons of MnDOT activities with those of other agencies. Because survey responses for traffic signal support system practices could not be captured in a single table in this report format, we present findings in two groups to accommodate easy comparison of individual agencies with Minnesota practices: Group A (Minnesota, Illinois, Indiana, Ohio and Ontario) and Group B (Minnesota, Pennsylvania, Quebec, Utah and Columbus).

Preventive Maintenance

MnDOT conducts preventive maintenance with six actions of the 10 maintenance items presented in the survey: maintaining rodent control in cabinets, lubricating cabinet hinges and other moveable hardware, cleaning or replacing air filters, cleaning terminal blocks on pole bases, tightening bolts and anchor rods, and checking and replacing fuses (Table 2). However, supporting documentation indicates that a large range of activities fall to staff conducting preventive maintenance in varying frequencies; detailed checklists and documents described in **Detailed Findings** show another 29 items dealt with annually, 20 more biannually and 21 more every three years.

Indiana DOT typically conducts four of the maintenance items in response to inspection results. In addition to the activities listed in Table 2, Illinois DOT also conducts communications to master controllers, and testing of conflict monitors and malfunction management units (MMUs). Illinois DOT described weekly and bimonthly maintenance and inspection items, as well as annual maintenance items.

Ohio DOT attends routinely to all six items MnDOT addresses, as well as to three more. How frequently Ohio DOT maintains these elements appears to be contingent on inspection results. Ontario addresses four of the six items MnDOT selected in its survey answer, as well three others. As with several other agencies, Ontario indicates the timing of maintenance activity follows inspection, which occurs annually for traffic signals.

Table 2. Traffic Signal Preventive Maintenance Actions (Group A)

Maintenance Item	Minnesota	Illinois	Indiana	Ohio	Ontario
Cabinet rodent control	X		X	X	
Lubrication of cabinet hinges, locks, door	X			X	X
Clean or replace air filter	X	X	X	X	X
Upgrade controller firmware				X	
Check and adjust detection zone alignment		X		X	X
Clean sensors		X		X	X

Maintenance Item	Minnesota	Illinois	Indiana	Ohio	Ontario
Check and clean terminal blocks on pole bases	X			X	
Tighten bolts, anchor rods	X	X		X	X
Check and replace fuses	X	X	X	X	X
Group lamp/bulb replacement			X		X
Other	X	X			

In Group B (Table 3), Pennsylvania DOT attends to nine of the 10 presented maintenance items, excluding only checking and cleaning terminal blocks at pole bases, which MnDOT includes in its practice. Pennsylvania DOT is currently revising its preventive maintenance procedures, but most activities are conducted every six or 12 months. New procedures, described in **Detailed Findings**, entail a significant number of maintenance and inspection items, much like the documentation shows for MnDOT activities.

Quebec only identified tightening of anchor rods and bolts as a maintenance task, which it requires during structural inspections. Quebec does not prepare guidelines or schedules for preventive maintenance activity; rather, it leaves such tasks to territorial authorities.

Utah DOT selected eight of the 10 items in Table 3 and indicated that there are a large number of other items it addresses in preventive maintenance. Additional documentation showed that some maintenance activities are performed annually from the ground and some are conducted every two years from a bucket.

Table 3. Traffic Signal Preventive Maintenance Actions (Group B)

Maintenance Item	Minnesota	Pennsylvania	Quebec	Utah	Columbus, Ohio
Cabinet rodent control	X	X		X	X
Lubrication of cabinet hinges, locks, door	X	X		X	X
Clean or replace air filter	X	X		X	X
Upgrade controller firmware		X		X	

Maintenance Item	Minnesota	Pennsylvania	Quebec	Utah	Columbus, Ohio
Check and adjust detection zone alignment		X		X	X
Clean sensors		X		X	X
Check and clean terminal blocks on pole bases	X			X	X
Tighten bolts, anchor rods	X	X	X		X
Check and replace fuses	X	X			X
Group lamp/bulb replacement		X		X	
Other	X			X	

Columbus also performs eight of the 10 preventive maintenance items as routine tasks, and action is driven by its inspection schedule, which requires conflict monitors and MMUs to be tested annually and each signal at least once every four years.

Maintenance Item Trends

Of the preventive maintenance items detailed in Tables 2 and 3, some activities were more common to respondent agencies. Cleaning and replacing air filters and checking and replacing fuses were routine activities for eight of the nine surveyed agencies. Tightening anchor bolts and anchor rods was regular for seven agencies. Six agencies also regularly deal with rodent control in cabinets, check and adjust detector alignment, and clean sensors.

Other Maintenance Items

MnDOT's preventive maintenance details, as described by the survey respondent, included a number of items listed as "other" in addition to the items presented in the survey; many of these may be associated with the current updating of MnDOT procedure. For more information on those details, see **Detailed Findings**.

Preventive maintenance activities that agencies outside of Minnesota conduct that were not listed in the 10 items presented in the survey, but described as "other," include:

- Communications to master controllers (Illinois).
- Conflict monitor/MMU testing (Illinois, Utah).
- Straightening and tightening heads (Utah).
- Ensuring correct placement of hoods, back plates, end caps and upper hand-hole covers (Utah).
- Cleaning cameras every year (Utah).

- Examining and cleaning cabinets (Utah).
- Analyzing detector performance (Utah).
- Checking and replacing cabinet power, wiring, switches and more (Utah).
- Testing preemption (Utah).

For more information and detail on Utah DOT's preventive maintenance activities, see **Detailed Findings**.

Frequency Trends

Frequency of preventive maintenance activities varied notably. The shortest scheduling periods fell to Illinois DOT, which indicated weekly, bimonthly and annual activities. Pennsylvania DOT indicated semiannual and annual activity. Annual activities were described by MnDOT, Ontario, Utah DOT and Columbus; all but Ontario indicated longer scheduling periods of two, three or four years for some items.

Ontario indicated most activity would fall to regional decision-making and inspections, and Indiana DOT, Ohio DOT and Quebec all tied preventive maintenance activity timing to inspection results.

Inspection

Inspections drive preventive maintenance activity quite directly for Indiana DOT, Ohio DOT, Quebec and Columbus. For Illinois DOT, inspection seems to entail certain maintenance activities, and for Ontario the two kinds of activities seem somewhat conflated, as well. For MnDOT, Pennsylvania DOT and Utah DOT the activities appear to be a little more clearly delineated as distinct preventive maintenance or inspection duties.

Table 4 shows routine inspection items conducted by agencies in Group A.

Table 4. Traffic Signal Inspection Items (Group A)

Inspection Item	Minnesota	Illinois	Indiana	Ohio	Ontario
Foundation	X			X	X
Anchor rods	X	X		X	X
Transformer base				X	
Pole	X	X	X	X	X
Pole foundation	X		X	X	X
Mast arm, upper	X	X			X
Mast arm, lower	X	X			X
Mast arm chord, upper connection	X	X			X
Mast arm chord, lower connection	X	X			X

Inspection Item	Minnesota	Illinois	Indiana	Ohio	Ontario
Luminaire extension	X				X
Camera extension	X				X
Cabinet: hinges, vents, etc.				X	X
Cabinet electronics and electrical		X	X		X
Wiring			X	X	X
Pedestrian buttons			X	X	X
Signal operation (at cabinet)		X	X	X	X
Signal unit: cracks, damage, corrosion, etc.		X	X	X	X
Lamps/bulbs			X	X	X
Service voltage			X	X	X
Other	X			X	

The MnDOT survey respondent on traffic signals indicated 10 of the presented items in Table 4 were routine inspection elements. A new structural inspection protocol in development may, according to adjoining documentation, expand that list to over 70 specific inspection and defect items, as described in **Detailed Findings**, below. The frequency of inspection was not indicated.

Illinois and Indiana DOTs both indicated nine elements of 19 in Table 4, though not the same nine items were routinely inspected. For Indiana DOT, inspections were conducted two times each year. For Illinois, inspections were conducted bimonthly and once per year.

Ohio DOT inspects 12 of the 19 inspection items presented in the survey, and inspections are conducted every two to five years. Signals are inspected annually, and signal structures when constructed and once every five years after construction. Inspection procedures were revised in 2019, as described in **Detailed Findings** and inspection items were expanded significantly; hardware and operational inspections now include over 200 items.

Ontario did not indicate how frequently it inspects traffic signal structures, but maintenance activity entails annual reports that presumably stand in for inspection. These visits require inspection of 18 of the 19 suggested inspection items presented in the survey and Table 4.

Pennsylvania DOT inspects 17 of the 19 listed traffic signal inspection items (Table 5), some once every six months, some once every year. The agency is revising its traffic signal inspection practices, as described in the **Detailed Findings**. Items for preventive maintenance and inspection number greater than 150.

Table 5. Traffic Signal Inspection Items (Group B)

Inspection Item	Minnesota	Pennsylvania	Quebec	Utah	Columbus, Ohio
Foundation	X	X	X		X
Anchor rods	X	X	X		X
Transformer base		X	X		X
Pole	X	X	X	X	X
Pole foundation	X	X	X		X
Mast arm, upper	X	X	X	X	X
Mast arm, lower	X	X	X	X	X
Mast arm chord, upper connection	X	X	X		X
Mast arm chord, lower connection	X	X	X		X
Luminaire extension	X		X		X
Camera extension	X		X		X
Cabinet: hinges, vents, etc.		X		X	X
Cabinet electronics and electrical		X		X	X
Wiring		X		X	X
Pedestrian buttons		X		X	X
Signal operation (at cabinet)		X		X	X
Signal unit: cracks, damage, corrosion, etc.		X	X	X	X
Lamps/bulbs		X		X	X

Inspection Item	Minnesota	Pennsylvania	Quebec	Utah	Columbus, Ohio
Service voltage		X		X	
Other	X	X		X	

Inspections for Quebec entail 12 of the 19 items presented in the survey. Guidelines require that during preventive maintenance, crews must verify the operating condition of nonstructural inspection items; presumably service voltage, signal operation and other such items fall into these maintenance crew responsibilities. Depending on the type of structural support, inspections must be conducted every two to five years.

Utah DOT inspection frequency was not indicated. The respondent indicated that 11 of the 19 listed inspection items are routinely checked during inspections. Although the respondent did not indicate how frequently inspections are conducted, a number of the annual preventive maintenance items described above may be inspection items. Additional documentation on inspection items and frequency is described in **Detailed Findings**.

Columbus selected 18 of the 19 listed inspection items as part of its inspection routine. As noted above, inspections occur every year for MMUs and conflict monitors, and every four years for signal support structures.

Inspection Item Trends

Traffic signal inspection items common to most agencies included poles, a unanimous structural inspection item in Tables 4 and 5. Eight of nine agencies inspect signal unit hardware cracks, damage and corrosion routinely. Seven of nine agencies inspect anchor rods, pole foundations, mast arm lower sections, mast arm upper sections and signal operations at the cabinet. Two-thirds of agencies indicated that they routinely inspect signal structure foundations, mast arm upper chord connections, mast arm lower chord connections, cabinet electronics, wiring, pedestrian buttons, and lamps or bulbs.

Other Inspection Items

The MnDOT respondent described a number of additional inspection items to elaborate on its selection of "other" items. For more information on the updated MnDOT traffic signal support system inspection practices, see **Detailed Findings**. Pennsylvania and Utah DOTs have also expanded inspection activities to include an extensive number of "other" items which, in some cases, are tied to or conducted as preventive maintenance activities. For more on Pennsylvania DOT and Utah DOT traffic signal inspection items, see **Detailed Findings**.

Ohio DOT described some additional inspection items that it would add to this list of 19, including:

- Cracks.
- Corrosion.
- Reflective tape.

Inspection Tools

Of the 22 inspection procedures—nine traffic signal inspection approaches, five lighting inspection protocols and eight overhead sign support system inspection processes—that agencies conduct, all involve visual inspections from the ground, and 18 also include visual inspections from a raised bucket.

For traffic signal inspections, which every agency indicated it conducted or required, as shown in Table 6, all agencies included visual inspections from the ground, and all except Indiana DOT and Utah DOT also used buckets. Five agencies used acoustic testing methods, as well, and three also conducted some form of remote, operational testing.

Table 6. Inspection Tools and Methods

Agency	Traffic Signal	Roadway Lighting	Overhead Sign Supports
Minnesota	B, G	G	G
Illinois	A, B, G	A, B, G	A, B, G
Indiana	A, G, R	N/R	N/R
Ohio	B, G	B, G	B, G
Ontario	B, G, R	B, G	B, G
Pennsylvania	A, B, G	N/R	B, G
Quebec	A, B, G	A, B, G, M	B, G, H
Utah	G	N/R	B, G, U
Columbus, Ohio	A, B, G, R	N/R	B, G

Table Key:

A	Acoustic
B	Bucket (visual)
G	Ground (visual)
H	Harness, rope or gantry
M	Magnetic particle inspection
R	Remote
U	Unmanned aerial vehicle
N/R	No response

Frequency Trends

Inspection frequency ranged from six times per year to once every other year for Illinois DOT, which had the shortest inspection periods. Indiana and Pennsylvania DOTs conduct inspections two times each year, with some items in Pennsylvania DOT inspected once per year. Ohio DOT requires inspections once per year for traffic signal heads, and once every five years for supports. Ontario requires inspection once a year, Columbus once per

year for conflict monitor units and MMUs, and once every four years for signals. In Quebec, depending on the type of structural support, inspection cycles may range from two years to five. MnDOT and Utah DOT inspection frequencies were not provided.

Cost–Benefits and Replacement

Cost–benefits data proved rare. Minnesota will be developing cost–benefits information associated with traffic signal inspection, but only Ohio DOT has conducted any cost–benefits assessment related to these topics. The agency has determined the benefit-to-cost ratio for operational inspection of traffic signals is 45-to-1.

Most agencies responded with information on the standards or basis they use for replacement of traffic signals and the other roadway assets. Six agencies cited traffic signal support condition as a factor (Table 7). Five agencies identified age or service life as a potential basis for replacement; four agencies described proximity to intersection construction or roadwork, two agencies mentioned damage from accidents and one agency indicated performance as a factor.

Table 7. Replacement Factors

Agency	Traffic Signal	Roadway Lighting	Overhead Sign Supports
Minnesota	A, C, P	A, C, P	A, C, P
Illinois	N/R	N/R	N/R
Indiana	A, C, P	N/R	N/R
Ohio	A, C	C	C
Ontario	A, D, P	A, D, P	A, D, P
Pennsylvania	C	N/R	C
Quebec	C, P	C, D, P	C, P
Utah	N/R	N/R	P
Columbus, Ohio	A, C, D, pf	N/R	C, P

Table Key:

A	Age or service life
C	Condition
D	Damage from accident
P	Proximity to road or structural work
pf	Performance
N/R	No response

Roadway Lighting

Six of nine agencies provided information on preventive maintenance and inspection of roadway lighting structures. Four agencies described replacement standards, but no agencies shared cost–benefits information.

Preventive Maintenance

MnDOT does not keep preventive maintenance schedules for lighting structures, but relies on inspection results to trigger preventive maintenance activity. The MnDOT respondent did not indicate that it conducts any maintenance items presented in the survey (Table 8).

Table 8. Roadway Lighting Preventive Maintenance Items

Maintenance Item	Minnesota	Illinois	Ohio	Ontario	Pennsylvania	Quebec
Lubrication of cabinet hinges, locks, door						
Clean sensors			X			
Tighten bolts, anchor rods			X	X	X	X
Check and clean base plates		X		X	X	
Check and clean pole to base connections		X		X	X	
Group lamp/bulb replacement			X			X
Other	X	X				

Illinois DOT tied preventive maintenance activity to its inspection schedules and frequencies, and conducts two of the six preventive maintenance activities listed in the survey. The Illinois DOT respondent added two additional maintenance elements: breakaway devices and foundations.

Ohio DOT selected three of the six preventive maintenance items as part of an annual preventive maintenance routine. Ontario also indicated it routinely conducts three of the activities, sharing with Ohio only one item: tightening bolts and anchor rods. Ontario did not indicated frequency of maintenance activity.

Pennsylvania DOT routinely addresses the same items as Ontario in its preventive maintenance tasks; the agency did not indicate the frequency of these actions. Quebec conducts two of the three tasks that Ohio DOT included in its list; bolt tightening is conducted during structural inspections, and lamp replacement occurs every two to three years.

<u>Maintenance Item Trends</u>

Four of the six agencies that conduct preventive maintenance activities indicated tightening bolts and anchor rods was a routine maintenance item for their roadway lighting structures. Three of six indicated checking and cleaning connection of poles to bases was another standard maintenance item. Only two agencies indicated

group lamp replacement was a regular preventive action, and only one selected sensor cleaning. No agency indicated lubrication of cabinet hardware as a regular maintenance item.

Other Maintenance Items

Illinois DOT identified two additional preventive maintenance items in its selection of "other":

- Breakaway device.
- Foundation.

The respondent also noted a number of high-mast support items in the agency response on other preventive maintenance items, although these were described as "inspection" items that, presumably, may require maintenance at the time of inspection or at a scheduled time based on inspection. These details are described in **Other Inspection Items** below.

Frequency Trends

MnDOT, Illinois DOT and Quebec tied preventive maintenance activity to inspection schedules and their frequency. Only Ohio DOT described a regular schedule of preventive maintenance actions, which occur once a year for roadway lighting structures.

Inspection

Although roadway lighting inspection drives preventive maintenance activity for MnDOT, it is more loosely tied with preventive maintenance for Illinois DOT, Ohio DOT and Quebec. For Ontario and Pennsylvania DOT, the two facets of managing lighting remain more distinct.

MnDOT inspects four of the eight items or elements listed in the survey (Table 9).

Table 9. Roadway Lighting Inspection Items

Inspection Item	Minnesota	Illinois	Ohio	Ontario	Pennsylvania	Quebec
Foundation	X	X	X	X		X
Anchor rods	X	X		X	X	X
Base plates	X	X		X	X	X
Pole to base connections		X		X	X	X
Poles	X	X	X	X	X	X
Wiring		X	X	X		
Luminaire function		X	X	X		
Remote monitoring system						
Other	X	X				

MnDOT inspects high mast light poles once every five years, but only for structural condition. The agency is developing an inspection protocol for standard light poles that would entail a 10-year inspection cycle; the new approach would include more than 30 inspection and defect items in four categories that match the four inspection items selected in Table 9.

Illinois DOT and Ontario inspect the same seven items of the eight elements listed in the survey. Ohio inspects four of the elements on the list. Pennsylvania DOT inspects four elements, and Quebec inspects five of the listed lighting structure elements.

Inspection Item Trends

All six agencies that describe inspection of lighting structures inspect poles. Five agencies inspect foundations, anchor rods and base plates. MnDOT, Illinois DOT, Ontario and Quebec inspect all three items; Ohio inspects foundations, and Pennsylvania DOT inspects anchor rods and base plates.

Other Inspection Items

Illinois DOT, as mentioned in **Other Maintenance Items** above, includes a number of "other" lighting structure inspection items, including:

- High-mast padlocks.
- High-mast power cord caps.
- High-mast winch assemblies.
- High-mast lighting rings.
- High-mast hoist and support cables.
- High-mast turnbuckles.

Inspection Tools

Five agencies—MnDOT, Illinois DOT, Ohio DOT, Ontario and Quebec—described inspection methods and tools they deploy. All five conduct visual inspections from the ground. Four of these agencies, MnDOT excepted, also use buckets for visual inspections. Illinois DOT and Quebec also use acoustic equipment for examining lighting supports. Quebec was the only agency that, in any inspection practice, also deployed magnetic particle inspection methods on high mast supports that show defects.

Frequency Trends

Four agencies described lighting structure inspection cycles, and periods were one, three, five or 10 years. Minnesota inspects high mast lighting once every five years, and may soon begin inspecting standard lighting structures once every 10 years. Illinois inspects high mast poles over 55 feet tall once every three years and standard lighting poles once every five years. It also, however, lowers high mast heads once a year for inspection. Quebec requires inspection of lighting structures every three to five years, depending on the type of lighting structure.

Ohio did not directly answer the question about inspection frequency, but links inspection to preventive maintenance activity that is scheduled once a year for lighting structures.

Cost–Benefits and Replacement

No agency has determined cost–benefits associated with inspection of roadway lighting.

Four agencies—MnDOT, Ohio DOT, Ontario and Quebec—provided some detail on the standards they use for replacement of roadway lighting structures. MnDOT, Ohio and Quebec all consider structure condition in replacement decisions. MnDOT, Ontario and Quebec consider a lighting structure's proximity to nearby roadwork as an opportunity for replacement. Age or service life weighs in replacement decisions for MnDOT and Ontario, and damage from accidents impacts replacement decisions for both Ontario and Quebec.

Overhead Sign Supports

Six of nine surveyed agencies provided information about preventive maintenance, inspection and replacement standards for overhead sign support structures: MnDOT, Ohio DOT, Ontario, Pennsylvania DOT, Quebec and Columbus. Utah provided information about both preventive maintenance and replacement, and Illinois DOT provided inspection information.

Preventive Maintenance

MnDOT did not select any one of the three preventive maintenance items presented in the survey for overhead sign support structures, but indicated that it routinely has someone tighten "loose nuts on footing connections." MnDOT did not indicate how frequently it schedules this service.

Table 10 summarizes preventive maintenance activity. Ohio DOT selected two of the presented maintenance items as part of its maintenance routine, and Ontario, Pennsylvania DOT and Quebec selected all three.

Table 10. Overhead Sign Supports Preventive Maintenance Items

Maintenance Item	Minnesota	Ohio	Ontario	Pennsylvania	Quebec	Utah	Columbus, Ohio
Repair/clean foundation and base plate			X	X	X		
Tighten anchor rods		X	X	X	X		
Tighten or repair connections		X	X	X	X		
Other	X						X

Quebec recommends to its regional agencies that maintenance activities begin during structural inspections, which are required every two to four years, depending on the type of support structure and its condition. Utah does not conduct or schedule any routine preventive maintenance activity for overhead sign support structures. Columbus is developing maintenance items and schedules that will be tied to inspection results, but at the time of the survey, sufficient information on overhead sign support maintenance activity and frequency was unavailable.

Maintenance Item Trends

Of agencies that selected preventive maintenance items, all four tighten anchor rods, and tighten or repair connections. Three agencies repair or clean foundations and base plates.

Other Maintenance Items

While Columbus is developing a preventive maintenance item protocol that would expand upon the presented items here, only MnDOT's respondent had another item to add:

- Tighten loose nuts on footing connections.

Frequency Trends

Only Quebec shared frequency information, indicating preventive maintenance was conducted during inspections every two to four years, depending on the type of overhead sign support structure.

Inspection

Seven agencies selected inspection items that are part of their routine inspections of overhead sign support structures (Table 11). MnDOT inspects four of the five items; Illinois DOT, Ohio DOT, Ontario, Pennsylvania DOT, Quebec and Columbus inspect all five items. Additional inspection items in Quebec include reflective film, graffiti and "elements hiding message."

Table 11. Overhead Sign Supports Inspection Items

Inspection Item	Minnesota	Illinois	Ohio	Ontario	Pennsylvania	Quebec	Columbus, Ohio
Foundation	X	X	X	X	X	X	X
Anchorage	X	X	X	X	X	X	X
Post	X	X	X	X	X	X	X
Truss	X	X	X	X	X	X	X
Connections, panel to support		X	X	X	X	X	X
Other						X	

Inspection Item Trends

As noted above, six agencies conduct all five of the presented inspection items, and MnDOT conducts five.

Other Inspection Items

Quebec described additional overhead sign support structure inspection items that include:

- Reflective film.
- Graffiti.
- Elements that hide sign messages.

Inspection Tools

Eight agencies shared information on inspection methods (Table 6), including Utah DOT, which did not clarify the tasks involved or frequency of its inspections of overhead sign support structures. Indiana did not share any information about overhead sign support activities.

All eight agencies that conduct or require inspection of overhead sign support structures identified visual inspection from the ground as one method. Seven of these, MnDOT excepted, also deploy buckets for inspections of overhead sign supports. Illinois DOT also conducts acoustic testing during inspection; Quebec also uses harnesses, slings and ropes. Utah DOT uses UAVs in its inspections.

Frequency Trends

Three agencies described the frequency of inspection activities. Ohio DOT conducts inspections every five years. In Pennsylvania, overhead sign support structures are inspected during their first year of service and at varying periods, depending on materials involved; aluminum structures are inspected every two years and galvanized steel structures every two to six years, depending on the condition and age. Quebec examines overhead sign structures once every two to four years, depending on the structure type and condition.

Cost–Benefits and Replacement

No agency provided cost–benefits information on overhead sign support structure preventive maintenance or inspection practices.

Seven agencies described their standards for replacement of overhead sign support structures (Table 7). Five agencies indicated structure condition was a factor in these decisions. Five noted that proximity to road or other nearby work provided legitimate opportunities for replacement. Two indicated service life or age was a replacement standard they used, and Ontario included accident damage in its replacement calculus.

Related Research

A limited, preliminary literature review helped guide decisions on which states and provinces to survey, and citations from relevant documents found in this search were used to augment some of the survey findings described in **Detailed Findings**. Additional resources are presented in four categories: maintenance practices, inspection practices, service lives and replacement scheduling, and quantification of maintenance benefits.

Next Steps

Going forward, MnDOT may wish to consider:

- Following up with participating agencies that indicated their inspection or preventive maintenance practices were under review or development, including:
  - Ohio DOT's revisions to traffic signal inspection practices.
  - Pennsylvania DOT's revisions to preventive maintenance and inspection practices with all three asset types.
  - Utah DOT's work on overhead sign support asset management practices.
  - Columbus' new preventive maintenance program for overhead sign supports.
- Updating this analysis based on review and analysis of MnDOT's revisions to its asset inspection protocols.
- Gathering similar information from some of the recommended municipality contacts supplied by survey respondents.

Detailed Findings

Introduction

The MnDOT Asset Management Program and Office of Traffic Engineering are seeking information from state departments of transportation (DOTs) and other transportation agencies about the state of the practice in preventive maintenance and inspection strategies designed to extend the service life of traffic signal, roadway lighting and overhead sign support structures. MnDOT is particularly interested in information about the expected service lives of these roadway assets, preventive maintenance and inspection activities and schedules, cost–benefits associated with preventive maintenance strategies and criteria used to determine when these asset structures should be replaced.

This investigation relied on a survey of transportation agencies that share similar climatic and environmental challenges that are faced in Minnesota and agencies that emerged as leaders in this area during a preliminary literature review. Results from the limited literature review of state and national research on these practices and the quantification of the benefits of such practices have augmented some of the information gleaned from survey responses described in this section.

Survey of Practice

An online survey was distributed to selected members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Maintenance and a Federal Highway Administration (FHWA) Asset Management group; recommendations from a Technical Advisory Panel (TAP); and from a limited literature search. Of the 21 transportation agencies surveyed, nine participated in the survey:

- City of Columbus, Ohio.
- Illinois DOT.
- Indiana DOT.
- MnDOT.
- Ohio DOT.
- Ontario (Canada) Ministry of Transportation.
- Pennsylvania DOT.
- Quebec (Canada) Ministry of Transportation.
- Utah DOT.

Six of the nine agencies (Illinois, Minnesota, Ohio and Pennsylvania DOTs; Ontario Ministry of Transportation; and Quebec Ministry of Transportation) included details on preventive maintenance and inspection for traffic signals, roadway lighting and overhead sign support structures. Utah DOT and the City of Columbus provided details on traffic signals and overhead sign supports; Indiana DOT provided information on traffic signals only.

Survey questions are provided in Appendix A. The full text of survey responses is provided in a supplement to this report. Appendix B provides the contact information for survey respondents, as well as for other contacts recommended by respondents.

Summary of Survey Results

MnDOT typically expects longer service lives of its structures than do most of the agencies that participated in this survey. While Quebec expects 35 years of service from its traffic signal structures, MnDOT and several other states and provinces expect 30 years. For high mast lighting, MnDOT's expectation of 50 years of service exceeds

the service lives expected by other participating agencies. MnDOT's expectation of 60 years of service from overhead sign supports, a shift in newly developed standards from the previous expected life of 50 years, also exceeds the expectations of other participants.

MnDOT and Ohio and Pennsylvania DOTs take similar approaches to preventive maintenance and inspection of these assets, and all are revising their approaches. Agencies that participated in this study appear to have more detailed preventive maintenance and inspection protocols for traffic signal structural systems than for roadway lighting and overhead sign support systems. Inspection practices universally embraced visual surveys from the ground, and almost as universally included the use of crane or lift buckets. Acoustic tools were also commonly embraced in inspections.

Ohio associates a 45-to-1 benefit-to-cost ratio with inspections of traffic signals. This is the only cost–benefits data participating agencies shared. Asset replacement standards appeared more fully defined for traffic signals and overhead sign supports than for roadway lighting.

As with MnDOT, many agencies assign responsibility for management of these assets individually; a different representative often provided details on maintenance and inspection for each asset type described by a responding agency.

Survey responses from each agency are summarized below.

Minnesota Department of Transportation

Two MnDOT transportation officials responded to the survey, providing details on both preventive maintenance and inspection for each of the three roadway asset types. MnDOT also provided preventive maintenance and inspection forms and checklists. A new inspection protocol for most of these assets is under review.

Traffic Signals

Minnesota expects a 30-year service life from traffic signal structures within its system.

Preventive Maintenance

Preventive maintenance activity includes six of the 10 specific elements detailed in Table 2. Additional activities include checking line voltage, checking and replacing detectors, looking for damage on signal heads and hardware, conducting intersection walkthroughs and upgrading firmware as needed. Signal operators conduct preventive maintenance annually, electronic technicians conduct preventive maintenance every two years, and electricians every three years.

Minnesota Copy of Combined Signal PMs (Appendix C) describes annual items repaired or checked by signal operators, including 11 electronic items, five electrical items and 13 signal operations items. It identifies 20 electronic system items addressed every two years by electronic technicians and also identifies 10 electronic system items, eight electrical system items and three signal operations items addressed every three years by electricians.

Minnesota Operation Check Checklist (Appendix D), Minnesota Signal PM Procedure (Appendix E) and Minnesota PM Check Sheet with Component Inventory (Appendix F) describe procedures and checklists for electronic technicians and supervisors, as well as a checklist that addresses cabinets, intersection buttons and hardware, detection operation and cabinet condition activities and documentation.

Related Resources

Re-Tightening the Large Anchor Bolts of Support Structures for Signs and Luminaires, An Chen, Connor Schaeffer, Yinglong Zhang, Brent Phares, Behrouz Shafei, Mijia Yang, Zhibin Lin and Shree Paudel, Minnesota Department of Transportation, August 2018.
http://www.dot.state.mn.us/research/reports/2018/201827.pdf
Researchers studied maintenance needs for re-tightening anchor bolts on supports for overhead signs, high-mast light towers and tall traffic signals, and developed snug-tight values and the relationship of torque, tension and nut rotation with recommendations for specifications.

Related Resource:

Improved Specifications for Tightening Anchor Bolts on Signs, Luminaires and Traffic Signals, Minnesota Department of Transportation, October 2018.
www.dot.state.mn.us/research/TS/2018/201827TS.pdf
This two-page Technical Summary describes the findings from the research report.

Phase II: Re-Tightening the Large Anchor Rods of Support Structures for Signs and Luminaires, Minnesota Department of Transportation, start date: May 2019.
https://researchprojects.dot.state.mn.us/projectpages/pages/projectDetails.jsf?id=21939&type=CONTRACT&jftfdi=&jffi=projectDetails%3Fid%3D21939%26type%3DCONTRACT.
From the project page summary: With the to-be-obtained field performance data, this proposed Phase II project will refine the specifications, along with completing other needed research to complete the specifications with regard to snug-tight conditions, alternative bolt materials and sizes, grip lengths, continuing fatigue tests, collecting monitoring data, etc.

Inspection

Traffic signal inspections appear to be conducted by signal operators, electronic technicians and electricians, as well as by separate structural inspectors. It is not clear how frequently separate structural inspections will be conducted; MnDOT is establishing a new structural inspection program for traffic signals. New program goals will aim for inspections at least once every 10 years and more frequently if an inspection result suggests the need. Inspections are currently conducted visually from the ground, though the new program may add the use of craned buckets.

Inspection elements identified in the survey include 10 of the 19 elements presented, detailed in Table 4. A draft signal structure inspection sheet from 2019 (Appendix G) indicates structural inspections under consideration will evaluate foundations, anchor rods and washers, transformer bases, pole condition and damage, upper and lower masts and connections, and luminaire and camera extension conditions. The inspection form delineates 72 specific inspection and defect items. Inspectors must identify the presence or absence of defects, and describe dimensions, ratings, action items and more for defects in nine categories:

- Foundation defects, such as delamination of concrete, cracks and exposed reinforcement steel.
- Anchor rod damage, such as nut connection problems or thread engagement issues.
- Transformer base defects, including base plate corrosion, nuts and bolts corrosion, weld condition, cracking at base plates or in bolts, dents and gouges.
- Pole damage including corrosion or section loss in the base plate, cracks or fractures in base plates or stiffeners, welding racks, dents, pitting or corrosion in the pole itself, and bending and tilting.
- Upper mast arm straps and connectors.

- Lower mast arm straps and connectors.
- Upper mast arm chord connections for weld cracking, missing nuts and bolts, misalignment and contortion, pitting and more.
- Lower mast arm chord connections for the same defects.
- Luminaire and camera extensions for weld cracking in bases, missing or loose nuts and bolts, holes, corrosion pitting, and cracking.

Cost–Benefits and Replacement

MnDOT is establishing cost–benefit information for regular traffic signal structural inspections, and the agency hopes to extend traffic signal support system service lives from 30 years to 40 years.

Replacement schedules, as indicated in Table 7, are based on these service lives of 30 to 40 years, although each MnDOT district addresses signal replacements differently based on funding. Age, condition of signals and construction project proximity factor into decisions, though the new inspection may shape future replacement schedules.

Contact: Susan Zarling, Minnesota Department of Transportation, 651-234-7052, Susan.Zarling@state.mn.us.

Roadway Lighting

MnDOT expects 50 years of service from high-mast light poles and 30 years from standard lighting support poles.

Preventive Maintenance

Minnesota has no standard preventive maintenance schedule for lighting structures; preventive maintenance activity follows from inspection recommendations.

Inspection

Conducted visually from the ground, standard five-year inspections of high-mast light poles do not include electrical inspection. A structural inspection program is being developed to inspect standard lighting poles every 10 years, or more frequently if an inspection's results indicate the need.

High-mast supports are inspected visually from the ground and consider four of the eight lighting structure elements presented by the survey: poles, foundations, anchor rods and base plates. Minnesota Lighting Structure Inspection DraftF3 (Appendix H) indicates requirements and a checklist for the new standard lighting structure inspection guidelines under consideration.

The new inspection process under consideration breaks lighting structures into four categories of elements, with ratings, comments and action items to be indicated for 13 specific inspection items. For the same four categories, the form provides a checklist of defect items. For each of the 21 items in the four categories, inspectors must indicate whether the defect is present or not; describe its number and dimensions; and include comments, ratings and action items for each. These items include:

- Foundation defects, including corrosion of screws, cracks in concrete, reinforcement conditions and deformation.
- Anchor rod damage, nut connection issues, and rod thread engagement.
- Base and base plate condition, including corrosion, slip fitter presence, welds, cracking and displacement.

- Pole defects, including corrosion and section loss of base plates, cracks or fractures on the base plates, weld connections, bending or tilting, corrosion and pitting.

Cost–Benefits and Replacement

MnDOT did not provide information about cost–benefits associated with preventive maintenance and inspection practices pertaining to roadway lighting structures, but indicated that the agency generally considers replacement based on 30- to 40-year service lives it projects for standard lighting poles, or 50-plus years for high-mast supports. As with traffic signal structures, indicated in Table 7, individual MnDOT districts replace structures based on these service life terms, observed structural condition and proximity to nearby roadwork.

Contact: Susan Zarling, Minnesota Department of Transportation, 651-234-7052, Susan.Zarling@state.mn.us.

Overhead Sign Structures

Minnesota expects 50 years of service from its overhead sign structures. However, new design life standards may update this to 60 years.

Preventive Maintenance

The only routine preventive maintenance activity MnDOT performs with overhead sign structures is to tighten loose nuts on footing connections. No scheduling information was provided.

Inspection

MnDOT inspectors conduct visual surveys from the ground and focus on foundations, anchorage, posts and trusses. Inspection frequency was not indicated.

Appendix I provides MnDOT's draft inspection form for overhead sign structure inspections under consideration. The inspection form requires ratings and comments on 31 specific items in 11 element categories, as well as an indication of the presence or absence of each item, like washers on anchorages, cover plates on posts, spalling or vegetation growth in the foundation. The form also asks inspectors to indicate defects on specific elements, including size, ratings and repair actions. The categories and defect types include:

- Right foundation, with defects including concrete delamination, cracks in concrete, exposed repair, dents and damage. (This list is repeated in categories for left and center foundations.)
- Right anchor rods, including rod damage, nut connection problems and rod thread engagement issues. (This list is repeated in categories for left and center anchor rods.)
- Right post, with defects including stiffener weld cracks, section lost in base plates and posts, tilting, and impact damage. (This list is repeated in categories for left and center posts.)
- Truss, with defects such as broken members, missing or loose hardware, corrosion and weld cracks.
- Connection, panel to support, with defects such as missing hardware, connection corrosion loss, weld conditions and impact damage.

Cost–Benefits and Replacement

MnDOT did not describe cost–benefits associated with preventive maintenance and inspection of overhead sign structures. Replacement is based on age or years of service. At 50 years or if the structure is impacted in some way by another project and has less than two-thirds of its design life left, it may also be replaced. Condition ratings of poor or less will also trigger replacement. New standards may change this replacement schedule to 60 years if extruded panels show, upon inspection, that they will exceed their expectation of 50 years.

Contact: Josephine Tayse, Minnesota Department of Transportation, 651-234-7371, Josie.Tayse@state.mn.us.

City of Columbus, Ohio

A representative from the City of Columbus, Ohio, provided details on both preventive maintenance and inspection for traffic signals and overhead sign support structures. The only detail the respondent offered on roadway lighting was to note that its preventive maintenance and inspection of span wires is addressed in the same way it handles traffic signals. The survey respondent indicated willingness to share an inspection sheet for traffic signals and provided a copy of an inspection sheet used with overhead sign supports.

Traffic Signals

Columbus expects a 30-year service life from new traffic signal structures within its system, but expects fewer years of service from signal heads, span wires and more.

Preventive Maintenance

Columbus relies on an "extensive inspection process" that drives maintenance; each signal is inspected once every four years, and conflict monitor units and malfunction management unit (MMUs) are tested annually. Rebuilds and refurbishment are common; the city refurbishes about 20 signals a year with new wiring, work on signal heads, painting of poles or other upgrades. The agency fully rebuilds about five signals each year.

Routine preventive maintenance includes attention to eight of the 10 maintenance items presented in the survey, as shown in Table 3.

Inspection

The inspection process entails examination of 18 of the 19 listed inspection items in the survey and Table 5, above—every item except service voltage. Inspections include visual examination from the ground and from buckets, acoustic emissions testing and remote operational monitoring.

Cost–Benefits and Replacement

Columbus provided no answers to questions on cost-benefits associated with its inspection and preventive maintenance of traffic signals. On replacement of traffic signals, the respondent described the use of a rating system that weighs performance, years of service and signal condition in replacement decisions. The respondent added that crash data at intersections also informs rebuild decisions.

Contact: Ryan Lowe, City of Columbus, 614-645-8490, RJLowe@columbus.gov.

Overhead Sign Structures

Columbus expects 30 years of service from overhead sign support structures.

Preventive Maintenance

Columbus is developing maintenance items and schedules in a new preventive maintenance program. As with traffic signals, the program will rely on inspections to trigger preventive maintenance; inspections had not been sufficiently completed at the time the agency replied to the survey to indicate maintenance actions or frequency.

Inspection

Inspection of overhead sign structures begin with visual examinations from the ground, followed by use of a bucket when something of concern has been noted. Inspection items include all items detailed in Table 11.

The Columbus Ohio OSS Inspection Form (Appendix J) for these structures requires inspectors to rate structural conditions of foundations, anchor bolts, end frames and poles, cantilevers and spans, signs and protection barriers according to various qualities on a four-point scale (from 1 for poor to 4 for very good). The spreadsheet also requires repair recommendations rated from 1 as high priority to 3 as low priority.

Cost–Benefits and Replacement

The Columbus respondent provided no answers to questions on cost–benefits associated with its inspection and preventive maintenance of overhead sign supports. Replacement decisions will be based on condition assessments from inspections; typically, Columbus replaces overhead supports as part of capital projects.

Contact: Ryan Lowe, City of Columbus, 614-645-8490, RJLowe@columbus.gov.

Illinois Department of Transportation

One representative of Illinois DOT responded to the survey, providing details on both preventive maintenance and inspection for each of the three roadway asset types.

Traffic Signals

Illinois expects a 30-year service life from traffic signal structures within its system.

Preventive Maintenance

Preventive maintenance activity includes five of the 10 specific elements detailed in Table 2, above. In addition to the selected activities, comments identify two other operational maintenance items: communications to master controllers and conflict monitor/MMU testing.

Illinois DOT included a detailed list of preventive maintenance action items and scheduled maintenance and inspection periods or response timing:

- When reported or observed: signal alignment, controller problems, LED signal heads and module replacement (based on number of indicators failed, within 24 hours for red indicators, 48 hours for others), painting of components.
- Weekly items: master controller systems repair to maintain signal control and communication.
- Bimonthly items: cabinet inspection; observe signals; test and inspect detectors; inspect, maintain and clean video detection systems; controller check, including removal and repair, and software check; fuse and breaker checks.
- Annual items: signal head visibility, removal and pruning of obstructions; hardware inspection, including mast arm assemblies, poles, brackets, traffic and pedestrian signal heads, and “close-up arm’s length investigation of the mast arm, pole, mast to pole connection, base plate, and anchor bolts”; visual inspection of connections for defects, cracks, corrosion, weld condition and more.
- Biannual items: conflict monitors and MMUs, with replacement of failed units.

Inspection

Traffic signal inspection methods include ultrasound testing as well as visual inspection from the ground and from buckets. Inspection elements identified in the survey included nine of the 19 elements presented, detailed in Table 4. The agency did not include information on inspection schedules aside from the periods noted in its preventive maintenance description in the preceding section, which included bimonthly, annual and biannual items for inspection.

Cost–Benefits and Replacement

Illinois DOT provided no answers to survey questions on cost–benefits and replacement standards for traffic signal support structures.

Contact: Kyle Armstrong, Illinois Department of Transportation, 217-782-2076, Kyle.Armstrong@illinois.gov.

Roadway Lighting

Illinois DOT expects 30 to 40 years of service from roadway lighting structures.

Preventive Maintenance

Illinois DOT described its inspection period requirements, suggesting maintenance functions as a response to needs identified by inspectors. The agency inspects high mast towers every three years, poles of 55 feet or shorter every five years, but high mast lighting heads annually by lowering heads for examination.

In addition to checking and cleaning base plates and pole to base connections, preventive maintenance also includes checking breakaway devices and foundations.

Inspection

Inspections entail ultrasound testing and visual examinations from the ground and from buckets. Specific inspection items included seven of the eight items presented in the survey, as presented in Table 9.

High-mast pole inspection includes padlocks, power cord caps, winch assemblies, lighting rings, hoist and support cables, and turnbuckles.

Related Resource

"Structural Health Monitoring of High Mast Light Towers Using Acoustic Emission," Alireza Farhidzadeh, Mark R. Jenkins, Richard L. Reichenbach, Richard S. Gostautus and Terry A. Tamutus, *TRB 96th Annual Meeting Compendium of Papers*, Paper #17-05235, 2017.
Citation at https://trid.trb.org/view/1439056
From the abstract: In addition to the mechanics of luminaire inspection, HMLTs [high-mast light towers] are subject to dynamic wind loading and differential thermal expansion which causes the structures to sway and bend. … This presents a safety risk to the traveling public and maintenance personnel with the potential for severe damage to vehicles, property or even grave injury. In 2014 Illinois Department of Transportation (IDOT) started investigating cost-effective technologies for accurately detecting and locating the early stages of crack initiation and propagation. Acoustic emission (AE) showed promise as it offered a non-intrusive, quick and reliable alternative to current inspection procedures. … [A]dditional research was conducted on several HMLTs supplied by the Pennsylvania Department of Transportation (PennDOT).

Cost–Benefits and Replacement

Illinois DOT's response included no answers on questions of replacement standards and cost–benefits associated with preventive maintenance and inspection of lighting structures.

Contact: Kyle Armstrong, Illinois Department of Transportation, 217-782-2076, Kyle.Armstrong@illinois.gov.

Overhead Sign Supports

Illinois expects 30 to 40 years of service from its overhead sign support structures.

Preventive Maintenance

The agency did not provide information about preventive maintenance of overhead sign support structures.

Inspection

Inspections may include ultrasound testing and visual inspection from the ground or from a bucket. Scheduling periods were not provided, but Illinois DOT inspects each of the five items listed in the survey for overhead sign support inspections, as indicated in Table 11.

Cost–Benefits and Replacement

Illinois DOT did not respond to survey questions pertaining to replacement standards and cost–benefits associated with preventive maintenance and inspection of overhead sign support structures.

Contact: Kyle Armstrong, Illinois Department of Transportation, 217-782-2076, Kyle.Armstrong@illinois.gov.

Indiana Department of Transportation

Indiana DOT provided details on preventive maintenance and inspection of traffic signal structures.

Traffic Signals

Indiana DOT expects traffic signal poles to provide a service life of 25 years, cabinets a life of 15 years and controllers from five to 10 years.

Preventive Maintenance

Preventive maintenance activities appear to be conducted in response to inspection findings. Routine activities include four of the 10 maintenance items detailed in the survey and in Table 2, above.

Inspection

Traffic signal inspections include visual examinations from the ground and remote operational monitoring. Indiana DOT conducts at least two routine inspections at each intersection every year. Technicians clean, visually inspect and conduct routine repairs in these semiannual visits. Staff evaluates signal timing with remote monitoring; the agency is adding the capacity to notify technicians of hardware problems to remote monitoring.

Remote monitoring methods include ultrasound testing as well as visual inspection from the ground and from buckets. Inspection elements identified in the survey included nine of the 19 elements presented, detailed in Table 4, above.

Cost–Benefits and Replacement

The agency identified as a cost–benefit associated with both preventive maintenance and inspection activities for traffic signal structural supports “visual inspection when scheduled maintenance activities are performed.” “Checking for failed detector amplifiers to improve efficiency” was also cited as a cost–benefit associated with inspection of traffic signal electronics.

Decisions to replace signal structures are judgment-based on the age of the structure, its condition and any improvements required for the intersection itself.

Contact: Ed Cox, Indiana Department of Transportation, 317-899-8601, ECox@indot.in.gov.

Ohio Department of Transportation

Three transportation officials from Ohio responded to the survey, providing details on both preventive maintenance and inspection for each of the three roadway asset types. Ohio DOT also provided inspection forms and checklists.

Traffic Signals

Ohio expects a 30-year service life of the traffic signal structures in its system.

Preventive Maintenance

Preventive maintenance activity includes nine of the 10 specific elements detailed in Table 2, above; Ohio DOT selected more of the presented activities than any other agency. In addition to the activities conducted by MnDOT, Ohio DOT upgrades controller firmware, checks and adjusts detection zone alignment, and cleans sensors.

In response to a question about preventive maintenance scheduling of structural and electrical elements, the Ohio DOT respondent referred to inspection schedules, suggesting preventive maintenance may be contingent on inspection results.

Inspection

Inspection schedules evidently identify necessary preventive maintenance activity. Signal supports are inspected at least once every five years. New supports are inspected when constructed and signals are inspected annually. Inspections are conducted visually from the ground and from craned buckets.

Inspection elements include 12 of the 19 listed elements in the survey, detailed in Table 4, above. Inspectors also look for cracks and corrosion, and inspect reflective tape on the structures. Inspection forms include Ohio TEM 496-1 Form_Signal Support Inspection (Appendix K), Ohio TEM 496-7 Form_Signal Inspection (Appendix L) and Ohio Traffic Signal Final Inspection Form (2019 Spec) Revised-05-01-2019_Checklist (Appendix M). (It is not clear whether the 2019 revision replaces one or both of the two inspection forms; this may warrant further investigation with Ohio DOT.)

Support inspection includes foundation concrete, anchor bolts and nuts, and soil conditions. The Inspection form for supports note materials characteristics such as galvanized elements, paint or wood materials; requires inspection of structural members, structural connections and down guys; and asks inspectors to identify damage and pitting, respectively, and classify surface rust as minimal, moderate or severe.

The signal inspection form asks inspectors to categorize condition as satisfactory, unsatisfactory, N/A or repaired for each of the following eight element categories:

- Traffic signal head, including alignment, re-lamping dates, clearance measurements, and cleanliness and condition of lenses, lamp orientation, visor condition, individual lamp operation, flashing performance, detection performance, water leaks and water leakage.
- Overhead signal support system, including messenger wires inspected for rust, grips, clamps, tightness of pole clamp bolts, wiring, clamp assemblies and pins, lashing rods and signal cables.
- Controller and cabinet, including 19 subcategories, including intersection documentation, all detector operations, wires and cables, cabinet seals, lock conditions, cabinet lamps and filters, wire terminals, load switches, grounds, lighting arresters, and hinge lubrication.

- Signal strain and wood poles in seven subcategories, including tightness of anchor bolts, presence of hand hole covers, grounding, pole caps, foundations, down guys and wooden pole condition.
- Power service condition, including weather heads, wiring chaffing, splicing, switch and meter boxes.
- Loop detectors and sealant, including crack fillers, exposed wires and pavement cracking.
- Pedestrian operation, including signal head alignment and operation.
- Pull boxes (if all have been located, if they all retain their lids, drainage, labeling of wiring, wiring and conduit condition, seals and markings).

The recently revised signal inspection checklist includes items to be marked as meets, deficient or N/A with respect to requirements, and expands its checklist to include 185 items in the following categories:

- Warranties, with two items.
- Controller and cabinet, including 25 inspection items.
- Cabinet, with one item.
- Operational checks, including 13 items.
- Radar detection, including 12 items.
- UPS, including three items.
- UPS operational checks, including four items.
- Loop detectors, including seven items.
- Trenching, including four items.
- Batteries, including five items.
- Supports, including 16 items.
- Pedestrian signals and ADA information, including 19 items.
- Mast arms and signal cables, including three items.
- Span wire and signal cables, including nine items.
- Signal heads, including 19 items.
- Pull boxes, including 20 items.
- Tether and back plates, including 23 items.

Related Resources

Evaluation of Overhead Support Inspection Program, Richard Gostautas, Douglas Nims, Eric Steinberg, Liangbo Hu and Ken Walsh, Ohio Department of Transportation, 2015.
http://worldcat.org/webharvest/h1426860694480/viewonline
From the abstract:

> This study evaluated the adequacy and frequency of the current structural support inspection program for overhead sign supports (including bridge mounted), mast arm signal supports and high mast light supports. While Ohio Department of Transportation (ODOT) provides statewide guidance to all 12 districts with regards to support inspection, each district may implement different procedures to meet the needs of the representative district, as along as state requirements are met. To assess the current program, a detailed, hands-on inspection was conducted on 202 supports. These results were then compared to the previous ODOT inspection results which use a ground based, visual inspection process with sounding of the anchor bolts by hammer. The hands-on inspection process found almost 1.87 times more deficiencies.

Investigators describe the field inspection program in Chapter 4 (starting on page 29 of the report, page 41 of the PDF). They describe findings of overhead sign support inspections in Chapter 5 (starting on page 40 of the

report, page 52 of the PDF); high mast light supports in Chapter 6 (starting on page 71 of the report, page 83 of the PDF); and traffic signal supports in Chapter 7 (starting on page 78 of the report, page 90 of the PDF).

"Field Study of Ohio's Structural Support Inspection Program for Overhead Signs, Traffic Signals and High-Mast Lights," Hamed Ghaedi, Douglas Nims, Richard Gostautas, Eric Steinberg, Liangbo Hu and Kenneth Walsh, *2550 Transportation Research Record*, pages 15-21, 2016.
Citation at https://trid.trb.org/view/1392459
From the abstract: The Ohio Department of Transportation (DOT) undertook a field study to evaluate its overall structural inspection programs for overhead sign supports (including those mounted on bridges), high-mast light supports, and traffic signal supports. This paper describes the Ohio DOT's current support inspection program, the field study performed and the recommendations that resulted from the field study. This research evaluated the adequacy and frequency of the current structural support inspection program for the studied supports. To assess the current program, a detailed, hands-on inspection was conducted on 202 supports. The results were then compared with the Ohio DOT's current ground-based, visual inspection process. The hands-on inspection process found almost 87% more deficiencies; some deficiencies detected during the hands-on inspections could not have been observed from the ground. In addition, the different inspection procedures used by each district often produced inspection reports that varied in the amount of information and level of details collected during inspection. Recommendations were made to address the inventory process and inspection procedures for each type of support. A long-term goal should be to establish the current structural adequacy of every support in the Ohio DOT's inventory at the time of inspection.

Cost–Benefits and Replacement

Ohio indicated a benefit-to-cost ratio of 45-to-1 for traffic signal operation inspection. Support structure replacements are made on the basis of the 30-year expected service life and deterioration condition.

Contact: Charlie Fisher, Ohio Department of Transportation, 614-644-0270, Charles.Fisher@dot.ohio.gov.

Roadway Lighting

Masts, poles and structures for roadway lighting are expected to serve for 50 years.

Preventive Maintenance

Preventive maintenance is conducted annually for lighting structures and includes three of the six specific activities presented in the survey: tightening of bolts and anchor rods, group replacement of lamps, and cleaning of sensors.

Inspection

Inspections are conducted visually from the ground and from a bucket, and evaluation is conducted on poles, foundations, wiring and luminaire function. Frequency of inspection was not indicated; presumably, it occurs during annual preventive maintenance activity.

Cost–Benefits and Replacement

Ohio DOT associates no specific cost–benefits with lighting preventive maintenance or inspection activity. The agency's basis for replacing lighting is deterioration of a structure's condition.

Contact: Kevin Duemmel, Ohio Department of Transportation, 614-728-2450, Kevin.Duemmel@dot.ohio.gov.

Overhead Sign Structures

Ohio expects 50 years of service from its overhead sign structures.

Preventive Maintenance

Routine preventive maintenance activity entails tightening or repairing of connections, and tightening of anchor rods, though not on any schedule specified in the response.

Inspection

Inspections are conducted visually from the ground and from buckets, in intervals of at least five years. Foundations, anchorage, posts, trusses and connections of panels to the support structure are evaluated. Field inspectors evaluate the condition of concrete foundations, anchor bolts and nuts, and soil (Appendix N). End frames and poles are inspected in terms of the members and the connections, damage and pitting must be identified, and surface rust categorized as minimal, moderate or severe. Inspectors evaluate cantilever or span members and connections, sign attachments and attachments to frames or poles, identify damage and pitting, and again classify surface rust as minimal, moderate or severe. Structural components are also listed, with inspectors required to indicate whether the unit is fluorescent or one of two types of mercury vapor, and whether the bracket requires repair.

Cost–Benefits and Replacement

Ohio indicated it has not associated any costs–benefits with preventive maintenance and inspection of overhead sign structures, and replacement is made on the basis of deteriorated condition.

Contact: Kevin Duemmel, Ohio Department of Transportation, 614-728-2450, Kevin.Duemmel@dot.ohio.gov.

Ontario Ministry of Transportation

Ontario Ministry of Transportation (MTO) provided answers and details on both preventive maintenance and inspection for each of the three roadway asset types.

Traffic Signals

Ontario MTO indicated specific service life expectations for five components of traffic signal systems:

- LED signal modules: five years.
- Electronics and communications equipment: seven years.
- Signal heads: 10 years.
- Hangars and support structures, cabinets and distribution equipment: 20 years.
- Mast arms, poles and underground “plant”: 30 years.

Preventive Maintenance

Preventive maintenance activity includes seven of the 10 items presented in the survey, as shown in Table 2, above. The respondent notes that maintenance standard specifications require inspection and reporting once per calendar year.

Inspection

Most traffic signal controllers can be accessed remotely for operational monitoring. In addition to remote inspection, traffic signal structures are evaluated visually from the ground and from buckets. While inspection

frequency or scheduling was not described, the maintenance requirement of annual reporting on signal condition presumably covers inspection.

Ontario MTO inspection requirements include investigation of 18 of the 19 suggested inspection items, as shown in Table 4, omitting only transformer bases from its selections.

Cost–Benefits and Replacement

Cost–benefit data was not available for any preventive maintenance or inspection practices with traffic signals. Replacement is based on item life expectancy, damage from accidents and proximity to "major capital work."

Contact: Ousama Shebeeb, Ontario Ministry of Transportation, 1-289-219-2514, Ousama.Shebeeb@ontario.ca.

Roadway Lighting

Ontario MTO expects 30 to 40 years of service from roadway lighting poles, mast arms and underground plants.

Preventive Maintenance

Although the agency did not indicate the frequency of its preventive maintenance activities for roadway lighting, it tightens bolts and anchor rods, checks and cleans base plates, and checks and cleans pole-to-base connections.

Inspection

Inspections of lighting structures in Ontario are conducted visually from the ground and from buckets, although at what frequency MTO did not indicate. Inspection items, as indicated in Table 1, include all hardware inspection items, as well as luminaire function, but not remotely monitored operation.

Cost–Benefits and Replacement

Ontario MTO did not provide information on cost–benefits associated with various preventive maintenance and inspection activities for lighting structures. Replacement standards rely upon life expectancies for the asset, accident damage and proximity to major work.

Contact: Ousama Shebeeb, Ontario Ministry of Transportation, 289-219-2514, Ousama.Shebeeb@ontario.ca.

Overhead Sign Structures

Ontario MTO did not indicate service life expectations for overhead sign support structures.

Preventive Maintenance

The agency conducts each of the three overhead sign structure preventive maintenance actions presented in the survey, as indicated in Table 10, though MTO did not indicate how frequently this maintenance is done.

Inspection

Overhead sign support inspection in Ontario is conducted visually from the ground and from buckets, and entails each of the inspection items presented in the survey. MTO did not indicate the frequency of inspections.

Cost–Benefits and Replacement

MTO indicated it has no information available on cost–benefits associated with various preventive maintenance and inspection activities for overhead sign support structures. Replacement standards rely upon life expectancies for the asset, accident damage and proximity to adjacent major work.

Contact: Ousama Shebeeb, Ontario Ministry of Transportation, 289-219-2514, Ousama.Shebeeb@ontario.ca.

Pennsylvania Department of Transportation

Three transportation officials from Pennsylvania DOT responded to the survey, providing details on both preventive maintenance and inspection for each of the three roadway asset types. The agency sent supporting documents on preventive maintenance and inspection and indicated that it currently is revising its practices, including some documentation of new procedures, which are described below.

Traffic Signals

Pennsylvania DOT expects a 25-year service life from traffic signal structures within the state but does not own or maintain traffic signals. The agency provides municipalities with permits, the issuance of which requires municipalities to follow maintenance guidelines published by Pennsylvania DOT that were developed based on 20-year service life expectations. The agency's 2010 Traffic Signal Maintenance Manual (Publication 191, http://www.dot.state.pa.us/public/PubsForms/Publications/PUB%20191.pdf) is under revision; Appendix O provides a draft of the revised manual, which is referred to as Publication 191 (2020) throughout this section of this report.

Preventive Maintenance

Preventive maintenance activity includes nine of the 10 specific elements detailed in Table 3. Some support structure maintenance items are addressed every six months, some every 12. For the 2010 version of the Traffic Signal Maintenance Manual maintenance activities are captured in a preventive maintenance checklist, Form TE-973 (http://www.dot.state.pa.us/public/PubsForms/Forms/TE-973.pdf). The revised preventive maintenance approach includes a list of activities in Exhibit 5-1, Preventative Maintenance—Supports, on page 5-2 (page 32 of the PDF) of Publication 191 (2020). Items in the revised approach include:

- In the general category, 24 items, like checking paint or corrosion, repairing paint, verifying visually that nuts are tight and corrosion-free, pole plumbness checking and adjusting, inspection of welds and more. One item—paint repairs—is done as required. Six items fall into the six-month maintenance column, and 17 into the 12-month list.
- Another six items are listed in a category for mast arm supports, like inspecting horizontal and vertical angles of arms and poles, verifying washers in place, checking for cracks in base plates, and in welded connections; all are checked every 12 months.
- In strain pole supports, the five items, including checking for cracks in the shaft or base plate connection, bonding of span wires and visually inspecting tether wires, are also scheduled in 12-month intervals.

Controller assemblies are subject to preventive maintenance activities described in Publication 191 (2020) on page 5-4 (page 34 of the PDF) in Exhibit 5-2, Preventative Maintenance—Controller Assembly. The list includes:

- 34 items in the general category, with eight in the six-month activity column, 24 in the 12-month interval, and two in the "as required" column, although one of those is an operations review conducted every three to five years.

- Under Conflict Monitor Unit, two items in the six-month preventive maintenance interval, and three in the 12-month interval.
- Under Controller Unit (Electromechanical), three items at six months, and one at 12.
- In the category of Controller Unit, five items at six months, five more at 12, and controller firmware upgrades as required.

Publication 191 (2020) lists Electrical Distribution activities in Exhibit 5-4, Preventative Maintenance—Electrical Distribution, on page 5-7 (page 37 of the PDF). Breakdowns of items fall into five categories:

- In the general category, six items are addressed at six-month intervals, and seven more fall into the 12-month maintenance interval.
- In grounding and bonding, four items fall into six-month activities, and two into 12-month intervals.
- In junction boxes and conduits, eight items must be addressed at the 12-month maintenance interval, and three more as required.
- In emergency generator connection, four items fall into the 12-month interval.
- In uninterruptible power supply (battery back-up), two items must be addressed every six months, and eight additional items every 12 months.

Similar sections of Chapter 5 of Publication 191 (2020), with checklists, form requirements and charts address other asset element categories for traffic signals, including:

- Systems and communications, Exhibit 5-3, Preventative Maintenance—Systems and Communications on page 5-6 (page 36 of the PDF).
- Signal heads, Exhibit 5-5, Preventative Maintenance—Signal Heads on page 5-9 (page 39 of the PDF).
- Detectors, Exhibit 5-6, Preventative Maintenance—Detectors on page 5-11 (page 41 of the PDF).
- Advanced traffic signal technology, Exhibit 5-7, Preventative Maintenance—Advanced Traffic Signal Technology on page 5-13 (page 43 of the PDF).
- Signs and pavement markings, Exhibit 5-8, Preventative Maintenance—Signs and Pavement Markings on page 5-15 (page 45 of the PDF).
- Time clock flashing warning devices, Exhibit 5-9, Preventative Maintenance—Time Clock Flashing Warning Devices on page 5-16 (page 46 of the PDF).

Inspection

Traffic signal inspection practices also fall into the traffic signal preventive maintenance guidelines of Publication 191 (2010). Inspection items appear to be included in the preventive maintenance activities conducted at six-month and 12-month intervals.

Inspection includes 17 of the 19 inspection items presented in the survey, every item except luminaire extensions and camera extensions, as noted in Table 5. Publication 191 (2010) does not explicitly address traffic signal luminaires and only mentions cameras as being used in detection systems. Video cameras are considered one of three possible technologies, with radar and infrared, for detectors in Publication 191 (2020), and maintenance and inspection items are listed as noted above in Exhibit 5-6 on page 5-11 (page 41 of the PDF). Publication 191 (2020) only mentions luminaires as a single, 12-month interval inspection item in Exhibit 5-1, page 5-2 (page 33 of the PDF), under the general category of traffic signal supports.

Inspectors conduct visual inspections from the ground and from buckets, and use acoustic emissions methods for certain inspection items.

Related Resources

Traffic Signal Maintenance for the 21st Century in Pennsylvania, Steve Gault, Pennsylvania Department of Transportation, 2020.
See Appendix P.
The presentation focuses on preventive maintenance in slides 11-13, including inspection elements and technologies. Response maintenance is touched upon in slide 14 and the Pennsylvania DOT Traffic Signal Asset Management System (TSAMS) in slides 19-28.

Traffic Signal Portal, Pennsylvania Department of Transportation, July 28, 2020.
http://www.dot.state.pa.us/Portal%20Information/Traffic%20Signal%20Portal/Index.html
This web portal includes links to information and documents, including TSAMS information and approved product list bulletins.

Cost-Benefits and Replacement

Pennsylvania DOT has no available data on preventive maintenance and inspection activities related to traffic signal supports, electronics and operations. The agency also does not have a quantifiable standard or basis for replacement of signal support structures, except as shown in Table 7, for visible dents in vertical poles, a condition that warrants consideration of replacement.

Contact: Steve Gault, Pennsylvania Department of Transportation, 717-787-6988, sgault@pa.gov.

Roadway Lighting

Masts, poles and other structures supporting roadway lighting are expected to provide a 25-year service life.

Preventive Maintenance

Routine preventive maintenance activities include: tightening bolts and anchor rods, checking and cleaning base plates, and checking and cleaning pole-to-base connections. Schedules for such activity were not described.

Inspection

Inspection schedules were also not described. Four inspection items are routinely checked by Pennsylvania DOT lighting inspectors: poles, anchor rods, base plates and pole-to-base connections. Inspection tools or methods were not described.

Related Resource

"Structural Health Monitoring of High Mast Light Towers Using Acoustic Emission," Alireza Farhidzadeh, Mark R. Jenkins, Richard L. Reichenbach, Richard S. Gostautus and Terry A. Tamutus, *TRB 96th Annual Meeting Compendium of Papers*, Paper #17-05235, 2017.
Citation at https://trid.trb.org/view/1439056
From the abstract: In addition to the mechanics of luminaire inspection, HMLTs [high-mast light towers] are subject to dynamic wind loading and differential thermal expansion which causes the structures to sway and bend. … This presents a safety risk to the traveling public and maintenance personnel with the potential for severe damage to vehicles, property or even grave injury. In 2014 Illinois Department of Transportation (IDOT) started investigating cost-effective technologies for accurately detecting and locating the early stages of crack initiation and propagation. Acoustic emission (AE) showed promise as it offered a non-intrusive, quick and reliable alternative to current inspection procedures. … [A]dditional research was conducted on several HMLTs supplied by the Pennsylvania Department of Transportation (PennDOT).

Cost-Benefits and Replacement

The Pennsylvania DOT respondent did not indicate any cost–benefits associated to roadway lighting preventive maintenance and inspection practices, and did not indicate any basis or standard used for replacement strategies or scheduling.

Contact: Tim Carre, Pennsylvania Department of Transportation, 717-214-8727, TRCarre@pa.gov.

Overhead Sign Structures

Pennsylvania DOT expects 50 years of service from overhead sign support structures.

Preventive Maintenance

Pennsylvania DOT did not provide information about scheduling preventive maintenance of these structures, but indicated it routinely repairs or cleans foundations and base plates, tightens anchor rods, and tightens or repairs connections.

Inspection

Pennsylvania DOT visually inspects overhead sign support structures from the ground and from crane buckets and includes all five listed items in the survey and Table 11.

The agency's Bridge Safety Inspection Manual governs inspection procedures and frequency (https://www.dot.state.pa.us/public/PubsForms/Publications/PUB%20238.pdf). Sign structure inspection details are described in Section 2.11, Sign Structure Safety Inspections (beginning on page 93 of the PDF). Frequencies of inspection vary with sign material types, with two years a typical interval for aluminum overhead signs, and two to six years for galvanized steel overhead signs, depending on its assessed condition and age. All are inspected the first year after service, and then in the appropriate interval afterward (see Tables IP 2.11.3-1 and 2.11.3-2, beginning on page 94 of the PDF).

Cost-Benefits and Replacement

Pennsylvania DOT has not conducted cost–benefit analysis of overhead sign structure preventive maintenance activities, and described replacement standards as based on structure condition. If the support structure is in poor condition, it is replaced.

Contact: Tyler Culhane, Pennsylvania Department of Transportation, 717-787-7505, TCulhane@pa.gov.

Quebec Ministry of Transportation

Quebec Ministry of Transportation (MTQ) provided information about both preventive maintenance and inspection for each of the three roadway asset types.

Traffic Signals

MTQ expects 35 years of service from traffic signal support systems, though accident damage may impact the expectation. The network still features some structures installed as long ago as the 1960s.

Preventive Maintenance

MTQ routinely tightens bolts and anchor rods as a preventive maintenance activity. However, the agency recommends it be conducted during structural inspection. For the other nine maintenance items presented in the survey, the agency does not maintain general guidelines or schedules for preventive maintenance of traffic

signals that would be issued from a central office; territorial directors manage these activities without central directive.

Inspection

While MTQ relies on preventive maintenance to verify the condition of nonstructural elements of traffic signals, it issues guidelines for inspection of structural elements. Inspection, conducted visually from the ground and from buckets, entails 12 of the 19 items presented in Table 5. Inspection tools may also include ultrasonic testing of residual thickness of poles.

Inspection schedules call for examination every two to five years, depending on the structural support type. Guidelines are detailed in a French-only publication, "Manuel d'inspection des systèmes électrotechniques et des structures de signalization," which was not provided and may not be available electronically.

Cost–Benefits and Replacement

MTQ did not include cost-benefits associated with preventive maintenance and inspection activities for traffic signal structures. Replacement decisions are based on conditions that entail structural "defects that could present a risk to roadway users," as well as upon intersection replanning or geometric changes.

Contact: François Marchand, Quebec Ministry of Tranportation, 418-643-0800, ext. 23082, Francois.Marchand@transports.gouv.qc.ca.

Roadway Lighting

For standard roadway lighting structures, MTQ expects the same service lives as it does of traffic signals: 35 years in the absence of accidents. As with signals, it still maintains structures installed since the 1960s. Expectancies for high mast structures differ "because the vast majority have been installed after 1999."

Preventive Maintenance

MTQ's preventive maintenance approach to of roadway lighting is much the same as its approach to traffic signals. It recommends routinely tightening bolts and anchor rods as a preventive maintenance activity during structural inspection, and otherwise issues no general guidelines or scheduling directives, instead deferring preventive maintenance decisions to territorial authorities.

However, as shown in Table 8, group lamp/bulb replacements are routine. Territories report that they typically replace lamps and bulbs every two to three years.

Inspection

As with traffic signal inspection, MTQ relies on preventive maintenance activity to verify the integrity of nonstructural components of lights, but issues guidelines for structural inspection of standard and high mast roadway lighting structures. Inspection can be conducted visually from the ground and from buckets, and may include ultrasonic testing on poles, as well as magnetic particle inspection on high mast lighting structures on which defects have been observed. Mechanical systems do not need to be engaged—that is, mobile heads need not be lowered—during inspection of high masts. MTQ recommends territorial inspectors shut down electrical systems during structural inspections.

Otherwise, inspections entail five of the eight items listed in the survey for inspection, as shown on Table 9. Inspection guidance is detailed in the same French-only manual cited for traffic signal inspection above. Depending on the structure type, inspections must be conducted every three to five years.

Cost–Benefits and Replacement

MTQ did not include an answer to questions about cost–benefits associated with preventive maintenance and inspection activities for roadway lighting. Similar to its positions on traffic signal structure replacement, the agency bases replacement decisions on conditions showing structural defects that could present a risk for roadway users, as well as upon accidents and work to replan or enlarge roadways.

Contact: François Marchand, Quebec Ministry of Transportation, 418-643-0800, ext. 23082, Francois.Marchand@transports.gouv.qc.ca.

Overhead Sign Structures

MTQ service expectations for overhead signs support systems duplicate the 35-years expected of traffic signal and roadway lighting not subject to accidents, and also includes structures built since the 1960s.

Preventive Maintenance

MTQ recommends that preventive maintenance activities take place during structural inspections. Activities include each of the three items listed in Table 10.

Inspection

Detailed guidelines for inspection overhead sign support structures again can be found in the French-only manual cited above. Inspections will be conducted every two to four years, depending on the condition of structural elements and support types. Inspection items include the five detailed in Table 11, as well as reflective film, graffiti and elements hiding sign messages. Inspections may be conducted visually from the ground or from buckets, and may entail use of climbing harnesses, slings and ropes on trusses, and even gantries to ensure no obstruction of traffic.

Cost–Benefits and Replacement

MTQ provided no information on cost–benefits associated with various preventive maintenance and inspection activities for overhead sign support structures. To determine replacement, the agency relies on standards that include structural defects presenting risks to roadway users, as well as upon road replanning, geometric changes, new exits and sign replacement.

Contact: François Marchand, Quebec Ministry of Transportation, 418-643-0800, ext. 23082, Francois.Marchand@transports.gouv.qc.ca.

Utah Department of Transportation

Respondents from the Utah DOT provided details on preventive maintenance and inspection for traffic signals and overhead sign supports.

Traffic Signals

Utah has not determined traffic signal structure service life expectancies.

Preventive Maintenance

Preventive maintenance activity includes eight of the 10 specific elements detailed in Table 3. In addition to the selected activities, the respondent provided a detailed spreadsheet of traffic signal preventive maintenance activities (https://udottraffic.utah.gov/ATSPM/Images/Signal%20Maintenance%20PM%202020.xlsm). Updated in July 2020, the spreadsheet offers instructions, details on procedures, forms, signal locations and reporting

functions. It was not clear from this document what other maintenance items might be included in the Utah DOT process, and further consultation with the agency may be warranted. In reference to scheduling and frequency information, the respondent also deferred to this table, though whether listed dates from 2014 through 2018 indicated installation dates or service dates was not clear.

Utah DOT's 2016 Traffic Signal Management Plan (http://www.udot.utah.gov/main/uconowner.gf?n=29256708738824069) , describes biannual aerial preventive maintenance activities performed from a bucket (pages 14 and 15 of the plan, pages 22 and 23 of the PDF), including:

- Group replacement of signal LEDs and pedestrian heads.
- Straightening and tightening heads.
- Ensuring correct placement of hoods, back plates, end caps and upper hand-hole covers.
- Cleaning cameras every year after 2016.

Ground-level preventive maintenance activities described on page 15 (page 23 of the PDF) should be performed annually, and include:

- Examining and cleaning cabinets.
- Analyzing detector performance.
- Checking and replacing cabinet power, wiring, switches and more.
- Testing conflict monitors and MMUs.
- Testing preemption.
- Replacing cabinet filters, maintaining detectors and more.

Related Resource

Current Trends in Traffic Signal Maintenance: Agency Case Studies: UDOT, Mark Taylor, Utah Department of Transportation, 2020.
See Appendix Q.
This presentation describes a traffic signal management plan and a traffic signal maintenance and operations report in slides 10-16 (pages 11-17 of the PDF), and maintenance and inspection field tools in slides 18-20 (pages 19-21 of the PDF). Slides 22-24 (pages 23-25 of the PDF) describe maintenance training. Security locks are described in slides 31-33 (pages 33-35 of the PDF) and a shift from paper records to electronic on slides 34-49 (pages 36-51 of the PDF). Preventive maintenance is addressed in slides 50-56 (pages 52-59 of the PDF).

Traffic Signal Benchmarking and State of the Practice Report, National Operations Center of Excellence, Institution of Transportation Engineers, December 2019.
https://www.tsbenchmarking.org/wp-content/uploads/2020/03/TSBSOPR-Final-Report-NOCoE-ITE.pdf
From the abstract:

> This report summarizes past National Traffic Signal Report Card experience, new information from the 2018 Self-Assessment and other data sources, literature review and extended with current approaches and methods to delivering traffic signal program services to the traveling public.

Integration of signal maintenance processes into signal program management programs is described on page 25 of the report (page 41 of the PDF), identifying levels of integration. Maintenance of traffic signals is discussed on page 47 of the report (page 63 of the PDF). Figure 40 on page 49 (page 65 of the PDF) describes the various

levels of use by state/province, county and city management programs of asset management systems, work orders, spreadsheets and paper records in responding to maintenance needs. Utah DOT relies on automated traffic signal performance measures for managing timing and quickly identifying maintenance issues that impact traffic flow (pages 73 and 74 of the report, pages 89 and 90 of the PDF). This report also links to the 2016 Utah DOT Traffic Signal Management Plan discussed above.

Inspection

Utah DOT requires traffic signal inspections to be conducted visually from the ground. Inspection elements identified in the survey included 11 of the 19 elements presented, detailed in Table 5. The respondent indicated that many other inspection items could be found in the spreadsheet cited above. Frequency of inspections may also be found in this documentation. This, too, may warrant further investigation.

Cost–Benefits and Replacement

Utah DOT provided no answers to survey questions on cost–benefits and replacement standards for traffic signal support structures.

Contact: Mark Taylor, Utah Department of Transportation, 801-887-3714, Mark.Taylor@utah.gov.

Overhead Sign Structures

While Utah DOT has not formalized expected service lives for overhead sign structures, the service life for galvanizing is 30 years, at which point structures will be regalvanized or painted. The respondent indicated that the agency is currently evaluating its overhead sign structure asset management practices.

Preventive Maintenance

Utah DOT conducts and schedules no routine preventive maintenance of overhead sign support structures.

Inspection

Utah DOT did not respond to survey questions about inspection procedures and scheduling for overhead sign support structures. The agency conducts visual inspections from the ground and from buckets, as well as with unmanned aerial vehicles (UAVs).

Cost–Benefits and Replacement

Utah DOT associated no cost-benefits with preventive maintenance and inspection practices for overhead sign support structures. It replaces the structures when roadways beneath the signs undergo construction activity.

Contact: Glenn Blackwelder, Utah Department of Transportation, 801-518-4180, GBlackwelder@utah.gov.

Related Research

Below are citations from a limited literature search for studies published within the last 10 years that focused on preventive maintenance and inspection of traffic signals, roadway lighting and overhead sign structures. Findings from the literature search are presented in the following categories:

- Maintenance practices.
- Inspection practices.
- Service life and replacement scheduling.
- Quantifying maintenance benefits.

Citations in these sections are further categorized by traffic signals, roadway lighting and overhead sign structures.

Maintenance Practices

Traffic Signals

Current Trends in Traffic Signal Maintenance: Agency Case Studies, Institute of Transportation Engineers, July 28, 2020.
https://www.ite.org/events-meetings/ite-calendar/current-trends-in-traffic-signal-maintenance-agency-case-studies/
Webinar descriptions indicate the course addressed "internal self-assessments, preventative maintenance programs, traffic signal asset management/life cycle cost analysis, benchmarking protocols and guidelines for partnering between state and local agencies." Presentations from Pennsylvania and Utah DOTs are discussed in **Detailed Findings**.

"Strategic Methods for Modernizing Traffic Signal Maintenance Management and Quantifying the Impact of Maintenance Activities," Steven Lavrenz, Jim Sturdevant and Darcy Bullock, *Journal of Infrastructure Systems,* Vol. 23, Issue 4, 2017.
Citation at https://trid.trb.org/view/1464331
From the abstract:

> In a period of increasingly constrained budgets, traffic engineers must develop more cost-effective maintenance strategies for traffic signal systems. … This paper presents a method of using high-resolution signal controller data to identify intersections with failed inductive loop detection…. An application of this methodology is explored on a major urban arterial…. The results presented in this paper are easily implementable, given the increasing adoption of high-resolution signal controller data. Such methods can also be used to more clearly communicate maintenance success stories with the general public and elected officials.

Manual on Performance of Traffic Signal Systems: Assessment of Operations and Maintenance, Aleksandar Stevanovi and Danilo Radivojevic, Florida Department of Transportation, May 2017.
https://rosap.ntl.bts.gov/view/dot/32349
From the abstract:

> The annual evaluation of traffic signal systems on an agency level can be of great importance for identifying problems, self-assessment, budgeting, creating the strategy for future steps, etc. The most famous similar effort of this type is the National Traffic Signal Report Card (NTSRC), which is used as an evaluation

> methodology for agencies countrywide. The {proposed methodology] steps away from qualitative evaluation and grading, and presents a new set of procedures for implementation of quantitative, therefore more unbiased, evaluation methodology [to] enable self-evaluation and comparison between different agencies in terms of agency management, traffic signal operations, signal timing practices, traffic monitoring, data collection and maintenance. The annual evaluation is supported by weekly/monthly evaluation … created to reflect performance and reliability of a specific signal system on a weekly/monthly level.

Annual and monthly or weekly evaluation tools and methods are discussed in Chapter 3 (beginning on page 92 of the report, page 109 of the PDF), including maintenance activities, grading methods, performance and reliability indicators. Spreadsheet tools and user information are detailed in Chapter 4 (beginning on page 128 of the report, page 145 of the PDF) and in Chapter 5 (beginning on page 153 of the report, page 170 of the PDF), respectively.

Traffic Signal Management Plans: An Objectives- and Performance-Based Approach for Improving the Design, Operations and Maintenance of Traffic Signal Systems, Kevin Fehon and Pam O'Brien, Federal Highway Administration, November 2015.
http://www.ops.fhwa.dot.gov/publications/fhwahop15038/fhwahop15038.pdf
From the executive summary:

> The Federal Highway Administration (FHWA) has prepared this guidebook to assist transportation agencies across the country in better managing their traffic signal systems through systematic alignment of maintenance, design and operations activities and resources. It provides step-by-step instructions for documenting current activities, relating them to the agency's goals and transportation objectives, and offers a structure that shows how the activities of all staff involved in traffic signal management support those objectives.

Chapter 3 (beginning on page 17 of the report, page 27 of the PDF) describes a traffic signal management plan that includes evaluation methods on page 34 (page 44 of the PDF). An outline of signal management plans is provided in Chapter 4 (beginning on page 37 of the report, page 47 of the PDF) and focuses on maintenance beginning on page 39 (page 49 of the PDF). Case studies begin on page 51 of the report (page 61 of the PDF).

"Performance Measures for Traffic Signal Pedestrian Button and Detector Maintenance," Jay Grossman, Charles McKenzie and Darcy M. Bullock, *TRB 94th Annual Meeting Compendium of Papers*, Paper #15-3951, 2015.
Citation at https://trid.trb.org/view/1338348
From the abstract:

> The use of high-resolution data collected by traffic signal controllers … can also be used to develop maintenance related performance measures to help signal system operators find and correct faulty or misconfigured equipment in a timely manner, returning the system to optimal operation and efficiency. This research looked specifically at pedestrian buttons and vehicle detectors. Pedestrian button performance measures were developed to identify abnormal output from them. Determination of vehicle detector faults was also performed using an algorithm that compares current operation of a detector, based on the number of calls placed, to a historic baseline for the same detector. The length of the window of historic data needed to create a useful baseline was evaluated, as well as the standard deviation threshold used to indicate errors. A system of only identifying errors after three consecutive values above the threshold was implemented to reduce the number of false errors reported. The methodologies described were shown to be effective in detecting both complete detector failures as well as intermittent failures.

Roadway Lighting

"Analytic Hierarchy Process–Simulation Framework for Lighting Maintenance Decision-Making Based on the Clustered Network," Yuan Chen, Ahmed Bouferguene and Mohamed Al-Hussein, *Journal of Performance of Constructed Facilities,* Vol. 32, Issue 1, 2018.
https://ascelibrary.org/doi/full/10.1061/%28ASCE%29CF.1943-5509.0001101
From the abstract: Facility managers are responsible for system operations and confront challenges resulting from the considerable number of maintenance requests under various limitations (e.g., budget, labor resources). Therefore, maintenance activities need to be evaluated continually to improve their efficiency. As for the lighting system, the choice of maintenance methods [i.e., spot relamping (SR) and group relamping (GR)] has typically been made based on rules of thumb and experience. … The proposed framework … is composed of three phases: relamping cost evaluation, carbon dioxide (CO_2) emission evaluation and comprehensive evaluation for decision making on maintenance alternatives. A case study of lighting maintenance is provided to demonstrate the applicability of the framework to the selection of an optimal relamping alternative in consideration of cost and environmental protection.

Overhead Sign Structures

"Management and Maintenance of Sign Bridges, Cantilever Sign Structures and Mast Arm Structures on French National Roads Network," V. Bicilli, *Proceedings of the 25th World Road Congress*, 2015.
Citation at https://trid.trb.org/view/1633143
From the abstract: The 11,000 [kilometers] of roads in France's national network not under private concession are equipped with over 8,000 gantry, crane and high mast signs. … The French guide on maintaining and managing these road facilities defines the basic relevant concepts (e.g., description, technical context, responsibilities) and then lays out the corresponding three-stage process: 1) developing a comprehensive knowledge of the resource base; 2) monitoring and evaluating; and 3) performing the necessary maintenance and repairs. This methodology may be transposed to other countries [and includes] an annual structural inspection in order to identify problems potentially jeopardizing safety [and] an evaluation visit held once every [three] years targeting the state of repair. For this visit, conducted without any special means of access, each deficiency recorded gives rise to a quote for repairs — a periodic in-depth inspection, scheduled every [six] years (at most) and carried out by specialists given the means to fully access the structures. These monitoring actions result in contracting for maintenance and repair works. Ongoing maintenance, particularly at the level of anchorages, has helped to considerably extend the life cycle of these facilities. Specialized maintenance focuses on the structure's protective elements and minor flaws. Moreover, information is provided on the need for major repairs (methods, computations, etc.). Out of concern over the cost and reliability of repairs, it is necessary however to plan for the eventual replacement or definitive removal of the signs.

Inspection Practices

Traffic Signals

"Development of Resource Allocation Strategies for Operating and Maintaining Traffic Signal Systems," Pei-Sung Lin, Aldo Fabregas and Hongyun Chen, *Proceedings of the 10th Asia Pacific Transportation Development Conference*, pages 73-80, 2014.
Citation at https://trid.trb.org/view/1309310
From the abstract: Functional vehicle detection and signal system communication are essential for a traffic signal system to execute its intended coordinated signal timing plans. The degradations of vehicle detection and signal system communication could impose barriers to successful operations of a traffic signal system. To achieve and maintain an acceptable operational level set by a traffic agency, an agency has to prioritize its

resource allocation. This paper … uses the degradation index and traffic simulation to evaluate the effectiveness of major strategies to improve vehicle detection and signal system communication. These strategies include … increasing the frequency of inspection. … Finally, recommendations for optimal allocation of operation and maintenance resource allocation strategies for traffic signal systems are provided.

Roadway Lighting

High Mast Drone Inspection, Brian Stewart, Daniel Stock and Christopher Titze, New Jersey Department of Transportation, October 2018.
https://www.njdottechtransfer.net/wp-content/uploads/2020/03/NJ-2018-003.pdf
From the abstract:

> [Authors] quantify to the best extent possible the benefits of using an Unmanned Aerial System (UAS) approach to high mast light pole inspections compared to a traditional, ground-based approach across four project evaluation criteria: safety, efficiency (highway and data), time, and cost. This research … created case studies to explore inspection scenarios, and conducted a benefit-cost analysis to quantify the costs and savings of the various identified approaches.

Researchers compare UAS inspections to traditional methods in case studies beginning on page 6 of the report (page 11 of the PDF) and assess comparative time, cost and safety implications beginning on page 10 of the report (page 15 of the PDF).

Proof of Concept for Using Unmanned Aerial Vehicles for High Mast Pole and Bridge Inspections, Luis Daniel Otero, N. Gagliardo, D. Dalli, W-H Huang and P. Cosentino, Florida Department of Transportation, 2015.
Citation at https://trid.trb.org/view/1366484
From the abstract: Bridges and high mast luminaires (HMLs) are key components of transportation infrastructures. Effective inspection processes are crucial to maintain the structural integrity of these components. The most common approach for inspections is visual examination by trained and experienced inspectors. A proposed approach to assist inspectors during the visual inspection process is to use small unmanned aerial systems (sUAS) equipped with high-definition cameras to transmit video data of structural components in near real time. … In full coordination with Florida Department of Transportation (FDOT), limited field tests were conducted to collect image data of underside bridge sections and HMLs. … Preliminary results showed potential cost savings in man-hours by using an sUAS approach instead of conventional methods. Overall, results provided evidence that significant benefits can be obtained from using sUAS during bridge and HML inspections.

Overhead Sign Structures

"Condition Assessment of Ground-Mount Cantilever Weathering-Steel Overhead Sign Structures," Wail Zatar and Hai Ngyuyen, *Journal of Infrastructure Systems*, Vol. 23, Issue 4, 2017.
Citation at https://trid.trb.org/view/1467586
From the abstract: This paper is a part of an expansive research work aimed at assessing 82 weathering steel overhead sign structures (WSOSSs) in the Charleston Interstate System in West Virginia. A total of 26 comprehensive inspection forms were developed to objectively evaluate the current condition of 11 general types of sign structures. This article focuses on analyzing 25 single-armed and double-armed ground-mount-cantilever WSOSSs (GMC-WSOSSs). … As a result of this work, it is concluded that all the GMC-WSOSSs performed relatively well after more than 40 years of service and exposure to moist weather condition of Kanawha County (climate zone 4A). Specifically, as a result of the developed rating methodology, 52% of sign structures were found to be in fair condition and 48% were in good condition. The rating system is intended to

assist the West Virginia Department of Transportation in making rational decisions about whether there is a need to repair or replace at-risk elements, connections or structures.

Related Resources:

"An Inspection Framework for Assessing Condition of Ground Mount Truss/Cantilever Overhead Sign Structures," Wael Zatar, Hai Nguyen, Ted Whitmore and Ray Lewis, *TRB 94th Annual Meeting Compendium of Papers*, Paper #15-2824, 2015.
Citation at https://trid.trb.org/view/1337786
From the abstract: This paper is a part of a broad research effort aimed at evaluating 82 weathering steel overhead sign structures in Charleston Interstate System in West Virginia. Twenty-six comprehensive inspection forms were developed to objectively evaluate the current condition of 11 general types of sign structures. This paper focuses on analyzing the following two types of sign structures: (1) Type A: Double armed ground mount cantilever; and (2) Type B: Shoulder/median barrier mount two-dimensional truss. … Following the developed rating methodology, 57 percent of type A (8 sign structures) were found to be in fair condition and 43 percent (6 sign structures) were in good condition. On the other hand, 75 percent of type B (6 sign structures) were found to be in poor condition and 25 percent (2 sign structures) were in fair condition. The rating system is intended to assist the West Virginia Division of Highways (WVDOH) in making rational, objective decisions about whether there is a need to repair or replace at-risk elements or connections.

Evaluation of Weathering Steel Overhead Sign Structures in West Virginia, Wael Zatar and Hai Nguyen, West Virginia Department of Transportation, 2014.
Citation at https://trid.trb.org/view/1326941
From the abstract: This report presents the results and findings of the research work aimed at evaluating 82 weathering steel sign structures in Charleston Interstate System in West Virginia. Twenty-six comprehensive inspection forms were developed to objectively evaluate the current condition of the following sign structure types: single and double arm ground mount cantilever structures; bridge superstructure mount cantilever structures; retaining wall mount cantilever structures; retaining wall mount truss structures; two-dimensional and three-dimensional ground mount truss structures; bridge parapet mount truss structures; and bridge frame mount structures. The work included performing extensive field inspection of the elements of each sign structure including the foundations, drainage issues, grout pads, base plates, anchor bolts/nuts/washers, connections between base plates and vertical columns, vertical columns and horizontal chords, connections between vertical columns and horizontal chords, welded splice connections, and attachments. … Following the developed rating methodology presented in the report for the inspected weathering steel sign structures, seven percent were found to be at high risk, 50 percent were at moderate risk, and 43 percent were at low risk. The rating system is intended to assist the West Virginia Division of Highways (WVDOH) to make rational decisions on whether there is a need to repair or replace at-risk elements or connections.

"Detail Categories for Reliability-Based Fatigue Evaluation of Mast-Arm Sign Support Structures," Joseph A. Diekfuss and Christopher M. Foley, *Journal of Structural Engineering*, Vol. 142, Issue 7, 2016.
Citation at https://trid.trb.org/view/1401515
From the abstract: There is a need to understand variability in [sign and luminaire support structure] performance and to develop inspection protocols consistent with this expected performance to ensure public safety and to rationally disperse limited fiscal and personnel resources. Because mast-arm sign support structures are most often decommissioned when cracks are found, these protocols will focus on detecting crack initiation. Inspection protocols for assessing service life and the limit state of fatigue-induced crack initiation are most effectively developed using reliability-based procedures. The objective of this manuscript is to present two

methods for synthesizing archival fatigue test data into a form suitable for implementation in reliability-based procedures for fatigue-induced crack initiation assessment of mast-arm sign support structures. The methods culminate in statistical parameters suitable for lognormal models of fatigue life for connection details.

"Reliability-Based Fatigue Assessment and Inspection Protocols for Sign Support Structures," Christopher Foley and Joseph A. Diekfuss, *Structures Congress 2014*, pages 386-400, 2014.
Citation at https://trid.trb.org/view/1305451
From the abstract: There have been numerous examples of poor in-service performance of welded, tube-to-transverse plate connections within mast-arm sign support structures in the past several decades. A considerable amount of research has been devoted to identifying the structural response characteristics of these sign support systems and identifying how the connections within these systems can be repaired or designed to facilitate infinite service lives. Little attention has been given to using reliability-based approaches to assess the risk of fatigue-induced crack initiation in these structures. The present research effort focuses on systematically quantifying all sources of uncertainty found in these systems and formulating a reliability-based approach for prescribing inspection intervals corresponding to user-specified levels of risk of fatigue-induced crack initiation. The results indicate that implementation of state-of-the-art reliability-based assessment procedures can contribute toward formulating inspection protocols that are based upon owner-defined risk thresholds. The structural engineering community can use the results of this research effort to align inspection needs with limited fiscal and human resources. The procedures developed can also be readily extended to other infrastructure systems including bridges.

Service Life and Replacement Scheduling

Roadway Lighting

"Fatigue Life Assessment of Cracked High-Mast Illumination Poles," Mina Dawood, Raka Goyal, Hemant Dhonde and Timothy Bradberry, *Journal of Performance of Constructed Facilities*, Vol. 28, Issue 2, pages 311-320, 2014.
Citation at https://trid.trb.org/view/1303810
From the abstract: This paper presents the findings of a research program that was conducted to evaluate the probability of failure of high-mast illumination poles (HMIPs) with preexisting cracks at the pole-to-base plate connection detail. A simplified reliability-based analysis framework is presented to evaluate the safe service life of the cracked HMIPs. … The safe service lives of different standard HMIP designs that are commonly used by the Texas DOT are calculated. The results indicate that the degradation of the poles is predominantly attributable to vortex shedding-induced vibrations in the second and third vibration modes. The findings also demonstrate that the safe service life of a[n] HMIP depends primarily on the effective stress range at the base of the pole attributable to wind-loading effects.

Related Resource:

> **Fatigue Failure and Cracking in High Mast Poles**, Raka Goyal, Hemant B. Dhonde and Mina Dawood, Texas Department of Transportation, 2012.
> http://tti.tamu.edu/documents/0-6650-1.pdf
> *From the abstract:*
>
> > This report presents the findings of a comprehensive research project to investigate the fatigue cracking and failure of galvanized high mast illumination poles (HMIP). Ultrasonic inspection of poles throughout the state has revealed the presence of weld toe cracks at the shaft-to-base-plate connections of some galvanized poles that the Texas Department of Transportation (TxDOT) owns. … In the second phase, a comprehensive reliability analysis of several TxDOT pole configurations was conducted for different

regions in Texas to predict the fatigue lives of the cracked poles. Critical pole configurations and locations are identified to facilitate cost-effective decisions related to inspection, repair and replacement of poles.

Authors describe repair methods and present repair versus replacement cost analysis in Chapter 5 (starting on page 91 of the report, page 105 of the PDF). Inspection scheduling recommendations are presented on page 105 of the report (page 119 of the PDF).

"Estimating Asset Deterioration and Life Expectancy By Using Levels of Service," Paul D. Thompson, *Transportation Research Record 2285*, pages 19-26, 2012.
Citation at https://trid.trb.org/view/1129286
From the abstract: As agencies have implemented maintenance quality assurance processes over the past 10 to 15 years, the agencies have also begun to amass valuable databases of condition and performance data, often expressed in terms of levels of service. These databases address a wide range of asset types, especially roadway and roadside features such as signs, pavement markings, traffic signals, lighting, culverts, sidewalks, and curbs. … A few agencies have taken the next step in developing deterioration models to forecast changes in structure condition, either in the absence of maintenance activity or in response to specific agency actions or policies. … [Some] examples of bridge inspection and deterioration models already address a variety of nonbridge structures and a variety of performance concerns beyond physical deterioration. This study connects the level-of-service approach now frequently used in maintenance management with the quantitative forecasting of deterioration frequently used in bridge management. The result is a framework for prediction of levels of service and life expectancy that can be useful for management of all types of transportation assets.

Overhead Sign Structures

"Analysis of Three Sign Management Program Case Studies," Patricia Machado and William Rasdorf, *Public Works Management & Policy*, Vol. 25, Issue 1, pages 51-74, 2020.
Citation at https://trid.trb.org/view/1691505
From the abstract: To ensure sign visibility at night, the Manual on Uniform Traffic Control Devices (MUTCD) requires transportation agencies to meet minimum sign retroreflectivity levels through a sign maintenance program. To better understand current trends, the researchers conducted an extensive literature search that showed that expected sign life and nighttime inspection are the most used methods, followed by blanket replacement. The … research team also contacted three of the four largest state-maintained highway systems in the United States (North Carolina, Virginia and South Carolina) to discuss sign maintenance programs, implementation issues and best practices. The authors describe in this article the findings and conclusions drawn from these case studies that may help other agencies improve their sign maintenance practices.

Initial Analytical Investigation of Overhead Sign Trusses With Respect to Remaining Fatigue Life and Predictive Methods for Inspection, Husam Aldeen Alshareef, Hayder A. Rasheed, AlaaEldin Abouelleil and Rund Al-Masri, Kansas Department of Transportation, 2019.
https://rosap.ntl.bts.gov/view/dot/41967
From the abstract:

This study conducted fatigue evaluations using nominal axial member-specific stress ranges corresponding to a wind speed database for a 45-year period, as well as hundreds of structural analysis simulations. Potential fatigue failure was assessed for each member of the support structure by evaluating the ratio of consumed fatigue cycles to ultimate fatigue cycles using Miner's rule to estimate finite life. … This information can help inspectors identify for critical spots that may have developed fatigue cracks that otherwise would be difficult to detect. Two approaches were hypothesized to account for fatigue life

deterministically and probabilistically. … Users apply the results to study the behavior of overhead structures and identify critical spots that should be physically inspected and potentially replaced.

Researchers developed software to integrate with Kansas DOT's asset management software for sign trusses that would estimate remaining fatigue lives of individual elements of sign trusses in terms of years of service. In the report's conclusion (page 66 of the report, page 78 of the PDF), investigators describe key results from analysis for three structures subjected to wind speed data from eight locations over a period of decades, finding some at the end of their service lives after 45 years of applied data in the model.

Related Resource:

Initial Analytical Investigation of Overhead Sign Trusses With Respect to Remaining Fatigue Life and Predictive Methods for Inspection, Husam Aldeen Alshareef, Hayder A. Rasheed, AlaaEldin Abouelleil and Rund Al-Masri, Kansas Department of Transportation, May 2019.
https://rosap.ntl.bts.gov/view/dot/41966
This two-page technical summary presents the findings discussed in the previous citation.

Quantifying Maintenance Benefits

NCHRP Research Report: Consequences of Delayed Maintenance of Highway Assets, Carlos M. Chung, Soheil Nazarian, Marketa Vavrova, Margot T. Yapp, Linda M. Pierce, William Robert and Roger E. Smith, 2017.
Citation at https://trid.trb.org/view/1489457
From the abstract: Analytical tools are currently available to quantify the effects of the application of maintenance treatments for highway pavements, bridges and other assets. However, processes for using these tools to demonstrate the potential savings and performance enhancements that result from applying maintenance treatments at the right time are not readily available. Research was needed to develop such processes. … [A]ppendices (available on the TRB website only) describe the procedures for quantifying the consequences of delayed maintenance of [assets including] lighting … and highway signs.

"Managing Ancillary Transportation Assets: The State of the Practice," Margaret-Avis Akofio-Sowah, Richard Boadi, Adjo Amekudzi and Michael Meyer, *Journal of Infrastructure Systems*, Vol. 20, Issue 1, March 2014.
Citation at https://doi.org/10.1061/(ASCE)IS.1943-555X.0000162
From the abstract: This paper synthesizes the state of practice of ancillary transportation asset management to assess the needs for successful implementation of such programs by highlighting data collection strategies and costs, data analysis tools and data use in decision making, especially as it relates to asset prioritization and quantifying the benefits of ancillary asset management. The paper focuses on 10 asset classes selected from a review of literature [including] street lighting, traffic signals [and] traffic signs…. The results highlight the state of practice of managing ancillary transportation assets, revealing the dynamic nature of these activities as agencies evolve their activities to higher levels of program maturity.

Appendix A

Preventive Maintenance and Inspection for Traffic Signals, Roadway Lighting and Overhead Sign Structures: Survey Questions

The following survey was distributed to selected state departments of transportation and other transportation agencies expected to have experience with preventive maintenance and inspection of traffic signals, roadway lighting and overhead sign support structures.

Traffic Signals

1. What service life do you expect of traffic signal structures in your agency's system?
2. Please indicate which of the following activities you routinely conduct in structural and operational preventive maintenance for traffic signals. (Please check all that apply.)

    - Cabinet rodent control
    - Lubrication of cabinet hinges, locks, door
    - Clean or replace air filter
    - Upgrade controller firmware
    - Check and adjust detection zone alignment
    - Clean sensors
    - Check and clean terminal blocks on pole bases
    - Tighten bolts, anchor rods
    - Check and replace fuses
    - Group lamp/bulb replacement
    - Other (Please specify.)

3. Please describe or list preventive maintenance activity schedules your agency requires of traffic signal structural and electrical systems. If available, provide a web link to, or attach or email a copy of, preventive maintenance activities schedule(s) to Matt Mullins, matt.mullins@ctcandassociates.com.
4. Please indicate which of the following elements you include in structural and operational inspections of traffic signals. (Please check all that apply.)

    - Foundation
    - Anchor rods
    - Transformer base
    - Pole
    - Pole foundation
    - Mast arm – upper
    - Mast arm – lower
    - Mast arm chord – upper connection
    - Mast arm chord – lower connection
    - Luminaire extension
    - Camera extension
    - Cabinet: hinges, vents, etc.
    - Cabinet electronics and electrical
    - Wiring

- Pedestrian buttons
- Signal operation (at cabinet)
- Signal unit – cracks, damage, corrosion, etc. (please describe in Other, below)
- Lamps/bulbs
- Service voltage
- Other (please specify)

5. Please provide web links or forward inspection forms and inspection schedules for any and all selected inspection elements to Matt Mullins, matt.mullins@ctcandassociates.com.

6. Please indicate which methods or tools you use for traffic signal inspection. (Please check all that apply.)

    - Visual inspection from ground
    - Visual inspection from bucket
    - Inspection by unmanned aerial vehicle (UAV)
    - Acoustic emissions
    - Deterioration models
    - Remote operational monitoring
    - Other (Please specify.)

7. Please provide cost–benefit information your agency associates with the following. If available, please include a web link to relevant documents, or attach or email to Matt Mullins, matt.mullins@ctcandassociates.com.

    - Preventive maintenance activities for traffic signal structural supports
    - Preventive maintenance activities for traffic signal electronics
    - Preventive maintenance activities for traffic signal operations
    - Inspections for traffic signal structural supports
    - Inspections for traffic signal electronics
    - Inspections for traffic signal operations

8. Please describe what basis or standard you use for replacing traffic signal support structures. If available, include a web link to relevant documents, or attach or email to Matt Mullins, matt.mullins@ctcandassociates.com.

    - Performance
    - Age or years of service
    - Condition
    - Other (Please describe.)

9. Please use this space to provide any comments or additional information about your previous traffic signal responses.

Roadway Lighting

1. What service life do you expect from masts, poles or structures that support roadway lighting in your agency's system?

2. Please indicate which of the following activities you routinely conduct in structural and operational **preventive maintenance** for roadway lighting. (Please check all that apply.)

    - Lubrication of cabinet hinges, locks, door
    - Clean sensors
    - Tighten bolts, anchor rods
    - Check and clean base plates
    - Check and clean pole to base connections
    - Group lamp/bulb replacement
    - Other (Please specify.)

3. Please describe or list preventive maintenance activity **schedules** your agency requires of roadway lighting structural and electrical systems. If available, provide a web link to, or attach or email a copy of, preventive maintenance activities schedule(s) to Matt Mullins, matt.mullins@ctcandassociates.com.
4. Please indicate which of the following elements you include in structural and operational **inspections** of roadway lighting. (Please check all that apply.)

    - Foundation
    - Anchor rods
    - Base plates
    - Pole to base connections
    - Poles
    - Wiring
    - Luminaire function
    - Remote monitoring system
    - Other (Please specify.)

5. Please forward inspection forms and inspection schedules for any and all selected inspection elements to Matt Mullins, matt.mullins@ctcandassociates.com.

6. Please indicate which methods or tools you use for roadway lighting inspection. (Please check all that apply.)

    - Visual inspection from ground
    - Visual inspection from bucket
    - Inspection by unmanned aerial vehicle (UAV)
    - Acoustic emissions
    - Deterioration models
    - Remote operational monitoring
    - Other (Please specify.)

7. Please provide cost-benefits your agency associates with the following. If available, please include a web link to relevant documents, or attach or email to Matt Mullins, matt.mullins@ctcandassociates.com.

    - Preventive maintenance activities for roadway lighting structural supports
    - Preventive maintenance activities for roadway lighting unit electronics
    - Preventive maintenance activities for roadway lighting wiring

- Inspections for roadway lighting structural supports
- Inspections for roadway lighting unit electronics
- Inspections for roadway lighting wiring

8. Please describe what basis or standard you use for replacing roadway lighting. If available, include a web link to relevant documents, or attach or email to Matt Mullins, matt.mullins@ctcandassociates.com.

    - Performance
    - Age or years of service
    - Condition
    - Other (Please describe.)

9. Please use this space to provide any comments or additional information about your responses to previous roadway lighting questions.

Overhead Sign Structure

1. What service life do you expect from overhead sign **support structures** in your agency's system?
2. Please indicate which of the following activities you routinely conduct in structural **preventive maintenance** for overhead sign **support structures**. (Please check all that apply.)

    - Repair/clean foundation and base plate
    - Tighten anchor rods
    - Tighten or repair connections
    - Other (Please specify.)

3. Please describe or list preventive maintenance activity **schedules** your agency requires of overhead sign **support structures**. If available, provide a web link to, or attach or email a copy of, preventive maintenance activities schedule(s) to Matt Mullins, matt.mullins@ctcandassociates.com.
4. Please indicate which of the following elements you include in **inspections** of overhead sign **support structures**. (Please check all that apply.)

    - Foundation
    - Anchorage
    - Post
    - Truss
    - Connections, panel to support
    - Other (please specify)

5. Please forward inspection forms and inspection schedules for any and all selected inspection elements for overhead sign **support structures** to Matt Mullins, matt.mullins@ctcandassociates.com.
6. Please indicate which methods or tools you use for overhead sign **support structure** inspection (check all that apply).

    - Visual inspection from ground
    - Visual inspection from bucket
    - Inspection by unmanned aerial vehicle (UAV)

- Acoustic emissions
- Deterioration models
- Remote operational monitoring
- Other (Please specify.)

7. Please describe cost–benefits your agency associates with the following. If available, include a web link to relevant documents, or attach or email to Matt Mullins, matt.mullins@ctcandassociates.com.

    - Preventive maintenance activities for overhead sign support structure foundations
    - Preventive maintenance activities for overhead sign support structure anchorages
    - Preventive maintenance activities for overhead sign support posts
    - Preventive maintenance activities for overhead sign support trusses
    - Preventive maintenance activities for overhead sign support connection, panel to support
    - Inspections for overhead sign support structure foundations
    - Inspections for overhead sign support structure anchorages
    - Inspections for overhead sign support posts
    - Inspections for overhead sign support trusses
    - Inspections overhead sign support connection, panel to support

8. Please describe what basis or standard you use for replacing overhead sign **support structures**. If available, include a web link to relevant documents, or attach or email to Matt Mullins, matt.mullins@ctcandassociates.com.

    - Performance
    - Age or years of service
    - Condition
    - Other (please describe)

9. Please use this space to provide any comments or additional information about your responses to previous overhead signs support structure questions.

Metro Area Contacts

1. Please provide the name, agency, email and phone number for the best person(s) to contact for potential survey information from a large metropolitan agency in your state or province.

2. Please list names, agencies, email addresses and phone numbers for any other metropolitan agency contacts you recommend we contact.

Appendix B

Preventive Maintenance and Inspection for Traffic Signals, Roadway Lighting and Overhead Sign Structures: Contacts

Below is the contact information for the individuals responding to the survey for this report.

City of Columbus, Ohio

Ryan Lowe
Traffic Signals, Overhead Signs
City of Columbus
614-645-8490, RJLowe@columbus.gov

Illinois

Kyle Armstrong
Traffic Signals, Lighting, Overhead Signs
Illinois Department of Transportation
217-782-2076, Kyle.Armstrong@illinois.gov

Indiana

Ed Cox
Traffic Signals
Indiana Department of Transportation
317-899-8601, ECox@indot.in.gov

Minnesota

Susan Zarling
Traffic Signals, Lighting
Minnesota Department of Transportation
651-234-7052, Susan.Zarling@state.mn.us

Josephine Tayse
Overhead Signs
Minnesota Department of Transportation
651-234-7371, Josie.Tayse@state.mn.us

Ohio

Charlie Fisher
Traffic Signals
Ohio Department of Transportation
614-644-0270, Charles.Fisher@dot.ohio.gov

Kevin Duemmel
Lighting, Overhead Signs
Ohio Department of Transportation
614-728-2450, Kevin.Duemmel@dot.ohio.gov

Ontario

Ousama Shebeeb
Traffic Signals, Lighting, Overhead Signs
Ontario Ministry of Transportation
289-219-2514, Ousama.Shebeeb@ontario.ca

Pennsylvania

Steve Gault
Traffic Signals
Pennsylvania Department of Transportation
717-787-6988, sgault@pa.gov

Tim Carre
Lighting
Pennsylvania Department of Transportation
717-214-8727, trcarre@pa.gov

Tyler Culhane
Overhead Signs
Pennsylvania Department of Transportation
717-787-7505, tculhane@pa.gov

Quebec

François Marchand
Traffic Signals, Lighting, Overhead Signs
Quebec Ministry of Transportation
418-643-0800, ext. 23082,
Francois.Marchand@transports.gouv.qc.ca

Utah

Mark Taylor
Traffic Signals
Utah Department of Transportation
801-887-3714, Mark.Taylor@utah.gov

Glenn Blackwelder
Overhead Signs
Utah Department of Transportation
801-518-4180, GBlackwelder@utah.gov

Below is the contact information for individuals recommended for further information by survey respondents.

Minnesota

Bill Prince
City of Minneapolis
William.prince@minneapolismn.gov

Roy Doron
Hennepin County
Rolito.doron@hennepin.us

Pennsylvania

Marty McKinney
Cranberry Township, Pennsylvania
724-776-4806, ext. 1507,
Marty.McKinney@cranberrytownship.org

Quebec

David Bédard Dupuis
Ministère des Transports du Québec
david.bedard-dupuis@transports.gouv.qc.ca

Stéphan Galibois
Ministère des Transports du Québec
stephan.galibois@transports.gouv.qc.ca

Utah

L. Todd Wright
Lighting
Utah Department of Transportation
801-870-3626, LTWright@utah.gov

Appendix C

		Electronic	Electrical	Sig Ops
Electronic	PM Activity	2 YR PLAN	3 YR PLAN	ANNUAL PLAN
	Test NEMA conflict monitor	✓		
	Replace burned out load switches/check if they are seated	✓	✓	
	Check condition of Flash Transfer relays	✓		
	Check cabinet wiring	✓	✓	
	Measure the line voltage at the power panel	✓		
	Check conditon of power panel	✓		
	Check Fan, Light, GFI operation	✓		✓
	Check all detectors/check bad detector amps and replace them	✓	✓	✓
	Check EVP Card	✓		
	Check rack label	✓		
	Inspect Cabinet shell for exterior damage	✓		✓
	Check cabinet stickers and serial numbers	✓		
	Verify Cabinet Documents (prints and log book, etc). Review logs for any history to be aware of.	✓	✓	✓
	Test EVP and RR preemption/EVP indicator light	✓		✓
	Look for Bad Lamp or LED indications/aligned properly and check cabinet for blown fuses and malfunctioning	✓	✓	✓
	Day burn street lights/turn on any luminaires	✓	✓	✓
	Look for damaged/missing heads, visors, covers or other hardware	✓	✓	✓
	Check Pedestrian Push Button. Manually operate all ped buttons	✓	✓	✓
	Look for broken handholes covers/Intact/Clean	✓	✓	✓
	Upon returning to shop - generate Work Request for each signal, to document your PM - write another work request if repairs are necessary	✓	✓	✓
Electrical	PM Activity			
	Check Battery Back-up system		✓	
	Check for any loose hardware or bolts		✓	
	Verify proper no ped crossing sign is in place		✓	✓
	Verify poles have proper signs, stickers and are readable		✓	✓
	Walk all points of intersection check for hardware damage due to collision, rust, deterioration, vandalism, graffitti, etc. Poles, mast arms, bracketing, signs, visors, etc.		✓	✓
	Install and/or check mouse screens/seal conduits/dryer sheets		✓	✓
	Inspect Terminal Blocks and wiring		✓	
	Record in intersection log book (date, time, MESU PM, any problems found, sign name)/timing sheets		✓	✓
Sig Ops	PM Activity			
	Replace filter			✓
	Lubricate Door		✓	✓
	Lane Configuration on Plan			✓
	Detectors are assigned properly in controller			✓
	Clock time is accurate			✓
	YARP timing seems reasonable.			✓
	Look for unnecessary recalls - such as ped recalls			✓
	Check act rest in walks			✓
	Ped pavement markings			✓
	Check Base for gap, caulk if needed			✓
	Loops out of pavement		✓	✓
	Poles/Cabinet need painting		✓	✓
	Take Pictures			✓

Appendix D

Operation Check Checklist TAMS ID _____

1. When pulling up to intersection be observant of traffic flow, obvious equipment or cabinet damage, or malfunctioning signal equipment.

2. At cabinet
   - ☐ a. Look at logbook for recent activity
     - ☐ Log book has correct TAMS number
   - ☐ b. Check for accurate timing sheets and all cabinet documents
     - ☐ Timing Sheet
     - ☐ Layout
     - ☐ Detector Chart (update with TAMS number on server)
   - ☐ c. Replace cabinet filter
   - ☐ d. Check cabinet fan and light
   - ☐ e. Check for bad fuses for indication outputs
   - ☐ f. Check AC outlet/GFI operation
     - ☐ Note if no dedicated non-GFI outlet exists
   - ☐ g. Lubricate door/lock
   - ☐ h. Verify lane configuration and pavement markings on plan
   - ☐ i. Verify detector assignments are correct in all 4 detector plans and operating signal correctly
   - ☐ j. Verify detector amps are operating correctly and not in fault mode
   - ☐ k. Check controller for recalls and verify that they are needed, adjust accordingly
   - ☐ l. Check for rest in walk in controller, adjust as necessary
   - ☐ m. Verify clock settings
   - ☐ n. Check luminaire operation
   - ☐ o. Check firmware is 2.63 or greater (nothing over 2.64 for split phase) update as necessary
     - ☐ Check that the "MUTCD" option is "YES" and the "yellow-green" is "NO" (MM 2-5)
   - ☐ p. Take cabinet pictures (only using I-phone w/geo-locate enabled, even if some already exist)
     - ☐ Cabinet Door
     - ☐ Left inside wall of cabinet
     - ☐ Right inside wall of cabinet
     - ☐ Straight on cabinet
     - ☐ Meter Number
   - ☐ q. Verify that all equipment is correct in TAMS
     - ☐ Controller (type, serial number, firmware and OS version) _____
     - ☐ MMU/CMU
     - ☐ Detection equipment other than loops
   - ☐ r. Ensure Utility Meter number is correct in TAMS
   - ☐ s. Verify that MMU (If connected to the network) is set to the correct IP from Django

3. Walking the intersection
   - ☐ a. Physically check all pedestrian push buttons to verify pedestrian demand recognized by controller for each button (If APS buttons present verify and/or adjust programming to current standards)
   - ☐ b. Verify all proper signage is in place and legible
   - ☐ c. Look for broken or missing background shields or visors, etc.
   - ☐ d. Make note of all indication outages (also note if cabinet fuse blown)
   - ☐ e. Verify and note condition of pavement markings / crosswalks
   - ☐ f. Make note of pavement condition and loops coming out of pavement

- ☐ g. Look for broken hand holes and covers

4. Preemption, Vehicle and RR
   - ☐ a. Ensure EVP card is on in cabinet
   - ☐ b. Verify preemption settings in controller for all channels and associated controller logic
   - ☐ c. Test vehicle preemption and verify lamp operation using vehicle mounted emitter
   - ☐ d. For railroad follow procedure and parameters on Annual RR Preemption Inspection Form

5. Finalize operation check visit
   - ☐ a. Using laptop and Wi-Fi hotspot open TAMS
   - ☐ b. Find Operation PM work order in TAMS and enter your info
   - ☐ c. Each non-related issue requires another work request
   - ☐ d. Load cabinet photos From I-phone (geo-locate enabled) onto laptop and rename
     - ☐ Create Folder with TAMS ID and move photos into it
       - ☐ Cabinet Door (cab_d)
       - ☐ Left inside wall of cabinet (cab_l)
       - ☐ Right inside wall of cabinet (cab_r)
       - ☐ Straight on cabinet (cab)
       - ☐ Meter Number (Meter)
   - ☐ e. Sign logbook and put description of happenings during your intersection visit

Appendix E

ESS TRAFFIC SIGNAL PREVENTIVE MAINTENANCE STEPS

3/8/2017

____ Determine ESS responsibilities from the signal maintenance responsibilities list.

____ Open the signal cabinet and verify there are prints, intersection layout, wiring diagram and extra maintenance log sheets. Check the log book for any history of issues to be aware of.

____ Visually check for loose or disconnected wires, or any equipment that has shifted & does not appear to be in proper order.

____ Visually check to see if the load switches are properly seated in the cabinet and are working.

_____Inspect S.O.P cabinet or disconnects, Check the battery back-up system

____ Manually turn on any luminaires (if any) at the cabinet.

____ Walk to all points of the intersection, checking for hardware damage due to collision, excessive rust, deterioration, vandalism, graffiti, etc. Check everything – Cabinet(s), Poles, Mast Arms, Bracketing, Signs, Visors, etc.

____ Visually check for any loose hardware or bolts.

____ Verify all the traffic indications are functioning and aligned properly. (Look for blown fuses in cabinet for any malfunctioning indications.)

____ Manually operate all ped buttons & verify operation of the ped indications. Verify that no ped buttons are stuck constant calling. (Check the Ped Isolator in cabinet if any ped indications are malfunctioning.)

____ Verify the proper no ped crossing signing is in place & serviceable.

____ Verify Poles have the proper stickers and are readable.

____ Install and/or check mouse screens as needed.

____ Inspect Terminal Blocks & wiring in base of poles.

____ Locate all handholes & verify they are intact and clean (accessible), note any needing additional work.

____ Note any apparent loop malfunctions and test lead-in and loop, if bad notify signal operations and put loop on replacement list.

____ After luminaires have warmed up, check their proper operation – if luminaires need relamping, report problem to responsible agency.

____ Record in intersection log book date, time, ESS PM, any problems found, and sign your name.

____ Turn off luminaires (if turned on) and close the cabinet.

____ Close the PM work order and prepare new work requests for any additional work needed in TAMS.

____ Repair all signal problems that are responsibility of ESS, or report problems to the other responsible agencies or ESS dispatch.

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Appendix F

Electronics Technician Preventive Maintenance Check List

T.H. _____ @ _____ Date _____/ _____/ _____/

Arrival Time: _____ Depart Time: _____ Hours:_____ TAMS ID# _____

Cabinet

Conflict Monitor */ M.M.U.**……_____
** (MMU requires SDLC interface cable for testing)
Load Switches…….…_____

Flash Transfer Relays……..._____

Live Voltage..(>105 V to <125 V)…....._____

Gnd-Neutral Volt…(below 1 VAC)...._____

GFI/ Fan/Light Operation……..…..._____

Surge Suppressor LED ON/Lug Snug.._____

Replace Missing Fuse Holders…….._____

Intersection (use Comments if problems found)

Indications……..._____
Ped Buttons……_____
Hardware (Bases, Poles, Visors, etc)……_____
EVP & R.R. Preemption……_____
Does Name Match Listing (street names).…._____

Cabinet Documents OK Replace Missing

Prints……_____.…..._____.……_____

Log Book……_____.….._____……..._____

Detection Operation

Historic Faulting Detectors: _____

Loops reading bad from cabinet:_____

Turned OFF loops:_____ Rack Need Replacement? _____

Cabinet Condition

Is it a Steel Shell? _____ Need Paint (graffiti, scrapes)? _____ Damage (use comments)?
ESU Serial # Label _____ Stickers (three from 8 phase) _____ Door Stop ok? _____

Other Hardware (can use comments)? _____

*** To CLEAR the SSM12LE memory: Press-N-Hold bottom two buttons, then also hold down top button for a few seconds until "clr" shows on display. Now release all three. Then press the two bottom buttons again.**

Comments

Cab. Inventory Model Serial Number **Parts used:** Model Serial Number
Controller SN: _____ _____ _____ _____
CMU/MMU SN: _____ _____ _____ _____

Write **"CABINET PM"** in Log Book

Appendix G

Signal Structure Inspection General Information [Page 1 of 2]			
Inspection general information		**Signal System Description**	
Inspector name(s)/signature		TAMS ID & Signal System Name	
Inspection date		Signal System Class Code	
Inspection type		Responsible Party	
Overall Pole condition rating		Placeholder: Owner	
Overall comment		Year Installed/Open to Traffic	

Signal Pole Unit Description			
Pole Number /Pedestal Number /TAMS ID		Pole Height	
Assembly Type		Mast Arm Length	
Year Installed/Open to Traffic		Foundation Type	
Structure type		Coordinates (lat/long)	
Materials		Inspection Traffic Control	
Pole Style		Photos	

Element Inspection Data

Foundation Summary

Debris	◯Yes ◯No	Grout layer (grout pad)	◯Yes ◯No	Spalling	◯Yes ◯No
Erosion	◯Yes ◯No	Efflorescence/Chalking	◯Yes ◯No		

Anchor Rod Summary

Transformer Base

Overall Element Rating		Overall Element Comment		Overall Element Action Item	
Base Cover\Door	◯Yes ◯No	Rodent Protection	◯Yes ◯No	Displacement/Movement (Connection b/w Pole & Base)	◯Yes ◯No
		Debris	◯Yes ◯No	Exposed Wire in Base (Not connected to terminal block)	◯Yes ◯No

Pole Summary

Dents/Traffic Impact	◯Yes ◯No	Pole Missing/Down	◯Yes ◯No		

Mast Arm **Upper**

Mast Arm **Lower** (if applicable)

Mast Arm Chord **Upper** Connection

Missing Washers	◯Yes ◯No	Swing Away Hinge	◯Yes ◯No	Hinge Pin Present	◯Yes ◯No
Spot Weld Nut	◯Yes ◯No	Cotter Pins Present	◯Yes ◯No		

Mast Arm Chord **Lower** Connection (if applicable)

Missing Washers	◯Yes ◯No	Swing Away Hinge	◯Yes ◯No	Hinge Pin Present	◯Yes ◯No
Spot Weld Nut	◯Yes ◯No	Cotter Pins Present	◯Yes ◯No		

Luminaire Extension/Camera Extension

Missing Washers	◉Yes ◯No	Dented (Extension)	◯Yes ◯No	Accessories Connections	◯Yes ◯No

Defect Table (Foundation, Anchor Rods, Transformer Base, and Pole)

Element	Defect Type	Present	Quantity (units)	Length (ft)	Width (in)	Depth (in)	Comment	Rating	Action item	Condition Rating after repair
Foundation	Concrete Delamination	◯ Yes ◯ No								
	Cracks	◯ Yes ◯ No								
	Exposed Rebars/Reinforcement	◯ Yes ◯ No								
Anchor Rods	Rod Damage	◯ Yes ◯ No								
	Nut Connection Issue	◯ Yes ◯ No								
	Rod Thread Engagement Issue	◯ Yes ◯ No								
Transformer Base	Corrosion (Bottom Base Plates)	◯ Yes ◯ No								
	Corrosion (Bolts/Nuts/Washers)	◯ Yes ◯ No								
	Welds	◯ Yes ◯ No								
	Cracks (Bottom Base Plate)	◯ Yes ◯ No								
	Cracks (Bolts)	◯ Yes ◯ No								
	Dents/Nicks/Gouges	◯ Yes ◯ No								
Pole	Corrosion/Section Loss on Pole Base Plate	◯ Yes ◯ No								
	Cracks/Fracture on Pole Base Plate or Stifener	◯ Yes ◯ No								
	Weld Cracks (Pole)	◯ Yes ◯ No								
	Dents/Traffic Impact	◯ Yes ◯ No								
	Corrosion and Section Loss on Pole/Discoloration/Pitting	◯ Yes ◯ No								
	Bending/Tilting/Tilt Direction	◯ Yes ◯ No								

Defect Table (Mast Arms, Mast Arm Chord Connections, and Luminaire/Camera Extension)										
Element	Defect Type	Present	Quantity (units)	Length (ft)	Width (in)	Depth (in)	Comment	Rating	Action item	Condition Rating after repair
Mast Arm **Upper**	Sign panel straps/connections + other appurtenances (e.g. EVP)	◯ Yes ◯ No								
		◯ Yes ◯ No								
Mast Arm **Lower** (if applicable)	Sign panel straps/connections + other appurtenances (e.g. EVP)	◯ Yes ◯ No								
		◯ Yes ◯ No								
Mast Arm Chord **Upper** Connection	Weld Crack Gussets	◯ Yes ◯ No								
	Weld Crack End Plate to Mast Arm	◯ Yes ◯ No								
	Missing/Loose Bolts/Nuts	◯ Yes ◯ No								
	Oblong Holes (Deformed hole)	◯ Yes ◯ No								
	Misalignment	◯ Yes ◯ No								
	Distorted Connection	◯ Yes ◯ No								
	Crack on Mast Arm (Non-weld)	◯ Yes ◯ No								
	Corrosion Pitting	◯ Yes ◯ No								
	Weld Cracks at Swing Away Hinge	◯ Yes ◯ No								
Mast Arm Chord **Lower** Connection (if applicable)	Weld Crack Gussets	◯ Yes ◯ No								
	Weld Crack End Plate to Mast Arm	◯ Yes ◯ No								
	Missing/Loose Bolts/Nuts	◯ Yes ◯ No								
	Oblong Holes (Deformed hole)	◯ Yes ◯ No								
	Misalignment	◯ Yes ◯ No								
	Distorted Connection	◯ Yes ◯ No								
	Crack on Mast Arm (Non-weld)	◯ Yes ◯ No								
	Corrosion Pitting	◯ Yes ◯ No								
	Weld Cracks at Swing Away Hinge	◯ Yes ◯ No								
Luminaire Extension/Camera Extension	Weld Crack (Base to Extension)	◯ Yes ◯ No								
	Weld Crack (Base to Bolt Lug)	◯ Yes ◯ No								
	Missing/Loose Bolts/Nuts	◯ Yes ◯ No								
	Oblong Holes (Deformed Holes)	◯ Yes ◯ No								
	Cracking (Base/Connection)	◯ Yes ◯ No								
	Corrosion Pitting (Base/Connection)	◯ Yes ◯ No								
	Corrosion Pitting (Extension)	◯ Yes ◯ No								
	Crack on Extension (Extension)	◯ Yes ◯ No								

Appendix H

Lighting Structure Inspection General Information [Page 1 of 1]					
Inspection general information		**Lighting Unit Description**			
Inspector name(s)/signature		Pole Number /TAMS ID		Pole Style	
Inspection date		Lighting Unit Class Code		Pole Height	
Inspection type		Unit Installed Date		Mast Arm Length	
Overall Pole condition rating		Mounting Location		Anchor Rod Projection	
Overall comment		Coordinates (lat/long)		Mounting Type/Foundation Type	
Lighting System Description		Inspection Traffic Control		Traffic Direction	
TAMS ID/FEED POINT		Mounted Behind Guardrail		Coordinates (lat/long)	
Lighting System Class Code		Structure type		Inspection Traffic Control	
Primary Road Intersection		Materials		Photos	
Element Inspection Data					
Foundation Summary					
Debris	◯Yes ◯No	Grout layer (grout pad)	◯Yes ◯No	Grading	◯Yes ◯No
Erosion	◯Yes ◯No	Efflorescence/Chalking	◯Yes ◯No		
Anchor Rod Summary					
Base, Base Plate(s) & Pole-to-Base Connections Summary					
Overall Element Rating		Overall Element Comment		Overall Element Action Item	
Base Cover	◯Yes ◯No	Rodent Protection	◯Yes ◯No	Gouges/Nicks	◯Yes ◯No
Washers over hole	◯Yes ◯No	Debris	◯Yes ◯No	Pitting	◯Yes ◯No
Pole Summary					
Overall Element Rating		Overall Element Comment		Overall Element Action Item	
Dents/Traffic Impact	◯Yes ◯No	Pole Missing/Down	◯Yes ◯No		

Defect Table

Element	Defect Type	Present	Quantity (units)	Length (ft)	Width (in)	Depth (in)	Comment	Rating	Action item	Condition Rating after repair
Foundation	Corrosion (Screw In Foundation)	◯Yes◯No								
	Cracks (Concrete)	◯Yes◯No								
	Barrier/wall-mounted Reinforcement	◯Yes◯No ◯Yes◯No								
	Deformation (Screw In Foundation)	◯Yes◯No								
Anchor Rods	Rod Damage	◯Yes◯No								
	Nut Connection Issue	◯Yes◯No								
	Rod Thread Engagement	◯Yes◯No								
Base, Base Plate(s) & Pole-to-Base Connections	Corrosion	◯Yes◯No								
	Slip fitter	◯Yes◯No								
	Welds	◯Yes◯No								
	Cracking of the Base	◯Yes◯No								
	Rivets	◯Yes◯No								
	Dents/Gauges/Nicks	◯Yes◯No								
	Displacement/Movement (Connection b/w Pole & Base)	◯Yes◯No								
	Connection (If applicable)	◯Yes◯No								
Pole	Corrosion/Section Loss on Base Plate	◯Yes◯No								
	Cracks/Fracture on Base Plate or Stiffener Weld	◯Yes◯No								
	Weld Connection Bent Straw (If applicable)	◯Yes◯No								
	Gouges/Nicks	◯Yes◯No								
	Corrosion and Section Loss on Pole/Discoloration/Pitting	◯Yes◯No								
	Bending/Tilting/Tilt Direction	◯Yes◯No								

Appendix I

Overhead Sign Structure Inspection Form (v7.6m) [Page 1 of 2]					
Inspection information		**Overhead Sign Structure Description**			
Inspector name(s)/signature		Asset Type		Last Inspection Date	
Inspection date		Asset ID		Last Inspection Condition	
Inspection type		DMS Structure (Yes/No)		Support Position/Structure Location	
Overall Pole condition rating		Number of Posts		Route/Primary road	
Overall comment		OSS Design Type		Reference Post Offset	
		Year Installed/Open to Traffic		Traffic direction	
				Route type	
Element Inspection Data					
Left Foundation Summary		**Center** Foundation Summary		**Right** Foundation Summary	
Overall Element Rating		Overall Element Rating		Overall Element Rating	
Overall Element Comment		Overall Element Comment		Overall Element Comment	
Overall Element Action Item		Overall Element Action Item		Overall Element Action Item	
Vegetation growth in cracks	◯Yes ◯No	Vegetation growth in cracks	◯Yes ◯No	Vegetation growth in cracks	◯Yes ◯No
Spalling	◯Yes ◯No	Spalling	◯Yes ◯No	Spalling	◯Yes ◯No
Efflorescence	◯Yes ◯No	Efflorescence	◯Yes ◯No	Efflorescence	◯Yes ◯No
Grading Issues	◯Yes ◯No	Grading Issues	◯Yes ◯No	Grading Issues	◯Yes ◯No
Left Anchorages Summary		**Center** Anchorages Summary		**Right** Anchorages Summary	
Overall Element Rating		Overall Element Rating		Overall Element Rating	
Overall Element Comment		Overall Element Comment		Overall Element Comment	
Overall Element Action Item		Overall Element Action Item		Overall Element Action Item	
Total number of anchors		Total number of anchors		Total number of anchors	
Grout Present	◯Yes ◯No	Grout Present	◯Yes ◯No	Grout Present	◯Yes ◯No
Washer Missing	◯Yes ◯No	Washer Missing	◯Yes ◯No	Washer Missing	◯Yes ◯No
Left Post Summary		**Center** Post Summary		**Right** Post Summary	
Overall Element Rating		Overall Element Rating		Overall Element Rating	
Overall Element Comment		Overall Element Comment		Overall Element Comment	
Overall Element Action Item		Overall Element Action Item		Overall Element Action Item	
Cover plate present	◯Yes ◯No	Cover plate present	◯Yes ◯No	Cover plate present	◯Yes ◯No
Cover plate bolts present	◯Yes ◯No	Cover plate bolts present	◯Yes ◯No	Cover plate bolts present	◯Yes ◯No
Hand-hole welds satisfactory	◯Yes ◯No	Hand-hole welds satisfactory	◯Yes ◯No	Hand-hole welds satisfactory	◯Yes ◯No
Truss Summary					
Connection-Panel to Support Summary					
Overall Element Rating		Overall Element Comment		Overall Element Action Item	
Spalling around connection	◯Yes ◯No	Loose Posts Clips	◯Yes ◯No	Missing Post Clips	◯Yes ◉No
Loose Banding	◯Yes ◯No				

Defect Table - **Right** (Foundation, Rods and Post), Truss, and Connection-Panel to Support

Element	Defect Type	Present	Quantity (units)	Length (ft)	Width (in)	Depth (in)	Comment	Rating	Action item	Condition Rating after repair
Right Foundation	**Concrete delamination**	◯Yes ◯No								
	Crack in Concrete	◯Yes ◯No								
	Exposed Rebars /Reinforcement	◯Yes ◯No								
	Impact damage/Dents/Gouge	◯Yes ◯No								
	Reinforcement Section Loss	◯Yes ◯No								
	Guardrail Protection	◯Yes ◯No								
Right Anchor Rods	**Rod Damage**	◯Yes ◯No								
	Nut Connection Issue	◯Yes ◯No								
	Rod Thread Engagement Issue	◯Yes ◯No								
Right Post	**Base Plate/Stiffener Weld - Crack**	◯Yes ◯No								
	Base Plate - Section Loss Corrosion	◯Yes ◯No								
	Post - Section Loss Corrosion	◯Yes ◯No								
	Post - Tilt Perpendicular Exceedance	◯Yes ◯No								
	Post - Tilt Parallel Exceedance	◯Yes ◯No								
	Post - Impact damage/Dents/Gouge	◯Yes ◯No								
	Post - Crack	◯Yes ◯No								
Truss	**Broken Member**	◯Yes ◯No								
	Missing, Loose Hardware/Bolts	◯Yes ◯No								
	Corrosion	◯Yes ◯No								
	Truss Weld Crack/Deficient	◯Yes ◯No								
	Truss members impact damage/Distorted	◯Yes ◯No								
Connection-Panel to Support	**Missing, Loose Hardware/bolts**	◯Yes ◯No								
	Connection corrosion section loss	◯Yes ◯No								
	Connection welds – Cracked or Deficient	◯Yes ◯No								
	Impact Damage/Distortion	◯Yes ◯No								

Defect Table - **Left** (Foundation, Rods, Post) & **Center** (Foundation, Rods, and Post)										
Element	Defect Type	Present	Quantity (units)	Length (ft)	Width (in)	Depth (in)	Comment	Rating	Action item	Condition Rating after repair
Left Foundation	Concrete delamination	◉ Yes ○ No								
	Crack in Concrete	○ Yes ○ No								
	Exposed Rebars /Reinforcement	○ Yes ○ No								
	Impact damage/Dents/Gouge	○ Yes ○ No								
	Reinforcement Section Loss	○ Yes ○ No								
	Guardrail Protection	○ Yes ○ No								
Left Anchor Rods	Rod Damage	○ Yes ○ No								
	Nut Connection Issue	○ Yes ○ No								
	Rod Thread Engagement Issue	○ Yes ○ No								
Left Post	Base Plate/Stiffener Weld - Crack	○ Yes ○ No								
	Base Plate - Section Loss Corrosion	○ Yes ○ No								
	Post - Section Loss Corrosion	○ Yes ○ No								
	Post - Tilt Perpendicular Exceedance	○ Yes ○ No								
	Post - Tilt Parallel Exceedance	○ Yes ○ No								
	Post - Impact damage/Dents/Gouge	○ Yes ○ No								
	Post - Crack	○ Yes ○ No								
Center Foundation	Concrete delamination	○ Yes ○ No								
	Crack in Concrete	○ Yes ○ No								
	Exposed Rebars /Reinforcement	○ Yes ○ No								
	Impact damage/Dents/Gouge	○ Yes ○ No								
	Reinforcement Section Loss	○ Yes ○ No								
	Guardrail Protection	○ Yes ○ No								
Center Anchor Rods	Rod Damage	○ Yes ○ No								
	Nut Connection Issue	○ Yes ○ No								
	Rod Thread Engagement Issue	○ Yes ○ No								
Center Post	Base Plate/Stiffener Weld - Crack	○ Yes ○ No								
	Base Plate - Section Loss Corrosion	○ Yes ○ No								
	Post - Section Loss Corrosion	○ Yes ○ No								
	Post - Tilt Perpendicular Exceedance	○ Yes ○ No								
	Post - Tilt Parallel Exceedance	○ Yes ○ No								
	Post - Impact damage/Dents/Gouge	○ Yes ○ No								
	Post - Crack	○ Yes ○ No								

Appendix J

THE CITY OF COLUMBUS

OVERHEAD SIGN SUPPORT INSPECTION

SUPPORT INFORMATION

Support Identifier:		Mile Marker:	
Route:		Direction:	

STRUCTURE DESCRIPTION

Support Material:		Installation Year:	**Unknown**
Span Material:		GPS Latitude:	
Support Type:		GPS Longitude:	
Flange Type:			
# of Lanes Under Structure:		RT Edge of Road to Supp.:	FT
# of Sign Panels:		LT Edge of Road to Supp.:	FT
Sign Description:			

STATUS

Prompt Corrective Action Required:	
Overall Rating:	
Further Inspection Required:	
Summary of Status:	

INSPECTOR

Name:	
Date Inspected:	

RATING REPORT

Condition Rating Definitions:	
Rating	Description (No comment required on any item rated 1 or 2)
4	Very Good - New/like-new condition
3	Good - Minor damage, deterioration, or misalignment, structurally sound
2	Fair -Moderate damage/deterioration that does not significantly affect the element strength/integrity.
1	Poor - Major or multiple defects that significantly impacts the serviceability or integrity of the structure.

Rating	**Overall Summary of Structure Condition**

Rating	**Component**	**Description of Deficiencies**	
S.01	FOUNDATION		
		Cracks:	Soil Erosion:
		Concrete Spalling:	Buried/Covered:
S.02	ANCHOR BOLT		
		Corrosion:	Nuts Loose:
		Cracks:	Washers Missing:
S.03	END FRAME/POLE		
		Endframe/Pole Corrosion:	Cracking:
		End Frame/Pole Damage:	Wire Entrance Cap Missing:
		Handhole Covers Missing:	Pole Cap Missing:
		Missing Bolts:	Bolt Corrosion:
		Weld Cracking:	Weld Corrosion:

Rating	Component	Description of Deficiencies	
S.04	CANTILEVER/ SPAN		
		Cantilever/Span Corrosion:	Cantilever/Span Cracking:
		Cantilever/Span Damage:	Cantilever/Span Corrosion:
		Handhole Covers Missing:	End Caps Missing:
		Missing Bolts:	Bolt Corrosion:
		Weld Cracking:	Weld Corrosion:
S.05	SIGNS		
		Sign Attachment Corrosion:	Sign Attachment Deformations:
		Attachment Missing Hardware:	Sign Damage:
		Sign Lighting Missing Hardware:	Sign Obstruction/Overgrowth:
S.06	PROTECTION/ BARRIER		

REPAIR RECOMMENDATIONS

Definitions	
Priority	Definition
1	High Priority - Structure or a component is structurally unsafe: cracks in critical members, cracked or broken members in danger of falling, numerous cracked or missing sign clips that could lead to a sign to fall, etc…
2	Middle Priority - Deficient Components which do not immediately threaten structural integrity or safety, ruptured or cracked secondary members, a loose bolt or two at a connection or splice, etc..
3	Low Priority - Components with minor structural deficiencies, minor loss of protective coating, minor foundation cracks, minor cracks in secondary members, etc…

No.	Element	Repair Recommendations	Priority Code

Appendix K

Signal Support Inspection Form

Support Information

Support Identifier: _____ Date: _____

Route: _____ Direction: _____

Intersection of: _____and _____

Design No.: _____

Support Type: _____ Strain Pole _____ Mast Arm _____ Sign _____ School

_____ Other: _____

Foundation

_____ Concrete Condition _____ Soil Condition _____ Anchor Bolts/Nuts

Comments: _____

_____

Support Condition

_____ Galvanized _____ Painted _____ Wood

_____ Structural Members _____ Structural Connections _____ Down Guy

Damage? _____ Yes _____ No Pitting? _____ Yes _____ No

Surface Rust: _____ Minimal _____ Moderate _____ Severe

Comments: _____

_____

Inspected by: _____ Date: _____

Form 496-1.

Appendix L

Form 496-7. Signal Inspection Form

TRAFFIC SIGNAL FILE NUMBER: LOCATION:
COUNTY AND ROUTE NUMBER: ODOT SIGNAL SYSTEM NUMBER:

DATE INSPECTED: _____/_____/_____ TIME REQUIRED: _____
CONTROLLER TYPE: _____ ODOT NUMBER: _____
MONITOR MODEL: _____ CM: □ ODOT NUMBER: _____
MMU: □ COORDINATION TYPE:_____
INSPECTED BY: _____ TITLE: _____
INSPECTED BY: _____ TITLE: _____

1 TRAFFIC SIGNAL HEAD	**Satisfactory**	**Unsatisfactory**	**N/A**	**Repaired**
1.1 Alignment	□	□	□	□
1.2 Date re-lamp	Date re-lamped ____/_____/_____			
1.3 Clearance Height	Clearance Ft._____ In._____		□	
1.4 Condition including the following: lens (dirty, burns, holes), lamp orientation, visors, lamps (all burning), signal head cable condition(splices/wear), Prepare to Stop When Flashing sign, above ground detection, water leaks	□	□	□	□

2 OVERHEAD SIGNAL SUPPORT SYSTEM

2.1 Condition including the following: messenger wire for rust, grips, 3-bolt clamps, pole clamp bolts tight, wire entrance and pin wear, span wire signing, pole clamp assembly and clevis pin wear, lashing rods, signal cable	□	□	□	□

3 CONTROLLER & CABINET

3.1 Intersection documentation
□ Present & Current □ Present & Not Current □ Not Present

3.2 Conflict Monitor or MMU (12 mo. inspection)	Date: ____/_____/_____			
3.3 All detection operational**	□ All working	□ 1 Detector Failed	□ 2 or more Failed	
3.4 Wires and cables labeled	□	□	□	□
3.5 Cabinet sealed to foundation	□	□	□	□
3.6 Lock condition (including Power Service)	□	□	□	□
3.7 Filter Clean (Size___X____X____)	□	□	□	□
3.8 Cabinet lamp working	□	□	□	□
3.9 GFCI receptacle (test)	□	□	□	□
3.10 Wire terminations tight	□	□	□	□
3.11 Prepare To Stop When Flashing Timing (Ph.__= ____sec.) (Ph.__= ____sec.)	□	□	□	□
3.12 Load switch indicators lighting	□	□	□	□
3.13 Preemption	□	□	□	□
3.14 Cabinet earth ground (___ohms)	□	□	□	□
3.15 Lightning arresters	□	□	□	□
3.16 Housing conduit sealed	□	□	□	□
3.17 Cabinet fan / thermostat	□	□	□	□
3.18 Cabinet clean? need vacuuming?	□	□	□	□
3.19 Cabinet hinges, need lubricated?	□	□	□	□

Form 496-7. Signal Inspection Form (Continued)

		Satisfactory	Unsatisfactory	N/A	Repaired
4	**SIGNAL STRAIN AND WOOD POLES**				
4.1	Anchor bolts tight	☐	☐	☐	☐
4.2	Hand hole covers in place	☐	☐	☐	☐
4.3	Pole grounds	☐	☐	☐	☐
4.4	Pole cap in place	☐	☐	☐	☐
4.5	Concrete foundation	☐	☐	☐	☐
4.6	Down guys	☐	☐	☐	☐
4.7	Wood pole condition	☐	☐	☐	☐
5	**POWER SERVICE**				
5.1	Condition including: weather head, wire chaffing, splices at top of pole, switch box condition, meter box				
6	**LOOP DETECTORS & SEALANT**				
6.1	Cracks filled with sealant	☐	☐	☐	☐
6.2	No exposed wires	☐	☐	☐	☐
6.3	No pavement cracks (Note crack repair in comments for crack sealant repair crew scheduling)				
7	**PEDESTRIAN OPERATION**				
7.1	Including: pedestrian head aim/alignment, pedestrian head working	☐	☐	☐	☐
8	**PULL BOXES**				
8.1	Condition including: all located, lids on all, draining properly, wires and cables labeled, wires and conduit in good shape, conduit sealed, lid marked **"Traffic"**	☐	☐	☐	☐

Item #	Comments

ODOT TRAFFIC SIGNAL INSPECTION CHECKLIST

Project Number/PID _____ Date _____

Project Engineer / Supervisor _____

Signal Contractor _____

Final Inspector _____

Intersection _____

Note: Checklist based on 2019 Construction & Material Specifications.

OSIS No: _____

Controller/Make/Model No: _____ S/N: _____

MMU: _____ S/N: _____

Cabinet Type: _____ S/N: _____

Meets	Deficient	N/A	**WARRANTY INFORMATION:**
☐	☐	☐	1. Ensure that each unit has a permanent label or stamp indicating the date of shipment. Controller, Monitor, BIU, 2070 CPU board, field I/O module, Front Panel (CMS 733.02B)
☐	☐	☐	2. CMS 733.02B Furnish 60-month warranties or the manufacturers' standard warranty, whichever is greater for the following equipment: **1. NEMA Controller Equipment** a. TS-2 Controller Units, including ATC controller b. Bus Interface Units c. Malfunction Management Units d. TS-1 Conflict Monitors **2. CalTrans Controller Equipment** a. Model 2010 or 2018 Conflict Monitor Units b. ATC Rackmount Controller c. 2070L, 2070LX, and 2070E Controller Units including the following subassembly units: (1) 2070-1E, 2070-1B, and 2070-IC CPU Board (2) 2070-2A Field I/O Module (3) 2070-3B Front Panel. (4) 2070-6A,B. Ensure that the warranty period begins on the date of shipment to the project. **Ensure that each unit has a permanent label or stamp indicating the date of shipment.**

Comments:

Meets	Deficient	N/A	CONTROLLER & CABINET:
☐	☐	☐	1. Is the cabinet sealed to the concrete base (and/or riser) with waterproof material? (TC-83.20 & CMS 633.08)
☐	☐	☐	2. Are all tags or labels properly installed and legible including the service wire, phase numbers and directions? (CMS 632.05)
☐	☐	☐	3. Are the connectors soldered on the loop lead in wires? (CMS 632.23)
☐	☐	☐	4. Is all field wiring neatly arranged and routed to prevent being pinched when the cabinet door is closed and free of debris? (CMS 633.08)
☐	☐	☐	5. Is the work pad in place? (CMS 633.11)
☐	☐	☐	6. Was the work pad poured separate from the foundation pour? (CMS 633.11)
☐	☐	☐	7. Is all wiring (except power) fitted with spade terminals? (CMS 633.08)
☐	☐	☐	8. Is all power wiring fitted into spade, screw, or spring terminals? (CMS 633.08)
☐	☐	☐	9. Is there LED lighting in the cabinet? (CMS 733.03)
☐	☐	☐	10. Is the controller cabinet properly grounded (max 10 ohms)? (CMS 625.16) Ground Rod Readings=
☐	☐	☐	11. When shorted, does the conflict monitor cause the intersection to go to flash? (CMS 733.03)
☐	☐	☐	12. Is the control equipment, terminal blocks, or shelves no closer than 6" to the top of the foundation? (CMS 633.08)
☐	☐	☐	13. Is there ½" preformed joint filler between foundation and adjacent paved areas (this includes work pad)? (TC-83.20)
☐	☐	☐	14. Does the enclosure include a vent, fan and thermostat? (CMS 733.03)
☐	☐	☐	15. Is the conduit sealed with a removable sealing compound? *No foam sealer!* (CMS 633.08)
☐	☐	☐	16. Are the proper diodes cut on the permissive card (2070)? Additional diodes shall not be allowed to be removed.
☐	☐	☐	17. Are there two (2) sets of equipment lists, operation and maintenance manuals, and board-level schematic and wiring diagrams of the UPS, and the battery data sheets? (CMS 633.05 and UPS Note)
☐	☐	☐	18. SD card or data key present?
☐	☐	☐	19. Does the cabinet have the proper finish inside and out as per plan (CMS 733.03)
☐	☐	☐	20. Is all the equipment as per plan or ODOT approved? (CMS 733.03)
☐	☐	☐	21. Is the pole-mounted cabinet at the proper height? Less than 36” tall cabinet equal 30” +/- 3”. Over 36” tall cabinet equal to 23” +/- 3”. (TC-83.10)
☐	☐	☐	22. Are all wire terminals tight? (CMS 632.28)
☐	☐	☐	23. Is the cabinet air filter in place and clean? Front and/or Back (CMS 733.03)
☐	☐	☐	24. Are all unused conductors grounded in the controller cabinet?
☐	☐	☐	25. In a TS-1 cabinet, are the neutral (AC-) and grounding bars in the controller cabinet NOT connected together? (CMS 733.03.A.2.g) In a TS-2 cabinet, are the neutral (AC-) and grounding bars in the controller cabinet connected together? (CMS 733.03.B.1.b)

Comments:

Meets	Deficient	N/A	CABINET:
☐	☐	☐	1. Do all empty conduits have an HDPE insulated copper tracer wire, 12 AWG minimum, installed and then have all the ends sealed? (CMS 625.12)

Comments:

Meets	Deficient	N/A	OPERATIONAL CHECKS:
☐	☐	☐	1. Upload timings from controller. Are they per plan, including correct clearance intervals and for concurrent phases?
☐	☐	☐	2. Do the detectors work for the assigned detector in the proper phase?
☐	☐	☐	3. Do the detectors place a call to the controller on the proper phase?
☐	☐	☐	4. Does the controller call in the proper direction and movement?
☐	☐	☐	5. Do all movements come in when a call is placed on a detector for that movement?
☐	☐	☐	6. Do ped push buttons put a call into the controller through the DC isolator?
☐	☐	☐	7. Does the controller receive the pedestrian call and call in the proper movement?
☐	☐	☐	8. Is the Leading Pedestrian Interval (LPI) properly programmed? See OTO's Traffic Signal Resources Guide regarding LPI.
☐	☐	☐	9. Hook up generator and make sure generator panel works correctly.
☐	☐	☐	10. Do the left turn phases not conflict with WALK indication on intersecting street and/or driveway?
☐	☐	☐	11. Is the controller programmed properly for the UPS alarms? (ON Battery, Battery 2 Hour Timer, Low Battery)
☐	☐	☐	12. Flash All Red (or Y/R) as per plan?
☐	☐	☐	13. Countdown peds go to zero on yellow?

Comments:

Meets	Deficient	N/A	RADAR DETECTION:
☐	☐	☐	1. Are the radar sensors aimed/aligned properly?
☐	☐	☐	2. Are the detection zones at the proper location? Confirm in software.

☐	☐	☐	3. Are the controller detector channels assigned to the proper detection zone?
☐	☐	☐	4. Are the sensors grounded?
☐	☐	☐	5. Was dielectric grease used on the sensor's electrical connections? (inside the military connector)
☐	☐	☐	6. Are all conduit entrances, ends of bracket arms, etc. sealed? Grommets in place, if necessary?
☐	☐	☐	7. Is the cabinet interface panel properly installed?
☐	☐	☐	8. Are the cables tagged?
☐	☐	☐	9. Is the Ethernet module in place?
☐	☐	☐	10. Is all mounting hardware tight and none missing?
☐	☐	☐	11. Has strain relief been provided for the pigtail between the splice box and the sensor?
☐	☐	☐	12. Was the existing Loop Lead-In Cable removed per the plan note?

Comments:

Meets	Deficient	N/A	**UPS:**
☐	☐	☐	1. Does the UPS have lightning surge protection? (CMS 733.09)
☐	☐	☐	2. Does the UPS include a backlit LCD display that includes an event counter, hour meter, line and battery voltages/percentages and fault status? (CMS 733.09)
☐	☐	☐	3. Are the UPS alarms wired to the controller backpanel? (ON Battery, Battery 2 Hour Timer, Low Battery)

Comments:

Meets	Deficient	N/A	**UPS OPERATIONAL CHECKS:**
☐	☐	☐	1. Does UPS take over when disconnect is opened?
☐	☐	☐	2. Does Manual Bypass switch remove power from the UPS input on the terminal block?
☐	☐	☐	3. Check line voltage of cabinet with AC power and after UPS is tripped.
☐	☐	☐	4. Confirmation light installed and functioning?

Comments:

Meets	Deficient	N/A	LOOP DETECTORS:
☐	☐	☐	1. Were the corners, cracks, and/or joints drilled with a minimum diameter 1-1/4” drill bit? (TC-82.10)
☐	☐	☐	2. Is the lead-in conduit installed a minimum of 2 feet from edge of pavement (not shoulder, normally the white line) or edge of full depth shoulder? Conduit shall not go through curb and/or gutter (TC-82.10)
☐	☐	☐	3. Is the Lead-in cable twisted 3 to 5 turns per foot from the loop to the splice? (CMS 632.23)
☐	☐	☐	4. Is cured loop sealant flush with or higher than the pavement surface? (CMS 632.11)
☐	☐	☐	5. Are all adjacent loop slots a minimum of 1'-0" apart? (TC-82.10)
☐	☐	☐	6. If loop crosses joint in concrete pavement, was a 3” x 3” square of material removed and filled with elastic join material or asphalt across joint? (TC-82.10)
☐	☐	☐	7. Are the detector loops installed at the proper location as per plan?

Comments:

Meets	Deficient	N/A	TRENCHING:
☐	☐	☐	1. Is the trench at final grade and restored? (CMS 107.10) a. If noted in the plans, is the area seeded?
☐	☐	☐	2. Is the trench in paved areas restored? (CMS 625.13)
☐	☐	☐	3. Is the trench 24 inches deep and less than 12 inches wide? CMS 625.13
☐	☐	☐	4. Have the conduit threads been protected with zinc paint? (CMS 625.12)

Comments:

Meets	Deficient	N/A	BATTERIES:
☐	☐	☐	1. Are batteries deep cycle, sealed prismatic lead-calcium based AGM/VRLA (Absorbed Glass Mat / Valve Regulated Lead Acid)? (CMS 733.09)
☐	☐	☐	2. Are batteries rated for 105 Ahrs? (CMS 733.09)
☐	☐	☐	3. Are batteries labeled to operate over a temperature range of -13 °F to +165 °F (– 25 °C to +74 °C)? (CMS 733.09)
☐	☐	☐	4. Are batteries **placed on** battery heater mats in the enclosure? (CMS 733.09)
☐	☐	☐	5. Disconnect and load test each battery

Comments:

Meets	Deficient	N/A	**SUPPORTS:**
☐	☐	☐	1. Is all the hardware on the poles: caps, covers, etc. (TC-81.10 & TC-81.21)
☐	☐	☐	2. Is pole essentially vertical or slightly raked away from intersection? (CMS 632.16)
☐	☐	☐	3. Is the pole/pedestals properly grounded (max 25 ohms)? Table below. (CMS 625.16)
☐	☐	☐	4. Are all scratches coated with zinc coating? *Do not use galvanizing spray* (CMS 711.02)
☐	☐	☐	5. Are all required washers and nuts in place? (CMS 630.06) *Leveling nut underneath. Plain structural washer & anchor nut on top.*
☐	☐	☐	6. Does it appear that anaerobic adhesive (lock-tite) was used on anchor bolt? (CMS 630.06)
☐	☐	☐	7. Are all conduits 2” minimum above foundation but less than the height of the anchor bolts? (TC-21.20)
☐	☐	☐	8. Are all conduits into the pole sealed? (CMS 625.12)
☐	☐	☐	9. Are the anchor bolts the proper height above the foundation? (TC-81.10 & TC-81.21) *The top of the bolt should be one full bolt thread above the nut so that water does not sit in there.*
☐	☐	☐	10. Is there at least one conduit ell in addition to the grounding PVC, even if not used (minimum 2" conduit) (TC-21.20)
☐	☐	☐	11. (*Only if there is a plan note requiring it*) Do all the poles contain permanent legible markings indicating month/date of fabrication, pole gauge, bottom diameter, pole height, bolt circle, anchor bolt diameter, flange bolt diameter, quadrant and intersection? Do all the arms contain permanent legible markings indicating month/date of fabrication, arm gauge, arm diameter, arm length, connecting flange bolt diameter, quadrant and intersection?
☐	☐	☐	12. Are the cable support assembles in place and the correct size? (CMS 732.17). Cable and wire inside of poles shall include cable support assemblies. (CMS 632.21 and TC-84.20)
☐	☐	☐	13. Does the strain pole have at least one 2-inch cable entrance with a weather head and a welded blind half-coupling? (CMS 732.12)
☐	☐	☐	14. Is the pole properly grounded, cad welded with 2 coats of varnish applied over the welds and exposed cable? (CMS 625.09)
☐	☐	☐	15. Are all unused holes plugged? (CMS 732.11, TC-81.20)
☐	☐	☐	16. Are the pole identification tags present? (TC-81.10, TC-81.21)

Pole Ground Readings							
NW		NE		SW		SE	

Comments:

Meets	Deficient	N/A	PEDESTRIAN SIGNALS & ADA INFORMATION:
☐	☐	☐	1. Is the bottom of the pedestrian signal head 8' to 9' above the walk? (TC-85.10)
☐	☐	☐	2. Is the front of the pedestrian signal head visor (or sun shade) more than 2' from the face of the curb? (TC-85.10)
☐	☐	☐	3. Is the pedestrian signal head properly oriented to its crosswalk? (CMS 632.08)
☐	☐	☐	4. Is there an unobstructed path to the pushbutton (no guardrail, no unpaved surface)? (PROWAG R204)
☐	☐	☐	5. Does the curb ramp have an all-weather surface/detectable warning? (BP-7.1)
☐	☐	☐	6. Is the pushbutton installed between 1.5 ft. and 6 ft. from the edge of the curb, shoulder, or pavement? If exceptions, the pushbutton should not be further than 10 ft. from the edge of the curb, shoulder, or pavement. (OMUTCD Fig. 4E-3)
☐	☐	☐	7. Are two pedestrian pushbuttons on a corner separated by at least 10 feet? (OMUTCD Fig. 4E-3)
☐	☐	☐	8. There should be no visible wiring on the pedestrian pushbutton? (CMS 632.09)
☐	☐	☐	9. Are all pedestrian signs installed and oriented correctly? (CMS 632.09)
☐	☐	☐	10. Is the bottom of the pedestrian pushbutton 3'-6" to 4'-0" above the walk? (TC-85.10)
☐	☐	☐	11. On steel poles the pushbutton and pedestrian signal heads must have a ¾" diameter rubber grommet installed where the signal cable passes through the pole. (TC-85.10)
☐	☐	☐	12. The cover assembly shall be attached to the housing by stainless machine screws resulting in a weatherproof and shock proof assembly. (CMS 732.06)
☐	☐	☐	13. Any unused conduit attachment holes shall be plugged. (CMS 632.08 and CMS 632.09)
☐	☐	☐	14. Are the pedestrian pushbutton signs in place on all corners oriented parallel to the crossing and as per plan? (CMS 632.09)
☐	☐	☐	15. Are all pedestrian signal head visors and lenses of the proper material and color as per plan? (CMS 732.05)
☐	☐	☐	16. Are the pedestrian pushbuttons operational?
☐	☐	☐	17. Do the pedestrian pushbuttons call the proper phase?
☐	☐	☐	18. Do countdown peds go to zero on yellow?
☐	☐	☐	19. Do all ADA compliant items meet (#4, 5, 6, 7, 10, 14)? If not, email all exceptions/reasoning for these deficiencies for record keeping to the ODOT ADA Office, Sarah.Wade@dot.ohio.gov

Comments:

Meets	Deficient	N/A	SERVICE:
☐	☐	☐	1. Can the service be padlocked in the ON or OFF position? (CMS 732.21)
☐	☐	☐	2. Is conduit of the size and type shown on the plans? (CMS 625.12)
☐	☐	☐	3. Were all conduit nipples coated with zinc paint? (CMS 625.12)
☐	☐	☐	4. All service hardware shall have connections sealed as to have no water leaks? (TC-83.10)
☐	☐	☐	5. Is disconnect furnished with a padlocked keyed to the maintaining agency? (CMS 631.06)
☐	☐	☐	6. Is power feed run through a disconnect before it is run inside the signal pole? (TC-83.10)
☐	☐	☐	7. Is the ground rod and cable connected by an exothermic weld over the weld and exposed cable? (CMS 625.16)
☐	☐	☐	8. Are the cable tags attached to all services wires except bare ground bonding cables? (CMS 625.17)
☐	☐	☐	9. Conduit risers mounted on painted poles shall be painted to match the poles. (CMS 632.24)
☐	☐	☐	10. All conduit fittings in steel poles for the service disconnect switch shall be a welded blind half coupling. (TC-83.10)
☐	☐	☐	11. Is the lock in place on the "Service Disconnect" switch? (CMS 631.06)
☐	☐	☐	12. Is the disconnect switch the proper height? (TC-83.10)
☐	☐	☐	13. Is the neutral bar in the "Service Disconnect Switch connected directly to the pole grounding lug? (CMS 725.19.F)
☐	☐	☐	14. Is the ground wire connected from the ground rod directly to the disconnect switch neutral (AC-) then to the pole? (G&B Note and TC-83.10)

Comments: Meter #

Meets	Deficient	N/A	MAST ARMS & SIGNAL CABLES:
☐	☐	☐	1. Is the wire chafing against mounting brackets? (TC-85.20)
☐	☐	☐	2. Are there no splices in the wire, except between: A) Detector wire and lead-in-cable (CMS 632.23) B) Power cable and power supply source or service cable (CMS 632.23) C) Long lengths of interconnect or service cable (CMS 632.23)
☐	☐	☐	3. Have the Cable Support Assemblies (Grips) been properly installed? (CMS 632.21) Max 4 cables per grip.

Comments:

Meets	Deficient	N/A	SPAN WIRE AND SIGNAL CABLES:
☐	☐	☐	1. Are bull rings located as per plan? (CMS 632.22)
☐	☐	☐	2. Is the wire chafing against any span hanger or other type of mounting brackets? (TC-85.20)
☐	☐	☐	3. Is the messenger wire sag between 3% and 5%? Check using a tension force gauge. (CMS 632.22)
☐	☐	☐	4. Are the drip loops greater than 6" where cabling comes out of Blind Half Coupling at Strain Pole? TC-84.20
☐	☐	☐	5. Were 3 bolt clamps used to attach the span wire to the shackle? (TC-84.20)
☐	☐	☐	6. Is the lashing rod the proper size for the conductors being wrapped? (CMS 632.22, 732.18)
☐	☐	☐	7. Are there no splices in the wire, except between: A) Detector wire and lead-in-cable (CMS 632.23) B) Power cable and power supply source or service cable (CMS 632.23) C) Long lengths of interconnect or service cable (CMS 632.23)
☐	☐	☐	8. Tag end of span wire shall be Min. of 12 inches long and Max. of 24 inches long and be served or clamped. (TC-84.20)
☐	☐	☐	9. Have the Cable Support Assemblies (Grips) been properly installed? (CMS 632.21) Max 4 cables per grip.

Comments:

Meets	Deficient	N/A	SIGNAL HEADS:
☐	☐	☐	1. Is the signal head height between 17 and 19 feet? (TC-81.21) *Non-ODOT maintained signals are allowed to be between 15 and 19 feet if the maintaining agency agrees.*
☐	☐	☐	2. Are the signal heads hanging plumb? (CMS 632.06 & TC-85.20)
☐	☐	☐	3. Are all LEDs oriented correctly installed in the UP position?
☐	☐	☐	4. Are signal heads more than 8 feet apart? (OMUTCD 4D-15-(F))
☐	☐	☐	5. Is each signal face oriented to its traffic approach? (CMS 632.06)
☐	☐	☐	6. Are spade terminals used, not wires wrapped around the screw? (CMS 632.05)
☐	☐	☐	7. Are all wire entrances facing the direction of the controller housing? (ODOT preference)

☐	☐	☐	8. Are signal heads sealed with silicone against water leakage? (Sealed: CMS 732.01, 732.02, 732.03, 732.05; With Silicone: Typical plan note from TEM 442-13)
☐	☐	☐	9. Is all hardware used to join optical sections together (tri-stud) stainless steel? (CMS 732.01) *Not zinc plated. Zinc plated is shiny like it is chromed. Stainless steel is barely magnetic. Test with a magnet*
☐	☐	☐	10. Do all signal heads have at least 6-inch drip loops? (TC-85.22)
☐	☐	☐	11. Are all set screws and locking nuts tight?
☐	☐	☐	12. Are all unused openings plugged?
☐	☐	☐	13. Are balance adjusters required by the Plans? (CMS 632.06)
☐	☐	☐	14. Are all signal heads visors and lenses of the proper material and color as per plan? (CMS 732.01)
☐	☐	☐	15. Are the “optically programmed” heads masked properly or according to the plan? (CMS 732.02)
☐	☐	☐	16. Do the OPTICOM receiver heads have a weep hole drilled in the bottom?
☐	☐	☐	17. Are all signal heads placed as per plan?
☐	☐	☐	18. Are the signals installed using an extender hanger at the top of the signal? Bottom tether anchor extenders shall only be used if there is interference between the backplate and tether wire.
☐	☐	☐	19. Are supplemental, pole mounted signals installed 11’ to 12’ above the pavement? (TC-85.10)

Comments:

Meets	Deficient	N/A	**PULL BOXES:**
☐	☐	☐	1. Are pull boxes installed to grade? (CMS 625.11)
☐	☐	☐	2. Is the pull box installed on a 6" gravel base? (CMS 625.11)
☐	☐	☐	3. Are all tags/labels in place and legible? (CMS 632.05)
☐	☐	☐	4. Is there duct seal in all the conduits entering the base of a signal pole, sign support, light pole, light tower or pad mounted equipment? (CMS 625.12)
☐	☐	☐	5. Is the proper ID “TRAFFIC” or “ELECTRIC” on the pull box lid? (CMS 725.08.B)
☐	☐	☐	6. Are there bolts in the pull box lid? *Shall be countersunk hex head or socket head cap screws* (HL-30.11)
☐	☐	☐	7. Splice kits are completely filled with sealant and air voids are less than 1/4"? (TC-82.10)
☐	☐	☐	8. Are all the openings, around conduits or knockouts, sealed? (HL-30.11)
☐	☐	☐	9. If plan specifies, are drains installed to under drains or side slopes? (HL-30.11)
☐	☐	☐	10. If underdrain for pull box installed & plan note specifies it, is the vent screen fitting at the outlet installed?
☐	☐	☐	11. Are all ends of rigid metal conduits capped with proper bushings? (CMS 625.12)

☐	☐	☐	12. Are bolt holes in metal diagonal pieces not in the concrete pull box itself? (HL-30.11)
☐	☐	☐	13. Is the equipment grounding conductor attached to the frame diagonal? (CMS 625.11)
☐	☐	☐	14. Is there a durable label reminding of the need to lubricate the threads of the cover hold down screws with grease or anti-seize compound on the inside of the frame or upper wall? (HL-30.11)
☐	☐	☐	15. Are all metallic items enclosing electrical conductors bonded together and to a good earth ground? (CMS 625.12)
☐	☐	☐	16. Are the Splice Kits ODOT approved? (CMS 632.23)
☐	☐	☐	17. Is “cement grout” in place around the conduits that enter the pull box? (HL-30.11)
☐	☐	☐	18. Are the pull boxes the correct size and type according to the plan? (HL-30.11)
☐	☐	☐	19. Is the final grade and seeding complete around the pull boxes? (CMS 625.01,625.11,632.01,HL-30.22, and HL-30.11)
☐	☐	☐	20. Do all empty conduits have a HDPE insulated copper tracer wire, 12 AWG minimum, pull wire installed and then have all the ends sealed? (CMS 625.12)

Comments:

Meets	Deficient	N/A	**TETHER & BACKPLATES:**
☐	☐	☐	1. Is S-hook and turnbuckle at least at one end of simple span or at all ends of complex span?
☐	☐	☐	2. Is S-hook closed at pole end?
☐	☐	☐	3. Is 1/8” stainless steel wire wound around turnbuckle to prevent turning of turnbuckle?
☐	☐	☐	4. Is tether installed horizontally?
☐	☐	☐	5. Is S-hook properly sized? 3 / 8” for Pole Design No 1-4 1 / 2” for Pole Design No. 5-14
☐	☐	☐	6. Is safety tie installed at each turnbuckle?
☐	☐	☐	7. Is safety tie 1x19, 1 / 8” stainless steel wire?
☐	☐	☐	8. Is safety tie slack but not so slack that it touches pole?
☐	☐	☐	9. Does the safety tie have three clips per end at 3-1/4” spacing?
☐	☐	☐	10. Is safety tie thimble clamp less than 6” from messenger wire clamp?
☐	☐	☐	11. Does tether wire have a vertical clearance of 17 feet to 19 feet over the roadway?
☐	☐	☐	12. Is tether wire 1 / 4” ASTM A475 Utilities Grade wire?
☐	☐	☐	13. If heads have backplates, is the tether wire below the backplate? (TC-85.21)
☐	☐	☐	14. Is tether wire in the bottom of the breakaway clamp?

☐	☐	☐	15. Do backplates have 2” wide continuous fluorescent yellow reflective border? (TC-85.21)
☐	☐	☐	16. Are backplates aluminum? (CMS 732.22)
☐	☐	☐	17. Does backplate extend 5” beyond the outside of the signal assembly on all sides? (CMS 732.22)
☐	☐	☐	18. Are there no gaps between the backplate and the signal head or between signal sections? (CMS 732.22)
☐	☐	☐	19. Is all assembly and mounting hardware stainless steel? (CMS 732.22)
☐	☐	☐	20. If used, are machine nuts thread-deforming or nylon locknuts? (CMS 732.22)
☐	☐	☐	21. Rivets shall not be used for mounting the backplate. (CMS 732.22)
☐	☐	☐	22. Were a minimum of four mounting points used on each signal section for attaching the backplate? (CMS 732.22)
☐	☐	☐	23. Is the tether wire tension adjusted to minimize movement of signal heads in high winds? Typical tension is 600-800 lbs (check with tension gauge).

Comments:

Form 296-4. Overhe d S gn Support Inspe t on

Support In orm t on

Support Identifier: _____ Date: _____
Route: _____ Direction: _____
C - R - S: _____Mile Marker: _____

Design No.: _____ Bridge Mtd Foundation? ____Yes ____No
Support Type: ____Cantilever ____Box Truss ____Bridge Mtd ____Skewed Bridge Mtd
____Span Wire ____Monotube ____Butterfly ____Semi-Overhead
____Other: _____

Found t on

____Concrete Condition ____Soil Condition ____Anchor Bolts/Nuts
Comments: _____
_____

nd Fr me/Pole

____Structural Members ____Structural Connections
____Damage? ____Yes ____No ____Pitting? ____Yes ____No
____Surface Rust: ____Minimal ____Moderate ____Severe
Comments: _____
_____

C nt lever/Sp n

____Structural Members ____Structural Connections
____Sign Attachments ____Attachments to End Frame/Pole
____Damage? ____Yes ____No ____Pitting? ____Yes ____No
____Surface Rust: ____Minimal ____Moderate ____Severe
Comments: _____
_____

Stru tur l Components o S gn L ght ng

Type: ____Fluorescent ____Mercury Vapor TC-31.21 (New Design
____Mercury Vapor TC-31.20 (Old Design ____Repair Brkt? ____Yes ____No
Comments: _____
_____

Inspe ted by: _____ **D te:** _____

Appendix O

Traffic Signal Maintenance Manual

Bureau of Maintenance and Operations

pennsylvania
DEPARTMENT OF TRANSPORTATION

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PUB 191 (09-20)

There are hyperlinks throughout this document that should provide network connections to other publications, regulations, Vehicle Code, etc. There are also hyperlinks that reference other sections, exhibits, or appendices within this manual, and these should assist you in navigating.

Internet links often change without notice and may change more frequently than updates to this publication. Updated links will be maintained on the PennDOT Traffic Signal Portal. Please use the signal portal if the links in this publication are broken.

Although not obvious by their color, the Table of Contents and the List of Exhibits also work as hyperlinks. Simply, left click on the section or exhibit number, title, or page number and your computer should take you to the proper page.

You may also find the bookmarks on the left side of the screen helpful.

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LIST OF EXHIBITS

APPENDICES

1. INTRODUCTION

1.1 Publication Purpose

This publication provides Department policies, procedures, and guidance relative to the maintenance of all types of traffic signals. This publication is intended for traffic signal owners and those maintaining traffic signals on behalf of traffic signal owners.

The term "traffic signal" describes all power-operated traffic control devices by which traffic is warned or directed to take some specific action, which includes the following:

- ✓ Traffic control signals, also known as "red-yellow-green" traffic signals, which alternate assignment of right-of-way at an intersection
- ✓ Flashing beacons (also known as flashing warning devices), including warning beacons, stop beacons, intersection control beacons, school zone speed limit beacons, and rectangular rapid flashing beacons
- ✓ Emergency vehicle access signals
- ✓ Lane-use control signals
- ✓ Ramp metering signals
- ✓ In-roadway lights

Power-operated signs, steadily-illuminated pavement markers, warning lights, and steady burning electric lamps are not traffic signals.

1.1.1 PennDOT Traffic Signal Publications

Although this publication is dedicated to the maintenance aspects of traffic signals, it is important to understand all applicable activities and authority regarding traffic signals, in the following categories:

- ✓ **Laws and Regulations –** federal and state laws & regulations dictate various authorities, requirements and role responsibilities regarding traffic signals
- ✓ **Planning -** traffic signals must be planned, funded, and approved with engineering studies including warrant analysis prior to installation and activation
- ✓ **Design –** traffic signals must be designed in accordance with federal and state standards and policies
- ✓ **Construction –** traffic signals must be installed, modified, and reconstructed in accordance with approved plans and specifications
- ✓ **Maintenance –** operating traffic signals must be supported with response & preventative maintenance to sustain intended performance and longevity of the signal locations

Exhibit 1-1 shows the applicable laws, regulations and primary publications for the design, construction and maintenance of traffic control signals. While **Exhibit 1-1** lists various Department publications under Planning & Programming, Design, Construction and Maintenance bins, the maintenance of traffic signals will involve some of these publications, regardless of the area they are assigned. In fact, there are references throughout this publication to Publications 35, 46, 149, 408, etc.

Proper maintenance of traffic signals will not only keep the signals working for many years but will ensure that the integrity of the initial design and installation standards & specifications are upheld during maintenance practices. Therefore, persons or organizations that maintain traffic signals must understand the comprehensive nature of these traffic signal policies so that proper materials are used and maintenance practices performed.

Exhibit 1-1 Applicable Laws, Regulations, and Publications and References

Laws		Title 75 Pa.C.S. Vehicle Code Chapter 61	Title 75 Pa.C.S. Transportation Chapter 92	
Regulations		United States Code (USC) 23 CFR, Part 655	Manual on Uniform Traffic Control Devices (MUTCD)	Title 67 Pa. Code Chapters 205, 212, and 441
PennDOT Publications	**Planning & Programming**	Pub 10 Design Manual Part 1	Pub 851 TSMO Guidebook: Part I, Planning	
	Design	Pub 13M Design Manual Part 2	Pub 14M Design Manual Part 3	Pub 46 Traffic Engineering Manual
		Pub 149 Traffic Signal Design Handbook	Pub 212 Official Traffic Control Devices	Pub 236 Handbook of Approved Signs
	Construction	Pub 35 (Bulletin 15) Approved Products	Pub 72M Roadway Construction Standards	Pub 111 Traffic Control – Pavement Markings & Signing Standards (TC-8700 Series)
		Pub 148 Traffic Signal Standards (TC-8800 Series)	Pub 213 Temporary Traffic Control Guidelines	Pub 408 Highway Construction Standards
		Pub 647 ITS Standard Drawings (ITS-1200 Series)	Pub 669 Traffic Signal Inspection Pocket Guide	
	Maintenance	Pub 23 Maintenance Manual	Pub 191 Traffic Signal Maintenance Manual	

Publications are available electronically from PennDOT's Traffic Signal Portal. The Traffic Signal Portal also contains policy issued by Strike-off Letter which has not yet been incorporated into publications.

1.2 Traffic Signal Responsibilities in Pennsylvania

1.2.1 Installation, Modification, and Removal of Traffic Signals

Authority to install, modify or remove traffic signals is summarized in **Exhibit 1-2**.

Before installing a new traffic signal or undertaking a major modification to an existing traffic signal, an Intersection Control Evaluation shall be completed to determine the appropriate traffic control at the location. A traffic signal is only one alternative to be considered. Refer to Publication 10X, *Design Manual Part 1,* Part 1X, Appendix AI and the Traffic Signal Portal ICE page for more information.

Exhibit 1-2 Summary of Agency Roles and Responsibilities

Action	Responsibility	
	Department	Local Authorities
Approve erecting traffic signals on state highways	■ ①	②④⑥
Approve erecting traffic signals on local highways	■ ①	②③
Approve the revision of a traffic signal or the complete removal of a traffic signal on state highways	■ ⑤	②④⑥
Approve the revision of a traffic signal or the complete removal of a traffic signal on local highways	■ ⑤	②③
Pay for the traffic signal installation	⑦⑩	■ ⑧
Pay for traffic signal maintenance and operation, including signs, pavement markings, and other items on the approved traffic signal permit	⑩	■ ⑧⑨
Implement design modifications	⑩	■ ⑧

■ Agency with primary responsibility (○ refer to notes for legal authority, conditions, and exceptions)

① The Pennsylvania Vehicle Code, 75 Pa. C.S. §6122(a)(2), requires local authorities to obtain approval from the Department prior to erecting any traffic signal within their boundaries except where Department regulations provide otherwise.

② The Pennsylvania Vehicle Code, 75 Pa. C.S. §6122(c), allows the Department to enter into agreements with local authorities transferring to them the authority to install official traffic-control devices without specific State approval provided they conduct traffic and engineering studies and conform with Department standards. Local authorities with a Transfer of Authority Agreement may approve traffic signals on state owned roadways without specific Department approval. See Publication 46, Chapter 4 for more information about Transfer of Authority Agreements.

③ Title 67 Pa. Code §212.5(c)(1) eliminates Department approval to install, revise, or remove traffic signals **on local highways** in any municipality with current municipal traffic engineering certification in accordance with Title 67 Pa. Code Chapter 205, *Municipal Traffic Engineering Certification*. See Publication 46, Chapter 4 for more information about Municipal Traffic Engineering Certification.

④ Title 67 Pa. Code §212.5(b)(1)(ii)(B) eliminates Department approval to install, revise, or remove traffic signals **on state highways** in cities of the first and second class (Philadelphia and Pittsburgh, respectively) unless the city does not have municipal traffic engineering certification in accordance with Chapter 205.

⑤ Title 67 Pa. Code §212.5(b)(1)(iii) requires Department approval to install, revise, or remove traffic signals **on state highways** by local authorities other than cities of the first and second class.

⑥ Title 67 Pa. Code §212.5(b)(1)(v)(A) requires Department approval to install, maintain, and operate traffic signals on state highways, including changes to the traffic restriction.

⑦ The Department may help underwrite the costs of traffic signals within Department construction projects or through funding programs.

⑧ Local authorities are responsible for the installation, maintenance, and operation of traffic signals with written Department approval **on state highways** per Title 67 Pa. Code §212.5(b)(1)(v)(A) and **on local highways** per Title 67 Pa. Code §212.5(c).

Title 67 Pa. Code §212.5(b)(v)(A) assigns the installation, maintenance and operational responsibilities of traffic signals to the municipalities. Therefore, municipalities own the traffic signals in their jurisdiction, and assume the maintenance and operational responsibilities.

⑨ Local authorities are responsible for all signs and markings included on the Department-approved traffic signal plan per Title 67 Pa. Code §212.5(b)(1)(v)(A), unless indicated otherwise on the traffic signal plan.

⑩ Title 74 Pa. C.S. §9202(i), added by Act 101 of 2016, allows the Department to own, install, replace, synchronize, time, operate or maintain a traffic signal and all associated signs and markings if the Department publishes the location of the signal or the critical corridor as a notice in the Pennsylvania Bulletin. This authority may exist in any municipality.

Department approvals in accordance with **Exhibit 1-2** are carried out through a permitting process described in **Section 1.3**. Publication 46 indicates permittees must agree to maintain and operate the traffic signal prior to the Department reviewing the warrants for installation of a new traffic signal. This commitment includes maintaining all of the appurtenances, hardware, software, timing plan(s), and any other traffic control devices that are included on the traffic signal permit.

1.2.2 Manufacture and Sale of Traffic Signal Equipment

PennDOT is required to approve all traffic-control devices available for manufacture and sale in Pennsylvania in accordance with 75 Pa. C.S. §6127 and Title 67 Pa. Code §212.8(b)(4), which includes the following traffic signal equipment:

- ✓ Controller units
- ✓ Signal heads—lane-use traffic control, pedestrian, and vehicle
- ✓ Detectors—pedestrian and vehicle
- ✓ Load switches
- ✓ Flasher units
- ✓ Time clocks
- ✓ Relays
- ✓ Preemption and priority control equipment
- ✓ Electrically-powered signs—variable speed limit signs, blank-out signs and internally illuminated signs, including School Speed Limit Signs
- ✓ Portable traffic-control signals
- ✓ Local intersection coordinating units
- ✓ Dimming devices
- ✓ In-roadway warning lights
- ✓ Auxiliary devices and systems

Traffic control devices approved by PennDOT for sale in Pennsylvania are contained in Publication 35 (Bulletin 15). Traffic signal owners shall only use approved equipment when installing, modifying, or repairing traffic signals.

In addition to the regulations for sale of traffic control devices described above, PennDOT also approves construction materials related to traffic signals, including structural steel and aluminum. These construction materials are also listed in Bulletin 15 and should be used for all traffic signal work, including maintenance.

1.2.3 Maintenance of Traffic Signals During Construction

Construction contracts may modify the permittee's maintenance responsibilities for the duration of the construction project, as indicated in the contract specifications.

For signals modified as part of PennDOT construction projects, the maintenance responsibilities during construction are provided in Publication 408, Section 950.3(g), unless otherwise modified by project special provisions. The standard provisions for PennDOT construction contracts indicate:

- For new traffic signal installations, the construction contractor is responsible for all traffic signal equipment and components through completion of the 180-day operational support period.
- For retrofits of existing permanent traffic signals, the construction contractor is responsible for all newly installed traffic signal equipment and components through the 180-day operational support period. The construction contractor shall assume responsibility for the traffic signal cabinet and contents if new equipment or components are installed within the cabinet. The permittee is responsible for all other traffic signal equipment and components.

1.2.4 Publication 191 Overview

Exhibit 1-3 lists some key points for the Permittee from each of the chapters in this publication.

Exhibit 1-3 Key Permittee Points from Publication 191 Chapters

Chapter		Key Points Regarding Permittee Requirements
1	Introduction	✓ Authority to install, modify or remove traffic signals is established by PA Laws & Regulations, see **Section 1.2** ✓ The traffic signal permit is the official document issued by the Department to Permittees for each traffic signal, and it identifies the approved design and operation of the traffic signal, see **Section 1.3** ✓ Prior to making any changes in the operation of a traffic signal, the Permittee shall always contact the appropriate Department Engineering District to request approval, see **Exhibit 1-4**
2	Agreements/Contracts	✓ The Traffic Signal Maintenance Agreement is between the Department and the Permittee. It addresses the required maintenance & operation of the traffic signal installation, including recordkeeping requirements, see **Section 2.1** ✓ Even if a permittee uses a maintenance contractor, the permittee is still ultimately responsible for traffic signal ownership, maintenance, and operations, see **Section 2.3**
3	Maintenance & Operations Program	✓ Permittees should establish a programmatic approach to traffic signal management and operations, see **Chapter 3.** Including, ▪ Budgeting, life cycle analysis, insurance coverage ▪ Qualified maintenance personnel, equipment & inventory resources ▪ Performance measures
4	Maintenance Classifications	✓ Three traffic signal maintenance classifications, see **Section 4.1**: ▪ Preventative maintenance ▪ Response maintenance ▪ Operational maintenance ✓ Traffic signal modifications are sometimes necessary to accommodate traffic changes, improve safety, or for other reasons ✓ Proposed design modifications must first be approved by the Department and the Traffic Signal Permit updated to reflect this modification, see **Section 4.5**
5	Preventative Maintenance	✓ Traffic signal preventative maintenance and operation is the responsibility of the Permittee and shall be accomplished according to the activities & scheduling intervals identified in **Chapter 5** ✓ Preventative maintenance can also trigger response maintenance activities
6	Response Maintenance	✓ Traffic signal response maintenance and operation is the responsibility of the Permittee and shall be accomplished according to the activities & response/repair intervals identified in **Chapter 6** ✓ Maintenance staff should carry sufficient supplies to address common problems quickly and maintain a reasonable inventory of spare parts ✓ PennDOT provides two customer service platforms that the traveling public can utilize to share their concerns regarding traffic signal maintenance and/or operations. PennDOT will coordinate with Permittees on concerns related to traffic signals to ensure a timely notifications and response.
7	Asset Management	✓ PennDOT's Traffic Signal Asset Management System (TSAMS) is an internet-based database to capture and maintain traffic signal asset related data for all traffic signals in Pennsylvania, see **Section 7.1** ✓ Permittees should keep all traffic signal records within TSAMS, either through direct entry of data into electronic forms in TSAMS or via attachment of paper forms in TSAMS, see **Section 7.2** ✓ Permittees considering the attachment of other equipment on traffic signal structures must contact the appropriate PennDOT District Traffic Engineer to discuss the request so that the procedure in **Section 7.3** is followed

Chapter		Key Points Regarding Permittee Requirements
8	Training	✓ Ensure that maintenance personnel and/or the permittee's maintenance contractor are properly trained to repair all of the traffic signal components to comply with the approved traffic signal permit, see **Chapter 8** ✓ The International Municipal Signal Association (IMSA) offers various training and certification courses, see **Exhibit 8-1**

IMPORTANT

- ✓ Prior to making any changes in the operation of a traffic signal, the permittee shall always contact the appropriate Department Engineering District to request approval, see **Exhibit 1 4**.
- ✓ PennDOT generally will not approve a traffic signal permit revision if the traffic signal is not in compliance with the currently approved permit. Therefore, the Permittee must ensure compliance with the traffic signal permit.

1.3 Traffic Signal Permit

PennDOT approval of traffic signals in accordance with the Vehicle Code and Chapter 212 is through a permitting process, as defined in Publication 46, Chapter 4. The term "permittee" is used throughout this publication to refer to the owner of a traffic signal who has been issued a permit by PennDOT to install or modify the signal. The term includes municipalities, local authorities, counties, and PennDOT, as may be defined in statute or regulation.

Permittee is used in this publication to refer to the owner of a traffic signal which has been issued a permit by PennDOT to install or modify the signal. The term includes municipalities, counties, local authorities, and PennDOT, as may be defined in statute or regulation.

The traffic signal permit is an official document issued by the Department for each traffic signal, and it identifies the approved design and operation of the traffic signal. An original traffic signal permit (including all revisions) should be kept up-to-date and be properly stored at the permittee's office, and a signed copy should be kept inside the appropriate traffic signal cabinet. PennDOT will upload approved permits to PennDOT's online Traffic Signal Asset Management System (TSAMS), where they can be obtained electronically.

The traffic signal permit contains information regarding the operation of the traffic signal and the placement of signal equipment, signing, and markings. The traffic signal permit includes the following:

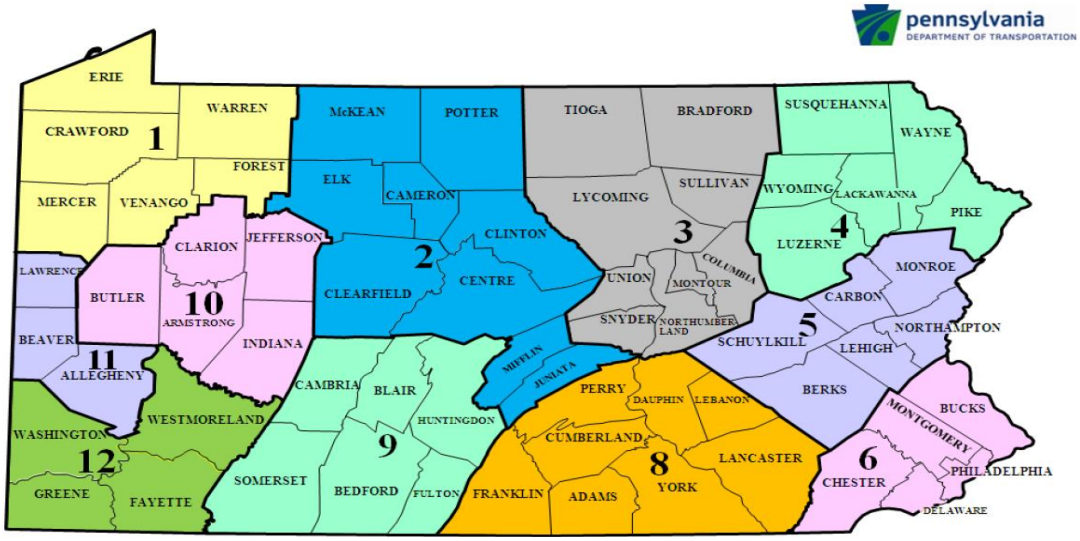
- ✓ Form TE-964, Traffic Signal Permit (Sheet 1)
- ✓ Condition Diagram (1 or more sheets)
- ✓ Coordination/System Timings, if applicable (may be included on condition diagram, a separate sheet, or reference a separate System Permit)

Additional information regarding traffic signal permits is contained in Publication 149.

1.4 PennDOT Traffic Signal Contacts

Questions relative to the design, construction, maintenance, and operation of a traffic signal should be directed to the appropriate PennDOT Engineering District Traffic Unit (see **Exhibit 1-4**). District and Central Office contact information is maintained on the Traffic Signal Portal. These individuals will be able to either answer questions directly or provide additional guidance as to the proper contact person.

Exhibit 1-4 PennDOT Engineering Districts



1.5 Definitions

Appendix A is a glossary that includes definitions of many words and terminology. Therefore, when these words, terminology and publications are referenced in these chapters, they have the meanings indicated.

1.6 Miscellaneous Reference Documents

A list of miscellaneous reference documents with links to the original source material is contained on the Traffic Signal Portal.

2. TRAFFIC SIGNAL AGREEMENTS & CONTRACTS

Traffic Signal Permits issued by PennDOT indicate that it is the permittee's responsibility to maintain the traffic signal in a safe condition at all times. This chapter discusses the Traffic Signal Maintenance Agreement form used to establish maintenance requirements for all signals owned by a permittee as well as additional Highway Occupancy Permit requirements.

Traffic signal owners must understand the maintenance responsibilities for a traffic signal before applying for a permit. Although it may seem very simple and practical, effectively managing safety and operations at a traffic signal may become a difficult task. PennDOT reaffirms the maintenance responsibilities with a traffic signal owner before approving new traffic signals or any revision to existing traffic signals as specified in Title 67 Pa. Code Chapter 212.

If the District determines that a traffic signal is not being properly maintained and safety is being compromised, the Department will immediately notify the municipal traffic signal owner to take appropriate corrective action.

The Department further maintains the right to take corrective action on the municipality's behalf if proper maintenance is not performed and charge the permittee for costs incurred.

2.1 Municipal Traffic Signal Maintenance Agreements

2.1.1 General Provisions

The "Commonwealth and Municipal Traffic Signal Maintenance Agreement" (Traffic Signal Maintenance Agreement) addresses the required maintenance and operation of all traffic signal installations owned by a municipality, and it implements requirements in Title 74 Pa. C.S. Chapter 92. Effective upon issuance of this publication, a Traffic Signal Maintenance Agreement must be in place prior to issuance of a new or revised traffic signal permit to a permittee. The standard Traffic Signal Maintenance Agreement applies to all traffic signals owned by the permittee in perpetuity. Only one Traffic Signal Maintenance Agreement is required for a permittee, regardless of the number of traffic signals owned.

The Traffic Signal Maintenance Agreement is a standard agreement using approved language from the Department's Office of Chief Counsel (OCC); therefore, the language should not be altered. The official template agreement is available from PennDOT OCC's SharePoint site, with a public version available for municipalities on the PennDOT Traffic Signal Portal.

The Traffic Signal Maintenance Agreement requires the municipality to indicate if maintenance will be done with in-house personnel or via contract, and if by contract, it requires a municipality to provide the name of the contractor and a copy of the agreement/contract between the municipality and the contractor.

The execution of a municipality-wide Traffic Signal Maintenance Agreement using the current template from OCC supersedes the maintenance requirements which may have previously been adopted for traffic signals, including maintenance agreements for a federal or state funded project using Preapproved Form 18-K-392, and maintenance provisions contained in PennDOT Form TE-160 for individual signals.

In accordance with Commonwealth policy for agreements, a resolution of the governing body is typically required to establish the authority of the individual who signs the agreement on behalf of the municipality.

2.1.2 Initial Agreement

A Traffic Signal Maintenance Agreement shall be prepared using the form from PennDOT OCC's SharePoint site and shall be fully executed prior to the following, regardless of the funding source:

- ✓ Installation of the first traffic signal in a municipality
- ✓ First time traffic signal modification within a municipality, if the permittee has not already executed an agreement

Municipalities are encouraged to execute a Traffic Signal Maintenance Agreement covering all signals in the municipality as soon as possible to ensure timely permit issuance.

2.1.3 Preventative and Response Maintenance

The level of preventative maintenance and response maintenance that is required by the traffic signal permittee is discussed in **Chapter 4** of this publication.

2.1.4 Recordkeeping

Because accurate maintenance records are essential to document the preventative maintenance schedule and to be better able to estimate the need for spare hardware, each permittee is required to maintain a master signal maintenance log, and records of all response and preventative maintenance activities.

Since permittees sometimes contract with different maintenance contractors, the importance of maintaining good records cannot be overemphasized. It is important that responsible parties follow the documentation procedures indicated in **Section 7.2** for preventative and response maintenance activities.

2.1.5 Maintenance Organization

Permittees are required to provide the minimum personnel classifications identified in **Chapter 3** to properly maintain the traffic signal equipment and must secure training for staff.

2.1.6 Permittee Contact Information

The permittee shall provide contact information for both non-emergency and emergency periods, including information for a contracted maintenance provider, if applicable. The contact information shall be maintained in TSAMS, including prompt updates whenever personnel changes or a contracted provider changes.

2.1.7 Authority to Apply for Traffic Signal Approval

A signed Traffic Signal Application, Form TE-160, shall be submitted by the municipality to install or revise a traffic signal, subject to the terms of the Traffic Signal Maintenance Agreement.

The individual signing Form TE-160 must have been granted signature authority, typically by resolution of the governing body. The permittee may establish signature authority for both execution of the Traffic Signal Maintenance Agreement and future submissions of Form TE-160 by the same resolution. This is recommended to expedite subsequent signal change requests, since submissions would not be delayed waiting for a monthly meeting of the elected officials. A sample resolution providing joint signature authority is provided in **Appendix B**.

A permittee may alter the signature authority by adopting a new resolution of the governing body at any time.

2.2 Multi-Municipal Agreements

In the two following situations, it is necessary to have an agreement between the involved municipalities so that each municipality is aware of their fiscal and maintenance responsibilities:

- A traffic signal installed at an intersection that is in two or more municipalities
- An interconnected traffic signal system that involves more than one municipality

In both situations, all municipalities must work together to ensure proper system maintenance and operation in accordance with applicable permits. Also, there are certain maintenance elements that are shared in both of the above situations and without a pre-established cost basis, local authorities could end up thinking that they paid too high for their portion of the bill.

To ensure proper coordination in the above situations, each municipality should enter into a "Cooperative Memorandum of Understanding" for the multi-jurisdictional signal or signal system.

To ensure system uniformity, one agency should be assigned an oversight responsibility, and identified as Party #1 in the multi municipal agreement. For a single intersection, the oversight agency should typically be the municipality with the controller. However, for interconnected signal systems, the municipality with the oversight responsibility could be determined by any of the following considerations:

- The municipality with the master controller or backhaul communications drop
- Either the largest municipality or the one with the highest number of traffic signals in the system
- The municipality that houses the traffic signal system controller or central server

Additionally, the multi-municipal agreement should identify the following:

- The costs shared between the respective municipalities or the components of local traffic signals that each municipality is responsible for, and those components that are borne by an oversight organization.
- If costs are shared between the municipalities, define the method for cost sharing (such as percentages or the prorated number of the intersections within each municipality)
- The location of the system computer and any adaptive signal system equipment
- A willingness to support future additions to the system
- How to resolve conflicts

2.3 Service-Purchase Contracts

When permittees do not have the in-house expertise, staffing, equipment, or inventory of parts necessary to service and maintain traffic signal equipment, the prevailing method of maintaining traffic signals is by a traffic signal contractor. If a permittee is not prepared to maintain their own traffic signals, it is very important that they have a legal document in place to ensure that they can obtain maintenance repairs on a timely basis. Without a contract or agreement, it is very likely that repairs will not be completed in a timely manner, which in turn increases:

- ✓ Costs for temporary traffic control during outages
- ✓ Liability in the event of a crash due to improper operation

Even if a permittee uses a maintenance contractor, the permittee is still ultimately responsible for traffic signal ownership, maintenance, and operations. For this reason, the Department will only officially communicate with the permittee if they observe any deficiencies, and not with the contractor.

PennDOT's Center for Program Development and Management and the Auditor General issued guidance in October 2018 concerning liquid fuels expenditures by municipalities for traffic signal services, indicating:

- Traffic signals represent an element of highway maintenance; and procurement of highway maintenance services requires advertising and bidding, in accordance with a long-standing series of decisions by the appellate courts of the Commonwealth.
- To the extent that a political subdivision requires traffic signal repair services on an emergency basis, a competitively bid maintenance contract can and should include emergency call-out requirements, in accordance with PennDOT guidance on the subject.
- Traffic signals are not "public works" of the political subdivision. "Public works" as the term is used in the various municipal codes is limited to public utilities.
- Traffic signal maintenance, being part of highway maintenance, is not a professional service.

A number of options are available to select a traffic signal contractor, and all of the following are considered competitive bidding under the Pennsylvania Procurement Code:

- Low bid
- Qualifications-based selection
- Two-step process (first low bid, then request qualifications from say the two lowest bidders)

Using a low bid may be fairly simple for preventative maintenance elements, but a permittee generally needs to estimate a certain number of hours and replacement parts to consider the response maintenance side of the equation. Similarly, basing everything on qualifications (e.g., experience, expertise, personnel, project management, and the distance between the contractor's home base and the traffic signals) is subjective. Therefore, perhaps the best criteria are to make it a two-step process – request qualifications from the two or three lowest bidders and then make the final selection based on perceived qualifications. It is also a good idea to request references.

If the permittee uses a contractor to perform the maintenance of the signals, Section 3(b)iv of the Traffic Signal Maintenance Agreement requires that the permittee provides the Department with a copy of the document they use to obtain these services. Unlike the above Traffic Signal Maintenance Agreement between the Department and the permittee, there is no standard format for the document, which allows permittee and a maintenance contractor some creativity and flexibility. For example, permittees can call it a contract or an agreement; they can establish hourly labor and equipment charges; very detailed unit prices for almost countless types of equipment; etc.

A copy of one type of document is included in **Appendix C** as a "Municipal Service Agreement for Maintenance of Traffic Signals."

In general, a permittee is responsible for the maintenance of everything on the traffic signal permit plan, regardless of road ownership, including the traffic signal and all appurtenances (non-longitudinal pavement markings, signs, and any advance warning signs).

Traffic signal maintenance is critical to effectively ensure the safety and mobility of the traveling public through the intersection controlled by a traffic signal. Qualified personnel, maintenance equipment, and a current inventory of traffic signal equipment allow a municipality to obtain a better understanding of their current practices.

2.3.1 Typical Provisions

Permittees are encouraged to ensure that contracts or agreements between the permittee and the contractor address, as a minimum, the following issues to minimize potential legal battles:

- Establish duration of the contract or agreement (e.g., a 3-year contract with an option for renewal)
- Determine materials to be stockpiled by the contractor
- Define the schedule for annual preventative maintenance and the on-call response time
- Establish any charges and the periods of time they apply. For example, specify hourly charges for service personnel, flaggers, crane trucks, auger trucks, backhoes, etc., for both regular business hours and non-business hours (emergency call outs).
- Identify payment timeframes
- Define inventory and maintenance record-keeping responsibilities, including TSAMS updates
- Incorporate references to applicable publications listed in **Exhibit 1-1** of Publication 191

2.3.2 Accreditation – Department/IMSA

As noted in **Chapter 3**, the contractor and the permittee's personnel should be provided with the appropriate training to assure that they have a thorough understanding of current traffic signal technologies and proper maintenance procedures. The Department also encourages permittees to require their traffic signal maintenance contractor satisfactorily completes a certification program sponsored by a nationally recognized organization such as the International Municipal Signal Association (IMSA).

At a minimum, the Department recommends IMSA Work Zone Traffic Control Safety Certification (or LTAP's Temporary Traffic Control Training) and the IMSA Traffic Signal Level 1 Training to effectively understand traffic signal maintenance activities. IMSA Traffic Signal Level 2, IMSA Traffic Signal Level 3,

IMSA Traffic Signal Inspection, and other traffic signal courses may be desirable to obtain a full understanding of traffic signal maintenance and operations. (See IMSA for additional training details.)

2.4 Estimating Prices

Exhibit 3-2 includes some of the most common unit prices related to traffic signals. However, permittees are encouraged to use the unit prices from recent Department-administered projects to get a sense of current costs. Item Price History is provided in the Construction Projects Resources section of PennDOT's Engineering and Construction Management System (ECMS). Although these costs include typical labor costs, maintenance costs tend to be higher than new construction costs because old components frequently need to be removed before new components can be installed. In addition, maintenance normally involves smaller quantities than construction projects.

The primary benefit of understanding future costs is to avoid sticker shock and to help a permittee plan and budget for future upgrades.

2.5 Specifications

Permittees should use Publication 408 for all replacement components for the following reasons:

- ✓ The original construction used PennDOT's standards, and all replacement items should follow the same criteria so that the traffic signal continues to conform to the traffic signal permit
- ✓ Uniform, standardized specifications simplify installation and maintenance for contractors and makes it less likely that compatibility issues will evolve
- ✓ Sole source items tend to be significantly higher in cost

In the event that PennDOT does not have a specification, permittees are encouraged to keep their special provisions as generic as possible to avoid proprietary items. Only items critical to the interconnection of traffic signals should be considered as proprietary. However, permittees are encouraged to use similar equipment from one intersection to the next because this simplifies the formation of some traffic signal systems and reduces the necessary number of spare parts.

2.6 Highway Occupancy Permit Agreements

Title 67 Pa. Code §441.3 stipulates that a Highway Occupancy Permit (HOP) is required from the Department prior to:

- ✓ The construction or alteration of any driveway, local road, drainage facility, or structure within state highway right-of-way
- ✓ Connection to or alteration of a Department drainage facility

A HOP application should be submitted by the traffic signal owner (typically the municipality) if any of the following activities occur as part of traffic signal work within any state highway right-of-way:

- ✓ Embankment removal
- ✓ Curbing and/or sidewalk installation, including ADA ramps
- ✓ Drainage structures
- ✓ Changes in highway geometry
- ✓ Pavement widening
- ✓ Installation of additional lanes

Additional requirements for submission of HOP applications is included in Publication 282, *Highway Occupancy Permit Operations Manual.*

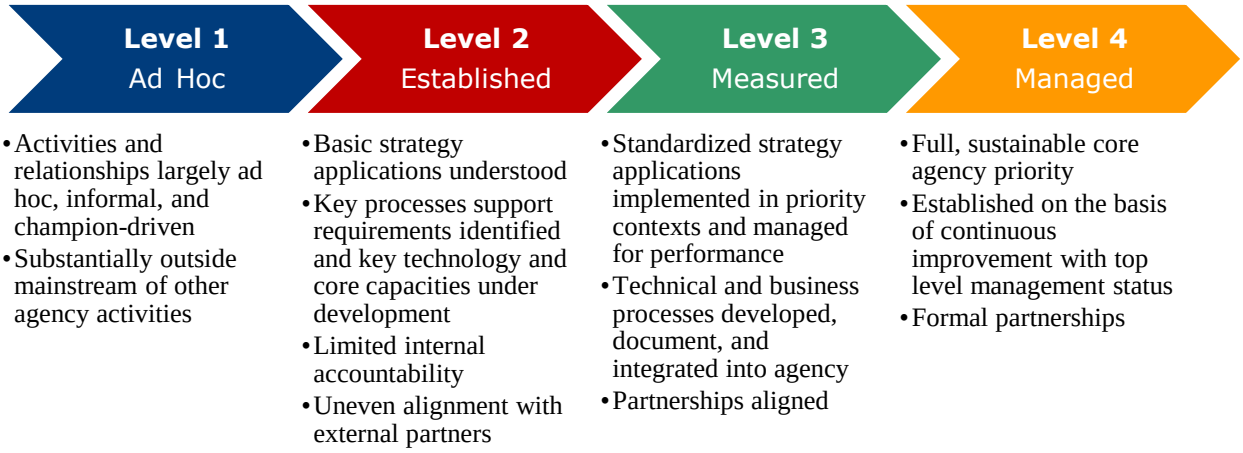
3. ESTABLISHING A TRAFFIC SIGNAL MAINTENANCE AND OPERATION PROGRAM

Traffic signal maintenance and operation shall be provided by the traffic signal owner, unless the signal owner has an agreement with another entity indicating otherwise. Maintenance shall be done in accordance with this publication. Operation includes continuously energizing the traffic signal to provide the operation identified within the traffic signal permit.

3.1 Traffic Signal Program Benchmarking

Traffic signal owners should establish a programmatic approach to traffic signal management and operations. This approach should link transportation goals to organizational capability to clarify how limited resources can be used to focus on doing what is most important, generally defined as providing good basic service. The capability maturity assessment technique can be used with the traffic signal program model. Additional information on this approach is contained in *Traffic Signal Benchmarking and State of the Practice Report*. The capability maturity model framework is illustrated in **Exhibit 3-1**.

Exhibit 3-1 Capability Maturity Model Levels



Source: *Traffic Signal Benchmarking and State of the Practice Report,* 2019

Traffic signal owners should periodically complete a self-assessment to gauge how well the agency is able to fulfill its traffic signal maintenance and operation requirements. It is recommended to complete a self-assessment at least once every five years, and when there are staff changes with oversight responsibility for traffic signals. Additional information is contained in **Appendix D**.

3.2 Budgeting

The cost for installing traffic signals at an intersection frequently exceeds $200,000 (in 2020 dollars). After a traffic signal is installed and tested, the permittee becomes responsible for the cost of maintenance and operation of the traffic signal. Since the permittee assumes liability, it is important that appropriate budgeting for insurance, preventative maintenance, and response maintenance associated with crashes and equipment failure be provided. Permittees are encouraged to track traffic signal maintenance costs using a dedicated account code within the 433 series recommended in the *Chart of Accounts* published through the Governor's Center of Local Government Services. Consistent cost tracking will help monitor trends for budgeting.

Preventative maintenance costs will escalate over time as equipment wears out and requires being replaced. More costly emergency repair costs will increase if proper preventative maintenance care is not provided.

Typical annual maintenance costs per intersection may range from $1,500 to $6,000 and depend on several factors such as the age and complexity of the traffic signal. Periodic operational maintenance, including retiming, should also be factored into the traffic signal budget.

3.2.1 Replacement Component Prices

Traffic signal unit prices for new/replacement products or operational improvements are included in **Exhibit 3-2**. The cost for work zone traffic control should be budgeted in addition to the unit costs in **Exhibit 3-2**. If the replacement includes modification to the traffic signal impacting the traffic signal permit, additional engineering costs will be required to revise the traffic signal permit.

Exhibit 3-2 Installed Unit Prices, in 2020 Dollars

Element	Installed Unit Prices*
Mast arms	$10,000 to $20,000/each
New controller unit (timer) in existing cabinet	$4,000/each
New controller assembly	$12,000/each
3-section, 12-inch LED signal head	$840/each
5-section, 12-inch LED signal head	$1,400/each
LED pedestrian signal head with countdown timer	$800/each
LED replacement bulb	$130/each
Pedestrian pushbutton	$400/each
Accessible pedestrian signals	$1,250/each
Loop detector	$1,200 to $1,800/each
Video detector	$5,500/approach $22,000/intersection
Radar detector	$8,000/approach $30,000/intersection
Junction box	$1,100/each
Emergency vehicle preemption (EVP)	$7,000/intersection
Signs, post-mounted	$55/square foot
Uninterruptible power supply (UPS)	$3,000 to $5,200/intersection
External generator panel (hook-up to accommodate a small generator)	$1,200
Stop bar (thermoplastic)	$125/lane
Lane use arrow pavement marking (thermoplastic)	$200 to $300/each
Traffic Signal Retiming & Analysis (recommended every 3 to 5 years for every traffic signal)	$1,000 to $8,000/intersection

*Unit prices derived from recent Department construction projects (bid prices) with traffic signal industry input.

3.2.2 Life Cycle Analysis

For budgeting purposes, it is also helpful to be aware of the typical service life of various traffic signal assets. Although unscientific, **Exhibit 3-3** shows the average estimated life expectancy, as interpreted by *Estimating Life Expectancies of Highway Assets, Volume1: Guidebook* (2012), NCHRP Report 713. However, the actual life of these traffic signal assets should be based on routine inspections and may vary as a function of the manufacturer, location, loading, environmental conditions (temperature and wind speed), etc. The life expectancy for equipment can often be extended through proper preventative maintenance.

Traffic Signals are an important part of the Long-Range Transportation Plan Asset Management effort. Municipalities should request their planning partners place a traffic signal improvement line onto the transportation improvement program (TIP). As long as it is on a regional TIP (even if locally funded for minimal amount), the funding stream can be adjusted. The purpose for a TIP line item like, “traffic signal

improvements region-wide: traffic signal infrastructure, timing, and operational modifications at: Location #1, Location #2, and at other locations to be determined" allows the possibility of federal funding for maintenance and operations to occur.

Maintaining installation dates and maintenance history in TSAMS (see **Chapter 7**) provides documentation from which life cycle analysis plans can be developed.

Exhibit 3-3 Estimated Service Life

Component or Material	Average Life (years)*
Tubular steel mast arms	20
Steel pole and span wire	20
Loop detector	7.5**
Non-invasive detector	10
Traffic controller	15
Controller cabinet	15
Twisted copper interconnect cable	20
Fiber optic cable	20
Incandescent lamps	1
LED lamps	6.5
Signal heads	20
Signs	12
Thermoplastic pavement markings	4

* Values from Tables 4-11, 4-12, 4-17 of *Estimating Life Expectancies of Highway Assets, Volume1: Guidebook (2012), NCHRP 713*, Transportation Research board of the National Academies, Washington, DC, 2012
** Average life for loop detectors is highly dependent upon pavement condition

3.3 Insurance

Permittees should maintain adequate insurance policies to cover property damage and liability issues related to traffic signals. For example, property insurance should cover traffic signal knockdowns and other damage from hit-and-run crashes, and at least temporarily cover costs to repair traffic signals until vehicle insurance claims are settled. In addition, liability insurance should cover any third-party actions alleging bodily injury, property damage or personal injury resulting from the operations of the permittee such as traffic signal design errors or signal malfunctions.

Traffic signals are susceptible to damage from a lightning strike, especially when located in open areas where the traffic signal is higher than the surroundings. For example, if lightning were to strike the traffic signals and destroy the controller or the wiring, and during the outage a serious crash occurred, a permittee could be legally challenged concerning the timeliness of the traffic signal repair. In this situation, a settlement could be large.

Similarly, if the permittee receives a safety complaint about the traffic signals and they do not address the concern, or at least not in a timely manner in the eyes of the court, a subsequent crash related to the concern could pose a large liability problem.

Therefore, a permittee needs to ensure that they are adequately covered to reduce exposure to tort claims.

3.4 Personnel/Resources

A permittee needs to determine the number of technically proficient staff members that can maintain their traffic signals to meet the guidelines established within this document. When sufficient permittee resources are not available, consider having a traffic signal contractor perform permittee's maintenance functions.

3.4.1 Maintenance Personnel

The qualifications of maintenance personnel are included in **Exhibit 3-4**. If the permittee does not employ staff in these positions, the permittee shall retain contracted services to fulfill these duties.

Exhibit 3-4 Recommended Qualifications for Maintenance Personnel

Personnel	General Tasks	Minimum Requirements
Signal Technician	Responsible for the operation and maintenance of traffic signals and all associated equipment.	▪ Ability to perform response maintenance on solid state equipment up to the device exchange level. ▪ Capability to diagnose a vehicle loop failure and initiate corrective action. ▪ Ability to tune detector amplifiers. ▪ Ability to follow wiring schematics, check and set timings from plan sheet and check all field conditions. ▪ Ability to perform preventative maintenance on all equipment and to maintain accurate records of all work performed.
Signal Specialist	Responsible for the diagnostics and repair of all traffic signal equipment including solid state equipment.	▪ Extensive training and troubleshooting skills in electronics and software. ▪ Ability to repair modules in the shop and to design test equipment needed to diagnose and repair a problem. ▪ Ability to make design modifications to implement or omit special functions. ▪ Ability to implement a recordkeeping system to include maintenance activities, inventory control and identification of recurring problems. ▪ Ability to perform all tasks required of a Signal Technician.
Traffic Engineer	Administrative position with prime responsibility for proper operation of traffic signal equipment. Supervises and plans activities of Signal Technicians and Signal Specialists to ensure adequate preventative and response maintenance programs.	▪ A thorough understanding of traffic signal design, installation, and maintenance. ▪ A working knowledge of the interaction between the following traffic characteristics: intersection geometry, traffic flow theory, control type (fixed time, actuated, etc.), signal phasing and timing, and interconnection. ▪ An ability to supervise subordinate personnel effectively in the assignment of their work. ▪ Possession of a college degree in engineering which includes course work in traffic engineering. ▪ Either four years' experience in the field of traffic engineering or its equivalent in graduate college work.

In order to adequately maintain traffic signals, a general rule-of-thumb is that a permittee should have one qualified technician for every 40 signalized intersections. However, additional technicians are required if the permittee has a variety of different types of traffic signal equipment, larger intersections, or older traffic signal equipment.

3.4.2 Equipment and Inventory

If a permittee elects to perform their own traffic signal maintenance they should either have the following equipment and supplies, or at a minimum have ready access to them via a rental agency or contractor:

- Vehicles, including bucket trucks
- Test equipment and tools
- Digital multimeter
- Controller and conflict monitor test equipment
- Detector sensor test equipment
- Small tools

- Vacuum cleaner
- Small generator for backup power for signals at major intersections during power outages
- A field laptop with appropriate traffic signal controller and detection software (if applicable)
- A small video monitor when using video detection systems (if applicable)
- Replacement parts: controllers, CMU or MMU units, cabinets, cabinet fans and bulbs, signal heads, mast arms and poles, pushbuttons, detectors, bulbs or LED modules, filters, emergency vehicle preemption equipment, conduit, signal cables, detector cables, communication cables, signs, etc.
- Work zone traffic control devices (including work zone attire and equipment as defined in PennDOT Publication 46 and Publication 213).

3.5 Underground Utilities

3.5.1 Marking of Traffic Signal Assets

Permittees (typically municipalities) fall under the definition of a facility owner in the Underground Utility Line Protection law, Act 287 of 1974, as amended by Act 50 of 2017. This law requires facility owners to:

- ✓ Be a member of the Pennsylvania One Call System, Inc.
- ✓ Respond to all notices through the One Call System within two business days
- ✓ Respond to designer requests for information within ten business days
- ✓ Mark, stake, locate or otherwise provide the position of lines at least one business day prior to the lawful start date of excavation
- ✓ Communicate directly to the excavator within two hours of renotification, and, if necessary and possible, go to the proposed work site to mark, stake or locate its underground lines or to verify the owner's lines are not within the area of the proposed work site
- ✓ Respond to emergency notifications as soon as possible following receipt
- ✓ Report alleged excavation violations resulting in damage to facility owner's traffic signal assets within 30 days after receipt of notice of damage

Traffic signal owners who fail to register for the One Call System cannot recover costs for damaged lines.

Traffic signal components which are considered "lines" and must be marked under the act are identified in **Exhibit 3-5**.

Exhibit 3-5 PA One Call Traffic Signal Terminology

Act 247 term	Traffic signal component
Underground conductor used in providing electric service	All traffic signal wiring
Underground conductor used in providing communication service	All traffic signal communications cable, including interconnect cable and fiber optic cable
Traffic loops	In-pavement inductive loop detectors and lead-in wire

3.5.2 Responsibilities Prior to Performing Maintenance Activities

Before performing any maintenance activities that involve excavations, perform required actions according to the provisions of Underground Utility Line Protection Law:

- ✓ The law contains provisions for design notifications, excavation notifications, and emergency notifications. Notification can occur online or by calling 8-1-1.
- ✓ Excavation work shall not begin until after the lawful start date indicated in the act.
- ✓ Locate and mark existing underground utilities in the field.
- ✓ After completing location and marking of the known utilities, field review the proposed work to ensure that no utility conflicts exist.

- ✓ Traffic signal equipment locations may need to be adjusted due to utility conflicts, which should be documented on final as-built plans.

3.6 Performance Measurement

Meaningful performance measures are central to implementing performance-based planning and management processes by linking objectives, strategies, and tactics.

Example traffic signal program objectives are shown in **Exhibit 3-6**.

Exhibit 3-6 Traffic Signal Objectives

<table>
<tr><td>Safety</td><td colspan="3">Assign right-of-way safely</td></tr>
<tr><td rowspan="4">Operations</td><td>Flow</td><td>Intersection</td><td>Network</td></tr>
<tr><td>Light</td><td>Minimize phase failures</td><td rowspan="2">Smooth flow</td></tr>
<tr><td>Uncongested</td><td>Equitable service</td></tr>
<tr><td>Congested</td><td>Maximize throughput</td><td>Manage queues</td></tr>
<tr><td rowspan="2">Organizational</td><td colspan="3">Responsive to stakeholder needs</td></tr>
<tr><td colspan="3">Comply with agency policies and standards</td></tr>
<tr><td rowspan="3">Maintenance</td><td colspan="3">Minimize life cycle costs</td></tr>
<tr><td colspan="3">Sustain infrastructure state of good repair</td></tr>
<tr><td colspan="3">Sustain system and technology reliability/state of good repair</td></tr>
</table>

Objectives can be further associated with strategic and implementation tactics as shown in **Exhibit 3-7**.

Exhibit 3-7 Traffic Signal Strategies, Tactics, and Measurement Targets

Objective	Strategy	Tactics	Measurement Targets
Assign right-of-way safely	Design intersection and signal operation to serve all users safely	▪ Physical: Heads, Poles, Pushbuttons, Detectors, Cabinets, Signing, Markings ▪ Timings: Clearances ▪ Phasing: Protected, Unprotected, Simultaneous	▪ Good visibility ▪ Abundant clarity ▪ MUTCD compliance ▪ Low crash history
Minimize phase failures	Serve all waiting vehicles	Actuation: ▪ Detectors ▪ Generation extension/gap timing ▪ Generous max times	▪ Green time is adequate most of the time ▪ Delay is within an acceptable range ▪ No phase failures (or no max outs)
Smooth network flow	Progression	Coordination (Pipeline): ▪ Controllers ▪ Communications ▪ System Software ▪ Timings: Cycle, Offset, Split, Sequence	▪ Maximize bandwidth ▪ Minimize arterial stops (number and duration) ▪ Side street delay at acceptable level
Maximize throughput	Fully utilize green time	▪ Disciplined Timings: Cycle, Split, Maximum Green, Reservice ▪ Detection: Residual Queuing	▪ High phase utilization ▪ Low unused green ▪ Low growth of residual queue ▪ High flow
Manage queues	Metering flow	▪ Disciplined Timings: Splits, Maximum Green, Reservice ▪ Detection: Queue Overflow	▪ Queue length at intended locations ▪ High throughput (at bottleneck)

Objective	Strategy	Tactics	Measurement Targets
Responsive to stakeholder needs	Response Maintenance	▪ Maintain enough spare equipment to restore full operation in timely manner ▪ Provide on-call staffing or contractors to respond to emergencies 24/7/365	▪ Average response time ▪ Average time to complete repair ▪ Percent of response calls fixed with parts from inventory
Comply with agency policies and standards	Design Modifications	▪ Physical: Heads, Poles, Pushbuttons, Detectors, Cabinets, Signing, Markings ▪ Timings: Clearances	▪ Minimize non-compliance elements
Minimize life cycle costs	Preventative Maintenance	▪ Assign expected lifespan to each traffic signal element, beyond which failure rate or performance is likely to be unacceptable, and plan for timely replacement	▪ Minimize operating equipment beyond expected lifespan ▪ Minimize emergency calls per intersection
Sustain infrastructure state of good repair	Preventative & Response Maintenance	▪ Schedule repair/replacement of components when potential failure is identified through preventative maintenance activities ▪ Provide on-call staffing or contractors to complete emergency repairs in a timely manner	▪ Minimize component failures ▪ Minimize down time for permitted traffic signal operation
Sustain system and technology reliability/state of good repair	Preventative & Response Maintenance	▪ Schedule repair/replacement of components when potential failure is identified through preventative maintenance activities ▪ Provide on-call staffing or contractors to complete emergency repairs in a timely manner	▪ Minimize down time for communication systems ▪ Minimize down time for detectors

3.7 Training

All traffic signal staff should receive training and certification whether they are permittee employees or contractor employees. Training opportunities are described in **Chapter 8**.

3.8 Coordination of Maintenance Activities

Coordination of maintenance and repair activities are important for any permittee, especially as the number of traffic signals a permittee maintains increases. Proactive and timely coordination with both internal and external parties will help ensure that traffic signal maintenance and repair work is planned and completed in a knowledgeable and efficient manner.

- ✓ Internal coordination with signal maintenance staff (in-house or contractor) to ensure the timely and cost-effective performance of required maintenance activities.
- ✓ Internal coordination with permittee staff regarding planned or proposed projects which may impact the current or planned traffic signal maintenance & operations.
- ✓ External coordination with other agencies regarding their planned or proposed projects which may impact the current or planned traffic signal maintenance & operations. This may include utility work, road work, or land developer work.
- ✓ External coordination with other permittees when a traffic signal or a coordinated traffic signal system is located in more than one municipality.

4. TRAFFIC SIGNAL MAINTENANCE CLASSIFICATIONS

4.1 Traffic Signal Maintenance Activity Classifications

The Department recognizes the following three different traffic signal maintenance classifications:

- Preventative maintenance
- Response maintenance
- Operational maintenance

4.1.1 Preventative Maintenance

Preventative maintenance, also known as routine maintenance, is the type of maintenance required to minimize the probability of one or more components of a traffic signal or system from malfunctioning. It also includes the repair or replacement of components, as needed, to maintain the traffic signal or system as it is intended to operate per the approved traffic signal permit. For additional information on preventative maintenance activities, please refer to **Chapter 5**.

Preventative maintenance is typically scheduled utilizing a program of inspection, service, and replacement at pre-determined intervals. A preventative maintenance inspection may identify the need for response maintenance or design modifications.

4.1.2 Response Maintenance

Response maintenance is required when:

- ✓ One or more components of a traffic signal or system fails, causing the traffic signal to malfunction and/or not operate as specified on the approved traffic signal permit
- ✓ Crashes or inclement weather events cause equipment failure
- ✓ Repairs are necessary to address issues identified during preventative maintenance checks

The typical process and key activities related to response maintenance are:

- **Receive notification** – Contractor/permittee notified there is a maintenance issue requiring attention
- **Site arrival** – Technician/contractor mobilizes and travels to the location of the issue
- **Issue diagnosis** – Technician/contractor diagnoses the issue and identifies remedial measures
- **Perform repairs** – Technician/contractor completes the repairs or identifies and initiates repair actions to be completed
- **Log activity** – Technician/contractor logs the response maintenance activities completed or planned

For additional information on response maintenance activities, please refer to **Chapter 6**.

4.1.3 Operational Maintenance

Operational maintenance is the type of maintenance required to identify and undertake operational changes or equipment upgrades needed at an intersection or within a system to respond to changes in traffic patterns over time. Operational maintenance is a subset of preventative maintenance, and an operational review should be regularly scheduled at 3 to 5 year intervals. Operational maintenance focuses on the functionality of traffic signals to meet mobility needs as opposed to the upkeep of the existing signal components. Probe data may be used to evaluate whether performance has degraded since the previous review to reduce data collection costs. For additional information on operational maintenance, please refer to the *Traffic Signal Timing Manual*, 1st Edition (FHWA, 2008) and the *Traffic Signal Timing Manual*, 2nd Edition (NCHRP, 2018).

Operational maintenance is typically a scheduled evaluation of an intersection or corridor but may be undertaken in response to a complaint or notification of an operational issue.

4.2 Traffic Signal Maintenance Responsibilities

Traffic signal maintenance and operation is the responsibility of the traffic signal owner and shall be accomplished according to the time frames identified in **Section 4.3**. Traffic signal owners and operators need to determine whether maintenance and operations responsibilities will be provided by either their own personnel and/or by outsourcing (contracted services). The following questions should be considered for a maintenance and operations program:

- What level of staffing is required?
- Does the agency wish to purchase and operate the equipment required for maintenance?
- What skill level is available from in-house staff, and what level can the agency afford to employ?
- If outsourced, does the agency have the right people to manage a contractor?
- How many similar maintenance contracts has the agency done?
- How many years has the agency done similar maintenance contracts?

If considering outsourcing the maintenance of traffic signals, various options are available. This may range from a contractor providing all labor and materials, to other combinations where a contractor would provide specific labor and/or materials with the remaining functions provided by the traffic signal owner. Outsourcing could also include contracting with another municipality. Failure to maintain traffic signals may result in:

- The traffic signal not operating in accordance with the Department-issued Traffic Signal Permit
- More liability for the traffic signal owner
- More capital costs for the signal owner
- Reduced life expectancy for traffic signal equipment
- Increased likelihood of malfunctions requiring response (emergency) maintenance

It is important to ensure that traffic signal owner staff and/or contractors have the appropriate training so that they are up to date with current traffic signal technologies and maintenance and operation procedures. In addition to being appropriately trained as agreed to in the Traffic Signal Maintenance Agreement (see **Section 2.1**), traffic signal maintenance personnel (traffic signal owner staff and/or their contractor) should satisfactorily complete a certification program sponsored by a nationally recognized organization such as the International Municipal Signal Association (IMSA), as described in **Chapter 8**.

Before any maintenance or operation activities are performed, appropriate work zone traffic control shall be in place according to Publication 213. Special consideration should be given to the application of traffic control measures and work zone activities within or adjacent to signalized intersections. Publication 213 specifies actions that should be taken prior to and during the performance of work related to or affecting the operation of traffic signals. Temporary traffic control adjacent to a traffic signal must not conflict with signal operations while the signal is functioning in steady (stop and go) mode.

4.3 Traffic Signal Maintenance Scheduling

Each traffic signal is comprised of many components which, when taken collectively, allow the intersection or signal system to operate efficiently and effectively. Some components are more critical to the continued operations of an intersection than others. As a result, signal components are classified into two categories, primary and secondary, as defined below:

- **Primary component** – A material, device, or activity that is paramount to the structural integrity, functionality, and/or performance of a traffic signal or system.
- **Secondary component** – A material, device, or activity that when malfunctioning and/or deficient may compromise the functionality and/or performance of a traffic signal or system.

Both primary and secondary components must be maintained; however, because of their critical nature, primary components are given scheduling and response time precedence.

- See **Chapter 5** for further details on preventative maintenance activities and scheduling intervals.
- See **Chapter 6** for details on response maintenance activities and response/repair intervals.

Exhibit 4-1 lists the primary and secondary components for each traffic signal functional area.

Exhibit 4-1 Primary and Secondary Components

	Primary Components	Secondary Components
Supports	▪ Mast Arm Support ▪ Strain Pole Support ▪ Pedestal or Wood Support ▪ Span Wire ▪ Foundation ▪ Anchor Bolts ▪ Guy Wire ▪ Grounding	▪ Pedestrian Stub Pole ▪ Mounting Hardware ▪ Tether Wire ▪ Hand Hole Covers
Controller Assembly	▪ Local Controller ▪ Conflict Monitor ▪ Flasher Unit ▪ Load Switches ▪ Power Supply ▪ Relays ▪ Radio Frequency Interference (RFI) ▪ Surge Protection ▪ Grounding	▪ Cabinet ▪ Time Clock ▪ Traffic Optimization Processor (i.e. adaptive, etc.)
Systems & Communications	▪ N/A	▪ Master Controller ▪ Time-Based Coordinator Unit ▪ Communications System ▪ Modem ▪ Router ▪ Server ▪ Systems Software
Electrical Distribution	▪ Wire and Cable ▪ Electrical Service ▪ Wire Connectors ▪ Ground Bushings and Lugs ▪ Ground Rods ▪ Generator Adaptor Kit ▪ Battery Back-up/Uninterrupted Power Supply (UPS)	▪ Conduit ▪ Junction Boxes ▪ Service Receptacle
Signal Heads	▪ Signal Housings ▪ Vehicle and Pedestrian Indications ▪ Optically Programmed Signal Heads ▪ Lane Use Control Signal Heads	▪ Backplates ▪ Mounting Hardware
Detectors	▪ Loop Amplifier ▪ Vehicle Detection System (Loop, Video, etc.)	▪ Pedestrian Push Buttons ▪ Accessible Pedestrian Signals (APS) ▪ Pre-emption Systems ▪ Transit Priority Systems
Signs & Pavement Markings	▪ Internally Illuminated and Blank Out Signs ▪ Signal Permit Signs	▪ Pavement Markings & Legends ▪ Delineation ▪ Other Traffic Control Signs
Services	▪ Indication Alignment ▪ Time, Phasing, and Sequencing Traffic Controller Settings ▪ LED Upgrade ▪ Operational Retiming	▪ Hand Hole ▪ Clear Obstructions for Signal Indications ▪ Clean Signal Lenses ▪ Paint of Structures ▪ Infestation Prevention ▪ Cabinet Air Filter

4.4 Maintenance Reporting and Documentation

Maintenance reporting and documentation shall follow the guidelines outlined in this publication as referenced in the permittee's Traffic Signal Maintenance Agreement.

4.5 Design Modifications

The design and operation of each signalized intersection and system should be reviewed on a regular schedule (e.g., every 2 to 3 years). The review should include preventative/response maintenance personnel and the permittee's traffic engineer. The permittee may also invite department traffic signal unit personnel to participate in the review. Ad hoc discussions leading to design modifications may occur more frequently.

Use Form TE-974 to capture the following information:

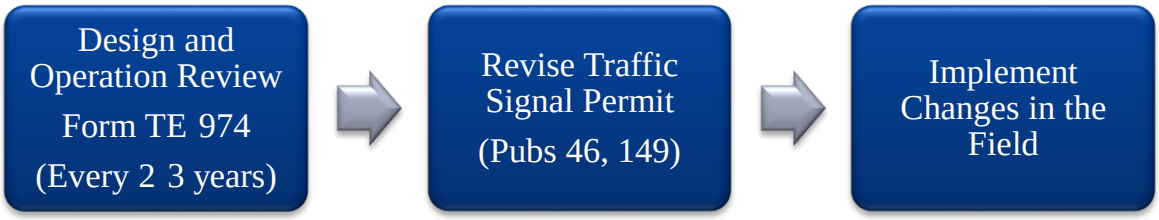
- ✓ Recurring maintenance problems
- ✓ Conformance with the approved plan
- ✓ Conformance with federal/state standards and state-of-the-art design features
- ✓ Compatibility with prevailing traffic demands and physical conditions of the approved traffic signal permit

The following reviews should also be conducted concurrently as part of a thorough design & operation review:

- ✓ Safety review
- ✓ Traffic demand review, when major changes in land use or roadway systems have occurred at nearby locations

Documentation of the Design and Operation Review on Form TE-974 should be uploaded to the intersection file in TSAMS. The design modification process is illustrated in **Exhibit 4-2**.

Exhibit 4-2 Design Modification Process



Maintenance personnel are in the best position to detect recurring problems or design deficiencies as part of their response and preventative maintenance responsibilities. Some recurring but correctable problems include:

- ✓ Traffic signal head visor damage
- ✓ Traffic signal head visibility issues
- ✓ Obstructions to pedestrian push buttons (i.e. snow)
- ✓ Traffic signal hardware knockdowns
- ✓ Detector alignment
- ✓ CCTV alignment

In addition, it is important that maintenance personnel and traffic engineers keep current with technology, standards, and practices so that necessary design modifications can be identified and proposed accordingly to improve signalized intersection performance. Examples include:

- ✓ Pedestrian countdown timers
- ✓ Advance pedestrian walk intervals
- ✓ Video detection
- ✓ Radar/Dilemma Zone detection
- ✓ Eliminating "blind clearance" left turn phasing (no yellow arrow)
- ✓ Modifying left turn phasing and incorporation of Flashing Yellow Arrow (FYA)
- ✓ 12-inch traffic signals instead of 8-inch
- ✓ Backplates and/or the addition of retroreflective borders
- ✓ Install louvers or optically programmed signal heads
- ✓ Adding overhead street name signs
- ✓ ADA curb ramps and/or accessible pedestrian signals
- ✓ Adding positive offset between opposing left-turn lanes to improve sight distance

Flashing Yellow Arrow left turn phasing and retroreflective border on backplates

"Blind clearance" left turn phasing

Upgrading 8" to 12" signal heads

All of this feedback by maintenance personnel assists designers in reviewing and making suggested improvements to the safety and operation of the traffic signals.

Location-specific constraints such as structural loading and roadway clearance should be reviewed to determine the feasibility of potential design modifications.

Note, except during emergency traffic control, or when otherwise authorized by the Department, proposed design modifications must first be approved by the Department by issuance of a revised traffic signal permit to reflect the modification(s).

5. PREVENTATIVE MAINTENANCE ACTIVITIES

Various components all work together to provide a fully functional traffic signal. Neglecting any one of these components can be detrimental to the safe and efficient operation of the entire traffic signal; therefore, it is important to maintain each and every one of these components.

By following the preventative maintenance activities and scheduling intervals for these components as identified in this chapter, the Permittee will help ensure the safe, efficient and proper operation of traffic signals that they own. A natural outcome of these regular preventative maintenance checks is the pro-active triggering of needed response maintenance repairs/replacements to address the identified issues. Issues noted during preventative maintenance which may result in immediate danger to the public shall be addressed through response (emergency) maintenance. Examples include structural degradation, failure of the signal to properly alternate right-of-way, and absence of a conflict monitor or MMU.

When performing preventative maintenance activities, applicable guidelines, specifications, and standards that are housed in the various publications identified in **Exhibit 1-1** will also need to be reviewed and applied by maintenance staff so that the integrity of the initially designed & installed traffic signal components are maintained. Each sub-section in this chapter identifies specific references for that particular signal component (supports, controller assembly, etc.), and should be reviewed and applied accordingly. Consult component manufacturers for specific maintenance recommendations (vendor contact information is contained in Publication 35 (Bulletin 15).

As a general matter, when traffic signal components are replaced, the material and construction specifications in Publication 408 should be followed, and materials and equipment from Publication 35 (Bulletin 15) should be used. Refer to **Section 1.2.2** for additional information regarding approved traffic control devices.

As identified in **Section 1.3,** the traffic signal permit is the official document issued by the Department for each traffic signal, and it identifies the approved design and operation of the traffic signal. It goes without saying that the signal permit is a key document to be referenced and assessed for compliance when performing preventative maintenance activities.

5.1 Traffic Signal Supports

Vehicular traffic signals are mounted to mast arms or suspended from span wire between strain poles. Vehicular traffic signals and all pedestrian signals are mounted to the mast arm pole, strain pole, or pedestal poles. Pedestrian stub poles can be used for mounting pedestrian push buttons.

While the main component of a traffic signal support is the pole structure itself, there are also other necessary components that make a complete support installation (including the foundation, pole/base connections, welded/bolted support connections, span/tether wire, bolts/washers/nuts, and support paint/coating). When performing preventative maintenance activities, it is important that all of these components are reviewed. Where bolted connections require remedial corrective action, new bolts, washers, and nuts must be used.

In addition to preventative maintenance activities, the various inspections related to welded and bolted connections also apply to the following situations:

- ✓ When inspecting new traffic signal installations
- ✓ When inspecting traffic signal installations in conjunction with the initial signal turn-on and the 30-day testing period

For addition information related to Supports, see the following references:

- ✓ Traffic Signal Portal – Manufacture Structure Drawings
- ✓ Publication 46 (Chapter 4)
- ✓ Publication 148 (TC-8801, TC-8803)
- ✓ Publication 149 (Chapters 5, 12 & 20)
- ✓ Publication 408 (Section 951)
- ✓ Form TE-974

The preventative maintenance activities/scheduling intervals for traffic signal supports (including mast arms, strain poles, pedestal poles, and pedestrian stub poles) are summarized in **Exhibit 5-1**.

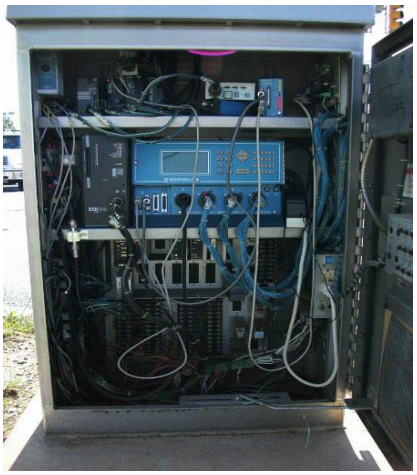
Exhibit 5-1 Preventative Maintenance - Supports

Traffic Signal Supports (Mast Arms, Strain Poles, Pedestal Poles, Pedestrian Stub Poles)	Maintenance Intervals		
	6 Months	12 Months	As Required
General			
Check paint condition and/or corrosion		X	
Paint repairs as needed			X
Check for obstructions in drain at pole base (clear drainage holes in pole bases if present)		X	
Inspect foundations for damage		X	
Inspect the foundation and base plate connection		X	
Verify that leveling nuts are in a snug-tight condition with the bottom of the base plate. Snug-tight is defined as the full force of a person on a 12-inch wrench		X	
Verify that a washer is present under each top nut to provide full bearing and to seal bolt hole gaps		X	
Visually verify that the top nuts are tight and free of corrosion		X	
Check condition of grout or rodent screen at pole bases; replace the grout or rodent screen if it has been removed		X	
Remove the grout or rodent screening under the base plate if there is evidence of anchor bolt weathering. Remove any debris, and examine the anchor bolts under the base plate, for signs of bending, cracking, etc.		X	
Adequately secure handhole covers (replace any missing covers)	X		
Inspect poles, transformer bases, and arms for damage caused by vehicle impacts, weather, or wear and tear (note any deficiencies)		X	
Check pole for plumbness, shim or adjust as necessary		X	
Check for rust and tightness of mounting hardware		X	
Check for missing pole caps and mast arm end caps; replace as required		X	
Check signal cable for wear at entrance of poles, brackets, signal heads and where it's lashed to the span wire. Install or replace rubber grommets as required.	X		
Check for wires/cables that may rub, or touch mast arm supports	X		
Check Guy Wires (inspect guy anchors for proper attachment and/or damage)	X		
Check galvanized nuts, bolts, and washers for any significant signs of corrosion		X	
Inspect for rust and cracks especially at seams, joints, and base plate		X	
Inspect 100 percent of all welds for visual evidence of cracking		X	
Document any evidence of weld metal or base metal cracking	X		
Document any adverse bolted connection findings	X		
Verify luminaire(s) are operational during dusk to dawn time periods		X	
Mast Arm Supports			
Inspect horizontal and vertical angles of arms and poles (check pole and/or arms for warping or other damage: note deficiencies)		X	
Visually inspect connections. The connection should be tight with no visible gap between the connection or flange plates, bolts, nuts, or washers.		X	
Verify that a washer is used between the connection or flange plate and each nut		X	
Visually inspect arm to column connections. The connection should be tight with no visible gap between the connection or flange plates, bolts, nuts, or washers.		X	
Check for cracks in the vertical column to base plate connection; any cracks generally initiate opposite the arm to shaft connection (about 180° from the centerline of the arm for single-arm structures)		X	
Check for cracks in the welded connection between the arm or column connection plates; any cracks generally initiate at the uppermost (12 o'clock) or lowermost (6 o'clock) positions of the connections due to the dead load and oscillation (galloping) caused by wind loads		X	

Traffic Signal Supports (Mast Arms, Strain Poles, Pedestal Poles, Pedestrian Stub Poles)	Maintenance Intervals		
	6 Months	12 Months	As Required
Strain Pole Supports			
Check for cracks in the shaft or column to base plate connection; any cracks generally initiate opposite the span wire connections		X	
Check condition of strain vises, if applicable		X	
Check bonding of span wire and tether wire to strain pole		X	
Visually inspect each tether wire for excess sag; adjust as necessary		X	
Inspect all connecting span wire hardware (anchors, guards, cable lashing, supporting brackets); tight or replace as necessary		X	

5.2 Controller Assembly

The controller assembly is the cabinet and all of the complete electrical and electronic components mounted inside the cabinet for controlling signal operation.



- ✓ Cabinet
- ✓ Controller Unit
- ✓ Conflict Monitor
- ✓ Flasher Units
- ✓ Load Switches and other

The controller unit is the heart of the controller assembly which selects and times signal displays. Several types of traffic signal controller units are used in Pennsylvania:

- ✓ **NEMA TS1**
  Use function-based standards that allow for interchangeability between manufacturers.
- ✓ **NEMA TS2**
  - Type 1 units allow for high-speed communication between equipment and for future expandability
  - Type 2 units retain the TS1 type connectors allowing for a degree of downward capability
- ✓ **Type 170**
  Older hardware-based controllers that were most often used in the City of Pittsburgh and Philadelphia. While no new installations are permitted by current specifications, many existing installations exist and must be maintained.
- ✓ **Type 2070**
  Advanced type of controller, modular in design, and use an open architecture allowing compatibility with off-the-shelf products. They allow for communications and are configurable for use with traffic management applications. Most often used in the City of Pittsburgh and Philadelphia.
- ✓ **Advanced Transportation Controller (ATC)**
  Provide an open architecture hardware and software platform that can support a wide variety of Intelligent Transportation Systems (ITS) applications including traffic management, safety, security and other applications.

For addition information related to Controller Assemblies, see the following references:

- ✓ Publication 46 (Chapter 4)
- ✓ Publication 148 (TC-8802)
- ✓ Publication 149 (Chapter 3)
- ✓ Publication 408 (Section 952)
- ✓ Form TE-974

The preventative maintenance activities/scheduling intervals for controller assemblies are summarized in **Exhibit 5-2**.

Clean and replace air filters

Exhibit 5-2 Preventative Maintenance - Controller Assembly

Controller Assembly	Maintenance Intervals		
	6 Months	12 Months	As Required
General			
Paint steel cabinet to prevent rusting			X
Check anchor bolts and banding for rust or tightness		X	
Check controller cabinet condition. If necessary, relocate so the controller is not damaged by vehicle impacts		X	
Lubricate door hinges and locks		X	
Clean/vacuum inside cabinet		X	
Verify conduit entering the cabinet is sealed. If necessary, re-seal conduit (use approved duct seal)		X	
Seal around cabinet base with silicone caulking		X	
Check gasket around cabinet door		X	
Check drain plug (if equipped); Check for obstructions in drainage if evidence of water accumulating in cabinet		X	
Check for infestation, address as needed		X	
Replace air filter	X		
Check operation of cabinet light and switch - replace if necessary		X	
Check fan operation (thermostat set to operate at 85 - 90 degrees Fahrenheit)		X	
Visually check wiring and connectors	X		
Check and tighten all terminal connections		X	
Verify that all spare conductors are landed on spare terminal blocks or taped off		X	
Verify all cables are tagged or otherwise identified		X	
Place latest permit plan and cabinet wiring diagram(s) in cabinet, if missing		X	
Check Power Supply module	X		
Check Load Switches and verify operation of each switch position	X		
Check conditioning of incoming line voltage		X	
Test Circuit Breakers (cabinet and main)		X	
Check police functions		X	
Verify operation of vehicle detectors (including timing of delayed or extended output)	X		
Verify vehicle and pedestrian calls		X	
Verify operation of detector panel relays		X	
Check flasher unit for proper operation	X		
Check Radio Frequency Interface	X		
Check Traffic Optimization Processor	X		
Verify correct date, time and DST (Daylight Saving Time) function for controller		X	
Verify communication with master controller, if applicable		X	
Place user and/or programming manuals in cabinet, if missing		X	
Note and record make, model, firmware version and serial number for controllers, conflict monitors and other major components		X	
Conduct Operational Review (see Section 4.1.3)			3-5 Years
Conflict Monitor Unit (or Malfunction Monitor Unit)			
Scan conflict monitor for logged events, note any entries		X	
During intersection operation, observe the conflict monitor indicators and/or display screen to verify sensing of all indications and proper monitor settings	X		
Verify operation of conflict monitor – remove load switch to create red fail and observe response of monitor	X		
Test conflict monitor by a computerized conflict monitor tester; replace monitor if it fails test		X	
Test the cabinet wiring and harnesses by using a jumper wire and pulling the load switch, if cabinets are frequented by rodents that chew on electrical wires/cables		X	

Controller Assembly	Maintenance Intervals		
	6 Months	12 Months	As Required
Controller Unit (Electromechanical)			
Check time, phasing and sequencing settings	X		
Check dial assembly for wear, burned contacts, key positions	X		
Check cam assembly for wear, cracks, burned contacts, tension on contacts	X		
Clean and lubricate cam assembly		X	
Controller Unit (NEMA, Type 170, Type 2070, ATC)			
Check time, phasing and sequencing settings (verify input time versus approved timing, including coordination and time-of-day parameters; yellow & red clearance intervals)	X		
Run internal diagnostic routine on the controller		X	
Upload controller timing and parameters via laptop; place copy in controller		X	
Check response to detector input	X		
Check indicator lamp and replace if burned out	X		
Check real time on clock	X		
Upgrade controller firmware to most current version, and also as appropriate to address items affecting operational efficiency and safety			X
If a master controller, check that is it operating appropriately, and signals are coordinated	X		
Disconnect controller from master (if applicable) and check that the signal goes into backup or free operation		X	
Verify that the permittee is on the manufacturers' mailing or email list so that they are notified of software or firmware upgrades		X	
Check the time provided for the pedestrian crossing. Any noticeably short timing for safe pedestrian crossing of the street should be reported and addressed.		X	

5.3 Systems and Communications

Coordinated signal timing is typically applied on corridors with closely spaced intersections (1/4 mile or less). The objective of coordinated traffic signals is to synchronize multiple intersections, reduce the number of stops along a corridor, and provide for a continuous flow of traffic at the target speed.

Maintaining communications between local controllers along a coordinated corridor and with the central system or master controller is critical to ensure the system operates as intended for smooth traffic flow. Communications infrastructure ownership should be verified before performing maintenance. PennDOT may own communications systems to facilitate signal operation across jurisdictional boundaries. Various systems and communication methods are used to coordinate traffic signals along a corridor:

Newer Technologies:

- ✓ Spread Spectrum Radio (Broadband)
- ✓ Cellular
- ✓ Fiber Optic
- ✓ Wireless Broadband
- ✓ Unified Command and Control

Older Technologies Still in Operation:

- ✓ Hardwire
- ✓ Telephone-Dialup
- ✓ Closed-Loop
- ✓ Spread Spectrum Radio (Serial)
- ✓ Time-Based Coordination
- ✓ GPS Time Clocks for Coordination

For addition information related to Systems and Communications, see the following references:

- ✓ Publication 46 (Chapter 4)
- ✓ Publication 149 (Chapters 11 & 12)
- ✓ Publication 408 (Section 953)
- ✓ Form TE-974

The preventative maintenance activities/scheduling intervals for systems and communication are summarized in **Exhibit 5-3**.

Exhibit 5-3 Preventative Maintenance - Systems and Communications

Systems and Communication	Maintenance Intervals		
	6 Months	12 Months	As Required
Perform preventative maintenance in accordance with the manufacturer's recommendations		X	
Check operation of the communication system ▪ Verify that communications between all system components is functioning ▪ Verify function of system components, including modems, ethernet/ethernet bridges, managed network switches, transmitter/receivers, antennas, servers, and system software	X		
Check master controller		X	
Check time-based coordinator unit; verify time clock is accurate and that it is adjusted for daylight savings time		X	
Check communication cables and connections	X		
Check mounting hardware		X	
Verify integration with Department's Unified Command & Control (UCC) where applicable	X		
Verify consistency between system database and controller databases, and ensure all databases match the approved permit	X		
Check overhead communications cables; verify that trees or vegetation are not encroaching on aerial lines. Address as necessary.		X	
Check fiber optic cable ▪ If aerial, check from where it is connected at the trunk line, check that all coils are secure and at the proper bend radius ▪ If attached to a wood pole, check that the drop and u-guard are secure ▪ In the controller cabinet, open the patch panel and check all tip connections		X	
Check wireless signal strength ▪ Test wireless signals at each intersection to verify they are operating within limits ▪ Adjustments shall be made to correct any deficiencies found in the communications system; including trimming of trees/vegetation that may be interfering with signal reception	X		

5.4 Electrical Distribution

Electrical distribution consists of all the electrical components that power and operate a traffic signal. Without a properly maintained and functioning electrical distribution the most state-of-the-art traffic signal would operate ineffectively.

- ✓ Electrical Service
- ✓ Junction Boxes
- ✓ Conduit
- ✓ Wire / Wire Connectors
- ✓ Grounding
- ✓ Surge Protection
- ✓ Generator Adapter Kit
- ✓ Uninterruptible Power Supply (UPS), and others

For addition information related to Electrical Distribution, see the following references:

- ✓ Publication 46 (Chapter 4)
- ✓ Publication 148 (TC-8804)
- ✓ Publication 149 (Chapter 8)
- ✓ Publication 408 (Section 954)
- ✓ Form TE-974

The preventative maintenance activities/scheduling intervals for electrical distribution are summarized in **Exhibit 5-4**.

Exhibit 5-4 Preventative Maintenance - Electrical Distribution

Electrical Distribution	Maintenance Intervals		
	6 Months	12 Months	As Required
General			
Measure service voltage	X		
Check physical condition of meter and power service disconnect box. Disconnect box should be properly locked and free of rust.	X		
Check Service Receptacle (check GFCI receptacle on power distribution panel: replace if necessary)		X	
Check wire and cable	X		
Check wire connectors		X	
Inspect all splices in each traffic signal pole base and handhole to verify they are all solidly connected and not degraded. If deterioration is identified, re-splice using splices consistent with National Electric Code (NEC) for wet environments.		X	
Visually check the condition of the traffic signal cable for dry rot, nicks, cuts or other damage to the outer jacket insulation; perform resistance and continuity tests, if required)		X	
Check all overhead cables and connections		X	
Check that signal cable is not rubbing against cable outlet (free-swinging, end-mounted signals only)		X	
Test for grounding, corrosion, and loose connections. Verify fuses or power breakers are functioning.		X	
Check relays and lightening arrestor for burned or pitted contacts	X		
Check the integrity of lightning arrestor	X		
Check all surge protectors for critical applications of controls or signals that exit or enter the cabinet, and the power supply. Includes: detectors, pedestrian pushbutton loops, service loops, communication systems, etc.	X		
Grounding and Bonding			
Check ground rod, clamp, and ground wire connections	X		
Check that each pole, metal conduit, metal junction box, and other required metal components are properly electrically bonded	X		
Check controller cabinet neutral and grounding bus		X	
Check the ground rod, clamp connection, and bonding of conduits (secure all straps and rod connections)		X	
Check ground bushings and lugs (check grounding bushings on rigid metallic conduit; replace as necessary)	X		
Handhole - check ground rod, clamp and ground wire connections	X		
Junction Boxes and Conduit			
Check that junction boxes are sealed from water with securely seated covers		X	
Clear lip of junction box cover to ensure proper seating of cover; tighten cover bolts if present		X	
Inspect inside the junction box for abnormal amounts of water or water damage. If water is present, take measures to drain by installing weep holes.		X	
Any junction boxes visibly cracked should be sealed or replaced			X
Replace any covers that are cracked or don't fit & seal properly			X
Check junction boxes for proper grade and any surrounding ground erosion that could draw water; note any deficiencies		X	
Clear debris and/or overgrowth around junction box		X	
Check visible conduit (check above ground conduit for damage; replace damaged and/or missing conduit straps)		X	
Check for any exposed ground conduit. ▪ If conduit is undamaged, bury it ▪ If conduit is crushed or cracked, it needs replaced and buried		X	
Fix any repairable penetrations of conduit which are damaged by equipment as follows: ▪ Sealed with electrical putty or an approved sealant as recommended by the cable or conduit manufacturer and in a manner that does not damage the cable ▪ Insert grade 3 or 4 stainless steel wool in the conduit before the sealant to prevent rodent infestation			X
Check the wiring insulation for damage which could cause electrical shorts		X	
Emergency Generator Connection			
Inspect the disconnect enclosure, transfer switch, surge protection, and connector cable assembly.		X	

Electrical Distribution	Maintenance Intervals		
	6 Months	12 Months	As Required
Check that the connector cable is ▪ Sufficient length to allow the attachment of an external power source in accordance with the latest NEC ▪ Compatible with the municipal generator and has neoprene all weather flexible protective boots on each end		X	
Check operation of the traffic signal for a minimum of five minutes using a municipal generator and provided cord		X	
Test the electrical automatic relay switch over		X	
Uninterruptible Power Supply (Battery Back up)			
Test the UPS in accordance with the manufacturer's specifications to verify that it is working properly		X	
Test battery(s) for loss of charge – **replace every 3 years**	X		
Check Uninterruptible Power Supply	X		
Verify automatic transfer switch operation		X	
Verify incoming line voltage		X	
Verify DC output to batteries		X	
Verify AC output on inverter		X	
Check electrical connections		X	
Test system via simulated power outage at cabinet		X	
Record events and run time either saved on UPS unit manually or uploaded to laptop		X	

5.5 Signal Heads

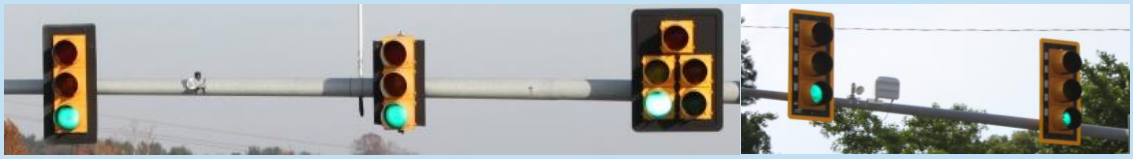
Traffic signal indications provide the driver or pedestrian with a visual sign as to when they can proceed through an intersection. It is essential that drivers and pedestrians have a clear view of the traffic signal indications. Therefore, the traffic signal indications should be routinely inspected to ensure that advance signs, foliage, or snow does not impair driver and/or pedestrian visibility.

Vehicular indications include red, yellow, green circular or arrow indications. Pedestrian indications typically include a Portland orange "hand" symbol and a white "person" symbol as well as a numeric countdown. This section explains not only these indications but the traffic signal housing in which the indications are installed.

A complete signal head assembly includes the following components:

- ✓ Housing / Reflectors / Backplates / Visors / Louvers
- ✓ LED Signal Modules (older signals may still use incandescent bulbs), or Optically Programmed Signal Heads for special-use situations
- ✓ Mounting Assembly Hardware

Damaged backplates should be replaced with aluminum, louvered backplates



Another type of signal head is the LED Lane-Use Traffic Control Signal. These lane-use signals are special overhead signals that permit or prohibit the use of specific lanes on a highway. Lane-use signals are typically used for reversible-lane control (see *MUTCD* Section 4M).

For addition information related to Signal Heads, see the following references:

- ✓ Publication 46 (Chapter 4)
- ✓ Publication 148 (TC-8805)
- ✓ Publication 149 (Chapter 6)
- ✓ Publication 408 (Section 955)
- ✓ Form TE-974

The preventative maintenance activities/scheduling intervals for signal heads are summarized in **Exhibit 5-5**.

Exhibit 5-5 Preventative Maintenance - Signal Heads

Signal Heads	Maintenance Intervals		
	6 Months	12 Months	As Required
General			
Check vehicle and pedestrian indications	X		
Check optically programmed signal heads	X		
Check lane use control signal heads	X		
Check alignment of vehicular signal heads (aim toward center of approach at a point approximately 150 feet in advance of stop bar)	X		
Check alignment and visibility restrictions of optically programmed heads and heads w/ louvers to verify they are operating properly with desired viewing intent	X		
Check alignment of pedestrian signal heads relative to the crossing they serve	X		
Check visibility of traffic signal indications to verify that advance signs, foliage, overhead utilities, etc. do not impair visibility. Schedule one of these semi-annual checks when leaves are present. Overhanging trees which block signal indications shall be trimmed in order to meet the visibility requirements in *MUTCD* Section 4D.12.	X		
Check horizontal lane-positioning of vehicular signal heads/signs to verify they are mounted according to Traffic Signal Permit		X	
Check the clearance between the roadway and the bottom of signals and/or signs located over the roadway; adjust height as necessary		X	
Check terminal block connections		X	
Housing Assembly (including: Backplates, Visors, Louvers, Lenses & Reflectors)			
Inspect signal housings for cracks, damage, and secure assembly of all attachments (backplates, visors, louvers, etc.). Tighten up as necessary.		X	
Clean and inspect backplates for cracks, damage and secure attachment. Tighten up as necessary. Backplates (dull black in color), including a 2 inch (minimum) fluorescent yellow retroreflective border, are required on all new traffic signals, including replacement of existing signal heads.		X	
Clean and inspect visors for cracks, damage and secure attachment. Tighten up as necessary. Visors must be dull black in color on the side toward the indication.		X	
Clean and inspect louvers for cracks, damage and secure attachment		X	
Check that when louvers are used, they are installed with tunnel or full-circle visors		X	
Clean and inspect lenses and reflectors, as necessary; replace those that are damaged		X	
For existing metal signal heads, check paint condition and repaint as necessary			X
Mounting			
Check for cracked and/or damaged mounting brackets		X	
Check gaskets and mounting hardware, retighten as necessary		X	
Check for wear on span wire and signal mounting hardware		X	
Check bushings on cable outlet and universal hangers, replace as necessary		X	
Check that signal heads on mast arms are mounted using fixed mounts unless approved otherwise on the Traffic Signal Permit		X	
Indications (LED Modules / Incandescent Lamps)			
Re-lamp all existing incandescent signal indications		X	
Replace incandescent indications with LED indications ▪ Proactively, as part of Permittee's signal planning & budgeting process ▪ When incandescent indications have reached the end of their useful life ▪ No change required on the traffic signal permit, but suggest notifying the District Traffic Engineer ▪ Update TSAMS as an inventory change			X
Check LED indications for brightness level to ensure replacement prior to complete failure. Note serial numbers and/or date of manufacture for LED modules		X	
Replace LED signal modules			5-7 years
Re-lamp all sealed beams for programmed signal heads		X	
Remove white strobe light indications within the red lens and replace with approved red indications; these type indications are prohibited (Section 4D.06 of the *MUTCD*)	X		

5.6 Detectors

Any traffic-responsive control system depends on its ability to sense traffic for local intersection control and/or system-wide adjustment of timing plans. Malfunctioning detection will typically result in a constant call, causing wasted time, increased delay, wasted fuel, and increased emissions as phases are served unnecessarily for the maximum time. Therefore, properly functioning detection is critical to an intersection's safe and efficient operation. To ensure maximum effectiveness of each device, it is recommended that manufacturer's recommendations are followed.

A traffic signal system accomplishes this by using one or more of the following detector types:

Vehicle Detectors (Pavement Invasive):

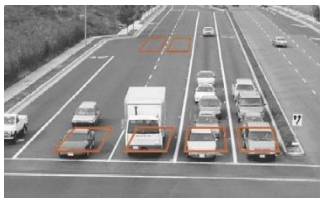
- ✓ Inductive Loops
- ✓ Magnetic
- ✓ Magnetometer (wireless transmit)

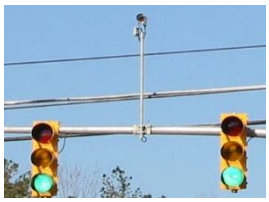
In-pavement sensors can fail for a number of reasons, including, but not limited to:

- Sensor sensitivity is set too low and in need of adjustment
- Pavement cracking and shifting
- Breakdown of wire insulation
- Poor sealants or inadequate sealant application
- Inadequate splices or electrical connections due to installation methods, moisture, or corrosion
- Damage caused by construction activities, including resurfacing and sidewalk/ADA ramp work
- Lightning/electrical surges
- "Stuck" sensor in which case the sensor detector can be reset

Vehicle Detectors (Pavement Non-Invasive):

- ✓ Radar
- ✓ Infrared
- ✓ Video (various technologies including thermal, omni-view, etc.)





Overhead sensors can fail for a number of reasons, including, but not limited to:

- Poor positioning and alignment of sensor devices, including post-installation movement of sensor
- Improper setup of vehicle detection zones
- Camera lens viewing impediments (dirt, moisture, sun, etc.)
- Sensor damage
- Software issues

Pedestrian Detectors:

- ✓ Pedestrian Pushbutton
- ✓ Accessible Pedestrian Systems

Preemption Detectors (Emergency Vehicles):

- ✓ Optical
- ✓ Acoustic
- ✓ GPS
- ✓ Pushbutton: located in an emergency services building (this is typically for signals immediately adjacent to the dispatch location)

Specialized Preemption Detectors

- ✓ Railroad Preemption (highway-rail grade crossings)
- ✓ Queue / Ramp Preemption
- ✓ Transit Signal Priority

Intersection/System Observation:

- ✓ CCTV

For addition information related to Detectors, see the following references:

- ✓ Publication 46 (Chapter 4)
- ✓ Publication 148 (TC-8803; TC-8806)
- ✓ Publication 149 (Chapters 7 & 10)
- ✓ Publication 408 (Section 956)
- ✓ Form TE-974

The preventative maintenance activities/scheduling intervals for detectors are summarized in **Exhibit 5-6**.

Exhibit 5-6 Preventative Maintenance - Detectors

Detection	Maintenance Intervals		
	6 Months	12 Months	As Required
General			
Perform preventative maintenance in accordance with the manufacturer's recommendations	X		
Verify that detectors are performing and operating as designed for the intersection per the Traffic Signal Permit	X		
Verify that the CCTV system is performing and operating as designed.	X		
Vehicle Detectors Pavement Invasive (Inductive Loops, Magnetic, Magnetometer)			
Visually inspect the sensor in the roadway	X		
Check sensor/lead-in splices	X		
Measure each loop sensor for resistance (R), inductance change DL%, and loop quality (Q)		X	
Check that all sensor leads are properly tagged		X	
Check sensor amplifiers for false actuations by vehicles in adjacent lanes	X		
Check sensor amplifier for fail light indicator	X		
Tune the detector if necessary (re-tune sensor detector amplifier at the cabinet if necessary)	X		
Check that the connectors are tight and secure	X		
Check that necessary delays are functioning properly	X		
Check wireless Magnetometer battery life and replace as necessary			X
Vehicle Detectors Pavement Non Invasive (Video, Radar, Infrared)			
Check alignment of detectors and verify detection zones are in proper location relative to lane(s) being detected with the proper traffic direction configured, as appropriate	X		
Check that detector device positioning is proper for the type of system used	X		
Check detector device mounting hardware for proper and secure connections		X	
Check that detector device cable connections are properly secured		X	
Inspect detector device for damage		X	
Verify operation of detector processor at cabinet		X	
Verify that detection system is using the latest software version and upgrade (update card firmware, if applicable)	X		
Verify detector cables are labeled for identification		X	
For video detection, assess impact of changes in sun's seasonal position on detection accuracy	X		
For video detection, check camera lens for moisture or dirt buildup; clean camera lens. (More frequent maintenance may be required during the winter months due to road salt spray)	X		
For radar detection, verify that gaps are being properly identified by the system and that vehicles are being detected in only one direction	X		

Detection	Maintenance Intervals		
	6 Months	12 Months	As Required
Pedestrian Detectors			
Verify the operation of each push button and visually verify pedestrian signal operation ▪ Check for button tightness ▪ Check housing for damage or signs of vandalism, replace as necessary		X	
Check push button signs for location, legibility, damage; clean as necessary ▪ If two buttons for crossing in different directions are located on the same support, the appropriate signing should be in place to ensure that it is clear and easily understood which button applies to which crossing ▪ Signs should be securely mounted and aligned with the appropriate crosswalk		X	
Verify accessible pedestrian system (APS) features are operating in accordance with the permit. Maintenance of APS includes ensuring none of the following has occurred or is occurring: ▪ No response to ambient sound ▪ Weak or no vibration ▪ Malfunction of audible message or tone, and direction ▪ Delay between onset of walk interval and start of speech message ▪ Failure due to wire short going to the vibrator cover/pushbutton ▪ Mechanical failure of pushbutton magnetic switch ▪ Failure of control board		X	
Vehicle Preemption Systems (Emergency and Specialized)			
Check/test emergency vehicle preemption (EVP) systems for proper timing and operation: ▪ Check that operation complies with traffic signal permit and current standards ▪ After the preempting vehicle has cleared the intersection and/or a preset time period, verify that the signal returns to normal operation. Pay special attention to the transitioning into and out of a preemption sequence; the interval timings for both vehicle and pedestrians should be verified. Any available logs should be checked for abnormal activity/inactivity. ▪ For Optical EVP systems, test for pick up, range, and that unwanted light refraction does not actuate other phases; adjust detectors as needed to optimize performance ▪ For Acoustic EVP systems, test the emergency vehicle sirens for compliance with Class A siren specifications ▪ For GPS EVP systems, there is little preventative maintenance required as problems with communication links are identified during normal use		X	
Optical & Acoustic EVP systems use fail safe, or confirmation lights, to provide indication to the driver that the approach is being preempted. When EVP is in operation, the confirmation light flashes for the preempted approach and is dark for the conflicting approaches. Maintenance responsibilities include: ▪ Verifying the lights are properly aligned with each corresponding approach and testing for confirmation light off/dark operation using the appropriate transmission signal for the particular area (acoustical, optical) ▪ Re-lamp confirmation lights, as needed		X	
Button-activated EVP operates typically from within a building such as a fire company/emergency building. Verify button operation and repair, replace, or clean as necessary.		X	
Check railroad preemption system. Verify that the system is working properly, refer to traffic signal permit, Publication 149 (Appendix D) and Publication 408, Section 953.		X	
Complete comprehensive joint inspections of preemption system for railroad interconnect in accordance with Federal Railroad Administration guidelines		X	
Check queue & ramp preemption system. Verify that the detection system is functioning properly, in accordance with the traffic signal permit		X	
Check transit priority system. Verify that the system is working properly. Transit signal priority software is used to manage the system, collect data, and generate reports. It is recommended that maintenance be performed by an experienced technician.		X	

5.7 Advanced Traffic Signal Technology

Adaptive signal systems provide responsive, real-time signal timings to match current traffic conditions along a corridor. Vehicle sensing is continually processed to generate new customized timing sequencing to best handle the present traffic flow conditions.

Adaptive signal systems utilize the following:

- ✓ Specialized adaptive system hardware
- ✓ Specialized adaptive system software
- ✓ Vehicle detection systems

For addition information related to Advanced Traffic Signal Technology, see the following references:

- ✓ Publication 46 (Chapter 4)
- ✓ Publication 149 (Chapter 11)
- ✓ Publication 408 (Section 957)
- ✓ Form TE-153
- ✓ Form TE-974

The preventative maintenance activities/scheduling intervals for advanced traffic signal technology systems are summarized in **Exhibit 5-7**.

Exhibit 5-7 Preventative Maintenance - Advanced Traffic Signal Technology

Verify that system can function in an actuated-coordinated mode or adaptive mode selectable by time of day and day of week, or as specified on the approved plans		X	
Verify that system accommodates queue preemption, if applicable		X	
Verify adaptive operation is using and receiving proper detection data to generate signal timings	X		
Verify remote communications connectivity to all field devices	X		
Login to commonwealth network to maintain password credentials			60 days
Verify that system can be operated and monitored from a TMC, if applicable	X		

5.8 Signs and Pavement Markings

Signing

At traffic signals, signing is used to regulate traffic flows, designate the use of approach lanes, restrict certain movements, and guide motorists. It is important that all signs pertaining to operation of the traffic signal be included on the permit and verified in the field during inspections. Missing signs could confuse motorists or cause a conflict that may otherwise not occur if the appropriate regulatory signs were in place. The following types of signs may be included on a traffic signal permit plan:

- ✓ **Overhead Signs**
  Generally, consists of signs mounted on mast arms or span wire. Most often these signs are mounted adjacent to the traffic signals. Examples include LEFT TURN YIELD ON GREEN, NO TURN ON RED, or Street Name signing. Signing is also mounted overhead in advance of a multilane intersection approach. This type of signing is referred to as lane use control signing and is important to direct motorists into the appropriate lanes to minimize the potential for sideswipe crashes.


Appropriate overhead lane use control

- ✓ **Ground Mounted Signs**
  Consist of turn restrictions, lane use control, and other regulatory signing
- ✓ **Pedestal Support Signs**
  Signs on traffic signal supports may include NO PEDESTRIAN CROSSING, push button signing, and sometimes RIGHT TURN SIGNAL signs
- ✓ **Internally Illuminated Signs**
  Unlike retroreflective signs that gradually deteriorate, when an internally illuminated sign stops working the message is not legible. In the past, this has been a specific problem with Signal Ahead (W3-3) signs, but it could also be an issue with signs used in conjunction with railroad preemption.

Replace signs with current version of sign from Pub 236

Pavement Markings & Legend Markings

Pavement markings provide the motorist with guidance so that they remain in the appropriate lane as they approach and travel through an intersection. Typical markings at intersections include lane lines, word and arrow markings, stop and yield lines, and crosswalks.

- ✓ **Longitudinal Markings**
  These include markings that run in the direction of travel. Currently on State highways, the Department maintains longitudinal pavement markings.
- ✓ **Transverse Markings**
  Transverse markings are those which run perpendicular to direction of travel. They include stop and yield lines, and crosswalks. Dotted extension lines connecting lanes through the intersection are also considered transverse markings since they are crossed by vehicles. Maintenance of these markings is the responsibility of the permittee even if the pavement markings are on a State road at a traffic signal, unless indicated otherwise on the traffic signal permit.
- ✓ **Legend Markings**
  Legend markings are used to designate the use of a lane. At signalized intersections, they frequently include “Arrows” and “ONLY” legends. Maintenance of these markings is the responsibility of the permittee, even if on a State road at a traffic signal, unless indicated otherwise on the traffic signal permit.

Traverse & legend markings need replaced frequently since they are driven over more often. Therefore, permittees are encouraged to use preformed thermoplastic material.

For addition information related to Signs & Pavement Markings, see the following references:

- ✓ *MUTCD* (Sections 2A.08 signs & Section 3A.03 pavement markings)
- ✓ Publication 46 (Chapters 2 & 3)
- ✓ Publication 111 (TC-8600, TC-8604, TC-8700C & TC-8702B)
- ✓ Publication 148 (TC-8801 & TC-8803)
- ✓ Publication 149 (Chapter 13)
- ✓ Publication 236
- ✓ Publication 408 (Sections 935, 936, 975, 976, & 1103)
- ✓ Form TE-974

The preventative maintenance activities/scheduling intervals for signs and pavement markings are summarized in **Exhibit 5-8**.

Exhibit 5-8 Preventative Maintenance - Signs and Pavement Markings

Signs and Pavement Markings	Maintenance Intervals		
	6 Months	12 Months	As Required
General Signing			
Check signing for conformance with traffic signal permit, looking for: ▪ Missing signs ▪ Incorrect signs ▪ Improper sign locations ▪ Existing field signal operation-related signs that need added to the permit	X		
Visibly check for damaged or older deficient signs	X		
Clean all signal permit signs (overhead, ground mounted, pedestal)		X	
Check that signs conform to the minimum sign retroreflectivity values in Section 2A.08 of the *MUTCD;* replace signs which do not meet minimum requirements		X	
Check structure mounting hardware to verify signs are properly angled/aimed & are securely fastened; tighten or replace banding as necessary		X	
Check that overhead mounting locations/spacings follow the recommendations provided in Publication 148	X		
Prior to adding additional overhead signs or replacing existing signs with larger sizes: ▪ Verify that the sign structure is capable of accommodating the additional loading (see Publication 149, Chapter 20) ▪ Obtain a required revision of the traffic signal permit			X
Check that ground mounted signs are securely fastened, tighten or replace fastening as necessary		X	
Check ground mounted signs for plumbness, damage to installation, and proper ground anchoring/breakaway connection	X		
Check other intersection & approach traffic control signs to verify that they don't impede or conflict with the operation of the traffic signal under the permit	X		
Internally Illuminated Signing			
Check internally illuminated signs & blank out signs for conformance with traffic signal permit	X		
Verify the transparent reflective sheeting is capable of being internally illuminated and is retroreflective when not energized	X		
For internally illuminated Street Name Signs show approved street name on both faces (double-sided), unless otherwise approved by the Department on the signal permit	X		
Verify that mast arm bracket connections are secure, and that any swing brackets allow the sign to swing freely		X	
Verify drain holes in the bottom of the sign are unobstructed and that no corrosion is present		X	
Inspect wiring from Internally Illuminated Sign to service disconnect box		X	
Inspect entrance junction box to verify a weather-tight seal is still provided to the sign assembly		X	
Inspect photocell and LEDs and replace as necessary		X	
Pavement Markings & Legend Markings			
Check pavement markings and legends for conformance with traffic signal permit, looking for: ▪ Missing markings ▪ Incorrect markings ▪ Improper marking locations ▪ Existing field signal operation-related markings that need added to the permit		X	
Restore pavement markings and legends as required.			X
Check that all pavement markings meet minimum marking retroreflectivity values in the Section 3A.03 of the *MUTCD*; replace pavement markings which do not meet minimum requirements			
Check delineation		X	

5.9 Time Clock Flashing Warning Devices

Flashing warning devices that are to be activated during certain time periods shall include a controller with time clock. It is important that these devices operate only when intended. For example, school zone speed limit sign flashers are activated only when school is in session. This enhances the meaning of the school zone speed limit. If the devices flash during non-school hours the device may generate motorist disrespect which in turn could affect the usefulness of other flasher installations.

Basic maintenance responsibilities include, setting clocks, programming a calendar (school, holidays, and specific dates) and disabling the device. When school is not in session (unexpected school closure for reason such as winter weather) school zone flashers shall be disabled.

For addition information related to Time Clock Flashing Warning Devices, see the following references:

- ✓ Publication 148 (TC-8801)
- ✓ Publication 149 (Chapter 15)
- ✓ Publication 236
- ✓ Publication 408 (Section 1103)
- ✓ Form TE-974

The preventative maintenance activities/scheduling intervals for time clock flashing warning devices are summarized in **Exhibit 5-9.**

Exhibit 5-9 Preventative Maintenance – Time Clock Flashing Warning Devices

Time Clock Flashing Warning Devices	Maintenance Intervals		
	6 Months	12 Months	As Required
Verify clock is set to the proper time of day and day of week		X	
Verify flasher is scheduled to operate at the proper times in accordance with the permit		X	
Verify static hours plates are consistent with electronic flashers and the permit, where applicable		X	
Check the total warning device assembly for soundness: ▪ Structural support (pole, anchoring foundation) ▪ Sign mounting hardware ▪ Flasher wiring		X	
If solar powered, check that the solar power system (panel dimensions and battery capacity) is properly sized to provide 24/7 operation: ▪ Check that batteries are in a lockable enclosure. ▪ Check that the design of the enclosure allows batteries to be easily removed and replaced.		X	
If solar powered, replace batteries			Every 3-5 years
Check that all power inputs are protected by fuses or other current limiting devices. If hardwired, check that wiring from sign is connected to a circuit breaker in the electrical service disconnect box.		X	
Verify that both solar powered and hardwired systems shall be able to recover from power loss and return to their operation state independent from user intervention		X	

6. RESPONSE MAINTENANCE

Various components all work together to provide a fully functional traffic signal. Neglecting any one of these components can be detrimental to the safe and efficient operation of the entire traffic signal; therefore, it is important to maintain each and every one of these components.

By following the response maintenance activities and corresponding response & repair intervals for these components as identified in this chapter, the Permittee will help ensure the safe, efficient and proper operation of traffic signals that they own. **Section 6.1** also identifies the difference between a temporary repair versus a final repair. A natural progression of response maintenance, especially if it is repetitive for similar issues, is to forward this information through proper channels as planned improvements or upgrades that may be necessary.

Maintenance staff should carry sufficient inventory supplies (spare parts such as LEDs, controllers, loop amplifiers, conflict monitors, emergency generators, etc.) to address common problems quickly.

While it may not be feasible to maintain an inventory of larger and more expensive equipment, such as mast arms and strain poles, it is prudent to keep necessary supplies that enable the temporary hanging of signal heads if a pole is knocked down. For example, keeping a few signal heads and span & tether wire that could be strung between remaining poles or having access to wooden poles.

When performing the response maintenance activities in this chapter, various publications identified in **Exhibit 1-1** should be consulted and applied by maintenance staff to ensure the integrity of the initially designed and installed traffic signal components are maintained. Each **Chapter 5** sub-section identifies specific references for that particular signal component (supports, controller assembly, etc.); these references also apply to the various components listed in **Section 6.1** as well.

As a general matter, when traffic signal components are replaced, the material and construction specifications in Publication 408 should be followed, and materials and equipment from Publication 35 (Bulletin 15) should be used. Refer to **Section 1.2.2** for additional information regarding approved traffic control devices.

As identified in **Section 1.3,** the traffic signal permit is the official document issued by the Department for each traffic signal, and it identifies the approved design and operation of the traffic signal. When performing response maintenance activities, reference the signal permit to ensure for compliance.

6.1 Response Maintenance Components

The response maintenance activities and their corresponding response and repair intervals for the various traffic signal components are summarized in the following seven exhibits:

- **Exhibit 6-1** Supports
- **Exhibit 6-2** Controller Assembly
- **Exhibit 6-3** Systems & Communications
- **Exhibit 6-4** Electrical Distribution
- **Exhibit 6-5** Signal Heads
- **Exhibit 6-6** Detectors
- **Exhibit 6-7** Advanced Traffic Signal Technology
- **Exhibit 6-8** Signs & Pavement Markings
- **Exhibit 6-9** Time Clock Flashing Warning Devices

Terminology associated with these seven exhibits is as follows:

- Business Hours: Monday through Friday, 7:00 AM to 5:00 PM, excluding state holidays, or as defined within a Traffic Signal Maintenance Agreement, Exhibit D (see **Section 2.1**)
- Non-Business Hours: Any time not during Business Hours as defined above

- Response Maintenance: see **Section 4.1.2**
- Response Interval: The duration of time between when either the signal owner or its contractor receives notification of a traffic signal malfunction(s) and the time in which the appropriate response staff arrives on-site to address the malfunction(s). For those components with a 2-hour response time, a longer response time may be justified due to extenuating circumstances such as a regional emergency, or exceptions previously agreed upon with the local PennDOT Engineering District.
- Repair Interval: The period of time in addition to the Response Interval for which to implement Temporary and/or Final Repairs depending on the type of malfunction experienced.
  - Temporary Repair: Use of temporary means or modes to temporarily restore the traffic signal to safe operations until Final Repairs can be completed. As a minimum, traffic signals should be set to operate in flashing mode, and not be left in an unlighted condition. For long term signal outages where sustained flashing mode is not possible, alternative traffic control methods need to be coordinated with the appropriate Engineering District.
  - Final Repair: The completed repair or replacement of failed components to restore the traffic signal to proper and safe operation in accordance with the approved traffic signal permit. Final repairs shall be completed as soon as possible within the time specified, unless a formal request for a time extension is agreed upon by the local Department Engineering District for reasons such as inability to complete repairs due to weather conditions, component fabrication constraints, or equipment availability.

Exhibit 6-1 Response Maintenance - Supports

Component	Response Intervals			Repair Intervals			
	Business Hours	Non Business Hours		Temporary Repair		Final Repair	
Support Structures (Mast Arm, Strain Poles, Pedestals, or Wood Poles)	2	4	hours	24	hours	30	days
Span Wire	2	4	hours	-	-	24	hours
Foundation	2	4	hours	24	hours	30	days
Anchor Bolts	2	4	hours	24	hours	30	days
Guy Wire	2	4	hours	24	hours	30	days
Grounding/Bonding	2	4	hours	24	hours	30	days
Pedestrian Stub Pole	24	72	hours	24	hours	30	days
Mounting Hardware	24	72	hours	24	hours	30	days
Tether Wire	24	72	hours	24	hours	30	days
Hand Hole Covers	24	72	hours	24	hours	30	days

Exhibit 6-2 Response Maintenance – Controller Assembly

Component	Response Intervals			Repair Intervals			
	Business Hours	Non Business Hours		Temporary Repair		Final Repair	
Local Controller	2	4	hours	24	hours	30	days
Conflict Monitor	2	4	hours	-	-	24	hours
Flasher Unit	2	4	hours	24	hours	30	days
Load Switches	2	4	hours	24	hours	30	days
Power Supply	2	4	hours	24	hours	30	days
Relays	2	4	hours	24	hours	30	days
Radio Frequency Interference (RFI)	2	4	hours	24	hours	30	days
Surge Protection	2	4	hours	24	hours	30	days
Grounding	2	4	hours	24	hours	30	days
Traffic Optimization Processor (adaptive)	2	4	hours	24	hours	30	days
Cabinet	48	72	hours	24	hours	30	days
Time Clock	48	72	hours	24	hours	30	days

Exhibit 6-3 Response Maintenance – Systems & Communications

Component	Response Intervals			Repair Intervals			
	Business Hours	Non Business Hours		Temporary Repair		Final Repair	
Master Controller	24	72	hours	24	hours	30	days
Time-Based Coordinator Unit	24	72	hours	24	hours	30	days
Modem	24	72	hours	24	hours	30	days
Ethernet/Ethernet Bridge	24	72	hours	24	hours	30	days
Managed Network Switch	24	72	hours	24	hours	30	days
Transmitter/Receiver	24	72	hours	24	hours	30	days
Antennas	24	72	hours	24	hours	30	days
Cables/Connections	24	72	hours	24	hours	30	days
Mounting Hardware	24	72	hours	24	hours	30	days
Server	24	72	hours	24	hours	30	days
Systems Software	24	72	hours	24	hours	30	days
Communications System	24	72	hours	24	hours	30	days

Exhibit 6-4 Response Maintenance – Electrical Distribution

Component	Response Intervals			Repair Intervals			
	Business Hours	Non Business Hours		Temporary Repair		Final Repair	
Wire and Cable	2	4	hours	-	-	24	hours
Electrical Service	2	4	hours	24	hours	30	days
Wire Connectors	2	4	hours	-	-	24	hours
Ground Bushings and Lugs	2	4	hours	24	hours	30	days
Ground Rods	2	4	hours	-	-	24	hours
Generator Adaptor Kit	2	4	hours	24	hours	30	days
Battery Back-up/Uninterrupted Power Supply (UPS)	2	4	hours	24	hours	30	days
Conduit	48	72	hours	24	hours	30	days
Junction Boxes	48	72	hours	24	hours	30	days
Service Receptacle	72	72	hours	24	hours	30	days

Exhibit 6-5 Response Maintenance – Signal Heads

Component	Response Intervals			Repair Intervals			
	Business Hours	Non Business Hours		Temporary Repair		Final Repair	
Signal Housings	2	4	hours	-	-	24	hours
Vehicle and Pedestrian Indications	2	4	hours	-	-	24	hours
LED Indication Visibility – caused by snow buildup in housing	2	4	hours	-	-	24	hours
Optically Programmed Signal Heads	2	4	hours	-	-	24	hours
Lane Use Control Signal Heads	2	4	hours	-	-	24	hours
Backplates	48	72	hours	24	hours	30	days
Mounting Hardware	24	72	hours	24	hours	30	days

Exhibit 6-6 Response Maintenance - Detectors

Component	Response Intervals			Repair Intervals			
	Business Hours	Non Business Hours		Temporary Repair		Final Repair	
Sensor Amplifier	2	4	hours	24	hours	30	days
Vehicle Detection System (Loop, Video, etc.)	2	4	hours	24	hours	30	days
Pedestrian Push Buttons	48	72	hours	24	hours	30	days
Accessible Pedestrian Signals (APS)	48	72	hours	24	hours	30	days
Emergency Vehicle Preemption Systems	48	72	hours	24	hours	30	days
Railroad Preemption System	2	4	hours	24	hours	30	days
Ramp and Queue Preemption System	2	4	hours	24	hours	30	days
Transit Priority Systems	48	72	hours	24	hours	30	days

Exhibit 6-7 Response Maintenance – Advanced Traffic Signal Technology

Component	Response Intervals			Repair Intervals			
	Business Hours	Non Business Hours		Temporary Repair		Final Repair	
Adaptive System – response to automated trigger alarm (for failure of an adaptive system component: detectors, communications, hardware, or software)	2	4	hours	24	hours	30	days

Exhibit 6-8 Response Maintenance - Signs & Pavement Markings

Component	Response Intervals			Repair Intervals			
	Business Hours	Non Business Hours		Temporary Repair		Final Repair	
Internally Illuminated and Blank Out Signs	2	4	hours	24	hours	30	days
Signal Permit Signs	2	4	hours	24	hours	30	days
Pavement Markings & Legends	48	72	hours	24	hours	30	days
Delineation	72	72	hours	24	hours	30	days
Other Traffic Control Signs	48	72	hours	24	hours	30	days

Exhibit 6-9 Response Maintenance – Time Clock Flashing Warning Devices

Component	Response Intervals			Repair Intervals			
	Business Hours	Non Business Hours		Temporary Repair		Final Repair	
Time Clock	24	72	hours	24	hours	30	days
FWD Schedule/Programming	24	72	hours	24	hours	30	days
FWD Operation	24	72	hours	24	hours	30	days
FWD Assembly (support, hardware, etc.)	24	72	hours	24	hours	30	days
FWD Networking (school zone flashers)	24	72	hours	24	hours	30	days

6.2 Customer Service

6.2.1 PennDOT/Municipal Partnership

Traffic signal permittees (typically municipalities) are responsible for the maintenance and operations of their traffic signals per the conditions of their traffic signal agreements and permits with the Department. It is a common misconception by the general public that PennDOT owns, maintains, and ultimately operates traffic signals. Even though this misconception exists, it is PennDOT's intent to partner with signal owners to provide timely and through customer service when addressing public concerns/issues of maintenance and operations.

6.2.2 Customer Service Tools

PennDOT provides two customer service platforms that the traveling public can utilize to share their concerns regarding traffic signal maintenance and/or operations:

1. 1-800-FIX-ROAD: Toll free hotline that connects callers directly to their local PennDOT County Maintenance Office to report maintenance concerns on state roads such as potholes, signage issues, signal concerns, etc. It is not used to report traffic accidents, disabled vehicles, or other emergencies as those calls are addressed with the 911 system.
2. Customer Care Center (CCC): Online resource to identify and describe maintenance concerns. There is a "Traffic, Signs, or Signals" concern type that may be chosen to record signal related concerns. From there, the customer can specifically identify that their concern is related to signals and is then able to record the location of the concern on an interactive map and add explanatory details.

Permittees are encouraged to publicize contact information for complaints and keep records of those received.

6.2.3 PennDOT Customer Service Process

The CCC is PennDOT's clearinghouse to receive, process and follow-up on all maintenance concerns regardless of source or method used, such as telephone (including 1-800-FIX-ROAD), letter, and police condition report. All concerns called into 1-800-FIX-ROAD shall be entered into the CCC as they are received. Reference PennDOT's Publication 23 (Chapter 24 – Highway Maintenance Customer Service Handling) for additional details regarding the process and roles for highway maintenance customer service handling.

For concerns identified as being related to traffic signals, a member of the District Traffic Unit shall be assigned the Responsible Person who will take action to address the concern regardless of who owns and maintains the traffic signal(s). It is recommended that each District provide their District CCC Coordinator with the name of at least one individual in their Traffic Unit who can be directly assigned as the Responsible Person for traffic signal concerns. The Responsible Person should make the initial customer contact within two working days of the "Received Date" listed for the concern record, as per Chapter 24 of Publication 23.

To ensure resolution and to provide the customer with quality feedback, the following steps are recommended to complete the review process for concerns related to a traffic signal:

- ✓ If additional information on the concern is needed, then contact the customer to discuss the concern in detail.
- ✓ Check if any current or future Department projects are planned for the intersection of concern.
- ✓ Contact the traffic signal permittee to discuss the concern and obtain information on the intersection as needed. If appropriate, inform the permittee that there is a traffic signal concern that they need to address and establish a timeframe for resolution. This established timeframe may require the "Estimated Completion Date" to be revised; see Section 24.7 of Publication 23, Chapter 24. The Responsible Person should use the "History" field (in a concern's "Problem Assignment/Work Progress" area) to document their correspondence.
- ✓ Once a concern is resolved and considered closed, the Responsible Person can close the concern by following the process outlined in Section 24.11 of Publication 23, Chapter 24. The Responsible Person is encouraged to attach applicable written correspondence or documentation within the CCC system.

7. ASSET MANAGEMENT

7.1 Traffic Signal Asset Management System (TSAMS)

PennDOT's Traffic Signal Asset Management System (TSAMS) is an internet-based database to capture and maintain traffic signal asset related data for all traffic signals in Pennsylvania.

There are two TSAMS modules for each asset, an Inventory Module and a Maintenance Module:

- ✓ **TSAMS Inventory Module** – a repository of assets, with details of major components and subcomponents. The Inventory Module provides a snapshot of current components and subcomponents and retains a history of removed components.
- ✓ **TSAMS Maintenance Module** – a history of asset-related activities providing information on the maintenance that has been performed, including what changes were made, who made the changes, how it was done, and why it was done

7.1.1 Background and Purpose

Historically, District offices and permittees collected and maintained various types of isolated data related to traffic signal assets. The data was locally managed using various databases, workbooks, and/or hard copy files. The purpose of TSAMS is to facilitate a centralized, user friendly, universal system that will benefit various stakeholders.

TSAMS stakeholders are:

- ✓ Traffic Signal Permittees (Municipalities and other Local Authorities)
- ✓ PennDOT Central Office & District personnel
- ✓ Planning Partners
- ✓ Signal Maintenance Contractors
- ✓ Signal Construction Contractors
- ✓ Traffic Signal Design Consultants
- ✓ Traffic Signal Operations Consultants

Benefits

Standardized asset management can facilitate the following traffic signal stakeholder activities:

- ✓ Municipal budgeting for maintenance and capital upgrades
- ✓ Municipal management of operations for traffic signal and traffic signal systems
- ✓ Municipal, county, and planning partner collective long-range planning efforts
- ✓ PennDOT administration of the Green Light-Go (GLG) and Automated Red Light Enforcement (ARLE) funding programs
- ✓ PennDOT reporting of statewide traffic signal asset needs and trends
- ✓ PennDOT evaluation of product performance and reliability to maintain the Approved Products List in Bulletin 15
- ✓ And more…

Equal access to standardized traffic signal data will provide stakeholders with the ability to holistically monitor and analyze the current state of traffic signal assets in Pennsylvania.

By working together to better understand the current state of the statewide traffic signal assets, stakeholders can help to make Pennsylvania traffic systems safer, more reliable, and less costly by ensuring that traffic signal assets receive regular preventative maintenance and that regional resources are effectively allocated towards the most pressing needs.

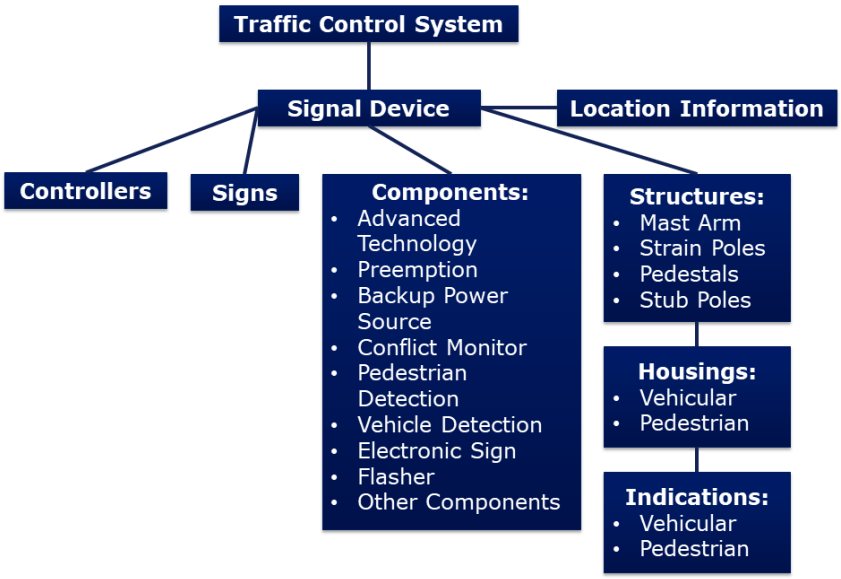
An important additional benefit of the TSAMS centralized system is the ready access to relevant data for user groups such as Central Office, Engineering Districts, Municipalities, Planning Partners, and Practitioners. For example, instead of having Districts and Municipalities handling the regular stream of traffic signal permit and information requests, planning partners and practitioners are able to directly view and download the relevant data from TSAMS (such as permits, current signal cabinet photos, equipment information, and more) entirely on their own.

TSAMS Asset Inventory Data Module

The TSAMS Inventory Module of the database includes existing traffic signal inventory data and related traffic signal documents. The system provides the ability to create new signal records or edit existing signal records. It also provides the ability to attach documents to each signal record.

The database provides traffic signal stakeholders the ability to identify the components of each signal and its attributes. **Exhibit 7-1** is a flowchart depicting the entry hierarchy for traffic signal components detailed in the database.

Exhibit 7-1 TSAMS Data Hierarchy



When selecting components for a signal record, the values (components and attributes, including cost information) available for selection come from an approved product database. Preapproved items in the database can be added, modified or deleted by request to the PennDOT TSAMS administrator.

Additionally, records for other signaling devices are similarly inventoried in TSAMS. These are referred to in TSAMS as "Non-Signals" and include:

- ✓ Intersection Control Beacon
- ✓ Electronic Sign
- ✓ Rectangular Rapid Flashing Beacon (RRFB)
- ✓ Flashing Warning Device
- ✓ Pedestrian Crossing Flashing Warning Device
- ✓ Roundabouts
- ✓ Ramp Meter
- ✓ In-Roadway Warning Lights
- ✓ School Area Flashing Warning Device
- ✓ School Zone Speed Limit Sign

The attachments which accompany the TSAMS database signal records fall into ten major categories and may include (as applicable):

- ✓ **Agreements**
  - Traffic Signal Maintenance Agreements
  - Memorandum of Understanding
  - Form TE-160 (Application for Traffic Signal Approval)
  - Form TE-952P (Application for Permit to Operate Temporary Traffic Control Signals)
- ✓ **Permits**
  - Form TE-964 (Traffic Signal Permit, Sheet 1)
  - Traffic Signal Permit Plans
  - Coordination Plans
  - System Permit Plan
  - Form TE-670 (Flashing Warning Device Permit)
  - Flashing Warning Device Permit Plans
- ✓ **Correspondence**
  - Correspondence related to permit issuance and revision
  - Complaints from the citizens and supporting documents
- ✓ **Design Documents & Drawings**
  - Construction Plans
  - CADD/MicroStation files
  - Americans with Disabilities Act (ADA) documents
  - Emergency preemption supporting documents
  - Product approval detailed design specifications
  - Product approval independent test reports
  - Shop drawings
  - Form TE-152 (Traffic Signal Proprietary Item Analysis Engineering and Traffic Study)
  - Form TE-153 (Pennsylvania Adaptive Signal Control System Evaluation)
  - Traffic Counts
  - Traffic Signal Design Report
- ✓ **Studies**
  - Clearance time calculations
  - Left turn phasing calculations
  - Turn lane evaluations
  - Form TE-110 (Turn Restrictions Engineering and Traffic Study)
  - Form TE-118 (No Turn on Red Restriction Study)
  - Form TE-150 (Traffic Signal Warrant Analysis)
  - Form TE-672 (Pedestrian Needs Accommodation at Intersection Checklist)
- ✓ **Traffic Analysis**
  - Capacity Analysis results output/worksheets
  - Capacity analysis models (Synchro, SimTraffic, HCS)
  - Timing Evaluations
- ✓ **Financials** (not currently in TSAMS but may be included in the future)
  - Schedule and budget documentation
- ✓ **Photographs**
  - Photographs of the intersection
  - Photographs of the equipment

TSAMS Asset Maintenance Data Module

The TSAMS Maintenance Module of the database includes the following Maintenance Functional Areas: maintenance operations, component maintenance, and custom maintenance components.

Maintenance records for each component will include:

- ✓ Date
- ✓ Start Time/End Time
- ✓ Repair Technician
- ✓ Maintenance Type
- ✓ Maintenance Task
- ✓ Equipment Used
- ✓ Adding New Components
- ✓ Removing Components
- ✓ Updating Existing Components Data
- ✓ Associated Costs

The attachments which may accompany the TSAMS signal maintenance records include (as applicable):

- ✓ Activities (not currently in TSAMS but may be included in the future)
  - Master intersection record
  - Preventative maintenance documentation
  - Response maintenance documentation
  - Form TE-974 (Design Modification Checklist)
  - Maintenance supporting documents and records
  - Inspection punch lists
- ✓ Photographs
  - Photographs of the intersection
  - Photographs of the equipment

7.1.2 TSAMS Stakeholder Roles

To accurately manage the over $1 Billion in traffic signal assets statewide and to make informed decisions regarding the operation, maintenance, and budgeting for those assets requires decisions based on quality data. Ensuring the quality and sustainability of data and information included in the TSAMS database depends on having a systematic approach to collecting, analyzing, and using this information. Signals, systems, and the corresponding traffic signal asset data are a shared responsibility requiring multi-jurisdictional cooperation and input of local municipalities, PennDOT, planning organizations, and other stakeholders.

Data Quality Control: Stakeholder Access Controls

To ensure the quality of the traffic signal asset data in the TSAMS database, PennDOT has established database security using Role-Based Access Controls (RBAC) through ECMS. The roles define which system functionality each TSAMS user can access, what data each TSAMS user can view, and what data each TSAMS user can enter or modify. Entries and changes to the database made by stakeholders with ECMS privileges will be routed through a quality assurance "protocol" depending on the nature of the entry and the RBAC clearance of the stakeholder.

Access to TSAMS is controlled by user IDs, passwords, and roles:

- ✓ Every TSAMS user (other than "guest users") will have a User ID from the PennDOT Engineering Construction Management System (ECMS), which currently provides security for many PennDOT systems
- ✓ Passwords are maintained by TSAMS users in ECMS, and logging into TSAMS requires a correct User ID and password combination
- ✓ Each User ID will be assigned at least one user role in the TSAMS system

As stated above, traffic signal stakeholders gain access to the TSAMS database through their ECMS account. Users who already have ECMS access to other PennDOT programs, but not TSAMS, will need to submit a request to their organization's ECMS Security Administrator for an adjustment to their ECMS privileges. Generally, users who do not currently have ECMS access must fill out the appropriate ECMS application forms.

For certain situations, a contractor may need temporary/short-term access to TSAMS to create or modify TSAMS records as part of a construction project. These users do *not* need to gain access to TSAMS through ECMS. They should instead register as a "guest user". Guest users can only make proposed edits to TSAMS records. These proposed edits must be approved by District Personnel to become permanent.

Additional information about accessing TSAMS as a registered ECMS user or as a guest user can be found in the TSAMS Access Guide in the key links section of the TSAMS log-in webpage.

Data Sustainability: Stakeholder Responsibilities for Entering & Maintaining Data

With the introduction of TSAMS, the recordkeeping associated with traffic signal assets has been centralized, thus facilitating the timely sharing of recordkeeping with the Department.

- ✓ The Traffic Signal Maintenance Agreement and Form TE-160 (Application for Traffic Signal Approval) require accurate and up-to-date recordkeeping as an essential component of traffic signal maintenance
- ✓ Act 89 (Title 74 Chapter 92) requires that traffic signal owners maintain traffic signals and update signal timings in accordance with these agreements
- ✓ Title 74 Chapter 92 requires that all traffic and intersection data for critical corridors be provided to the Department in a timely manner

To ensure the database remains current, and thus useful for decision making, stakeholders must make timely updates and entries into TSAMS. While the long-term goals of the Department include the data entry and data maintenance for all applicable TSAMS data fields and attachments in both the Inventory Module and Maintenance Module, the Department understands that, at this point in time, not all stakeholders have systems and processes designed to maintain all of the TSAMS data fields.

As such, the Department will provide a phased expansion of data entry and maintenance requirements for stakeholders, starting with the following initial TSAMS data responsibilities:

- ✓ **PennDOT District Personnel are responsible for ensuring that all signals within their respective District Boundaries have a record in TSAMS** and that the associated status, traffic signal permits, maintenance agreements, and TE-160's are current.
    - **Traffic Signal Status -** PennDOT District Personnel are responsible for updating the traffic signal status of the record in TSAMS (planned, testing, operational, etc.).
    - **Traffic Signal Permits -** PennDOT District Personnel are responsible for uploading current, approved traffic signal permit document into TSAMS at the time the permit is issued.
        - Signal Owners are still responsible for creating, updating, and securing PennDOT approval of the traffic signal permit documents (outside of the TSAMS context).
    - **TE-160's & Maintenance Agreements -** PennDOT District Personnel are responsible for uploading current, approved TE-160's and maintenance agreements into TSAMS at the time the TE-160's and agreements are executed.
        - Signal Owners are still responsible for creating, updating, and securing PennDOT execution of the TE-160's and maintenance agreements (outside of the TSAMS context) as described in **Chapter 2**.

- ✓ **PennDOT District Personnel are also responsible for reviewing and approving the proposed edits to TSAMS records (made by guest users) for the signals within their respective District Boundaries.**
- ✓ **Signal Owners (or their designated representatives) are responsible for uploading current traffic signal cabinet photos** (i.e. photos displaying the equipment inside the cabinet) for the signals under their ownership, within one week of any cabinet updates.

Specific funding programs may require the maintenance of additional TSAMS data. Stakeholders are strongly encouraged to enter and maintain more TSAMS data fields than what is currently required under these initial TSAMS data responsibilities.

Examples of the Data Responsibilities in Practice

The processes summarized on the following pages provide some examples of how and when the TSAMS data responsibilities should be effectively carried-out by the appropriate stakeholders.

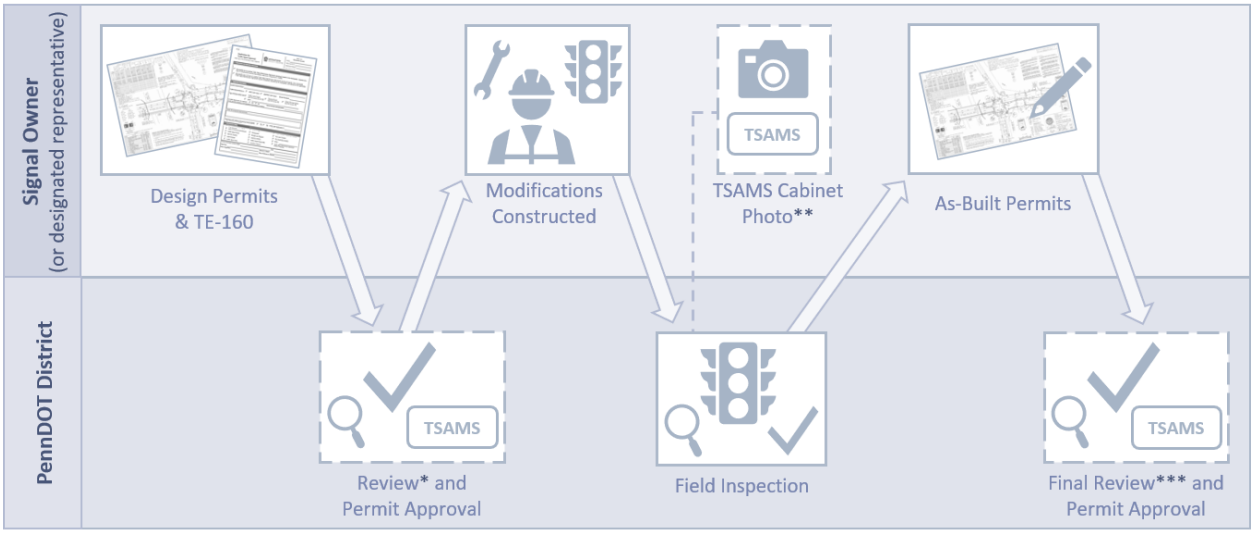
Did you know?

Because TSAMS is a web application, it is available anywhere there is access to the internet. Data can be entered using desktop, laptop, tablet, and cellular devices. This allows data to be updated when technicians are in the field making modifications to signals.

Traffic Signal Permit Modification Process

Exhibit 7-2 shows a summary of TSAMS data responsibilities when a Signal Owner (or their designated representative) wants to modify a traffic signal such that the current, approved traffic signal permit is no longer consistent with field conditions.

Exhibit 7-2 TSAMS Data Responsibilities during the Traffic Signal Permit Modification Process Flowchart

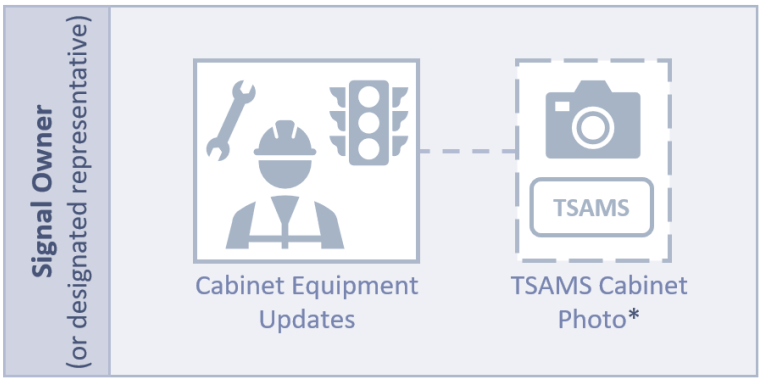


*The District uploads planned permits & TE-160 to TSAMS upon approval.
**The Permittee (or their designated representative) uploads a traffic signal cabinet photo to TSAMS during the District Field Inspection.
***The District uploads as-built permits to TSAMS upon approval.

Traffic Signal Cabinet Equipment Update

Exhibit 7-3 shows a summary of TSAMS data responsibilities when any preventative or response maintenance performed by the Signal Owner (or their designated representative) results in visual modifications to the inside of the traffic signal cabinet.

Exhibit 7-3 TSAMS Data Responsibilities during the Traffic Signal Cabinet Equipment Update Process Flowchart



*The Permittee (or their designated representative) uploads a traffic signal cabinet photo to TSAMS within one week of the update.

7.2 Documentation

Documentation is important for several reasons:

- Maintenance records are critical to ensure that traffic signal maintenance is performed at regular intervals
- Documentation of a traffic signal's equipment and operation may make future upgrades to the signal much easier and allows for sharing of information. Other public agencies may occasionally request this documentation, especially for nearby projects involving traffic signal installations or upgrades to ensure compatibility between traffic signals and having up-to-date plans with signal equipment/timing information helps ensure accuracy and allows for ease of information exchange.
- Historical measures of effectiveness (MOEs) can help justify appropriate changes in the traffic signal budget

7.2.1 Documentation Types

Regardless of the appropriate traffic signal maintenance and operations classification and/or how it's performed, one important but often neglected requirement of traffic signal maintenance is keeping relevant and up-to-date documentation. The records necessary for effective traffic signal maintenance fall into four basic categories: Maintenance Service Records, Signal Timing Charts, Traffic Signal Permit, and Maintenance Manuals/As-Built Plans. Some examples of traffic signal documentation include but are not limited to wiring schematics, controller time settings, software, conflict monitor programming sheet, manuals, technical publications, maintenance records, etc.

Maintaining up-to-date traffic signal maintenance records can help provide efficient service, detect and correct recurring problems, develop future maintenance schedules and strategies, and may protect a permittee from a tort liability claim. The following are types of traffic signal records that should be kept when managing maintenance activities:

- **Master Intersection Record** – list of all maintenance functions performed at the intersection, which should be updated within one day of the activity but no more than one week later
- **Preventative Maintenance Record** – a log for each preventative maintenance service that includes the date, tasks performed, and signatures of personnel performing the work
- **Response Maintenance Record** – a log recording the location, date, time, caller, receiver and complaint received, maintenance personnel, time dispatched, trouble found, and time cleared

- **Design and Operation Review Record** – a record of recurring maintenance problems, conformance with the approved plan, conformance with federal/state standards and state-of-the-art features, and compatibility with prevailing traffic demands and physical conditions of the approved traffic signal permit

7.2.2 Documentation Methods

A copy of all traffic signal records should be kept within TSAMS, either through direct entry of data into electronic forms in TSAMS or via attachment of paper documentation in TSAMS.

In the past, it was recommended to maintain paper records in the traffic signal cabinet. Traffic signal owners are encouraged to digitize these records and import to TSAMS to eliminate paper records, which has the following benefits:

- ✓ Paper records in field cabinets can be destroyed by insects and critters
- ✓ Paper records may be destroyed by disasters including severe weather and vehicle crashes
- ✓ Cabinet-based records only reflect work done while onsite and do not reflect remote changes, and field technicians may be missing relevant information when diagnosing problems
- ✓ Paper records may not be accessible during emergency situations when travel to the site is restricted

7.3 Attaching Other Equipment on Traffic Signal Structures

Traffic signal permittees may receive requests to install other equipment to traffic signal structures which is not directly associated to the function of operation of the traffic signal, including, but not limited to, security cameras, cellular antennas, and automated license plate readers. This policy is established to ensure the following:

- ✓ Additional equipment does not exceed the structural capacity of the traffic signal structures
- ✓ Additional equipment does not interfere with the traffic signal operation or create a distraction for drivers

7.3.1 Request Procedure

The following procedure shall be followed to request placement of other equipment on traffic signal structures.

Step 1: Notify the Department

The Department requires that the permittee considering other equipment on traffic signal structures contact the appropriate PennDOT District Traffic Engineer to discuss the request. The PennDOT District Traffic Engineer shall ensure the permittee is aware of the process described herein. Potential concerns should be discussed at this stage prior to developing and submitting a formal request.

Step 2: Submit a Request to the Department

The permittee shall submit the following to the appropriate PennDOT District Traffic Engineer:

- ✓ Contact information for the owner of the equipment to be installed on the traffic signal structure
- ✓ A letter from the permittee specifying the purpose and justification of the request, approval by the permittee of the request, and a statement indicating the equipment will not interfere with the operation identified on the traffic signal permit.
- ✓ Documentation that the other equipment on traffic signal structures will not cause confusion or distraction to any motorist. If it is determined after placement the other equipment creates confusion or is a driver distraction, it shall be removed immediately.

- ✓ An engineering study of the equipment placement, structural adequacy of the existing traffic signal structure, ADA accessibility, operational verification with relation to the traffic signal permit, and other appropriate evaluations needed to ensure the appropriate placement of the other equipment on the traffic signal structure. *Note: if structural adequacy cannot be verified then a new traffic signal support will need to be provided along with supporting calculations.* All engineering studies must be performed by a professional engineer licensed in the Commonwealth of Pennsylvania.
- ✓ Construction plans that provide location, connections, and other key information needed to connect to the traffic signal structure.
- ✓ A Highway Occupancy Permit if any additional adjustments such as placement of other equipment within the state highway right-of-way are required other than attaching to a traffic signal structure.
- ✓ If the permittee is requesting third party equipment that it would not own, then the following additional information would need to be provided:
    - A pole attachment agreement between the traffic signal permittee and the third party, which addresses the following:
        - Term of the agreement
        - Placement length
        - Construction
        - Third party contact information
        - Maintenance and operations plan
        - Access to the other traffic signal equipment
        - Relocation/replacement responsibility if the traffic signal structure is relocated or replaced by the traffic signal permittee or the Department
    - A letter from the third party verifying the other equipment will not affect the operation of the traffic signal
    - Equipment details, deployment purpose, placement information, design details, design notes, construction details, equipment grounding, and other information needed to successfully deploy the other equipment on the traffic signal structure

No devices shall be installed on the traffic signal structure unless approved by the appropriate PennDOT District Traffic Engineer.

Step 3: Department Review

The Department will review the request and provide the permittee with a written response from the District Traffic Engineer indicating one of the following:

- Approval of the request
- Rejection of the request with justification
- Request for additional information to be provided for further review

If additional information is requested, the permittee and the Department will continue to work together through the comments or additional information requests like any other traffic signal permit update request.

7.3.2 Permanent Documentation of Other Equipment

Since the other equipment does not relate to the traffic control, it shall not be shown on the traffic signal permit, and the traffic signal permit need not be updated. The engineering study for the device shall be documented in TSAMS so it is included in future structural calculations related to equipment on the same traffic signal structure.

8. TRAINING RECOMMENDATIONS

8.1 General

Training provides technical skills needed to effectively use and maintain and operate traffic signals. Training should reflect the actual need of the agency and its personnel. As traffic signals and their systems become more sophisticated, additional training may be warranted. If untrained personnel are used to maintain traffic signals there could be problems that are not identified, which could cost the permittee more in the long run.

Training also provides exposure to new hardware, software and concepts to help agencies stay on the leading technological edge.

Training is also available from traffic signal equipment suppliers. It is desirable to require equipment suppliers to commit an appropriate number of hours to train Department, permittees and maintenance contractors on the proper adjustments and operation of the new equipment. The session should include theory of operation, field adjustment/calibration to accommodate day-to-day operation, preventative maintenance, diagnostic software, and repair. This is a good way to incrementally expand personal knowledge.

8.2 PennDOT Traffic Signal Training Courses

PennDOT offers a variety of traffic signal training courses. Information on these are listed below and can be found on the Traffic Signal Portal.

8.2.1 Introduction to Traffic Signals Course

Overview

The self-study introductory traffic signals course that provides an overview of traffic signal procedures to Department personnel, municipal officials, planning partners, contractors, developers, consultant engineers, and other traffic signal stakeholders. This course is intended to be a high-level overview of various traffic signal items. The main emphasis is to provide an overview of the lifecycle of a traffic signal from initiation, warrants, design, operation and maintenance.

Participants will understand the various laws, regulations, standards, policy, and guidance information provided by the Department along with understanding the various components of a traffic signal. The course also serves as a refresher for experienced staff or as an introduction to additional subjects related to traffic signals outside of their current job duties.

At the end of this course, you will be able to:

- ✓ Locate and navigate the various publications related to traffic signals in Pennsylvania
- ✓ List the steps within a traffic signal agreement between the Department and other agencies
- ✓ Perform a partial traffic signal warrant analysis
- ✓ Identify various traffic signal components used in the field
- ✓ List the items in a typical traffic signal plan set
- ✓ Define common traffic signal timing and phasing terminology
- ✓ Define asset management and list the different types of traffic signal maintenance

8.2.2 Traffic Signal Design Course

This PennDOT Traffic Signal Design self-study is designed to enable the participants to obtain an understanding of the fundamental concepts and PennDOT standard practices related to the design of traffic signal systems within the Commonwealth of Pennsylvania. This course is structured to parallel the progression of decisions, activities and functions related to the design of traffic signal systems.

Participants will understand the various laws, regulations, standards, policy, and guidance information provided by the Department along with understanding the various components of a traffic signal. The course

also serves as a refresher for experienced staff or as an introduction to additional subjects related to traffic signals outside of their current job duties.

At the end of the course, participants will be able to:

- ✓ List the steps required to plan, design, and implement a signalized intersection
- ✓ Devise an appropriate data collection plan for planning, designing, and operating a signalized intersection
- ✓ Perform a warrant analysis using the MUTCD warrants, including PennDOT warrants
- ✓ Design basic phasing of the intersection – which movements will get a separate phase, and how they are numbered
- ✓ Determine location of signal supports, displays and detection
- ✓ Design the electrical distribution system for an intersection
- ✓ Select signal-related signs and pavement markings, including turning-movement signs, stop bars and crosswalks
- ✓ Create a traffic signal design report

8.2.3 Construction and Inspection Course

The Traffic Signal Construction and Inspection self-study addresses compliance with the applicable traffic signal construction documents (specifications, plans, standard drawings, etc.). Inferior work on signals or inadequate traffic management during project construction can create potentially dangerous conditions with liability impacts for local agencies. The purpose of this course is to introduce traffic signal construction and inspection issues.

Upon completion of the course, participants will be able to:

- ✓ Locate applicable Traffic Signal Catalog Cuts
- ✓ Describe the applicable Traffic Signal Proprietary Approvals
- ✓ List the Traffic Signal Product Approvals process
- ✓ List the important specification sections of Publication 408 and its requirements
- ✓ Understand and navigate Publication 669
- ✓ Traffic Signal Testing procedures
- ✓ Develop and modify a Traffic Signal Inspection Form

8.2.4 Maintenance and Operations Course

This PennDOT Traffic Signal Maintenance and Operations self-study was created from a need to understand that the congestion and delays that exist on our streets and roadways can be better managed with a thorough understanding of effective traffic signal operations and maintenance. Well maintained and operated traffic signal control projects are essential to this process. This course will focus on the proper elements of a well maintained and operated traffic signal system. The course is divided into two primary parts: Traffic Signal Operations and Traffic Signal Maintenance.

At the end of this Traffic Signal Construction and Inspection in Pennsylvania course, you are able to:

- ✓ List the types of traffic signal maintenance classifications
- ✓ Create the types of documents required for maintenance
- ✓ Describe typical maintenance activities
- ✓ Develop a traffic signal maintenance agreement
- ✓ Design basic phasing of the intersection
- ✓ Devise an appropriate data collection plan operating a signalized intersection
- ✓ Calculate signal timing for both actuated and coordinated operational strategies, including pedestrian clearance intervals
- ✓ Implement traffic signal timing and phasing plans

8.3 Local Technical Assistance Program (LTAP) Opportunities

The Pennsylvania Local Technical Assistance Program (LTAP) was created to share transportation knowledge, improve road maintenance and safety skills, and put research and new technology into practice at the municipal level.

The PennDOT Local Technical Assistance Program (LTAP) is one of 58 LTAP centers across the nation (one in each state, Puerto Rico and seven regional centers serving American Indian tribal governments.) These centers are dedicated to transferring transportation technology through training, technical assistance, and other customer services to municipal elected officials and their staff. The LTAP program is designed to help Pennsylvania's municipalities, which maintain over 77,000 miles of roadways, make the best use of their roadway maintenance dollars. PennDOT LTAP provides technical information and proven technologies dealing with roadway maintenance and safety methods to meet the growing demands on municipal governments. PennDOT LTAP has provided technology transfer services to Pennsylvania's 2,560 municipal governments since 1983.

8.4 IMSA Training

The International Municipal Signal Association (IMSA) offers various training and certification courses (see **Exhibit 8-1**). At a minimum, IMSA Work Zone Traffic Control Safety Certification (or LTAP's Temporary Traffic Control Training) and IMSA Traffic Signal Level 1 Training should be completed to effectively understand the traffic signal maintenance activities. IMSA Traffic Signal Level 2, IMSA Traffic Signal Level 3, IMSA Traffic Signal Inspection, and other traffic signal courses may be desirable for the municipalities and the maintenance contractors to obtain a full understanding of traffic signal maintenance and operations. Interested municipalities and municipal maintenance contractors can refer to IMSA for additional training details.

Exhibit 8-1 Available IMSA Training

Training	Description
IMSA Work Zone Traffic Control Safety Certification	▪ Training on Part 6 Temporary Traffic Control from the *MUTCD* ▪ Teaches principles to be observed in the design, installation, and the maintenance of traffic control to enhance motorist and worker safety in work zones
IMSA Traffic Signal Level 1 Training	▪ Designed for the entry-level technician that has had some prior training or experience in electrical technology ▪ Principals of operation and the primary electrical details of cabinet wiring and components ▪ Equipment, methods, and materials of signal system construction ▪ Basics of traffic signal design, maintenance, and legal issues
IMSA Traffic Signal Level 2 Training (Field Technician)	▪ Areas of training include worksite safety, maintenance of traffic, traffic signal system equipment standards and operation, installation inspection, troubleshooting, equipment repair, replacement and programming, test equipment, signal phasing and timing, detection, system communications, preventative maintenance, and documentation
IMSA Traffic Signal Level 3 Training	▪ An exam for which other training prerequisites are required along with a minimum level of experience
IMSA Traffic Signal Inspection	▪ Introduction to Traffic Signal Inspection ▪ Inspection of Underground Facilities ▪ Inspection of Traffic Signal Supports ▪ Inspection of Overhead Equipment ▪ Inspection of the Vehicular and Pedestrian Detection Systems ▪ Inspection of the Controller Assembly ▪ Safety Requirements ▪ Final Acceptance and Turn-On
Other Training	▪ May include training by vendors of a municipality's equipment to train personnel on unique operational characteristics and maintenance of that specific equipment

Traffic Signal Maintenance Manual

APPENDICES

Bureau of Maintenance and Operations

pennsylvania
DEPARTMENT OF TRANSPORTATION

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PUB 191 (09-20)

APPENDIX A. GLOSSARY

When used in this publication, the following definitions, terminology and titles have the meanings included herein:

AASHTO – The American Association of State Highway and Transportation Officials.

Actuated operation – A type of traffic control signal operation in which some or all signal phases are operated on the basis of actuation (vehicle detection, pushbutton, etc.).

ADA – Americans with Disabilities Act (1990).

Adaptive signal system – A technology using detection data and algorithms to adjust signal timing parameters for current conditions. Adaptive signal systems still rely on local controllers for many timing parameters and share many features of traditional systems, but they have more flexibility in how they adjust timing parameters.

As-built plans – A modified traffic signal plan showing the roadway geometrics and the traffic signals after completion of the construction project, showing any field adjustments due to structural shifts of signal supports, unanticipated corner radius changes, etc.

Conflict monitor -- A device housed in the controller cabinet which continuously checks for the presence of conflicting signal indications such as simultaneous green signal indications on both the mainline and side road approaches. If a conflict is detected, the monitor places the signals into a flashing operation.

Controller – The electronic device that controls the sequence and duration of traffic signal indications.

Department – Term used to reference the Pennsylvania Department of Transportation.

Detector – A device for indicating the presence of a vehicle or pedestrian.

Design modifications – A proposed change to the approved design and operation of an existing traffic signal or signal system to accommodate changes in prevailing traffic or physical conditions or update the installation to current state-of-the-art design. Typical modifications include addition or removal of signal phases or special functions; changes in signal displays, configurations, or locations; detector modifications; upgrading of equipment and communication systems; and revisions to related signs and pavement markings. These changes can be initiated by any involved party but cannot be physically implemented until the signal permit is updated.

Documentation – The information for the traffic signal or signal system, including the traffic signal permit, equipment manuals and warrantees, summary and detailed listing of all signal maintenance, and design modifications, etc.

Infrared detection – An overhead mounted device that illuminates a select area with low-power infrared energy supplied by light-emitting diodes (LEDs) or laser diodes, and then converts the reflected energy into an electrical signal to indicate the presence of a vehicle or person. Infrared detectors may have special applications for detecting pedestrians and bicyclists.

Incandescent indications – Vehicular or pedestrian signals, or a blank-out sign, that are illuminated with a traditional light bulb having a thin tungsten filament.

Intersection – The area embraced between the prolongation and connection of the lateral curb lines, or if none, the lateral boundary lines of the roadways (i.e., the traveled portion) of two or more streets or highways.

Isolated intersection – A signalized intersection that is located far enough from other signalized intersections so that the signal timing at the other intersections does not influence the traffic flow at this intersection.

Local controller – The controller located at an intersection and which operates the traffic signals only at that intersection and does not control or directly influence any other intersection.

Local authorities –

i. County, municipal and other local boards or bodies having authority to enact regulations relating to traffic.

ii. The term also includes airport authorities except where those authorities are within counties of the first class or counties of the second class.

iii. The term also includes State agencies, boards and commissions other than the Department, and governing bodies of colleges, universities, public and private schools, public and historical parks.

LTAP – PennDOT's Local Technical Assistance Program which is dedicated to transferring transportation technology through training, technical assistance, and other customer services to municipal officials and their staff (see https://gis.penndot.gov/LTAP).

Loop detectors – The most commonly used device to monitor traffic on the approach to a traffic control signal, consisting of multiple circles of wire in a basic square or rectangular shape that is buried within the roadway and which detects changes in their magnetic field caused by the metal in passing vehicles.

Maintenance service manuals – The document provided by the manufacturer of a piece of equipment that specifies how to adjust, clean, lubricate, calibrate, and otherwise maintain the equipment to ensure its proper operation and its longevity.

Maintenance service records – An accumulation of paperwork that captures all service performed to the traffic signals at a specific intersection. This paperwork identifies all inspections, cleaning, tightening, calibrations, adjustments, replacements, lubrications, etc., that were performed from either a preventative viewpoint, or repairs due to crashes or equipment failure.

MUTCD – The current edition of the *Manual on Uniform Traffic Control Devices*, as adopted by the Federal Highway Administration (FHWA), and available at http://mutcd.fhwa.dot.gov/.

Master controller – The controller that supervises and directs the timing patterns for all local controllers within a traffic control signal system for the purpose of coordinating the operation of the signal system to improve traffic flow and safety.

Microwave detection – Equipment that transmits an electromagnetic signal and compares the reflected signal from all objects in the protected area by use of the Doppler Effect, and based on a selected sensitivity level it determines if the detection criteria are met and if so advises the controller of the presence of traffic.

Operations – As it relates to traffic, this is the day-to-day control of traffic systems, including the analysis of the systems, detection of problems and deficiencies, setting of priorities, assignment of resources and development of improvements through geometric design, traffic control, or other means. Frequently referred to as "traffic operations."

Pedestrian detection – Hardware used to notify the traffic controller of the presence of a pedestrian, typically via a pushbutton.

Pretimed operation – A non-actuated traffic control signal where right-of-way at the intersection is assigned according to one or more predetermined schedules and is therefore not influenced by the presence or absence of traffic. Pretimed operation may also be referred to as fixed-time operation.

Preventative (routine) maintenance. Maintenance scheduled on a regular basis to minimize future maintenance and to maximize the life of the equipment. It includes inspection, calibration, cleaning, testing, sealing, painting, etc., in accordance with a predefined schedule. This maintenance is similar to the maintenance schedule for a vehicle.

Push button detection – A mechanical switch that when pushed or activate, it tells the controller of the presence of a pedestrian.

Radar detection – A detector that uses radar waves to track vehicles as they approach and leave an intersection.

Response maintenance – Emergency repair performed on an as-needed basis due to either equipment failure or a crash. Upon notification, the maintenance service team is dispatched to secure the site, diagnose the problem, perform the repairs, and record its activities as quickly as possible.

Signal timing charts – The table that captures the traffic signal timing analysis.

Surge Protection Devices (SPDs) – Any of a number of devices designed to protect electronic systems against damages caused by lightning or other electrical disturbances. When used on traffic signal equipment, these devices should conform to the National Fire Protection Association's NFPA 780 (installation of Lightning Protection Systems) standard. In accordance with the new guidelines, critical applications include inductive loops, video cameras, pedestrian pushbutton loops, service loops for controls or signals that exit or enter the cabinet, and the AC that supplies the power.

Traffic control signal -- The specific type of traffic signal that provides alternating stop and go traffic control with red-yellow-green (R-Y-G) signal indications.

Traffic signal – The broad category of highway lights including traffic control signals (provide alternating stop and go), pedestrian signals, flashing beacons, lane-use control signals, ramp metering, and in-roadway lights.

Traffic signal housing – The outer part of a traffic signal section that protects a light and other required components from the elements.

Traffic signal permit – The document approved by the Department to authorize the installation and operation of the traffic signal. The traffic signal permit is for a traffic signal at a specific intersection, and it includes the Traffic Engineering Form TE-964, and traffic signal plans showing the intersection plan sheets with the locations of the traffic signals, traffic signal supports, controller cabinet, junction boxes, detectors, stop lines, street names, approach grades, distance to nearest signals, etc., plus the traffic signal phasing diagram.

Traffic signal support – The physical means whereby signal heads, signs, and luminaires are supported in a particular location. Structural supports are to be designed to carry the loads induced by attached signal heads, signs, luminaires, and related appurtenances.

Traffic signal system – Two or more traffic control signals operating in coordination with each other.

Traffic signal timing – The analysis of intersection geometrics, speeds, and historical traffic volumes used to identify the specific duration in seconds for the green, yellow, red, Walk, and Don't Walk intervals of each phase. For traffic actuated signals, the traffic signal timing also includes information on the incremental extensions of the green intervals due to the continued presence of approaching vehicles.

Uninterrupted power supply (UPS) – A battery backup system designed to instantly provide electrical power for the operation of the controller and traffic signals during a power outage. UPS essentially became viable with the conversion to LED signals.

Video detection – The process of using a video imaging system to analyze the feed from a video camera mounted above the roadway to determine the presence or passage of vehicles in one or more specific travel lanes on an approach to the intersection.

Wireless detection – The use of equipment coupled with a radio transmitter that informs a receiver in the controller cabinet of the presence or passage of vehicles in one or more specific travel lanes. The type of detection may vary, but the radio transmission is used in lieu of wire or coaxial cable.

APPENDIX B. TMSA RESOLUTION

RESOLUTION

BE IT RESOLVED, by authority of the _____
(Name of governing body)

of the _____ , _____
County, and it
(Name of MUNICIPALITY)

is hereby resolved by authority of the same, that the _____
(designate official title)

of said MUNICIPALITY be authorized and directed to submit the attached Traffic Signal Maintenance

Agreement and to submit future modifications to the attached Traffic Signal Maintenance Agreement, either in writing or via electronic signature, to DEPARTMENT and to sign this Agreement on behalf of MUNICIPALITY.

ATTEST: _____
(Name of Municipality)

_____ By: _____
(Signature and designation of official title) (Signature and designation of official title)

I, _____, _____
(Signature and designation of official title) (Signature and designation of official title)

of the _____ , do hereby certify that the foregoing

is a true and correct copy of the Resolution adopted at a regular meeting of the

_____, held the _____ day of _____ , _____ 20 .

DATE: _____ _____
(Signature and designation of official title)

APPENDIX C. MUNICIPAL SERVICE AGREEMENT

MUNICIPAL SERVICE AGREEMENT
FOR MAINTENANCE OF TRAFFIC CONTROL SIGNALS

Agreement is signed, this _____ day of _____, 20___, with an effective date of _____, 20___ by and between _____, **INC.,** a _____ Corporation, with its principal place of business at _____, hereinafter known as "**XXXXXXXXXX**"

AND

(municipality) _____

(address) _____

(address) _____

(telephone) _____

hereinafter known as "**MUNICIPALITY**";

SAMPLE FORMAT

WITNESSETH:

WHEREAS, MUNICIPALITY and **XXXXXXXXXX** hereto desire to enter into a contract for the maintenance, service and repair of traffic control signals, situate and located in _____, _____ County; and

WHEREAS, MUNICIPALITY has by official and duly authorized action approved this municipal services agreement following a competitive bidding process or through other statute, law or regulation authorizing the services, maintenance and repairs contemplated by this Agreement for the benefit of **MUNICIPALITY,** and **XXXXXXXXXX** hereby relies upon said

representation for the purposes of providing maintenance, service and repair of traffic control signals and devices for the benefit of **MUNICIPALITY.**

NOW, THEREFORE, it is mutually agreed and represented as follows:

1. EXCLUSIVE CONTRACTOR. XXXXXXXXXX shall be the exclusive contractor for the maintenance, service and repair of all traffic control signals within **MUNICIPALITY** for the benefit of **MUNICIPALITY** during the term of this Agreement in accordance with the RFP submitted on _____, 20___.

2. SCOPE OF SERVICES. XXXXXXXXXX shall, subject to the general control of **MUNICIPALITY,** render and perform the following services:

(a) Afford **MUNICIPALITY** the full benefit of the experience, judgment, advice and assistance of its officers, employees and other members of its organization, in respect to all matters pertaining to the maintenance, service and repair of said traffic control signals; and

(b) Perform any maintenance, service, or repair of said traffic control signals; necessary to keep said traffic control signals in good working condition including, but not limited to the maintenance set forth in "Commonwealth of Pennsylvania, Department of Transportation's *Traffic Signal Maintenance Manual*" (Pub. 191) and updates associated therewith; and

(c) Twenty-four (24) hours on-call emergency service or repair; and

(d) Keep and maintain at all times records pertaining to the maintenance, service, or repair performed by **XXXXXXXXXX,** all of which shall be furnished to **MUNICIPALITY** upon reasonable request and uploaded to PennDOT's Traffic Signal Asset Management System (TSAMS); and

(e) Make purchases, and maintain an inventory of, necessary parts and supplies for maintenance, service, or repair of said traffic control signals, including, but not limited to, parts and supplies purchased at the request of **MUNICIPALITY**, which are unique to the traffic control signals in **MUNICIPALITY**; and

(f) **XXXXXXXXXX** shall maintain, and require all contractors and subcontractors working at **XXXXXXXXXX** direction to maintain, public liability and workmen's compensation insurance and shall submit certificates therefore to **MUNICIPALITY** upon reasonable request.

3. HOURLY RATES. **MUNICIPALITY** and **XXXXXXXXXX** agree that **MUNICIPALITY** shall pay **XXXXXXXXXX** in accordance with the following hourly rate schedule:

(a) Service Personnel. Request for service be paid at a rate of _____ dollars and _____ cents ($____.___) per hour, or prorated, for maintenance, service or repair of said traffic control signal(s) during regular business hours during the term of this agreement, and at the rate of _____ dollars and _____ cents ($____.___) per hour or prorated, for emergency requests for service not made during regular business hours.

(b) Flagger/Safety personnel. Flagger/Safety personnel shall be paid at a rate of _____ dollars and _____ cents ($____.___) per hour, or prorated, for maintenance, service or repair of said traffic control signal(s) during regular business hours during the term of this agreement, and at the rate of _____ dollars and _____ cents ($____.___) per hour or prorated, for emergency requests for service not made during regular business hours.

(c) Crane Trucks. Crane Trucks shall be paid at a rate of _____

dollars and _____ cents ($____.___) per hour during the term of this agreement

(d) Auger Trucks. Auger Trucks shall be paid at a rate of _____ dollars and _____ cents ($____.___) per hour during the term of this agreement

(e) Backhoe. Backhoe shall be paid at a rate of _____ dollars and _____ cents ($____.___) per hour during the term of this agreement.

(f) Digger Derrick. Digger Derrick shall be paid at a rate of _____ dollars and _____ cents ($____.___) per hour during the term of this agreement

(g) Regular Business Hours. For the purpose of this Agreement "regular business hours" shall be from _____ a.m. to _____ p.m. prevailing time, except Saturday, Sundays and legal holidays. Request for service made outside of Regular Business hours as defined herein, including calls made on Saturday, Sundays and legal holidays, shall be classified as emergency requests for service,

(h) Payment for services. **MUNICIPALITY** agrees to pay **XXXXXXXXXX** within a period of thirty (30) days after submission of an invoice by **XXXXXXXXXX** to **MUNICIPALITY**. Payments made by **MUNICIPALITY** after a period of thirty (30) days shall include a late fee of *one and one-half* percent (*1.5%*) of the total invoice submitted to **MUNICIPALITY** by **XXXXXXXXXX**. Failure of **MUNICIPALITY** to pay **XXXXXXXXXX** in accordance with the subparagraph shall constitute reasonable grounds and basis for **XXXXXXXXXX** to terminate the municipal services agreement without any further liability, claim or demand for traffic control maintenance, service and repair by **MNNICIPALITY**.

4. SERVICE AUTHORIZATION REQUESTS. **MUNICIPALITY** and **XXXXXXXXXX** agree that **XXXXXXXXXX** shall be authorized to respond to any request for regular or emergency services upon telephone or other form of request, verbal or written, by any

municipal agent, municipal police officer, State police officer, local or county emergency service manager or other duly authorized agent of **MUNICIPALITY** for necessary emergency service or repair of said traffic control signals within the timeframes indicated in PennDOT Publication 191, *Traffic Signal Maintenance Manual*, for response maintenance activites.

5. TRAFFIC CONTROL SIGNALS. For purposes of this Agreement, "Traffic Control Signals" shall be defined as any device, whether manually, electrically, or mechanically operated, by which vehicular and/or pedestrian traffic is alternately directed to stop and permitted to proceed.

6. TERM OF AGREEMENT/RENEWAL OF AGREEMENT. This Agreement shall be in force and effect for a term beginning with the dates hereof and shall continue for a period of one (1) year thereafter. Upon expiration of this Agreement, an option to renew all terms of this agreement can be executed in writing once agreed upon by both parties. Either party may terminate this agreement for any reason by providing the other party with sixty (60) days written notice.

7. MODIFICATIONS/INTERRETATIONS. This agreement represents the entire agreement between the parties. All modifications to the Agreement shall be in writing and signed by the authorized representative of the parties, and no verbal modification shall be binding or enforceable in any event. For purposes of contract interpretation, this Agreement shall be construed as if prepared for the benefit of both **MUNICIPALITY** and **XXXXXXXXXX.**

8. TERMINATION. If at any time the **MUNICIPALTY** shall be of the opinion and so certify in writing that **XXXXXXXXXX** is violating any of the conditions or covenants of this Agreement, or the specifications thereof, or is executing the same in bad faith or not in accordance with the terms thereof, the **MUNICIPALITY** may cancel and terminate this

Agreement by a written notice to be served upon **XXXXXXXXXX** at its office address set forth in this Agreement.

9. BINDING EFFECT. This Agreement shall be binding upon all parties hereto and their respective heirs, executors, administrators, successors and assigns.

10. NOTICES. All notices, demands and requests under this Service Agreement shall be in writing and shall be deemed given when sent by United States registered and/or certified mail, postage prepaid, return receipt requested, and addressed as follows:

TO **XXXXXXXXXX**: _____
_____
_____

TO **MUNICIPALITY**: _____
_____
_____

Notices, demands and requests which shall be served upon **XXXXXXXXXX** and/or **MUNICIPALITY** in the manner aforesaid shall be deemed to have been served and/or given for all purposes hereunder at the time such notice, demand or request shall be mailed by United States registered and/or certified mail as aforesaid, in any post office and/or branch post office regularly maintained by the United States Government. Either party may, by notice given to the other party, designate a new address to which notices, demands and requests shall be sent and, thereafter, any of the foregoing shall be sent to the address most recently designated by such party.

11. PENNSYLVANIA LAW. This Agreement shall be construed in accordance with the laws of the Commonwealth of Pennsylvania.

IN WITNESS WHEREOF, the parties hereto have executed, or caused to be executed by their duly authorized officials, this Agreement in duplicate, each of which shall be deemed an

original on the date first above written.

MUNICIPALITY	(S P E L L O U T XXXXXXXXXX's N A M E)
By: _____	By: _____
Title: _____	xxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxx
Address: _____	xxxxxxxxxxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxxxxxxxxxx
Address: _____	

APPENDIX D. TRAFFIC SIGNAL PROGRAM BENCHMARKING

Traffic signal owners should establish a programmatic approach to traffic signal management and operations providing a framework to intentionally link transportation goals such as safety, mobility, reliability, and state-of-good-repair to organizational capability to clarify how limited resources can be used to focus on doing what is most important, generally defined as providing good basic service. The capability maturity assessment technique can be used with the traffic signal program model. Additional information on this approach is contained in *Traffic Signal Benchmarking and State of the Practice Report*. The capability maturity model framework is illustrated below.

Capability Maturity Model Levels

- Activities and relationships largely ad hoc, informal, and champion-driven
- Substantially outside mainstream of other agency activities

- Basic strategy applications understood
- Key processes support requirements identified and key technology and core capacities under development
- Limited internal accountability
- Uneven alignment with external partners

- Standardized strategy applications implemented in priority contexts and managed for performance
- Technical and business processes developed, document, and integrated into agency
- Partnerships aligned

- Full, sustainable core agency priority
- Established on the basis of continuous improvement with top level management status
- Formal partnerships

Source: *Traffic Signal Benchmarking and State of the Practice Report,* 2019

Capability maturity can be measured across various dimensions, as described in the following sections. Traffic signal owners should periodically complete a self-assessment to gauge how well the agency is able to fulfill its traffic signal maintenance and operation requirements. In addition to the dimensions described herein, additional dimensions are described in the *Traffic Signal Benchmarking and State of the Practice Report*.

Systems and Technology

Systems and technology include local control, central control, detection, and communication systems.

Systems and Technology Capabilities

Grade	Level	Capability
A	**Level 4**	In addition to Level 3: ▪ Systems and technology performance measures are continuously evaluated to identify deficiencies and opportunities for improvement. ▪ Performance measures inform budget and resource allocation decisions. Asset management and system and technology investments are informed by performance measures.
B	**Level 3**	In addition to Level 2: ▪ Performance measures are established to validate that systems and technology provide the require functionality to execute needed operations and maintenance strategies and attain objectives.

		▪ Processes are established to periodically review systems performance measures. ▪ Traffic signal equipment is replaced/updated through regular upgrades that consider life cycle and functionality gaps.
C	**Level 2**	▪ Systematic processes (systems engineering, architecture standards, etc.) linking operations and maintenance objectives and needs to requirements are used for systems procurement. ▪ System performance is defined based on operations and maintenance objectives and strategies. ▪ System components are replaced based on life cycle and/or when improvements in functionality are needed.
D	**Level 1**	▪ Ad hoc selection of systems and technology is typically based on the preferences of key individuals. ▪ The appropriate function and performance of systems and technology is not well-defined and the capability to evaluate performance is limited and typically dependent on complaints. ▪ Systems and technology are not able to verify whether the signal operates in accordance with the PennDOT-issued permit. ▪ Visual observations and citizen complaints are used to determine the effectiveness of signal operation and maintenance. ▪ System components are typically replaced when there is equipment failure.

Adapted from *Traffic Signal Benchmarking and State of the Practice Report,* 2019

Signal Infrastructure

Signal infrastructure includes poles, mast arms, span wire, wiring, signal heads. Signs and pavement markings associated with the traffic signal operation and identified on the traffic signal permit are also considered part of the signal infrastructure.

Infrastructure Capabilities

Grade	Level	Capability
A	**Level 4**	In addition to Level 3: ▪ Infrastructure measures are regularly evaluated to ensure consistency with required condition and functionality. Gaps in functionality and opportunities for enhancement are monitored to identify needed investments.
B	**Level 3**	In addition to Level 2: ▪ Infrastructure condition is regularly monitored and recorded in an asset management system. ▪ Signal infrastructure is periodically reviewed for compliance with current PennDOT and national standards. ▪ Traffic signal equipment is replaced/upgraded considering life cycle and equipment condition.
C	**Level 2**	▪ Established specifications are used for procurement to ensure components meet operations and maintenance needs. ▪ Traffic signal permit condition diagrams are consistent with field conditions. ▪ As-built conditions are reflected with updated traffic signal permits and signal inventory in TSAMS.

		▪ Copies of the current traffic signal permit are readily accessible to support ongoing design, maintenance, and operations activities.
D	**Level 1**	▪ Ad hoc selection of components is made based on preferences of key individuals. ▪ Infrastructure condition is not regularly monitored or documented. ▪ Signal components which are replaced due to equipment failure or knockdowns is not updated on the traffic signal permit condition diagram. ▪ Field views are necessary each time design and operations activities are initiated since traffic signal infrastructure is unlikely to match the traffic signal permit and/or signal inventory in TSAMS.

Adapted from *Traffic Signal Benchmarking and State of the Practice Report,* 2019

Maintenance Business Processes

The maintenance business processes dimension goes beyond day-to-day activities and require broader institutional support and involvement to address. This dimension includes procurement processes, sustainable funding, internal awareness, and support.

Maintenance Business Process Capabilities

Grade	Level	Capability
A	**Level 4**	In addition to Level 3: ▪ Maintenance objectives, strategies, and performance measures are fully integrated across the program. ▪ The relationship between activities, processes, systems, and performance is acknowledged by efforts to predict, detect, and proactively make improvements. ▪ Processes are continuously improved validating the effectiveness of day-to-day activities, systems, and technology and workforce capabilities with performance measures. ▪ Design modifications are regularly implemented to address recurring maintenance and safety issues.
B	**Level 3**	In addition to Level 2: ▪ Measures (output and/or outcome) are defined for maintenance-related activities. ▪ Measures (output and/or outcome) are established to validate the attainment of maintenance objectives and the effectiveness of strategies. ▪ Reporting of maintenance output and outcomes is a core business practice.
C	**Level 2**	▪ Established maintenance strategies, activities, processes are practices to guide preventative, routine/scheduled, and emergency maintenance. ▪ Guidelines, checklists, or other documentation is available or under development to support traffic signal maintenance to ensure the reliability of infrastructure, systems, and technology. ▪ Efforts to make improvements to maintenance processes are limited, tend to be reactive, and have limited accountability.
D	**Level 1**	▪ Maintenance activities are not well-defined, ad hoc, and are driven by individuals who are equipped with or developing the skills and expertise to implement maintenance strategies. ▪ Little or no documentation exists to guide maintenance processes. ▪ Processes to evaluate infrastructure condition are ad hoc and not well-defined. The systems, technology, and infrastructure components may be dated

		(potentially obsolete), with gaps in functionality and typically replaced upon failure.

Adapted from *Traffic Signal Benchmarking and State of the Practice Report,* 2019

Management Processes

Management activities involve the budgeting and programming of general operating and capital improvement program budgets, staffing considerations and supervision for traffic signals, customer service to the public and elected leaders, and engagement with the media and stakeholders.

Maintenance Business Process Capabilities

Grade	Level	Capability
A	**Level 4**	In addition to Level 3: ▪ Program business processes are continuously improved by validating the effectiveness of the day-to-day activities, systems and technology, and workforce capabilities with measures. ▪ Asset management, funding processes, training, implementation of technology and innovation, and investments in innovation and technology are informed by evaluation measures. ▪ Priorities and investments are reference in the agency's strategic plan.
B	**Level 3**	In addition to Level 2: ▪ A set of measures (output and/or outcome) are defined for management-related activities as well as the overall program. ▪ The capability and processes to validate and routinely report on the attainment of program objectives and strategies is developed or under development. ▪ Asset management inventory is available.
C	**Level 2**	▪ The potential loss of continuity from attrition of key staff is mitigated by documenting program goals and objectives in the form of a Traffic Signal Management Plan (TSMP). ▪ Workforce competencies, asset inventories, procurement processes (e.g. systems engineering) are documented. ▪ An asset management system is available to track life cycle of equipment.
D	**Level 1**	▪ The traffic signal program goals and objectives are only articulated by one or more program champions, and documentation has not been fully-developed. ▪ The loss of key staff due to attrition or retirement presents a risk to continuity of administration activities. ▪ Little or no documentation exists to provide direction, vision, and goals to guide traffic signal program processes. ▪ Updates to existing guidelines are rare and not tracked.

Adapted from *Traffic Signal Benchmarking and State of the Practice Report,* 2019

Workforce

This dimension characterizes the people within the organization, who each carry beliefs, attitudes, and behaviors that are influenced by their education and training to produce knowledge. This dimension concentrates on the development, training, and competency of qualified staff across all levels in the program including technical, engineering, and management positions.

Workforce Capabilities

Grade	Level	Capability
A	**Level 4**	In addition to Level 3: ▪ Workforce competencies are evaluated to ensure consistency with industry standards and program needs, and routinely updated to improve competencies. ▪ Appropriate program performance measures are evaluated to identify and address potential gaps between staff capability and program needs. Training and certifications are prescribed to address gaps.
B	**Level 3**	In addition to Level 2: ▪ Workforce competencies are linked to current and planned program needs and monitored for consistency. ▪ Training and certifications are tracked to ensure that staff capability is consistent with program needs.
C	**Level 2**	▪ Workforce competencies are established and job descriptions are documented to support alignment of staff capability with design, operations, and maintenance strategies. ▪ Workforce development is supported fiscally with structured internal and/or external training and certification as appropriate to maintain competency.
D	**Level 1**	▪ The workforce maintains minimum levels of capability to complete required tasks. Workforce competencies/position descriptions are not well defined. ▪ Training is ad hoc and lacks formal structure. Funding to support training, development of core skills and certification is limited.

Adapted from *Traffic Signal Benchmarking and State of the Practice Report,* 2019

Traffic Signal Maintenance for the 21st Century in Pennsylvania

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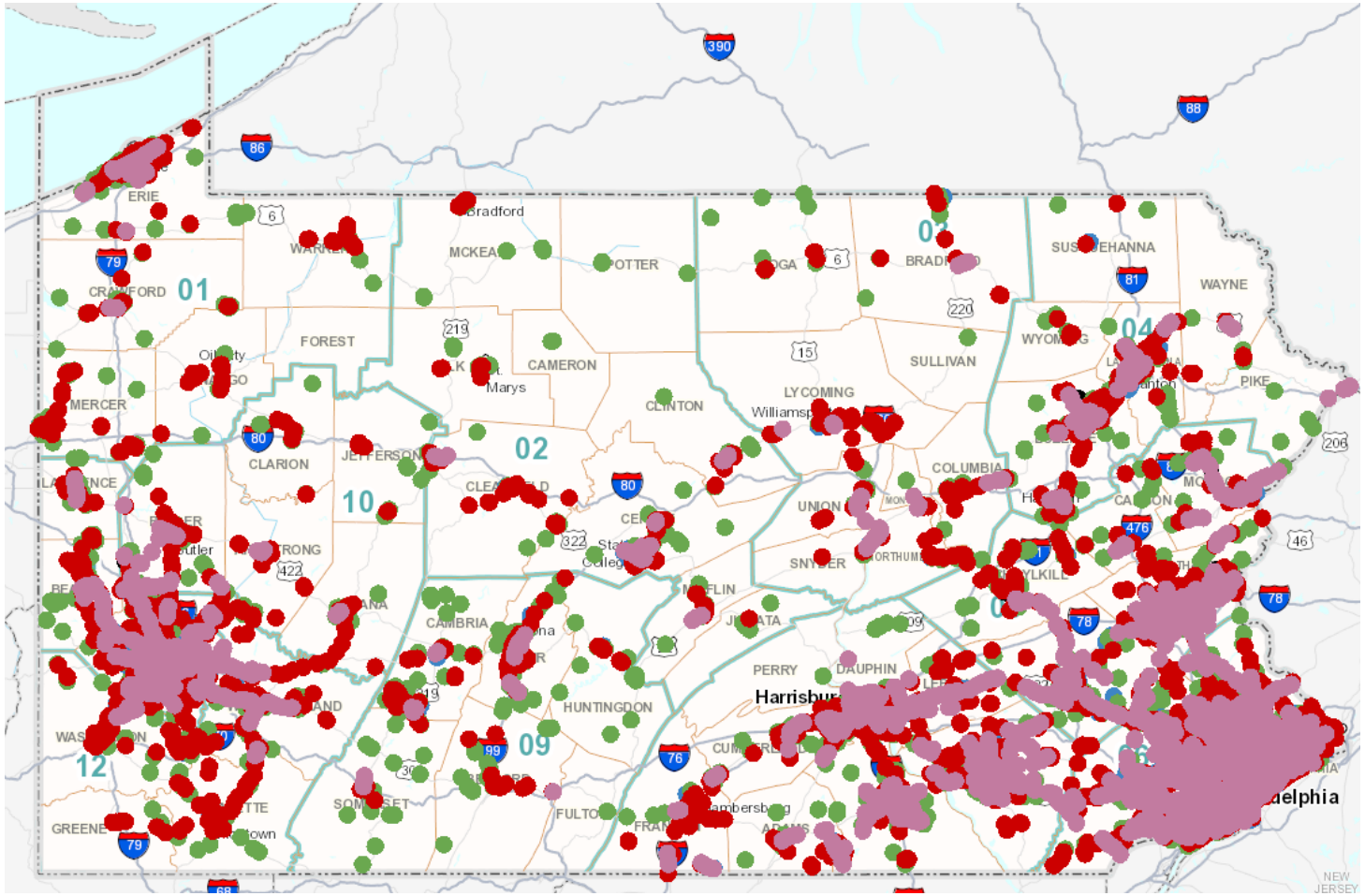
Pennsylvania Traffic Signals

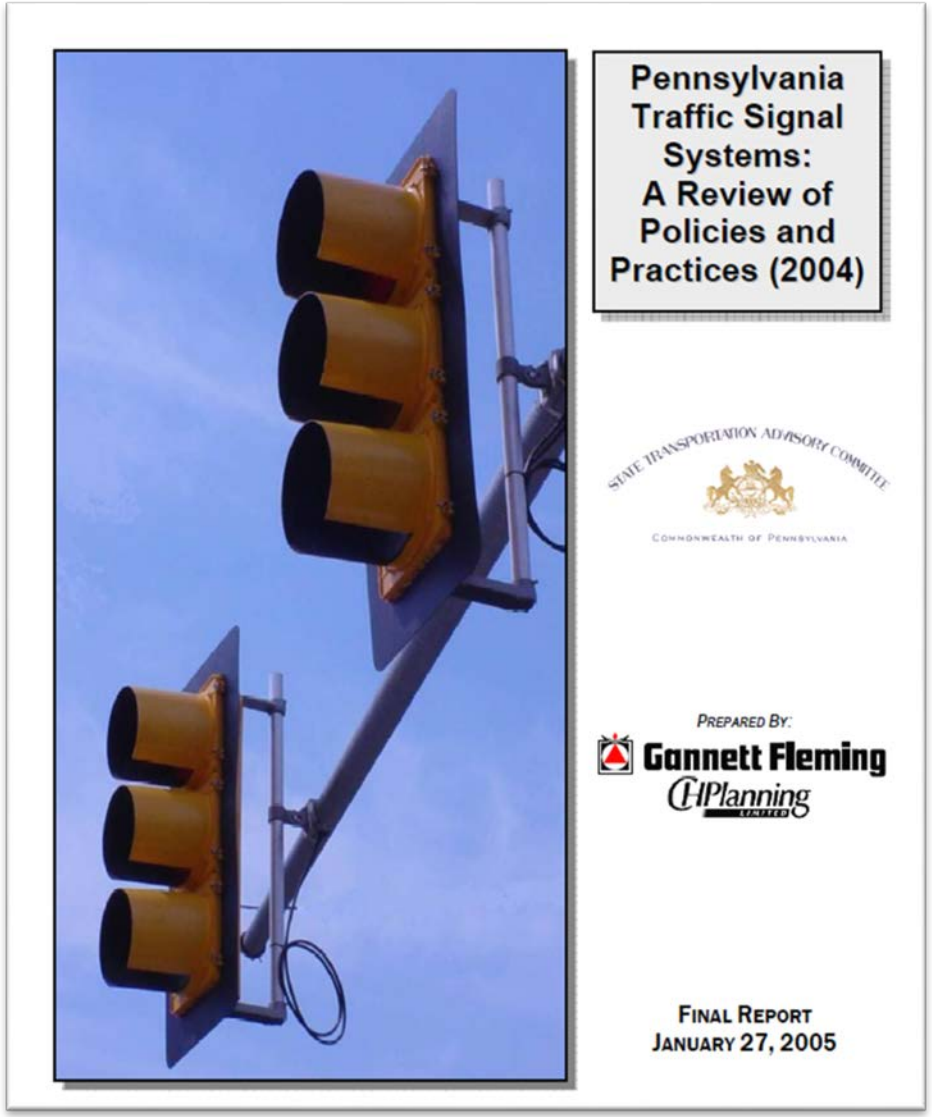
Municipalities	# of Signals
Philadelphia	2,940
Pittsburgh	608
9	101-202
23	50-100
19	40-49
35	30-39
51	20-29
155	10-19
239	5-9
369	2-4
297	1



Map Source: https://gis.penndot.gov/onemap/?map-id=20435

2005 TAC Report: Recommendations

- Develop an Asset Management System
- Pursue Tiered Operations and Maintenance
- Promote a “Holistic” Approach to Signal Management
- Expand Traffic Signal Enhancement Initiative (TSEI) and Congested Corridor Improvement Program (CCIP)
- Review and Update the Traffic Signal Permit Process
- Establish Operational Audits Program
- Complete Updates and Revisions to PennDOT Traffic Signal Publications
- Allocate a Portion of Any New Funding Increase to Signals
- Provide Incentives for Operational Enhancements
- Encourage Regional Maintenance Contracts for Operational Incentives



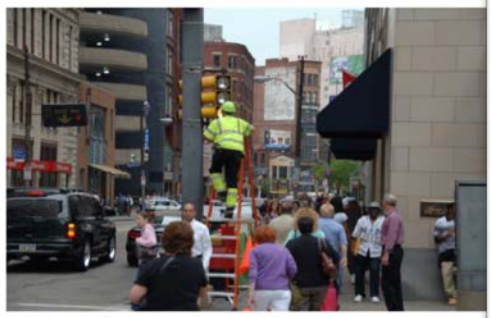
PennDOT Maintenance Standards

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

GUIDELINES FOR THE MAINTENANCE OF TRAFFIC SIGNAL SYSTEMS

PUB 191
1989 EDITION

pennsylvania
DEPARTMENT OF TRANSPORTATION

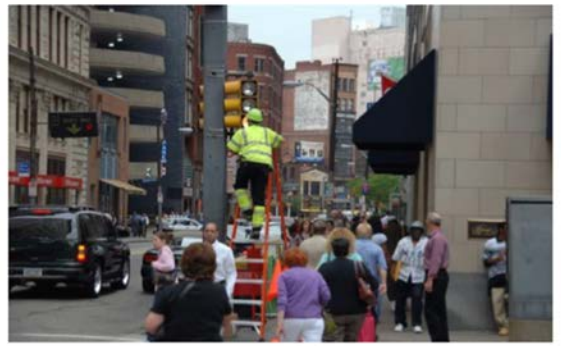


Guidelines for the Maintenance and Operation of Traffic Signals

Publication 191

October 2010

Traffic Signal Maintenance Manual



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PUB 191 (07-20)

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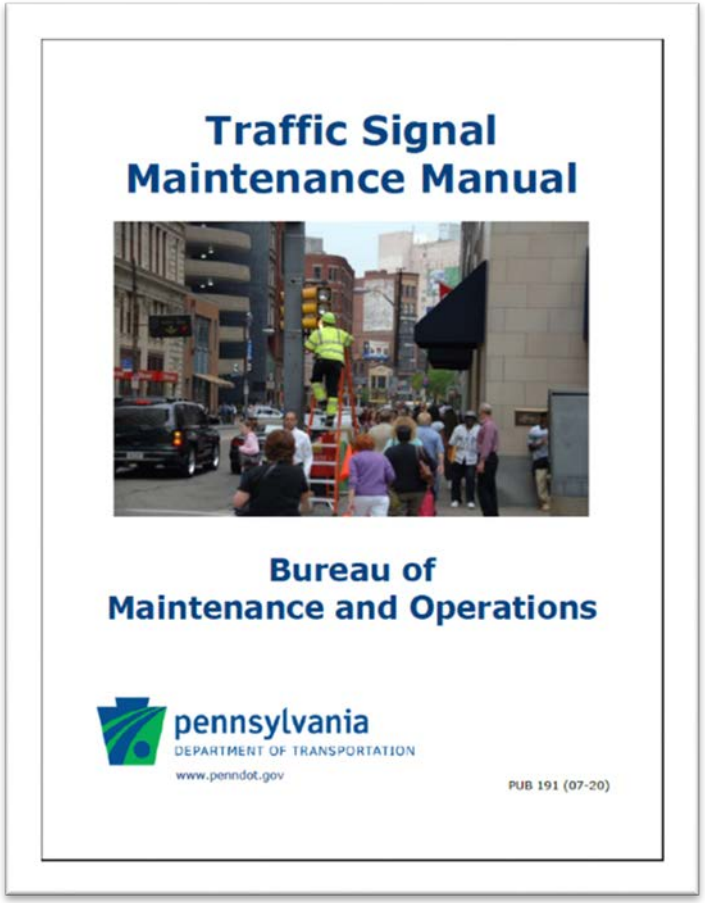
Publication 191 – 2020 Edition



- Reorganized and streamlined
- New content
  - Municipal Traffic Signal Agreements
  - Program Benchmarking
  - Asset Management
- Updated content
  - Maintenance checklists
  - Scheduling for primary/secondary components

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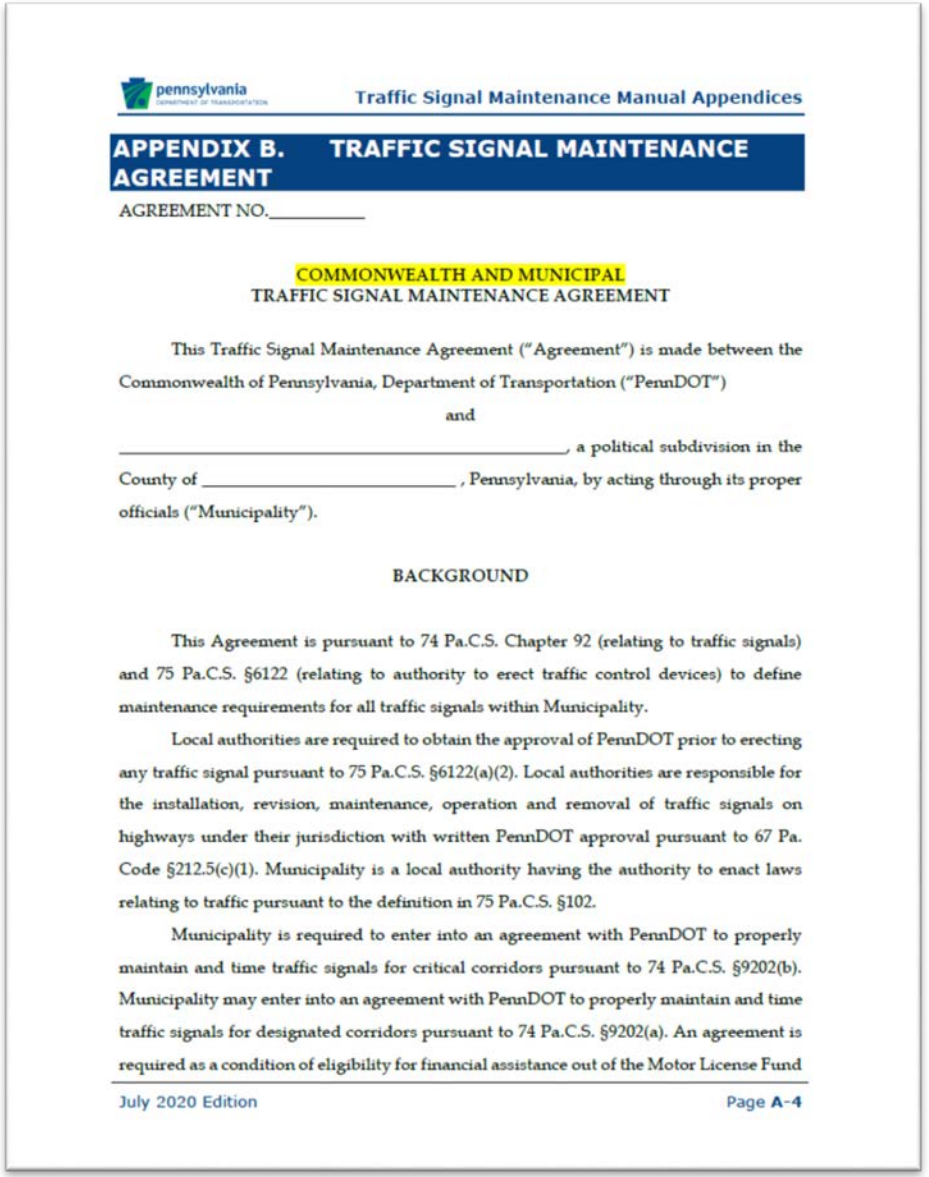
Maintenance Agreements

- Act 89 of 2013 statutory requirements
  - Municipalities required to enter into agreements with PennDOT to properly maintain and time traffic signals
  - Agreement is a required condition of eligibility for financial assistance
- Template agreement for all signals in municipality



pennsylvania DEPARTMENT OF TRANSPORTATION — Traffic Signal Maintenance Manual Appendices

APPENDIX B. TRAFFIC SIGNAL MAINTENANCE AGREEMENT

AGREEMENT NO._____

COMMONWEALTH AND MUNICIPAL
TRAFFIC SIGNAL MAINTENANCE AGREEMENT

This Traffic Signal Maintenance Agreement ("Agreement") is made between the Commonwealth of Pennsylvania, Department of Transportation ("PennDOT")

and

_____, a political subdivision in the County of _____, Pennsylvania, by acting through its proper officials ("Municipality").

BACKGROUND

This Agreement is pursuant to 74 Pa.C.S. Chapter 92 (relating to traffic signals) and 75 Pa.C.S. §6122 (relating to authority to erect traffic control devices) to define maintenance requirements for all traffic signals within Municipality.

Local authorities are required to obtain the approval of PennDOT prior to erecting any traffic signal pursuant to 75 Pa.C.S. §6122(a)(2). Local authorities are responsible for the installation, revision, maintenance, operation and removal of traffic signals on highways under their jurisdiction with written PennDOT approval pursuant to 67 Pa. Code §212.5(c)(1). Municipality is a local authority having the authority to enact laws relating to traffic pursuant to the definition in 75 Pa.C.S. §102.

Municipality is required to enter into an agreement with PennDOT to properly maintain and time traffic signals for critical corridors pursuant to 74 Pa.C.S. §9202(b). Municipality may enter into an agreement with PennDOT to properly maintain and time traffic signals for designated corridors pursuant to 74 Pa.C.S. §9202(a). An agreement is required as a condition of eligibility for financial assistance out of the Motor License Fund

Benchmarking: Capability Maturity Model

Level 1
Ad-Hoc

- Activities and relationships largely ad hoc, informal, and champion-driven
- Substantially outside mainstream of other agency activities

Level 2
Established

- Basic strategy applications understood
- Key processes support requirements identified and key technology and core capacities under development
- Limited internal accountability
- Uneven alignment with external partners

Level 3
Measured

- Standardized strategy applications implemented in priority contexts and managed for performance
- Technical and business processes developed, document, and integrated into agency
- Partnerships aligned

Level 4
Managed

- Full, sustainable core agency priority
- Established on the basis of continuous improvement with top level management status
- Formal partnerships

Adapted from *Traffic Signal Benchmarking and State of the Practice Report*, 2019

Traffic Signal Objectives

Safety	Assign right of way safely		
Operations	**Flow**	**Intersection**	**Network**
	Light	Minimize phase failures	Smooth flow
	Uncongested	Equitable service	
	Congested	Maximize throughput	Manage queues
Organizational	Responsiveness to stakeholder needs		
	Comply with agency policies and standards		
Maintenance	Minimize life cycle costs		
	Sustain infrastructure state of good repair		
	Sustain system and technology reliability/state of good repair		

Adapted from: Eddie Curtis & Rick Denney, FHWA

Example: Strategies, Tactics, Targets

Obj.	Strategy	Tactics	Measurement Targets
Assign right-of-way safely			

Example 2: Strategies, Tactics, Targets

Obj.	Strategy	Tactics	Measurement Targets
Smooth network flow			

Preventative Maintenance

Preventative Maintenance

- Address rodent infestations in cabinet
- Lubricate cabinet door hinges and locks
- Clean air filter every 6 months, replace every 12 months
- Upgrade controller firmware to latest version
- Measure service voltage
- Test operation for min. 5 minutes with emergency generator

Preventative Maintenance

- New(er) technologies:
  - Non-invasive detection (video/radar): check alignment of detection zones and adjust as necessary
  - Clean sensors (especially video detection)
  - Upgrade firmware on various components
  - Verify adaptive operation and fallback in event of adaptive failure
  - Verify connection to statewide network is functional (backhaul)

Response Maintenance

- Response Interval
  - Time from notification to arriving on-site
  - Primary components
    - 2 hours during business hours
    - 4 hours during non-business hours
  - Secondary components
    - 24 hours during business hours
    - 72 hours during non-business hours
- Repair Interval
  - Time after response to implement repairs
  - Temporary repairs: 24 hours
  - Final repairs: 30 days

Design Modifications

Implementing Best Practices

Design Modifications

Asset Management

- Improved maintenance and capital budgeting
- Improved management of operations
- Supports long-range planning efforts
- Supports funding assistance programs
- Supports evaluation of product performance to maintain QPL

Maintenance Objectives	Minimize life cycle costs
	Sustain infrastructure state of good repair
	Sustain system and technology reliability/state of good repair

PennDOT’s Traffic Signal Asset Mgmt. Sys.

pennsylvania
DEPARTMENT OF TRANSPORTATION

TSAMS

Traffic Signal Asset Management System

WELCOME to PennDOT's Traffic Signal Asset Management System (TSAMS).

TSAMS is a web-based application for managing...

- Signal and Non-Signal Asset Inventories
  - Traffic Signals
  - Emergency Traffic Signals
  - Electronic Signs
  - Flashing Warning Devices
  - In-Roadway Warning Lights
  - Intersection Control Beacons
  - Ramp Meters
  - Rectangular Rapid Flashing Beacons
  - School Zone Speed Limit Signs
- GIS Integration
- Maintenance Activity Tracking
- Signal and Non-Signal Systems Identification
- Approved Products Database
- Reporting & Advance Search

It is available **FREE** of cost to all stakeholders. If you are a new user click **here** for information on how to obtain access to **TSAMS**.

Login

Registered TSAMS users

User ID

Password

LOGIN

Forgot Your Password?

Returning Guest

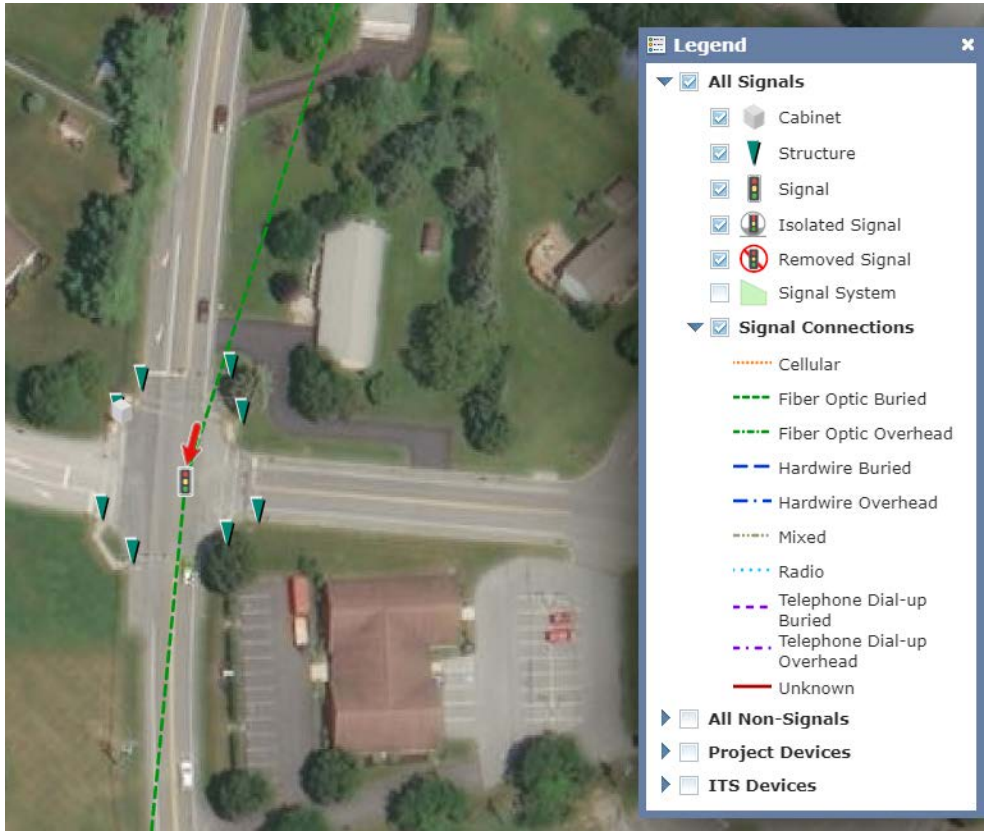
First Time Guest

Quick Links

Traffic Signal Portal
PennDOT Publications
Traffic Engineering Forms (TE-Forms)
511PA
d Construction Management System (ECMS)
stem (EPS)

ite Learning HUB

TSAMS: Inventory



Component Information

Component Type: Select — Add — Show Removed

Records 1 to 25 of 37 — Page 1 of 2 — Records Per Page: 25

Component	Manufacturer	Type	Ref ID	Component Status	Modified By	Modified Date
Flasher - 46424	Reno A&E	NA		Operational	MBAKER	07/08/2016
Detector Vehicle - 46417	Reno A&E	Loop		Operational	MBAKER	07/08/2016
Detector Vehicle - 46418	Reno A&E	Loop		Operational	MBAKER	07/08/2016
Detector Vehicle - 46419	Reno A&E	Loop		Operational	MBAKER	07/08/2016
Detector Vehicle - 46420	Reno A&E	Loop		Operational	MBAKER	07/08/2016
Detector Vehicle - 46421	Reno A&E	Loop		Operational	MBAKER	07/08/2016
Detector Vehicle - 46422	Reno A&E	Loop		Operational	MBAKER	07/08/2016
Detector Pedestrian - 867	PELCO	Push Button	12	Operational	Stephen A Gault/PennDOT	08/06/2017
Detector Pedestrian - 869	PELCO	Push Button	10	Operational	Stephen A Gault/PennDOT	08/06/2017
Detector Pedestrian - 870	PELCO	Push Button	11	Operational	Stephen A Gault/PennDOT	08/06/2017
Detector Pedestrian - 868	PELCO	Push Button	9	Operational	Stephen A Gault/PennDOT	08/06/2017
Conflict Monitor - 46423	Eberle Design Inc.	NA		Operational	MBAKER	07/08/2016
Controller - 89	Econolite Control Products	TS-2 Type 2		Operational	Stephen A Gault/PennDOT	10/11/2017
Controller - 8802	Econolite Control Products	Master Controller		Operational	Stephen A Gault/PennDOT	10/08/2018
Backup Power Source - 46425	Econolite	Cabinet		Operational	Stephen A Gault/PennDOT	08/06/2017
Backup Power Source - 46426	Unknown	Secondary Cabinet		Operational	MBAKER	07/08/2016
Structure - 397	Valmont	Mast Arm	2	Operational	Stephen A Gault/PennDOT	08/06/2017

SIGNAL HOUSING COMPONENTS

Component	Manufacturer	Type	Ref ID	Component Status	Modified By	Modified Date
Sign - 1433	Unknown	R10-3B (EDUCATIONAL PUSH BUTTON FOR WALKING PERSON SIGNAL)		Operational	MBAKER	07/08/2016
Sign - 1434	Unknown	D3-4 (SINGLE-LINE OVERHEAD STREET NAME)		Operational	MBAKER	07/08/2016
Signal Housing Pedestrian - 1094	Econolite Control Products	Single	11	Operational	Stephen A Gault/PennDOT	08/06/2017
Signal Housing Vehicular - 1096	Peek Traffic Systems	Polycarbonate	7	Operational	Stephen A Gault/PennDOT	08/06/2017

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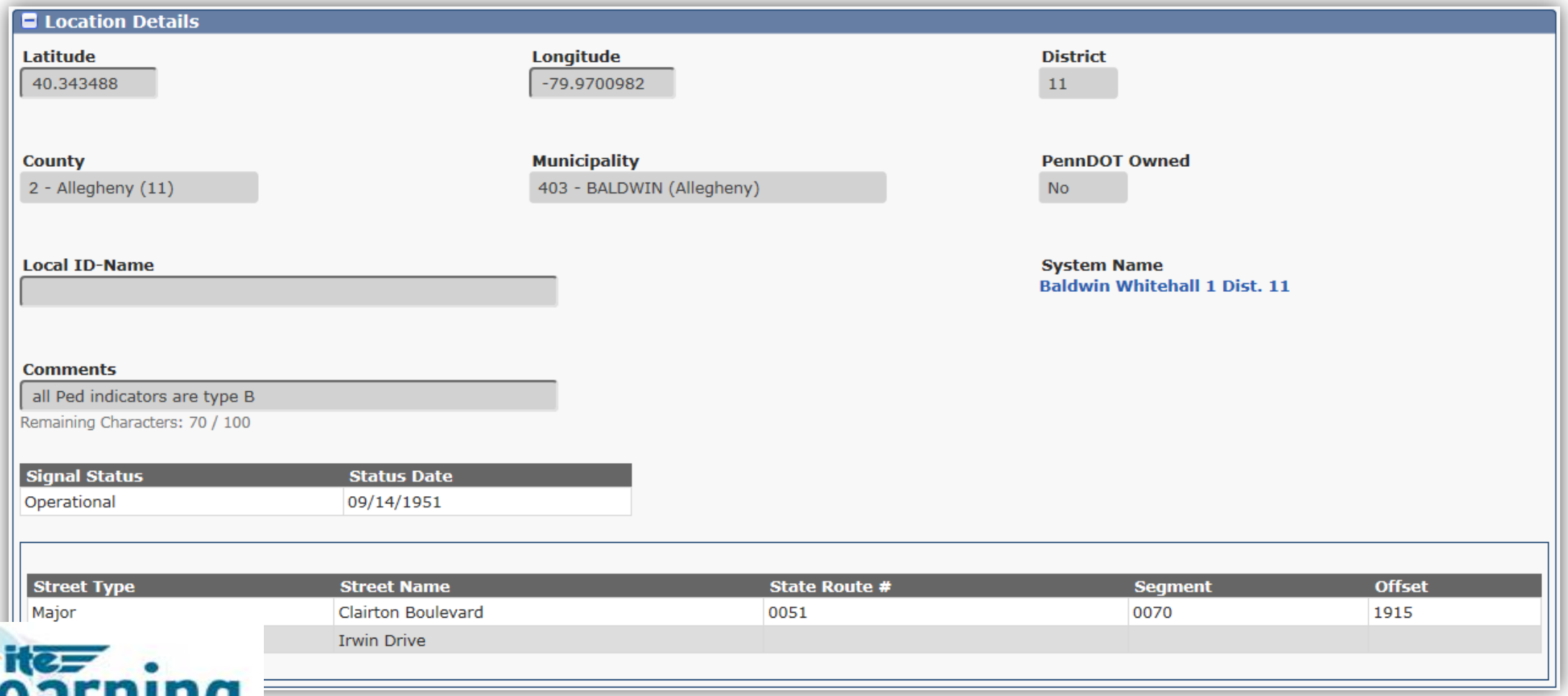
Inventory: Location Details



Location Details

Latitude
40.343488

Longitude
-79.9700982

District
11

County
2 - Allegheny (11)

Municipality
403 - BALDWIN (Allegheny)

PennDOT Owned
No

Local ID-Name

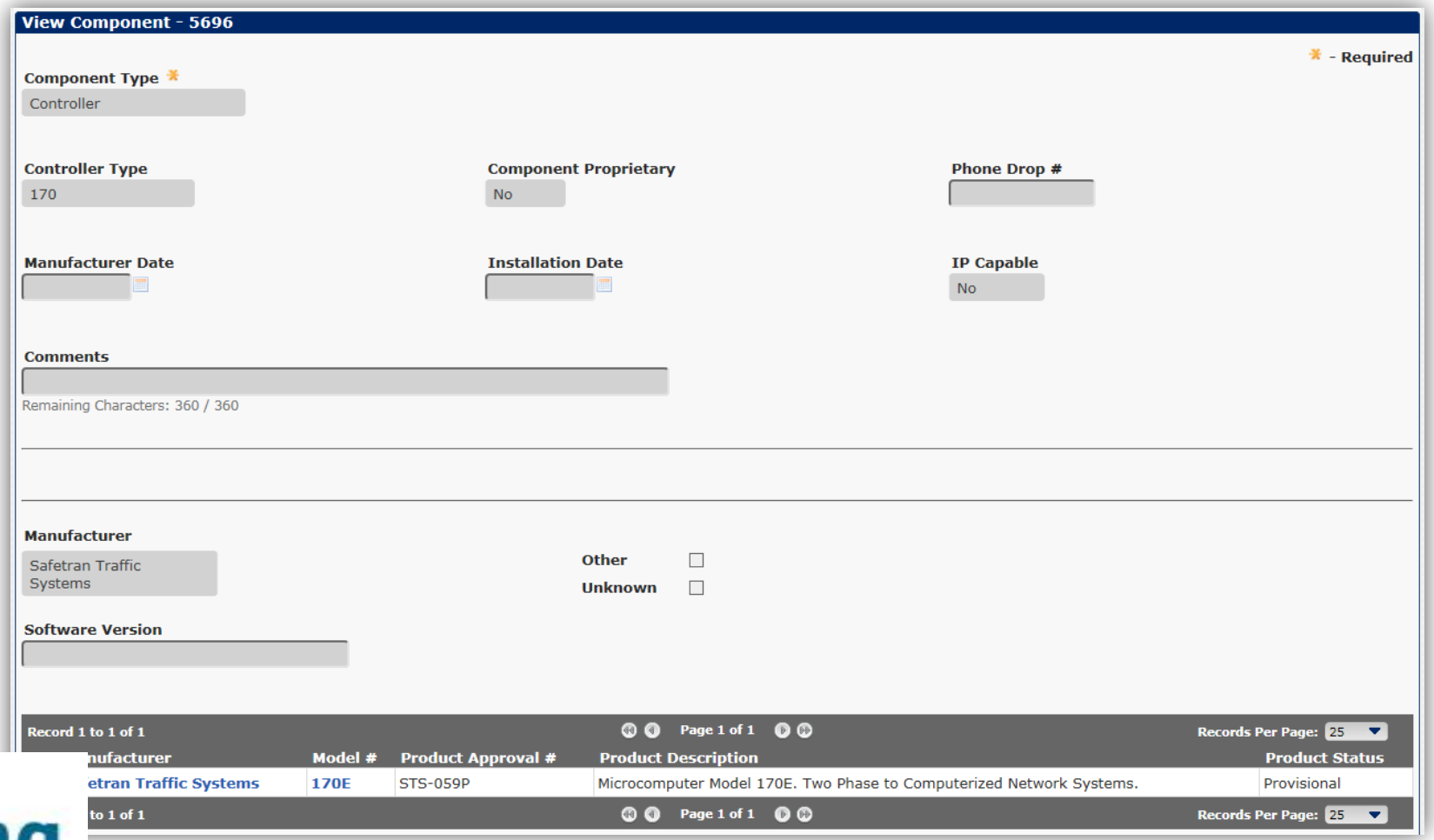
System Name
Baldwin Whitehall 1 Dist. 11

Comments
all Ped indicators are type B
Remaining Characters: 70 / 100

Signal Status	Status Date
Operational	09/14/1951

Street Type	Street Name	State Route #	Segment	Offset
Major	Clairton Boulevard	0051	0070	1915
	Irwin Drive			

Inventory: Component Details



Inventory: System Communications

Connections

Signal ID	Signal ID	Communication Method
TS0821404S002003	TS0821404S002103	Radio
TS0821404S002102	TS0821404S002104	Radio
TS0821404S002103	TS0821404S002104	Radio
TS0821404S002104	TS0821404S002105	Radio
TS0821404S002105	TS0821404S005984	Radio
TS0821404S002106	TS0821404S002103	Radio

Inventory: Capturing anomalies

TSAMS: Document Repository

Permit Documents

Date	Name	Type	Description	Attached By	
02/11/2015	T-299 Esbenshade Rd. (T-368) & Strickler Rd. (T-364) sheet 3 of 4.pdf	Permits	Current Traffic Signal Permit Page 3 of 4	Cory L. Poff	Edit Delete
02/11/2015	T-299 Esbenshade Rd. (T-368) & Strickler Rd. (T-364) sheet 4 of 4.pdf	Permits	Current Traffic Signal Permit Sheet 4 of 4	Cory L. Poff	Edit Delete
07/15/2014	T-299 Esbenshade Rd(T-368) & Strickler Rd(T-364) 4of4.pdf	Permits	(OLD) Traffic Signal Permit Sheet 4 of 4	Cory L. Poff	Edit Delete
07/15/2014	T-299 Esbenshade Rd(T-368) & Strickler Rd(T-364) 3of4.pdf	Permits	(OLD) Traffic Signal Permit Sheet 3 of 4 (07/15/2014)	Cory L. Poff	Edit Delete
07/15/2014	T-299 Esbenshade Rd (T-368) & Strickler Rd (T-364) sheet 2 of 4.xls	Permits	Current Traffic Signal Permit Sheet 2 of 4-Coordination Sheet	Cory L. Poff	Edit Delete
07/15/2014	T-299 Esbenshade Rd(T-368) & Strickler Rd(T-364) 1of4.pdf	Permits	Current Traffic Signal Permit Sheet 1 of 4	Cory L. Poff	Edit Delete

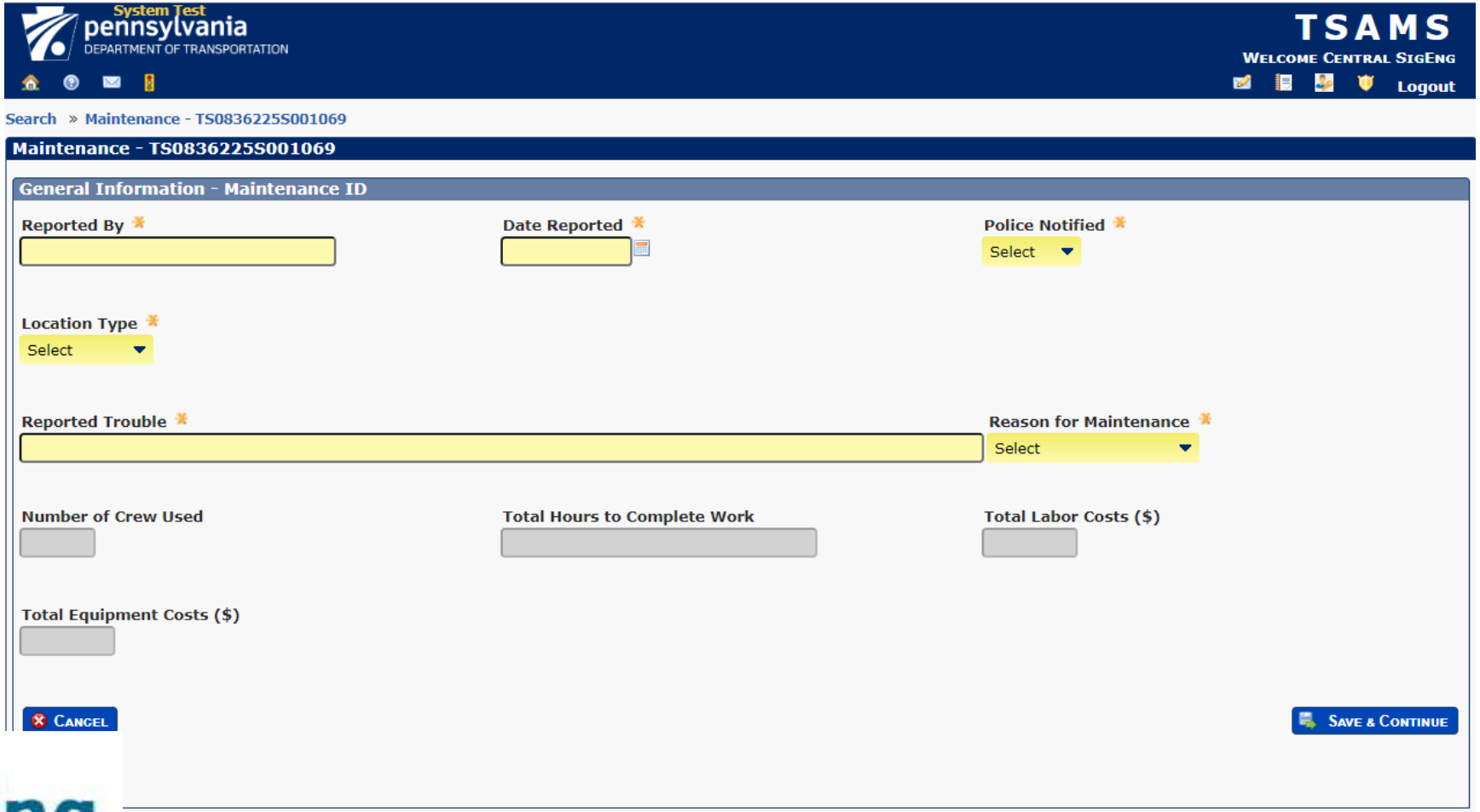
Manage Documents

Add Documents

Records 1 to 4 of 4 — Page 1 of 1 — Records Per Page: 10

Date	Name	Type	Description	Attached By	
04/21/2017	Coordination System Map(2 Signals).pdf	Design Documents & Drawings	Coordination System Map	Cory L. Poff	Edit Delete
03/13/2014	Application for Traffic Signal Approval - Signed2.pdf	Agreements	TE-160 Application for Traffic Signal Approval	Stephen A. Gault	Edit Delete
11/01/2013	Traffic Signal Design Package_Esbenshade and Strickler2.pdf	Design Documents & Drawings	Signal Design Study	Stephen A. Gault	Edit Delete
10/18/2013	Traffic Signal Study_Esbenshade and Strickler_revised.pdf	Studies	Traffic Signal Warrant Study	Stephen A. Gault	Edit Delete

TSAMS: Response Maintenance



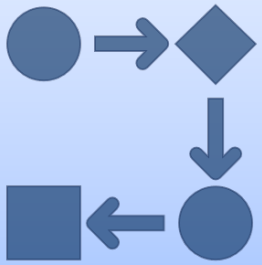
TSAMS Survey: Current Practices

81%

Municipalities use **contractors** for some or all traffic signal maintenance

75%

Municipalities still use **paper** records

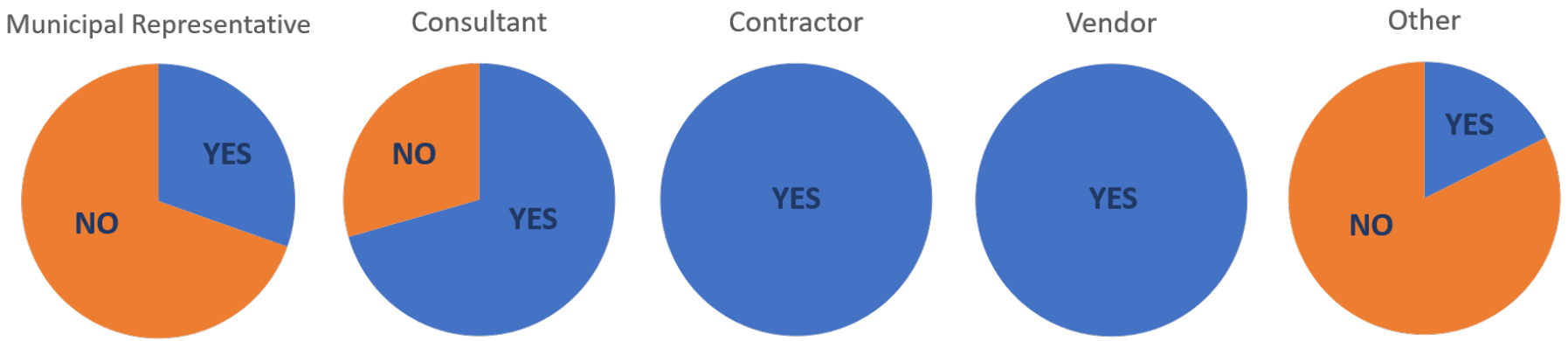


22%

Respondents attempted to **implement TSAMS** into their own operations

TSAMS Survey: Familiarity

Question: Are you familiar with TSAMS?



- Contractors and Vendors all know about TSAMS
- Most consultants know about TSAMS
- Few signal owners (municipalities) know about TSAMS

Signal Maintenance Summary

- Schedule regular preventative maintenance
- Plan for the unplanned response maintenance
- Ensure cross-jurisdictional partnerships are documented
- Keep good records, electronically

Q&A

Type your questions in the question pod if you haven’t already.

We will begin with answering at least one question from each participant, and return to answer the remaining as time allows. Anyone who asks a question that goes unanswered will receive an email following the webinar with an answer.

Appendix Q

Current Trends in Traffic Signal Maintenance:
Agency Case Studies: UDOT

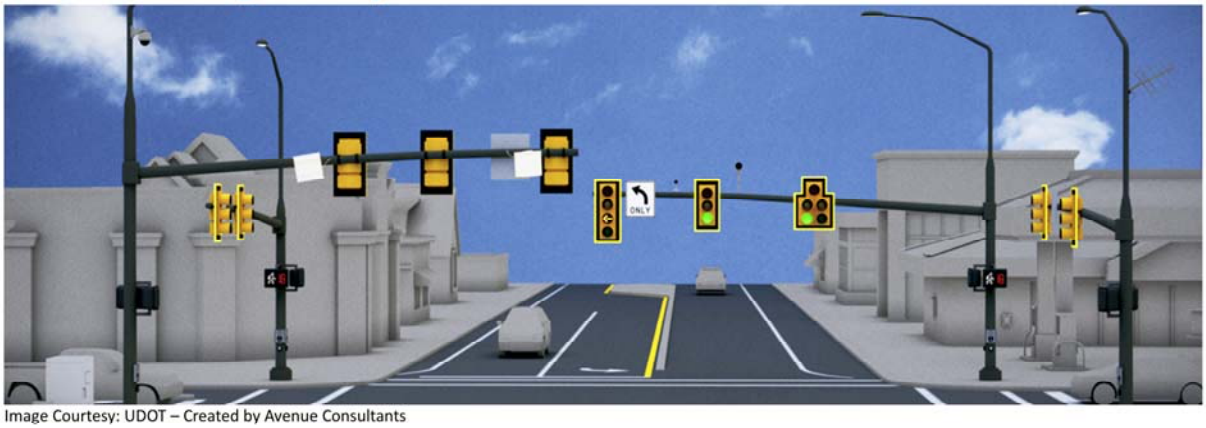


Image Courtesy: UDOT – Created by Avenue Consultants

Mark Taylor, P.E., IMSA II, PTOE
Traffic Signal Operations Engineer
Utah Department of Transportation

ITE Web Event: July 28, 2020

[Slide 1 Title]
Hello and welcome everyone. I'm Mark Taylor and have been asked to present to you all on UDOT's practices with traffic signal maintenance. I'm pleased to be presenting with my friend and colleague from Pennsylvania – Steve Gault. I do want to preface my discussions today to mention that UDOT still has a long way to go in improving traffic signal maintenance and hope you will find some of our practices helpful to you **[click]**.

Agenda

1. Utah Traffic Signals & Report Card
2. Training
3. Electronic Locks & Logbook
4. Preventative Maintenance & Asset Management

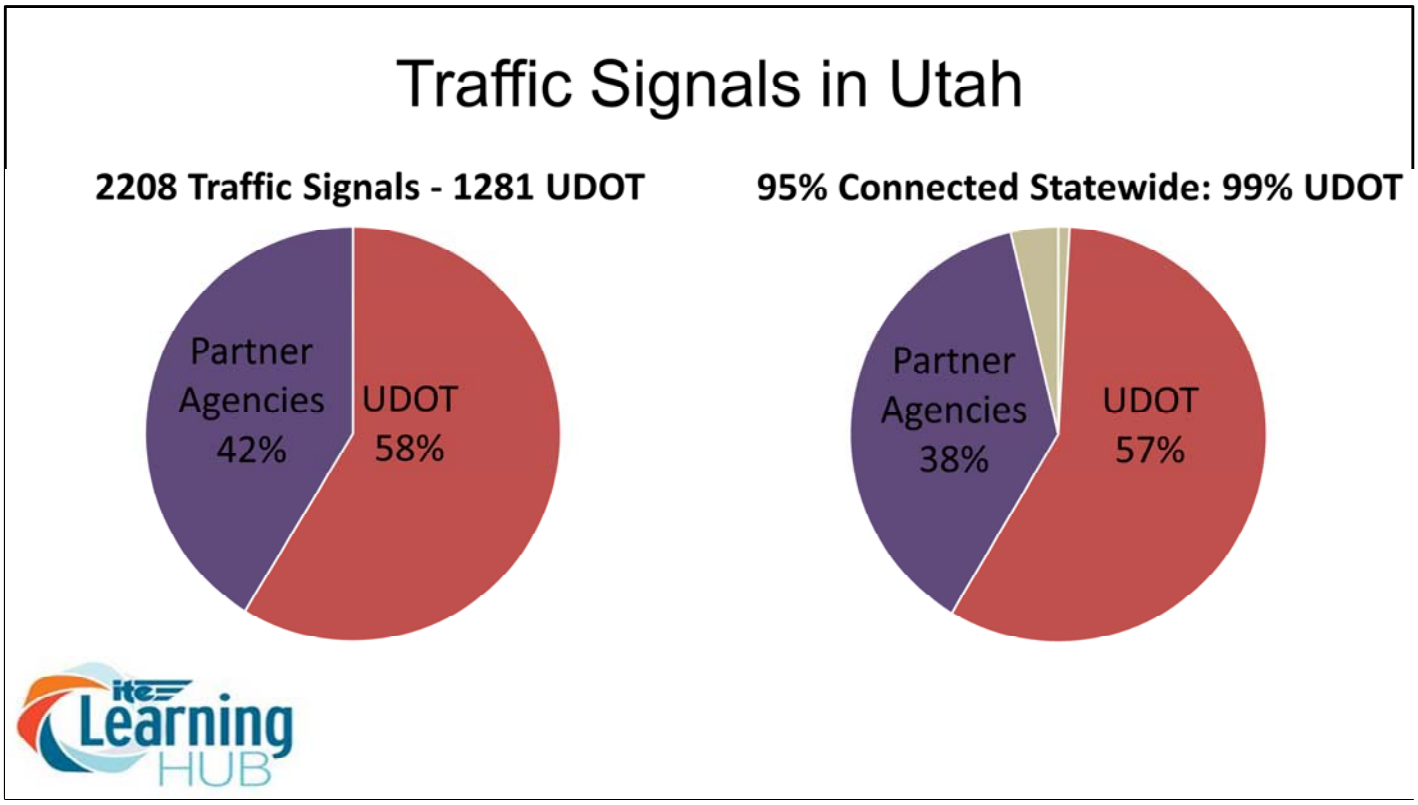
[Slide 2 Agenda]
There are four key areas I am going to cover. First, I will provide a brief overview of traffic signals in Utah and the national report card. Second, I will discuss signal training and some methods that have worked for us. Third, I will go over electronic locks for cabinets & electronic logbooks. Fourth, I will discuss preventative maintenance and asset management. **[click]**

1. UTAH TRAFFIC SIGNALS & REPORT CARD

- PARTNER AGENCIES
- RESOURCES
- REPORT CARD
- INNOVATION

Photo Courtesy: UDOT

[Slide 3 Traffic Signals & Report Card]
In this section, I will cover collaboration with partner agencies, the resources we use for signal operations and maintenance, the national report card, as well as an in-house or internal self-assessment that we complete most years, and some random case examples showing some innovative ideas. **[click]**



[Slide 4 Traffic Signals in Utah]
In Utah, there are a total of 2208 signals, where 58% or 1,281 are owned and operated by UDOT and the other 42% by various cities and counties. Currently, 95% of all signals are connected and UDOT's signals will be 100% connected by the end of the year. **[click]**

[Slide 5 Traffic Signal Owners]

There is a tremendous amount of cooperation, collaboration, sharing and trust with our local municipalities. So much, in fact that our Advanced Traffic Management System is jointly owned, managed and shared **[click]**. We share the same CCTV cameras, communications, and traffic signal central system. This slide shows all the jurisdictions who own at least one traffic signal. All 46 cities (except for two – Provo and Orem **[click]**) were done with hand shake agreements. Orem & Provo required cooperative agreements, due to previous trust issues. The cooperative agreements were painful, required several meetings at very high levels and attorney involvement. **[click]**

UDOT Traffic Signal Resources

	Engineer Manager	Engineer Consultant	Engineer (In-House)	Manager	Technician
Traffic Signals – Maintenance	0.5	0.5	3.5	-	17
Traffic Signals – Operations	0.5	5	2	-	4
ITS – Deployment & Maintenance	1	.5	1.5	3	8
Freeways – Operations & Maintenance	2	.5	2	-	4

Total Maintenance & Operations Budget for Signals (excluding salaries): $5M/Year

- 75 Signals / Technician for Maintenance
- 116 Signals / Engineer for Operations
- $2,850 / Signal for Maintenance Repairs per Year
- $1,075 / Signal for Operations Support per Year (not including 6 internal FTE's)

[Slide 6 Resources]

The question is sometimes asked, "How many personnel do you have for signal maintenance and operations?" It's a hard question to answer, as we outsource some of our operations work and use some contractor support for larger maintenance activities. In house, we have 17 technicians who are devoted to traffic signal maintenance, yielding a ratio of 1 technician for 75 traffic signals **[click]**. On the operations side, we have an in-house staff of two engineers and 4 technicians, yielding a ratio of 1 person for 116 traffic signals. Our yearly operations & maintenance budget (not including salaries and vehicles) is approximately $5 Million. Of the $5 million, approximately $1.3M is spent on operations consultant support, leaving $3.7M or about $2,850 to spend per intersection per year for equipment or any contractor maintenance support that may be needed. March 2009, the Federal Highway Administration published the guidebook, "Traffic

Signal Operations and Maintenance Staffing Guidelines", that recommends to provide one traffic engineer for every 75 to 100 signals and to provide one signal technician for every 40 to 50 signals. At UDOT, due to limited resources like most other jurisdictions, we are short of those guidelines and have to make the best out of the resources we have been provided. **[click]**

"""NOTES to Not Include in Discussion

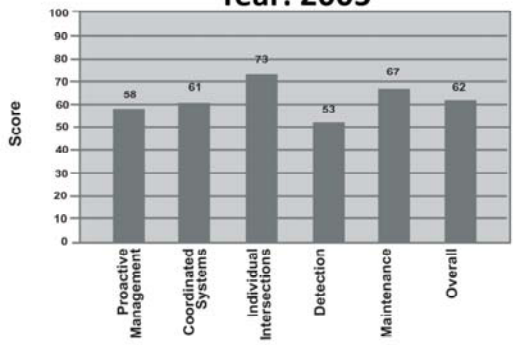
Traffic Signal Resources (Does NOT include ITS & Freeways)

- Traffic Signal Operations Support – 2 Consulting Firms - $275K/year each firm.
- Traffic Signal Desk Support in Control room – 1 Consulting Firm - $300K/year.
- Artificial Intelligence / Machine Learning Consultant - $250K/Year.
- Traffic Signal Maintenance Project Management – 1 Firm - $220K/Year.
- Total Operations and Maintenance Budget (Excluding in-house salaries): **$5M**

- Building Block Request
- - 1 Operations Engineer
- - 4 maintnenance technicians
- Building Block Request: 1 Signal Operations Engineer & 4 Signal Maintenance Technicians"""

ITE / FHWA / NOCoE National Report Cards

Year: 2005



Overall National Results: D-

https://www.ite.org/pub/?id=e2656526%2D2354%2Dd714%2D51ef%2D1767fbf279ff

Year: 2007

https://www.ite.org/pub/?id=e265c148-2354-d714-515a-eb251643bd2a

Year: 2012

https://www.ite.org/pub/?id=e265477a-2354-d714-5147-870dfac0e294

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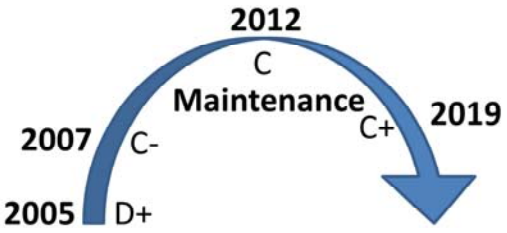
[Slide 7 National Report Card]
The Institute of Transportation Engineers in partnership with the Federal Highway Administration and the National Operations Center of Excellence have produced report cards on traffic signals. **[click]** The first was in the year 2005 and the score of signal maintenance was a D+ grade. The overall score was a D-. **[click]** Two years later in 2007, they conducted another report card and the maintenance grade moved up one notch. **[click]** Same story for 2012 that shows maintenance at a C and the overall score a D+. **[click]**

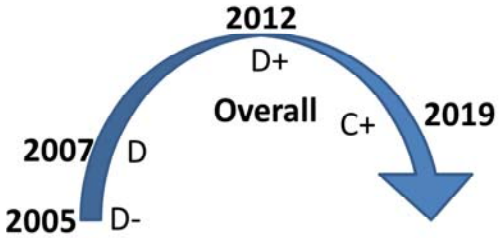
ITE / FHWA / NOCoE National Report Cards

Year: 2019

Systems and Technology	C+
Infrastructure	B-
Business Processes	
Design	C+
Operations	C+
Maintenance	C+
Management	C
Workforce	C+
Management and Administration / Leadership	
Culture	C+
Organization	C+
Collaboration	C+
Performance	C
OVERALL GRADE	C+

https://transops.s3.amazonaws.com/uploaded_files/TSBSOPR%20-%20Final%20Draft%20%28format%20fix%20needed%29.pdf





[Slide 8 National Report Card]

Last year, the report card was conducted again, with the grades all moving up another notch – maintenance a C+, the overall grade a C+. **[click]** This is a meaningful improvement; demonstrating agencies are using established processes to support management and operations of traffic signals to meet their own stated goals and objectives. As the national report card helps us as an industry measure our assessment, I strongly recommend that your agency conduct an internal self-assessments each year that are in line with your agency goals and objectives. **[click]**

“Improve Traffic Signal Operations”

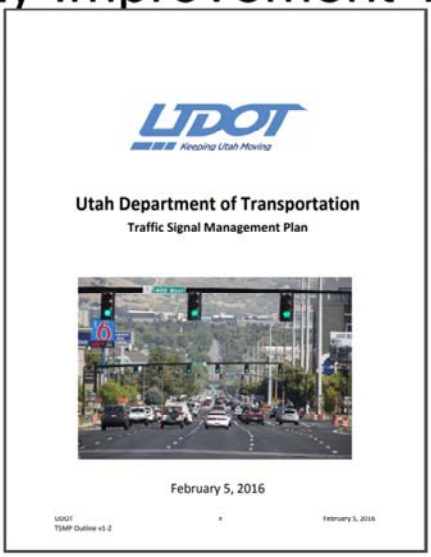
Governor Jon Huntsman

Photo Courtesy: State of Utah

Photo Courtesy: State of Utah

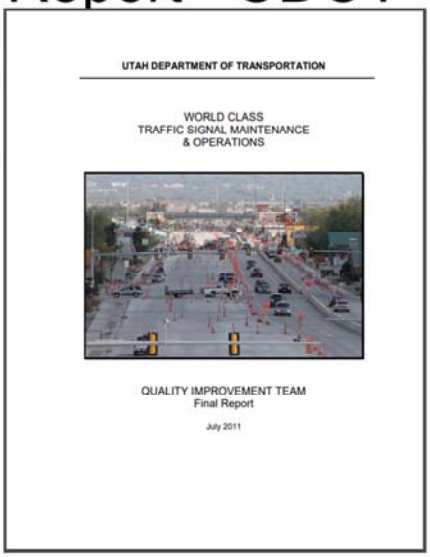
[Slide 9 Improve Traffic Signal Operations]
In 2011, our executive director was in the Governor’s office. The governor pointed out his window at all the traffic signals along State Street and challenged them to provide world-class traffic signal operations. We were then asked what it would take to make it happen. We produced a 37-page report and requested two additional full-time employees, a new Matrix organization better aligning our regions with central, and an additional $3 million per year funding. We received everything we asked for back in 2011. However, since then we have added an additional 169 traffic signals and numerous left turn phasing to our system without any additional funding or employee increases. **[click]**

Traffic Signal Management Plan & Quality Improvement Team Report - UDOT



https://udottraffic.utah.gov/ATSPM/Images/TSMP_UDOT_v1-2_2-5-16.pdf

44 Pages



https://udottraffic.utah.gov/ATSPM/Images/Signal%20Ops%20QIT%20Final%20Report%20Released.pdf

37 Pages

[Slide 10 TSMP & QIT]

Two documents that have greatly assisted us with signal maintenance, operations and management is the Traffic Signal Management Plan and a Traffic Signal Maintenance and Operations internal quality improvement team report. **[click]**

Internal Self-Assessment – UDOT - Staffing

STAFFING	2011	2013	2014	2015	2016	2019	2020
1 signal engineer for every 100 signals							
1 signal technician for every 50 signals							
On-going training program for signal technicians							
On-going training program for signal engineers							
Minimum qualifications for all signal staff (engineers and technicians)							
Signal timing and coordination expertise in the Regions							
Actively manage signal operations at the TOC Signal Desk							
Support the implementation of innovative projects							

https://udottraffic.utah.gov/ATSPM/Images/Signal%20Ops%20QIT%20Final%20Report%20Released.pdf

[Slide 11 Internal Self-Assessment - Staffing]
One thing we started to do in 2011 is an internal self-assessment, asking ourselves several questions that were in line with our goals and objectives. We have continued to perform the self-assessment most years, rating ourselves with a green, meaning "good", "yellow" meaning marginal, and a "red" meaning that we need to make improvements. For the most part, we made improvements, accept with the ratio of engineers and technicians for traffic signals, where we are now back in red. **[click]**

Internal Self-Assessment – UDOT – Signal Maintenance

SIGNAL MAINTENANCE	2011	2013	2014	2015	2016	2019	2020
90 – 95% of signal detection operational							
On-going funding for proactive signal equipment maintenance							
70% of maintenance resource and activity on proactive maintenance							
Performance measurement of signal maintenance							
Proactive routine maintenance program with documentation							
Annual conflict monitor testing with documentation							
Timeframe to resolve malfunctions							

[Slide 12 Internal Self-Assessment – Signal Maintenance]
Some of our maintenance goals were to have at least 95% of our detection operational; test our MMU's every year; responding to complaints quickly. Some goals are hard to measure, such as spending 70% of maintenance resources on proactive maintenance instead of putting out fires. However, the electronic logbook that I will discuss later will help with the measurement of this goal. **[click]**

Internal Self-Assessment – UDOT – Signal Operations

SIGNAL OPERATIONS	2011	2013	2014	2015	2016	2019	2020
Use of traffic signal control software to manage signal operations							
Re-time signals every 30 to 36 months							
Automated, real-time monitoring of signal system health and performance							
Performance measurement of signal operations							
Quality signal timing during construction							
Quality signal timing during incidents, civic events, and weather events							
Implementation of adaptive signal operations (includes P2P)							

[Slide 13 Internal Self-Assessment – Signal Operations]
The operations goals are centered around signal retiming on a regular basis, maintaining good operations during construction and special events, automated traffic signal performance measures and using advanced controller logic. **[click]**

Internal Self-Assessment – UDOT – Policy & Process

POLICY & PROCESS	2011	2013	2014	2015	2016	2019	2020
Communication to signals maintained at all times, incl. during construction							
Detection at traffic signals maintained at all times, incl. during construction							
Signal detection to be operational as designed when a signal is turned on							
Permit or third-party projects repair or replace damaged detection							
Signal timing parameters and coordination timings in plan sets							
Clear definition of roles and responsibilities for Regions & Central							
Signal design reviews by signal operations group							
Defined goals and procedures for incident and event management							

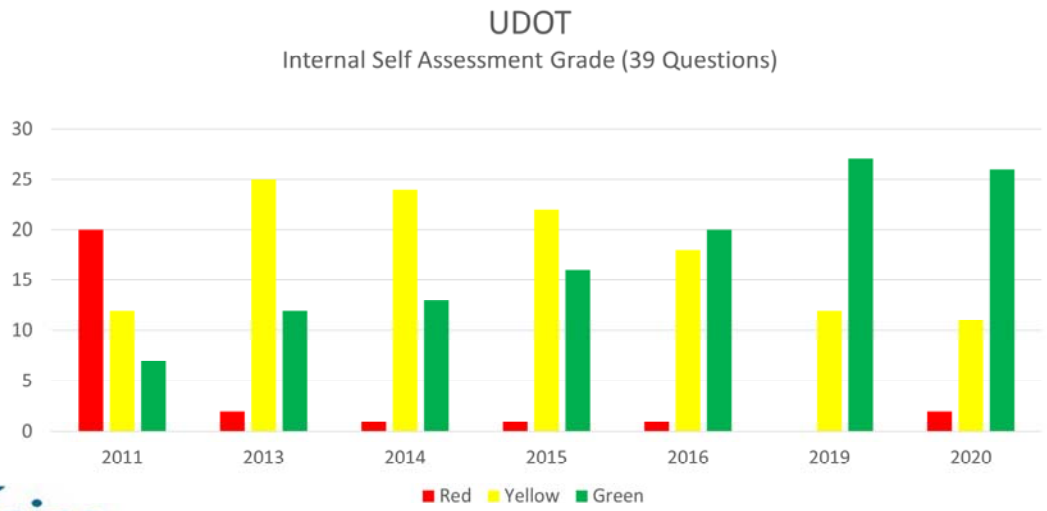
[Slide 14 Internal Self-Assessment – Policy & Process]
This table shows our rankings in terms of policies and processes. For example, if we can maintain power to the signals during construction, why can't we maintain communications and detection? Are our signals operating well when first turned on or are we a few weeks behind in making adjustments? If and when things are damaged, are we able to quickly repair them or do they go months not functioning properly?
[click]

Internal Self-Assessment – UDOT – Management & Planning

MANAGEMENT & PLANNING	2011	2013	2014	2015	2016	2019	2020
Traffic Signal Management Plan							
Asset management for signal system							
Inventory of signal system equipment and configuration							
Management of signal timing parameters							
Coordination with partner agencies							
High level communication between Regions and Central on timing issues							
Optimal use of signal maintenance and signal operations funding							
Plan to address long-term maintenance issues							
Plan to implement low-cost signal improvements for safety & operations							

[Slide 15 Internal Self-Assessment – Management & Planning]
This table shows the questions we would ask ourselves in regards to management and planning. In regards to the Traffic Signal Management Plan, we created it in 2016, but have not updated it since, hence why it went from red to green and back to yellow.
[click]

Internal Self-Assessment Questionnaire



[Slide 16 Internal Self-Assessment Questionnaire]
This chart shows the overall score of our yearly self-assessments. You can see that we have made substantial progress since 2011 in meeting most of our goals and objectives; however, with the rapid growth rate we're experiencing and the lack of increased funding and resources; we're moving backwards slightly. **[click]**

Procurement Contracts with Contractors Pre-Awarded

		Std Dwg	Spec	Unit	Price	
101	Underground Service Pedestal - New Installation w/ Base	SL	02892	Each	2,384.00	These items are mutually exclusive and should not be billed together. All these items assume contractor-furnished, single-meter service pedestals. All these items include all coordination and on-site cut-overs with the Utility to complete the service. "Underground Service Pedestal" includes removal of the old pole-mount service & riser, if present. "Install Pole Riser" includes all labor and materials for installation of a new pole-mount riser. "Service Pedestal Base" includes the removal and re-installation of the existing pedestal.
102	Replace Service Pedestal on Existing Base	SL	02892	Each	1,989.00	
103	Install Power Pole Riser	SL	02892	Each	295.00	
104	Service Pedestal Base Only (replace foundation - remove & reinstall)	SL	02892	Each	379.00	
	Signal					
105	Size 6 Cabinet - State Furnished	SL	02892	Each	673.00	Includes removal of the old cabinet, transport and salvage to UDOT or disposal as called for. Includes all wiring and labor to bring the signal back online.
106	5.5', 11' or 15' Traffic Signal/Ped Pole - State Furnished	SL	02892	Each	147.00	Includes transport and all other misc items required to install per UDOT spec.
107	Install Signal Mast Pole (Type-A, B, C) - State Furnished	SL	02892	Each	340.00	
108	Install 30 - 55 ft Mast Arm - State Furnished	SL	02892	Each	654.00	
109	Install 60 - 75 ft Mast Arm - State Furnished	SL	02892	Each	753.00	
110	Install 80 - 85 ft Mast Arm - State Furnished	SL	02892	Each	854.00	
111	Mast Arm Field Cut	SL	02892	Each	180.00	
112	Rake Signal Mast Pole / Arm	SL	02892	Each	593.00	Includes all equipment and labor required to adjust the tilt on an existing signal pole installation. Includes all crane work, bolt work, and adjustments to signal heads, mounts, and detection, as needed.
113	Type-0 Signal Head, Astro-Brac, LED's	SL	02892	Each	719.76	Includes all materials and installation for contractor furnished polymer signal head matching the current UDOT contract for this item. Includes all equipment assembly, transport, and either salvage to UDOT or disposal of the old device as called for by the project. Includes removal & replacement of existing head, if present. Includes 2" retro-reflective tape (3M Model 4081 FLR-Yellow, only) on the signal backplates. Includes TALON or GALAXY model astro-brac assemblies, with pole and feet.
114	Type I, II, III Signal Head, Astro-Brac, LED's	SL	02892	Each	1,020.83	
115	Type IV, VI Signal Head, Astro-Brac, LED's	SL	02892	Each	1,196.64	
116	Type V Signal Head, Astro-Brac, LED's	SL	02892	Each	1,509.76	
117	Type-VII (Dual-Red) Signal Head, Astro-Brac, LED's	SL	02892	Each	1,479.12	
118	HAWK Signal Head, Astro-Brac, LED's	SL	02892	Each	1,231.95	
119	Installation Only - Fully Assembled State Furnished Signal Head	SL	02892	Each	283.75	Installation of a fully-assembled signal head assembly, including LED's and astro-brac mount.
120	Assembly of State Furnished Signal Head	SL	02892	Each	49.00	Add-on, used when the contractor assembles a new signal head and mount from boxed material. May not be used in conjunction with the contractor furnished line items above.
121	LED Exchange (per Signal head)	SL	02892	Each	49.00	Add-on, used when the contractor is required by scope to remove and re-use existing signal head LED's when doing upgrades. **Does Not Apply to pedestrian heads.
122	Relocate Signal Head	SL	02892	Each	245.89	This item is only for pure-relocation work and may not be combined with any of the above items.
123	Vibration Miligator - State Furnished	SL	02892	Each	147.00	

[Slide 17 Procurement Contracts]

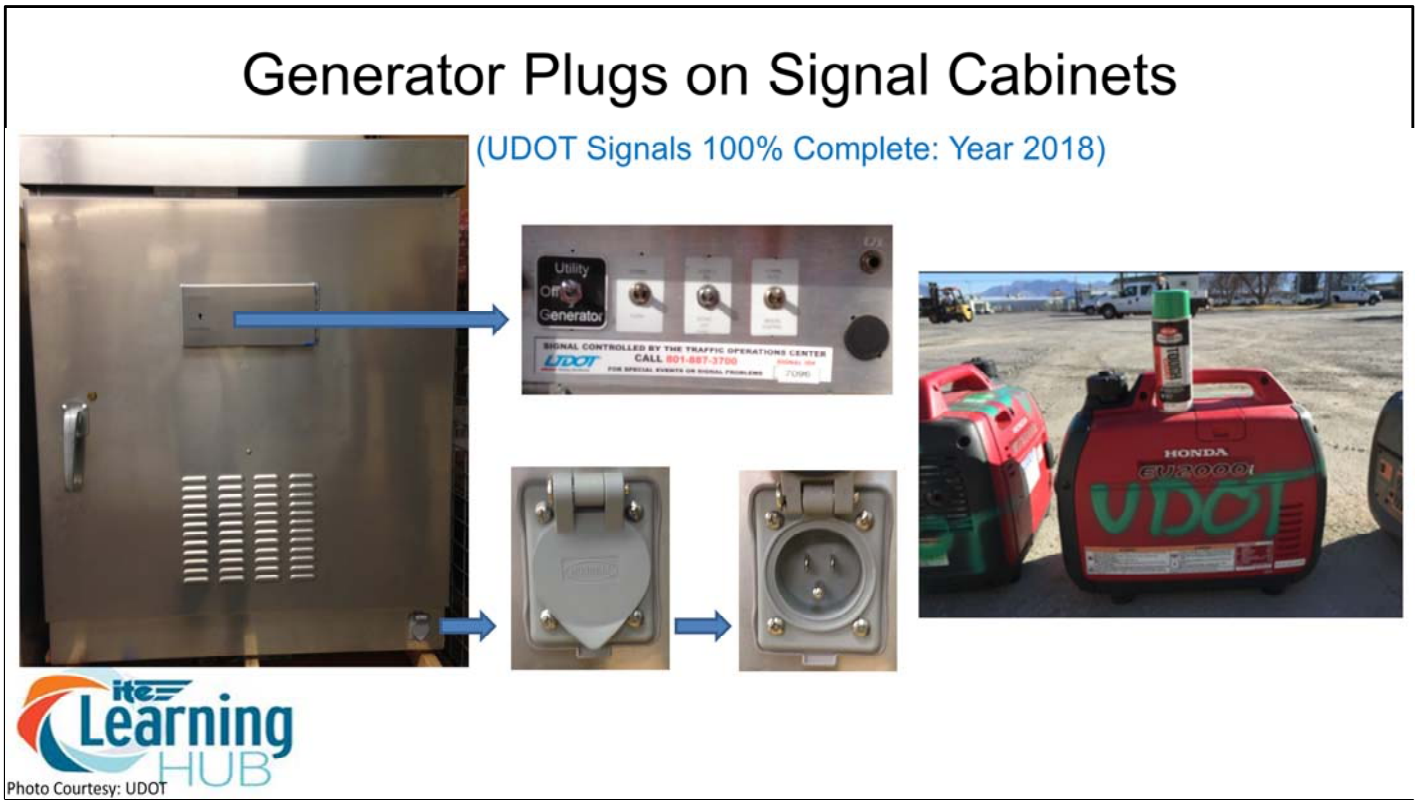
One thing that has helped us tremendously is to set up contracts with contractors for maintenance repair. We set up multi-award pre-bidded five-year contracts that list the price for each line item of work that we eventually may have them do. The contract is on-call and as needed with the prices already agreed upon in advance. This helps us supplement the work load of our internal signal maintenance teams, helps with the larger work items, and emergency repairs. **[click]**

Shelter when working at signal cabinets

Photo Courtesy: UDOT

Photo Courtesy: UDOT

[Slide 18 Shelter]
The next three slides will show some random and simple innovative solutions created by our signal maintenance technicians. One of our employees didn't like having the hot summer sun or cold rain/snow beat down upon him, so, he created this shelter for all of our employees. The shelters are small enough to fit in our work vehicles and set up in less than a minute. **[click]**



[Slide 19 Generator Plugs]
Our technicians installed generator plugs and transfer switches on all of our signal cabinets so when the power goes out, a portable generator can be installed quickly and easily. We purchased several dozen generators for our maintenance sheds that are scattered throughout the state so they can help us restore power to intersections within their shed boundaries.

Last year, we had an unfortunate situation where the power was out for three weeks at one of the intersections. Even though we had our generator chained up and spray painted with green epoxy paint, we had three stolen during this time. **[click]**

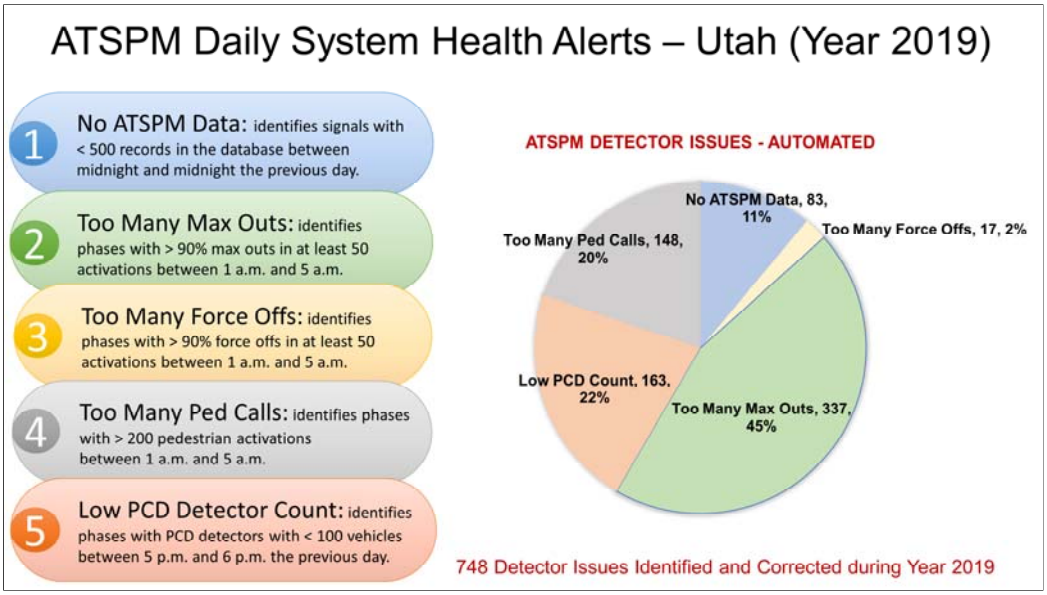
Elevated Generator Box to Prevent Theft

Photo Courtesy: UDOT


Photo Courtesy: UDOT


Photo Courtesy: UDOT

[Slide 20 Generator Box]
So the technicians created a metal box that can be secured 15 feet high on the mast arm to prevent the generators from getting stolen when they are left in place for a long time. **[click]**



[Slide 21 ATSPM WatchDog]

One of the most beneficial features of Automated Traffic Signal Performance Measures is automatic alerts for detection problems. Every weekday morning at 7:00 AM, an algorithm runs that looks for detector problems using the high resolution 1/10th second data. An email is sent flagging the concerns that are grouped in the five areas shown on the left. Such areas include No ATSPM data, too many maxouts or forceoffs, too many pedestrian calls or low Purdue Coordination Diagram counts. ***[Click]*** Last year alone on UDOT's traffic signals, we have identified and corrected over 700 detector issues – these are issues that we found right away before the public became annoyed enough to call us to complain.

2. TRAINING

- IN HOUSE
- CONTRACTORS & CONSULTANTS

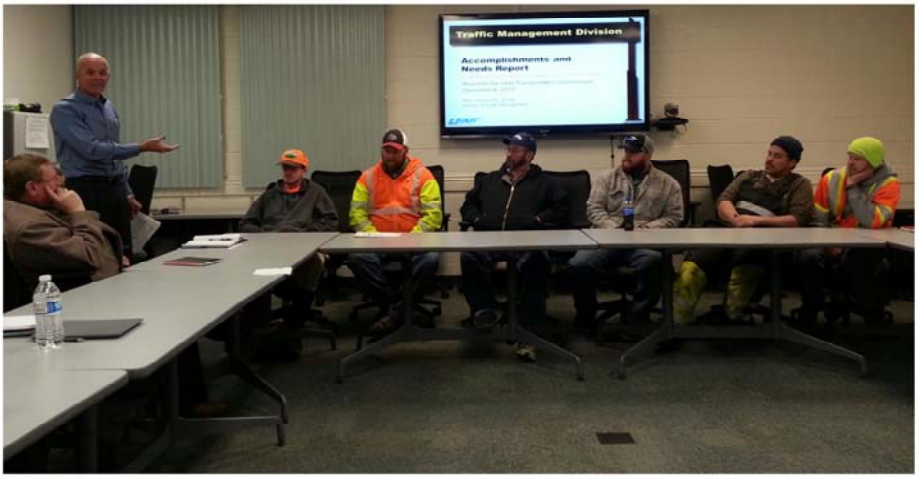
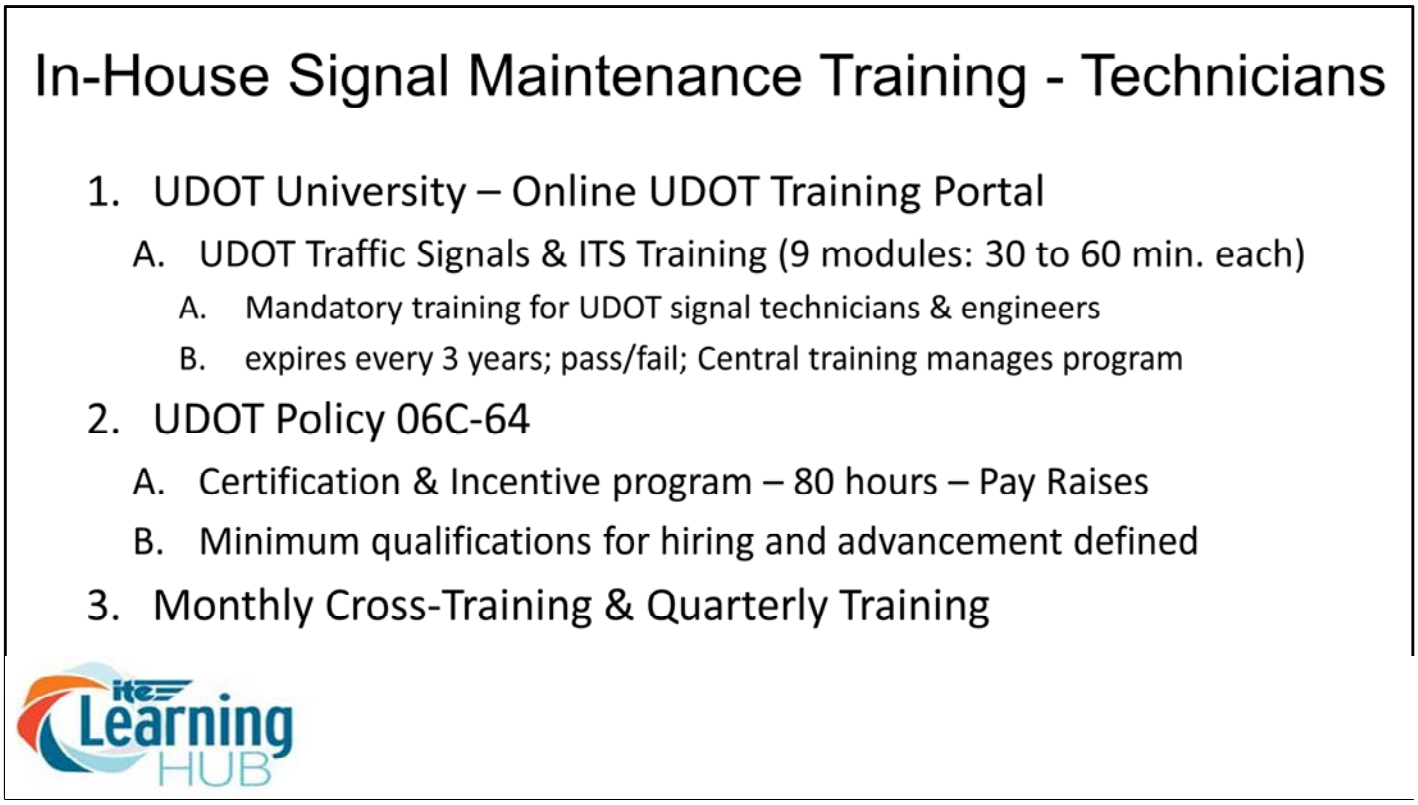


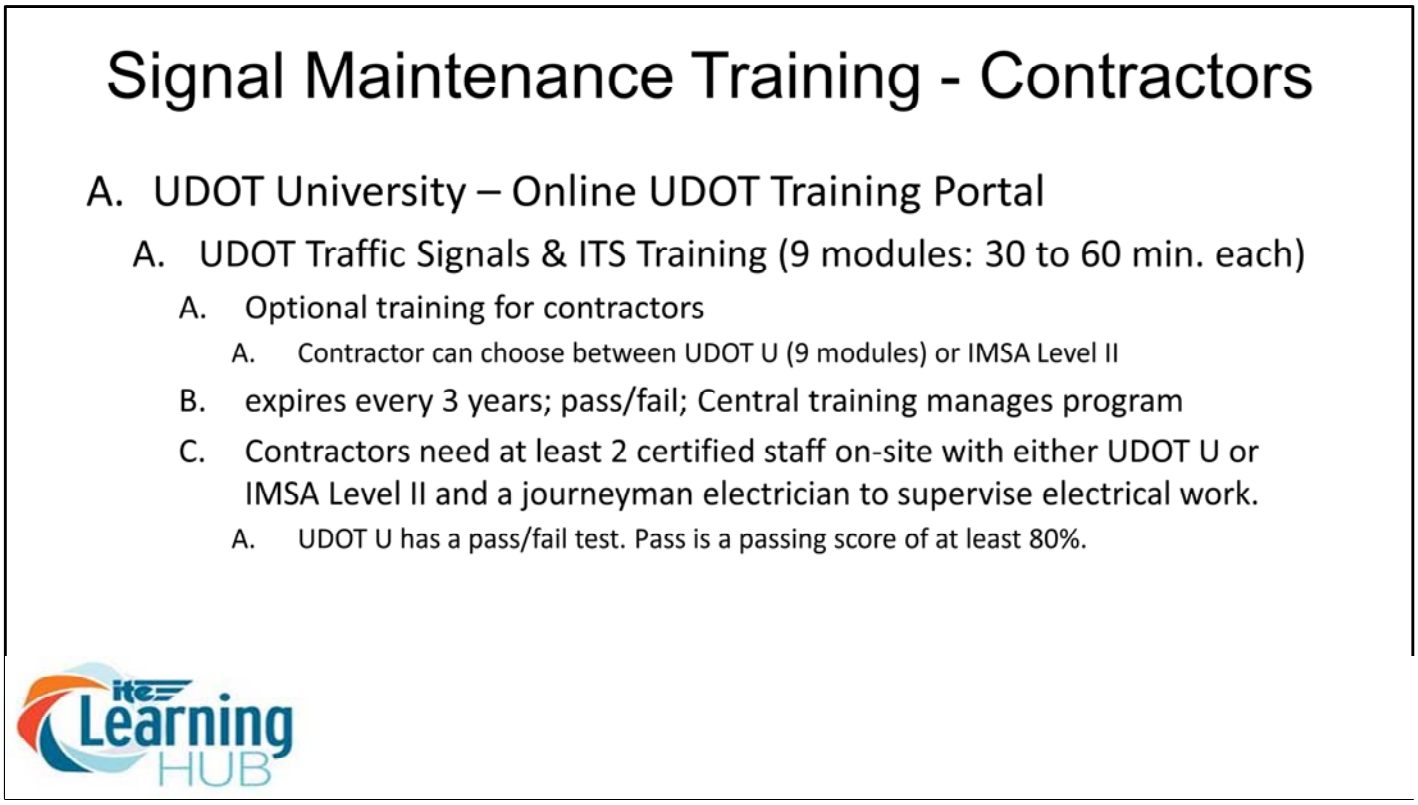
Photo Courtesy: UDOT

[Slide 22 Training]
In this section, we will cover training programs that are in place for UDOT employees, contractors and consultants. **[click]**



[Slide 23 In-House Training - Technicians]
Let's first look at our training program for our in-house signal technicians. There are three training programs in place.

1) UDOT University. UDOT University is an online training portal where UDOT manages all of our trainings, assigns specific training and tracks when certification expires and needs to be renewed. UDOT University has 100's of training programs that can be chosen or assigned. One of these programs is a UDOT Traffic Signals and ITS Training online course. We modeled this program from PennDOT's training program.
2) UDOT has a Certification and Incentive program for the technicians that recognizes and rewards technical skills, academic competence, longevity at UDOT and leadership skills. The employee has the opportunity to earn pay raises after they complete 80 hours of training that is above and beyond their normal job duties. The program also defines minimum qualifications for hiring and advancement.
3) Every month, we will cross-train employees and every three months, we bring all traffic signal personnel together (including some local jurisdictions) and have a four-hour training workshop. **[click]**



[Slide 24 Training - Contractors]
For contractors, we require that they be either IMSA level II or certified in the UDOT traffic signals and ITS training course. Most of them choose the UDOT course, as it is free and the information is more applicable to the work they perform in Utah. We require re-certification every three years and require at least two of the contractors on-site be certified. If doing electrical work, a journeyman electrician is required to be on site. **[click]**

UDOT University

https://utah-udotu.sabacloud.com

Learning • Innovation • Culture

Online Traffic Signals & ITS Training

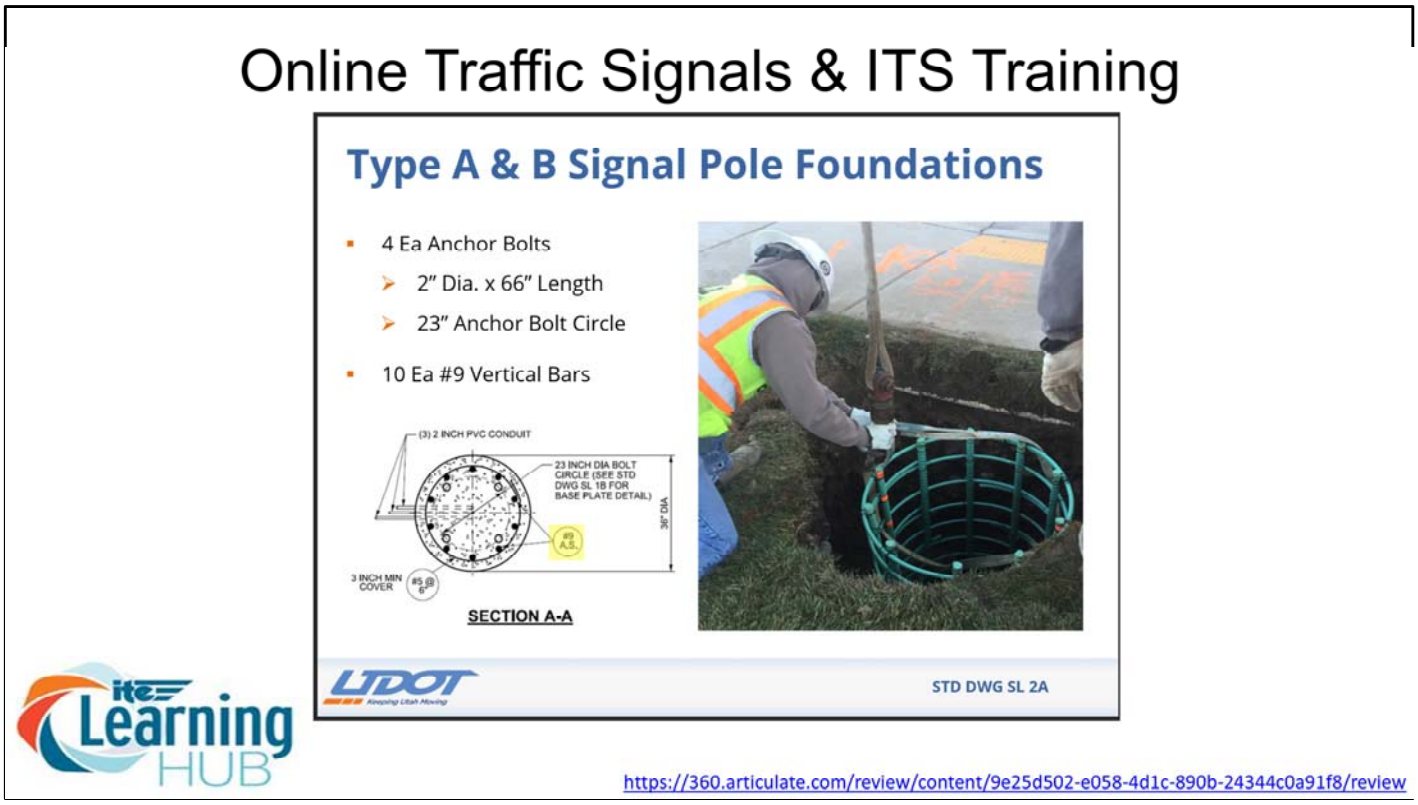
9 Modules 30-60 minutes each

- Preconstruction
- Underground
- Aboveground
- Lighting
- ITS
- Traffic Signal Wiring
- Project Acceptance
- Electronic Toll Collection

https://360.articulate.com/review/content/9e25d502-e058-4d1c-890b-24344c0a91f8/review

[Slide 25 UDOT U]

This is our UDOT University Online Traffic Signals & ITS Training Course. A link to the refresher training is shown below the graphic. However, for contractors and employees to complete the training, they will need to create an account on our UDOT U website and register so the training can be tracked. Every few months, our training department will send a list of people to my team who have passed the course so we can enforce compliance in the field during our inspections. Each of the 9 modules takes 30-60 minutes each. At the end a pass/fail grade is provided with a score of 80% needed for a passing grade. **[click]**



[Slide 26 UDOT U – Example A]
Here's a snapshot of the online training. The training is specific to our construction practices in Utah and are hyperlinked to our standard drawings for additional information. **[click]**

Online Traffic Signals & ITS Training

https://360.articulate.com/review/content/9e25d502-e058-4d1c-890b-24344c0a91f8/review

[Slide 27 UDOT U – Example B]
Here's another example. Because the course content is managed by UDOT, we're able to focus specifically on the equipment and practices we use in Utah. **[click]**

[Slide 28 UDOT U - Questions]
At the end of each learning module is a series of questions that are randomly generated. For example, there may be 50 questions in the bank but only 10 at a time will be asked. **[click]**

UDOT Policy 06C-64 – Advancement & Incentive Program for Technicians

- Incentive Pay Increases
  - 80 Hours of continuing education that is above and beyond current job requirements.
  - Electronic Technical Specialist II & III
    - Up to four 3% pay raises
  - Electronic Supervisor & Manager
    - An additional two 3% pay raises

Summary of Minimum Qualifications Required for Hiring and Advancement

	Electronic Technical Specialist I	Electronic Technical Specialist II	Electronic Technical Specialist III (Lead)	Electronic Supervisor	Electronic Manager
Technical Skills Prerequisite	None	Competency at ETS I	Competency at ETS II		
Minimum Combined Education and Work Experience	6 Months	2 Years	2 Years	3 Years OR IMSA Level III Certification	3 Years OR IMSA Level III Certification
IMSA Certification or Licenses	Must obtain Level I within one year of hiring	Level II Traffic Signal (If hired from outside UDOT, Level I and II must be obtained in one year)	Level III (Bench or Field) OR Traffic Signal Inspection and Highway Lighting OR Journey Electrician License	(If hired from outside UDOT, Level I and II must be obtained in one year)	(If hired from outside UDOT, Level I and II must be obtained in one year)

[Slide 29 Advancements & Incentives]
UDOT has a policy that defines our certification and incentive program for signal & ITS technicians. If the employee completes 80 hours of continuing education that is **above and beyond** their current job requirements, they can receive a 3% raise. They can do this up to four times and an additional two times if they're a supervisor or manager. Such courses include management courses taken on-line at UDOT U; technical courses taken at the college, or training courses offered by vendors.

The table on the right shows a summary of the minimum qualifications required for hiring and advancement at UDOT. For example, for the electronic technical specialist II rank, employees are required to be IMSA level II. However, the level III leads are required to be IMSA level III and/or have a journey electricians license. **[click]**

Cross Training – Year 2019

Electronic Technical Specialist Cross Training Program for 2019 Revision: February 22, 2019

	Employee	3/12/2019	4/9/2019	5/14/2019	6/11/2019	7/9/2019	8/13/2019	9/10/2019	10/8/2019	11/12/2019	12/10/2019
Region 1	Dave Townsend	Rick Hessheimer		Robert Newbold	Leon Hadley				Mike Xiras		
	Jereme Fullmer		Todd Wright					Rick Hessheimer		John Orvis	
	Josh Boudero	David Putnam			Mike Bishop	Mike Bishop			Chris Smith		Thomas Hammon
	Mack Bankhead			Kent Thurston			Andrew Wilde	Rich Williams		Tyson Larson (November 6th)	
Region 2	Dave Mount				Rick Hessheimer		Josh Boudero				
	Ron Bray		Mike Bishop	Graig Ogden (May 8th)			J.T. Dziatlik				
	Deloy Lebreton	Todd Wright				Chris Smith	Lee Thompson (August 7th)			David Putnam	
	Brennon Mascaro	Walter Wood	Andrew Wilde						Tyler Elkins	Mike Xiras	Eric Kinsman
	Thomas Hammon				Skyler Neilsen			Leon Hadley			
	Shaun Montgomery			Chris Smith				Glenn Burns			
Region 3	Eric Kinsman	Mike Bishop			Tyler Elkins				Robert Newbold	Rick Hessheimer	
	Craig Hamilton		Rick Hessheimer			Rich Williams				Josh Boudero	Chris Smith
	Skyler Neilsen	J.T. Dziatlik				Walter Wood	Brandon Clark	Mike Bishop			Glenn Burns
	Brian Harrison		Troy Noall	Thomas Hammon				Dave Mount			
TOC Signal Timing	Roy Gregerson	Jereme Fullmer		Eric Kinsman	Brandon Clark	Shaun Montgomery		Josh Boudero	Deloy Lebreton		
	Robert Newbold		Shaun Montgomery				Thomas Hammon			Kent Thurston	
	Glenn Burns		Mack Bankhead			Brian Harrison				Ron Bray	
	Troy Noall			Dave Mount	Mike Xiras		Skyler Neilsen	Craig Hamilton			Dave Townsend
TOC Freeway Management	Kent Thurston				Deloy Lebreton	Troy Noall			Jereme Fullmer		
	John Orvis	Mack Bankhead								Walter Wood	
	David Putnam										Jereme Fullmer
ATMS Maintenance	J.T. Dziatlik		Dave Townsend		Jereme Fullmer					Brian Harrison	
	Chris Smith	Glenn Burns					Roy Gregerson				
	Mike Bishop			Brennon Mascaro							Rich Williams
	Tyler Elkins					Ron Bray					
	Todd Wright							Kent Thurston			
	Brandon Clark								Eric Kinsman		
TOC ATMS Lab	Mike Xiras						Brennon Mascaro				Andrew Wilde
	Rick Hessheimer					Mack Bankhead			Troy Noall		
	Rich Williams		Brian Harrison					Robert Newbold		Roy Gregerson	
TOC Fiber	Leon Hadley	Ron Bray	Roy Gregerson			Robert Newbold	Jereme Fullmer			Skyler Neilsen	J.T. Dziatlik
	Andrew Wilde				Glenn Burns	Eric Kinsman		Dave Townsend			
	Walter Wood			Josh Boudero	Mack Bankhead				Craig Hamilton		
Region 4	Tyson Larson (Cedar City)			Jereme Fullmer			Shaun Montgomery		Ron Bray		
	Graig Ogden (Richfield)	Craig Hamilton			Chris Smith						Dave Mount
	Lee Thompson (St George)		Josh Boudero	Skyler Neilsen				Thomas Hammon		Dave Townsend	

ite Learning HUB

[Slide 30 Cross Training]

This shows our cross-training program. We take traffic signal employees from each region and cross-train them with other employees in the other regions and/or in the other ITS groups, such as freeway management, ITS maintenance or fiber. On the selected date each month, the person under the “date” column would meet at the office of the employee selected in the 2nd column at 7:00 AM and work a full-day with that person.

[NOTES to Skip:

1) It creates more defacto uniformity among the regions in signal maintenance best practices. They’re able to see new and different ways of doing things and different or better tools for the job. There have been several examples of requests for me to purchase new tools for some of the employees because they saw a new way of doing things from an employee in another region.

2) It creates friendships and personal relationships that come in very handy when they’re alone and pulling their hair out troubleshooting things. They now will pick up the phone and call a life-line call to their buddy who may be in a different region asking for advice.

3) Cross-training helps to educate the employees better with the work the other groups

do. For example, we have a dedicated fiber optics team with electronic technicians who maintain our fiber. During cross-training, a signal tech who rarely deals with fiber maintenance is getting schooled on how to troubleshoot it.] **[click]**

3. ELECTRONIC LOCKS & LOGBOOK

- ELECTRONIC LOCKS
- ELECTRONIC LOGBOOK

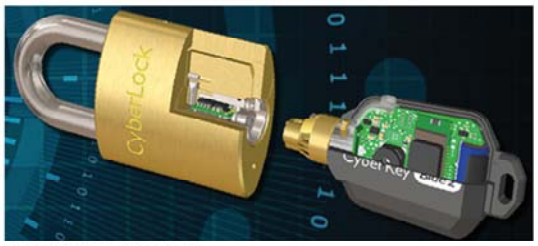


Photo Courtesy: CyberLock

Reports - Search/Download Logbook Entries

Search Criteria

Start Date 04/10/2020
End Date 07/09/2020
Location of Response OnSite Remote
Signal/Location
Comment
User
Reasons of Response
Complaint/Work Order (CW)
Preventative Maintenance (PM)
On-call/After Hours (EMR)
Failed Equipment (E)
Detection Related (D)
Timing (T)
Other (O)
Run Report
Download

Date of Response	DateCreated	Location ID	Intersection	Location of Response	Comment	User	Reason For Response
07/09/2020 17:46	07/09/2020 17:57	8403	Main St / SR-120 @ 800 S, RFD	Remote	In 650, renamed descriptions to match standard. Tried to discover matrix sensors in 650.	Shanisa Magoffin	D
07/09/2020 17:28	07/09/2020 17:28	6014	Redwood Rd / SR-68 @ Parkway Blvd / Founders Blvd, SSP	On Site	Performed timing routine maintenance. Upload and saved to the TOC.	Glenn Burns	PM

[Slide 31 Electronic Locks & Logbook]
In this section, we will discuss electronic locks and the electronic logbook. **[click]**

More Attention to Security at our Transportation Cabinets

Photo Courtesy: UDOT

March 26, 2019 – Report of suspicious people in our cabinet near Salt Lake City. We dispatched police to investigate.

Electronic Locks & Keys – Jan. 2020

Photo Courtesy: UDOT

Photo Courtesy: UDOT

[Slide 32 Security]
Last year, we received a report that some suspicious people were tampering with our cabinet. We dispatched the police to investigate. The people are from a private consulting firm working for us at UDOT; however, they were not wearing their safety gear like our policy requires. This situation brought to light a larger problem we have that it's very difficult to manage access to cabinets as the same key **[click]** that opens our cabinets is the same key that opens most signal cabinets. To make the problem worse, the keys to cabinets can be purchased on eBay. At the cabinet, thousands of dollars' worth of equipment resides, signal timing can be changed, and the private ATMS network can be accessed.

[click] So, in January of this year, we retrofitted all of the signal cabinets to electronic locks. **[click]**

Electronic Locks Install on Cabinet in Minutes

(Electronic Locks: No wires, no batteries, no communications)
(Electronic Keys: Power is provided by the key; audit trails; interfaces with central program)

Photo Courtesy: UDOT

Photo Courtesy: Medeco

Photo Courtesy: UDOT

Photo Courtesy: CyberLock

[Slide 33 Electronic Locks - Installation]
Retrofitting cabinets with electronic locks is really quite easy and takes just a few minutes to do in the field. In the lab, we take a corbin #2 lock and replace the cylinder with an electronic lock. We will also re-grease the locking mechanisms during the process. We then bring the lock to the field, remove four screws and install the new electronic lock. The electronic locks have no batteries & no wires. They receive their power from the electronic key who powers up the lock long enough for the key and lock to exchange information. Both the lock and key will time-stamp when and who opened it. When the key docs, it will upload its audit trail to the electronic lock program and receive additional encrypted permissions for another time period before the key expires. It is our practice to provide UDOT signal employees 11 days access each time they sync, contractors and consultants 7 days and UDOT shed supervisors who help us deploy generators to dark intersections 30 days.

[click]

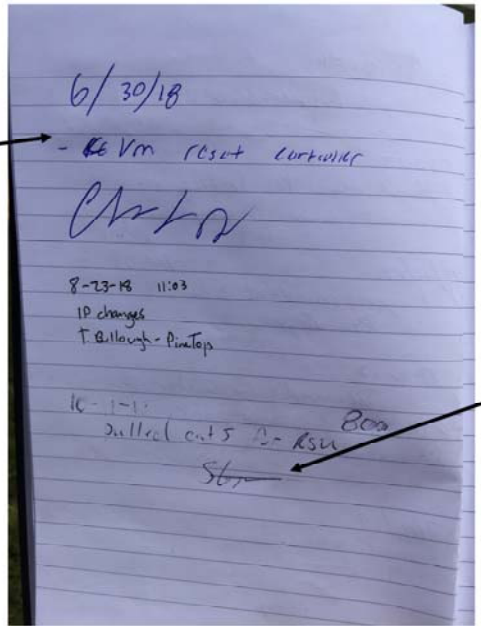
Time to Retire the Paper Cabinet Logbook?

Photo Courtesy: UDOT

[Slide 34 Paper Logbook#1]
The ITE Traffic Signal Maintenance handbook says that each signalized intersection should have a logbook inside the controller cabinet and that a bound composition notebook is best. The handbook was last published in 2010 and is currently in the process of being updated. You can see in the picture on this slide that paper logbooks do have some disadvantages, especially if a pesky mouse finds its way into the drawer and decides to make a nest from the notebook. **[click]**

Paper Cabinet Logbooks – Time for Change

Who is this person? What time of day did they make the entry?



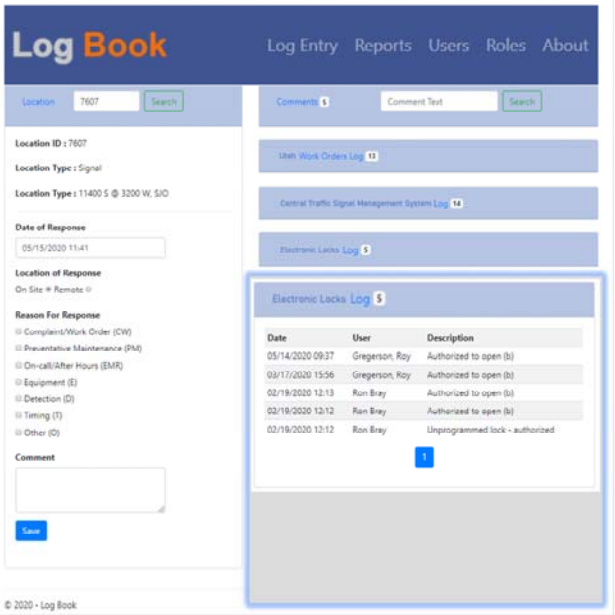
First and Last name is required.

[Slide 35 Paper Logbook#2]

There are also other challenges with the paper logbook, including the difficulty of reading the entry or even knowing who the person is **[click]** – or what time-of-day the entry was recorded. In addition, we have instructed everyone to clearly print the first and last name of the person but some people fail to heed to such requests. **[click]**

Why Use an Electronic Logbook?

1. Easier to retrieve, read, sort and analyze
2. Need a system to manage remote changes
3. Provide access to all agency programs
4. Improved management, security and accountability



[Slide 36 Why use electronic logbook]
Replacing the paper logbook with an electronic one can offer the agency benefits, including making it easier to retrieve, read, sort and analyze the records. Second, an electronic logbook provides a way to manage remote changes, as many remote changes go undocumented if there is not a way to record it electronically. Third, an electronic logbook program provides a means to display information from other agency programs. Fourth, an electronic logbook will improve management, security and accountability. In addition, one of UDOT's goals is to go completely paperless and doing away with the paper logbook helps our agency with that goal. **[click]**

QR Code Sticker on Inside Door of Signal Cabinet

(QR on left goes to electronic logbook; QR on right goes to Google Drive where signal documents are stored)

Photo Courtesy: UDOT

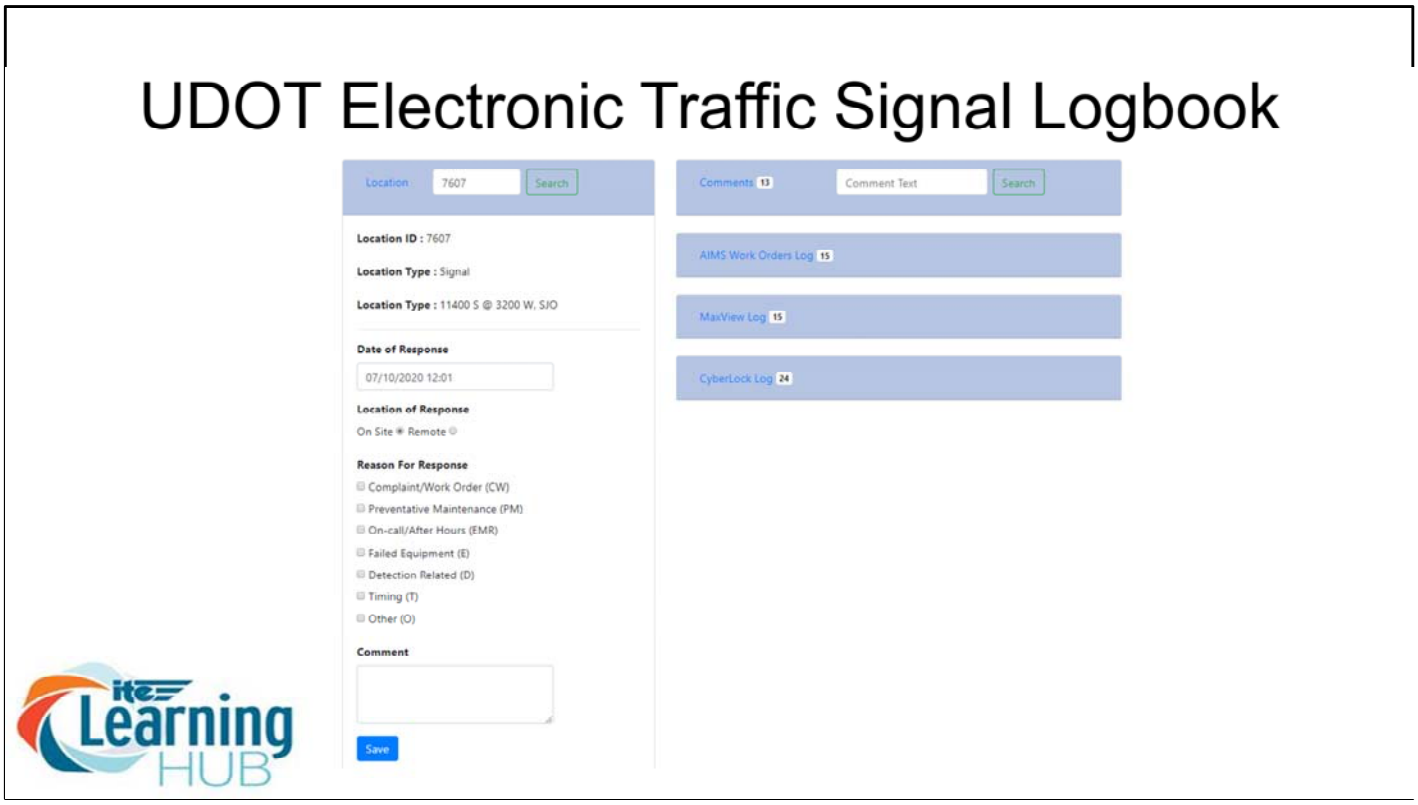
Photo Courtesy: UDOT

ite Learning HUB

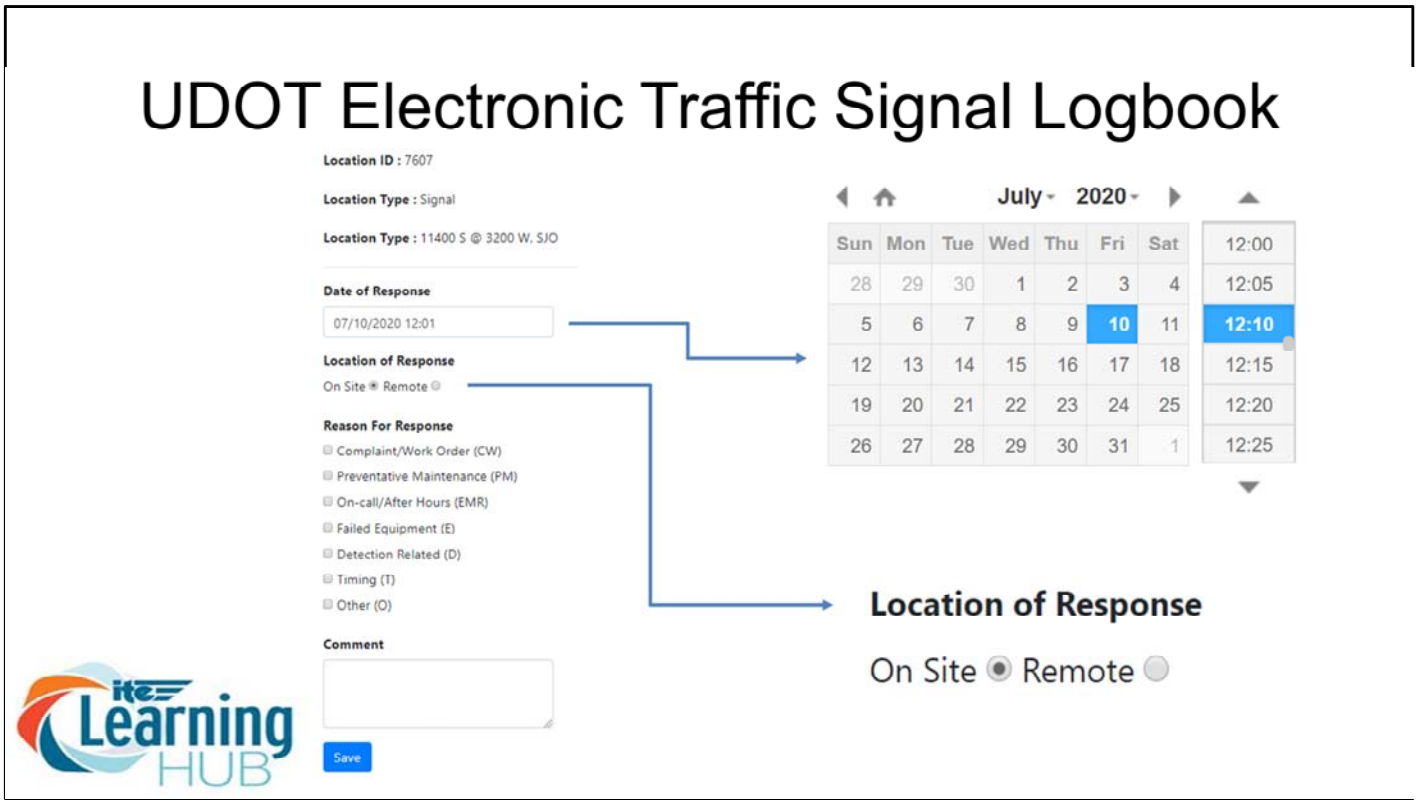
[Slide 37 QR Codes]

To access the electronic logbook, we have a QR code sticker on the inside door of the cabinet **[click]** that will take a person directly to the logbook or Google drive where we have electronic files for the intersection. The QR code on the left goes to the logbook and the QR code on the right goes to the Google drive where signal documents are stored. **[click]**

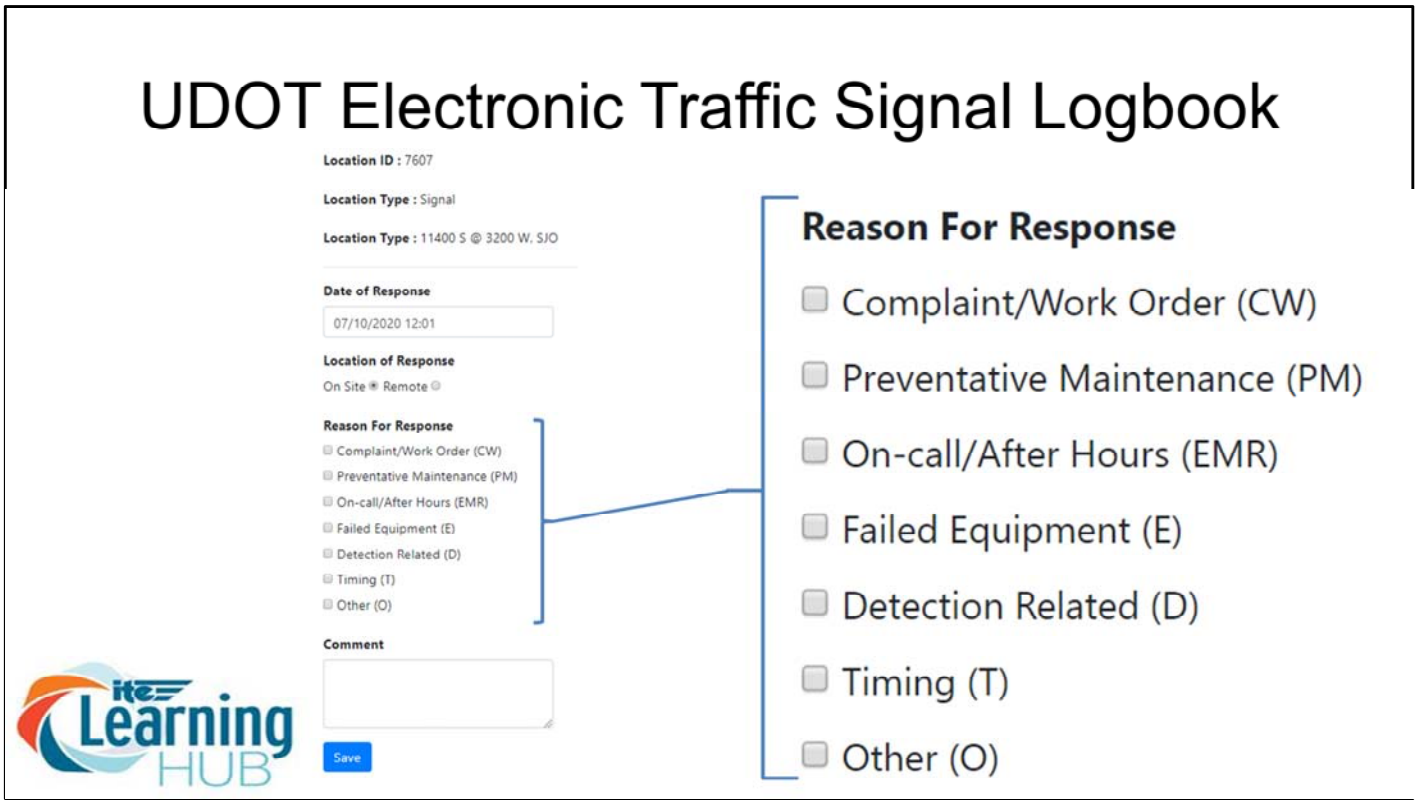
[Slide 38 Electronic Logbook #1]
Here's a snapshot view of the electronic logbook. A login is required with a username and password. The person then enters the signal ID number in the box or uses the QR code on the inside door of the cabinet. Accessing the electronic logbook can be done via a smartphone, tablet or PC. The source code is available for free on GITHUB but is highly customized for the UDOT environment and will take some development work to make it work for your needs. **[click]**



[Slide 39 Electronic Logook#2]
Once the intersection number is entered, the program takes you to a screen showing the address. The information on the left is where you enter information and on the right is where you see a history of changes made from other programs. **[click]**

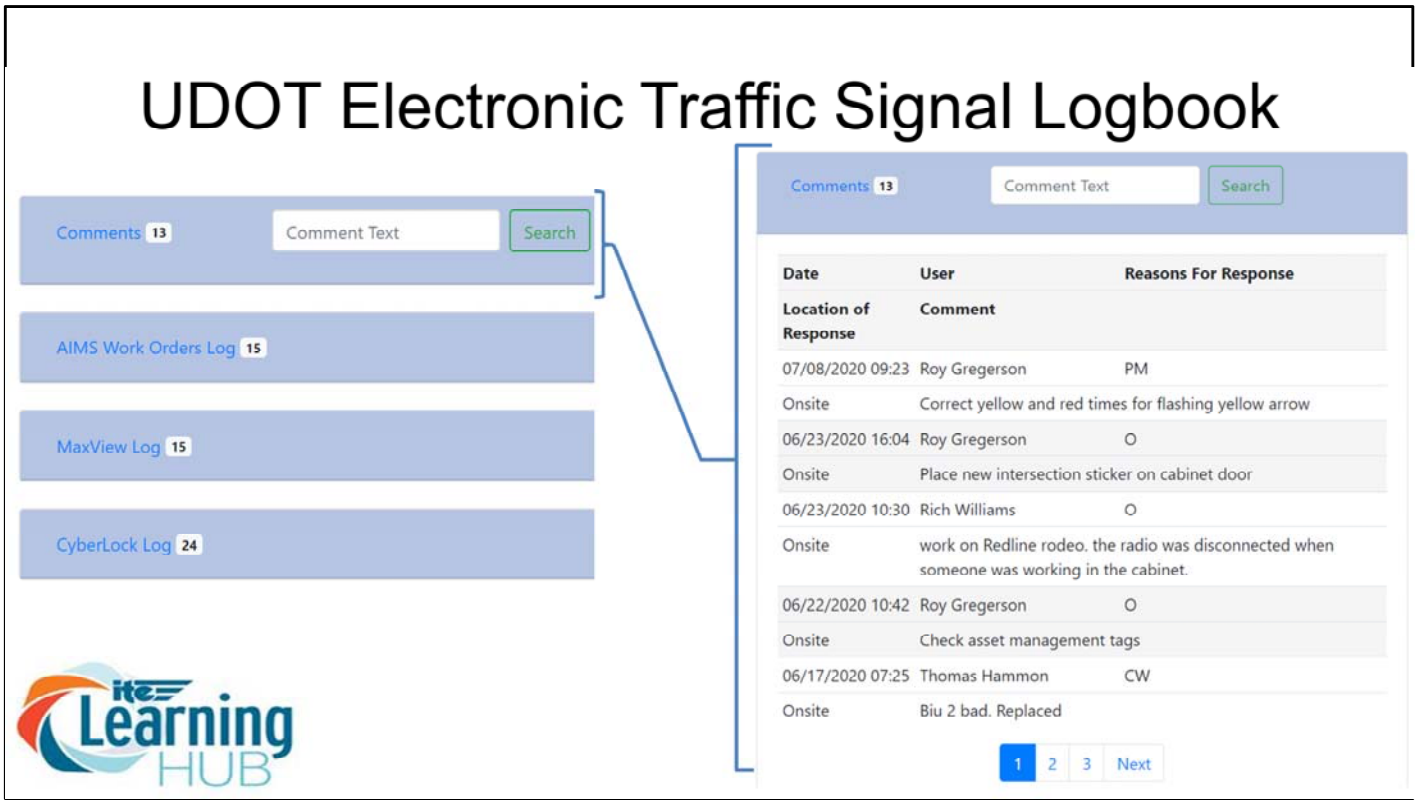


[Slide 40 Electronic Logook#3]
This is an enlarged picture of information the person would complete in filling out the logbook. **[click]** The date of response will default to whenever the logbook was opened but can be changed if needed. **[click]** The next question wants to know if you were onsite or making the change remotely. Remote changes logged in this program are only those that are not captured by any other program. **[click]**

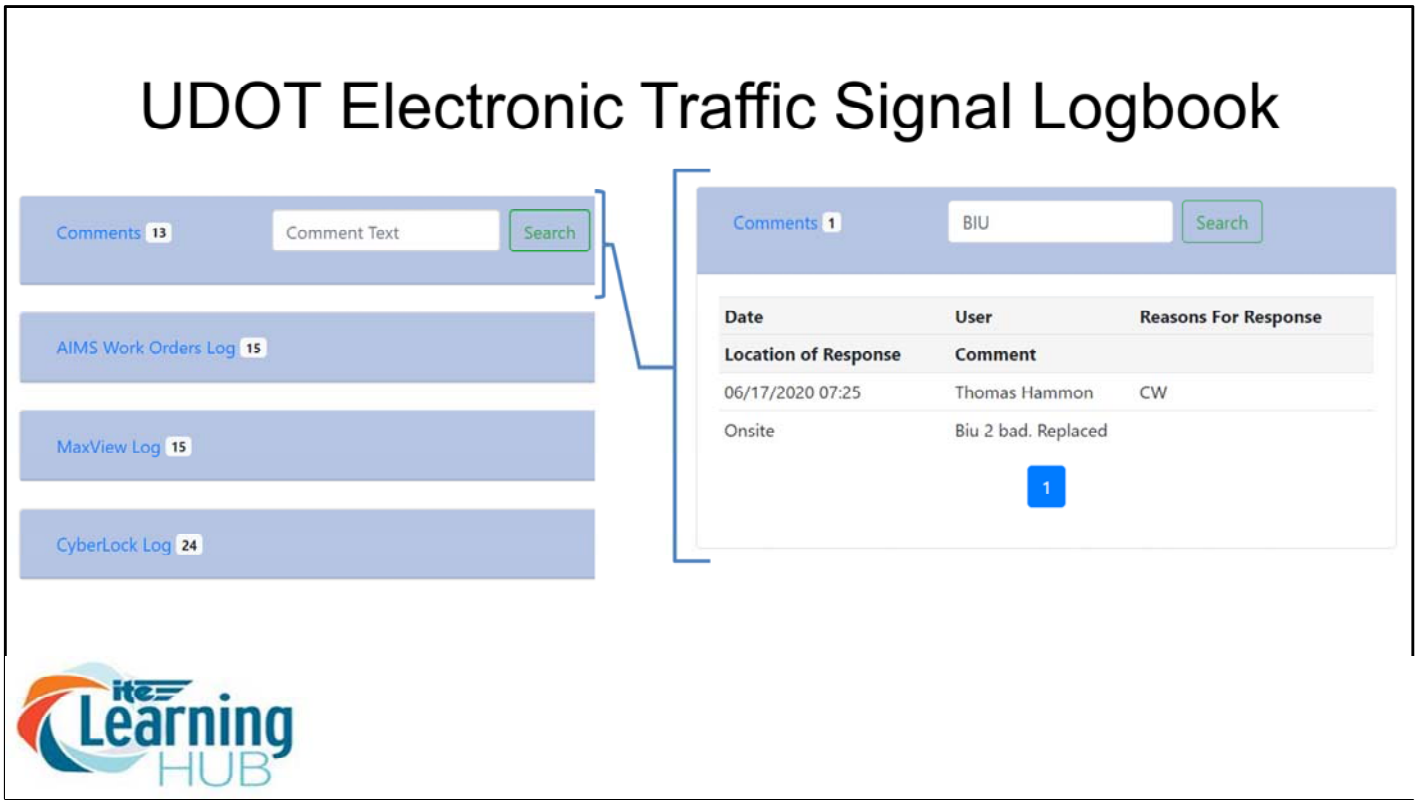


[Slide 41 Electronic Logook#4]
The next question wants to know why you were there. Was it a complaint or work order that brought you to this intersection? Were you doing preventative maintenance? Was the reason for response an emergency? Was failed equipment a cause? Was it detection or timing related or something else? **[click]**

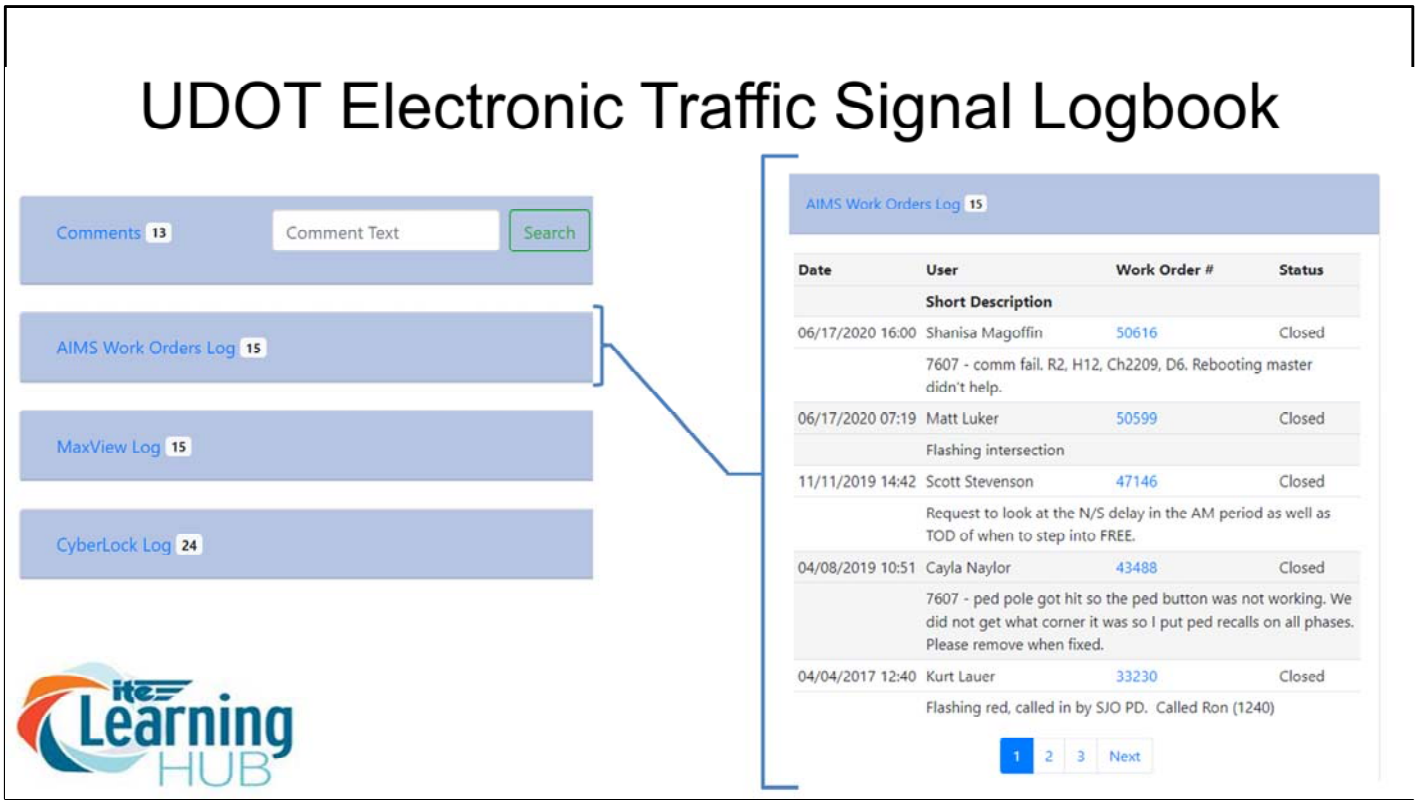
[Slide 42 Electronic Logook#5]
Next, you enter a detailed description of what you're doing and why. Once you click the "Save" button, the logbook entry is saved and forever stored in the system. **[click]**



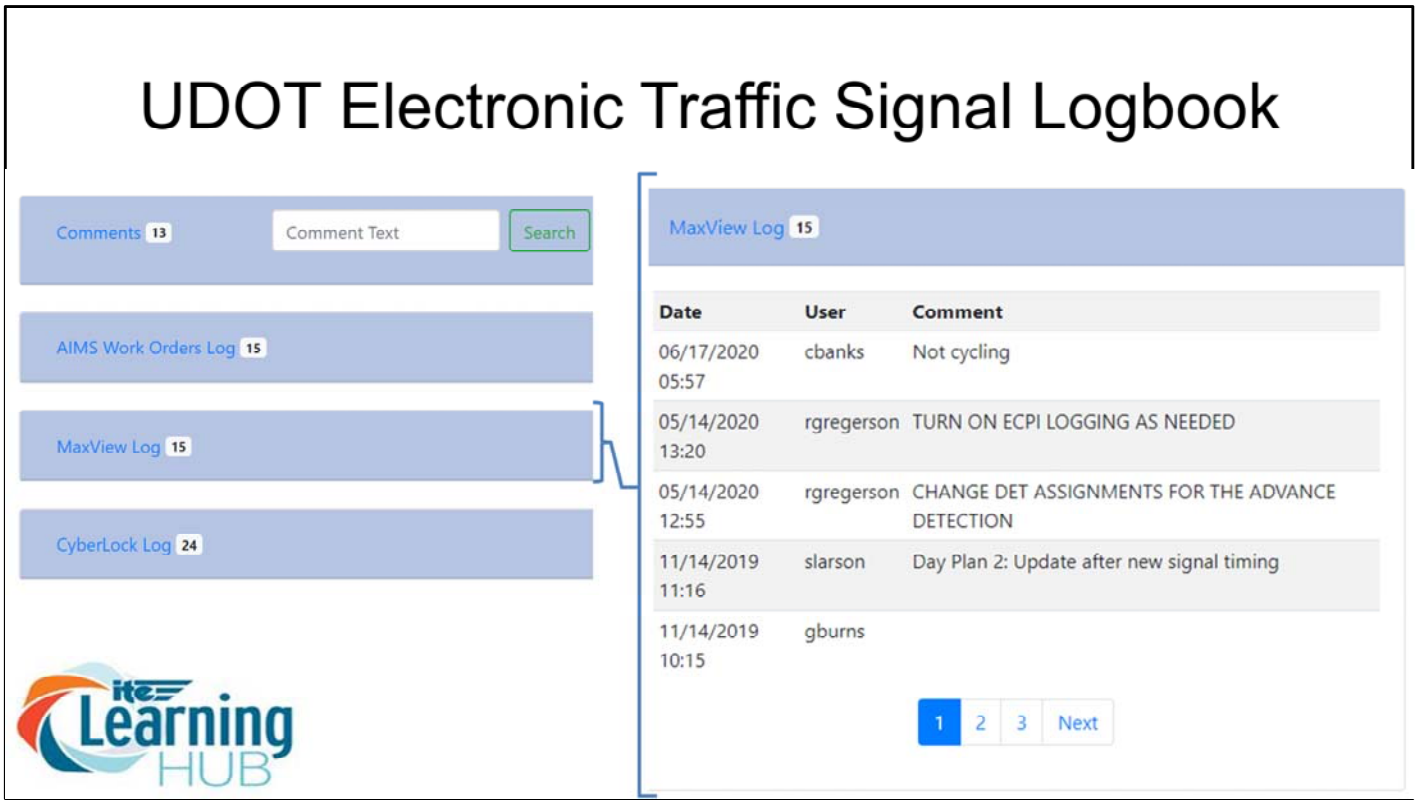
[Slide 43 Electronic Logook#6]
On the right side of the program, you can see a history of the logbook entries that are clearly written out, a timestamp of the entry and by whom. In addition, the "reason for response" is also recorded, so to provide easier sorting and reports. **[click]**



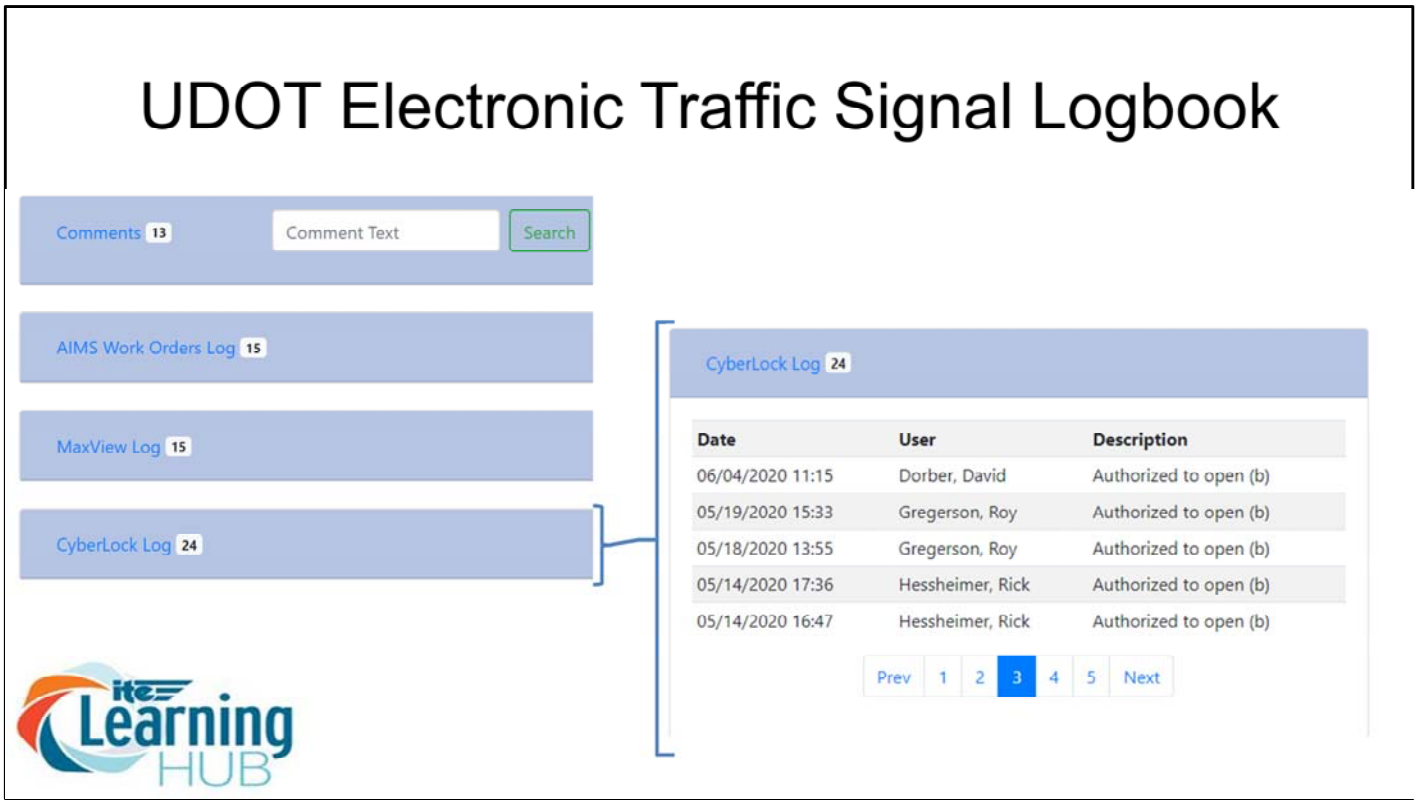
[Slide 44 Electronic Logook#7]
Also, there is a "search" bar so the person can sort the logs for key words and view all the entries pertaining to those comments. **[click]**



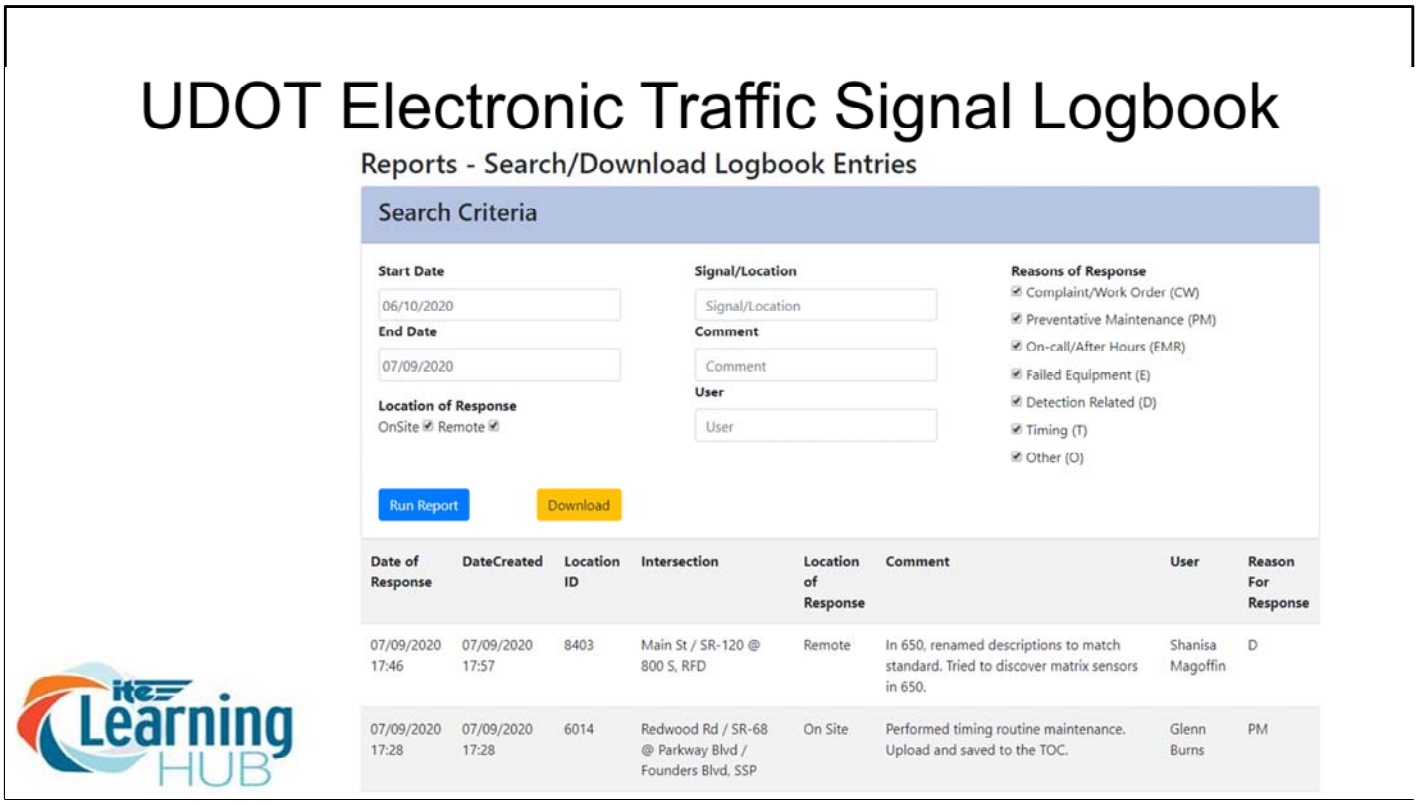
[Slide 45 Electronic Logook#8]
The work orders log box shows all of the work orders for this intersection. The data is transferred via a API so the tech can have better awareness of all issues at this intersection. **[click]**



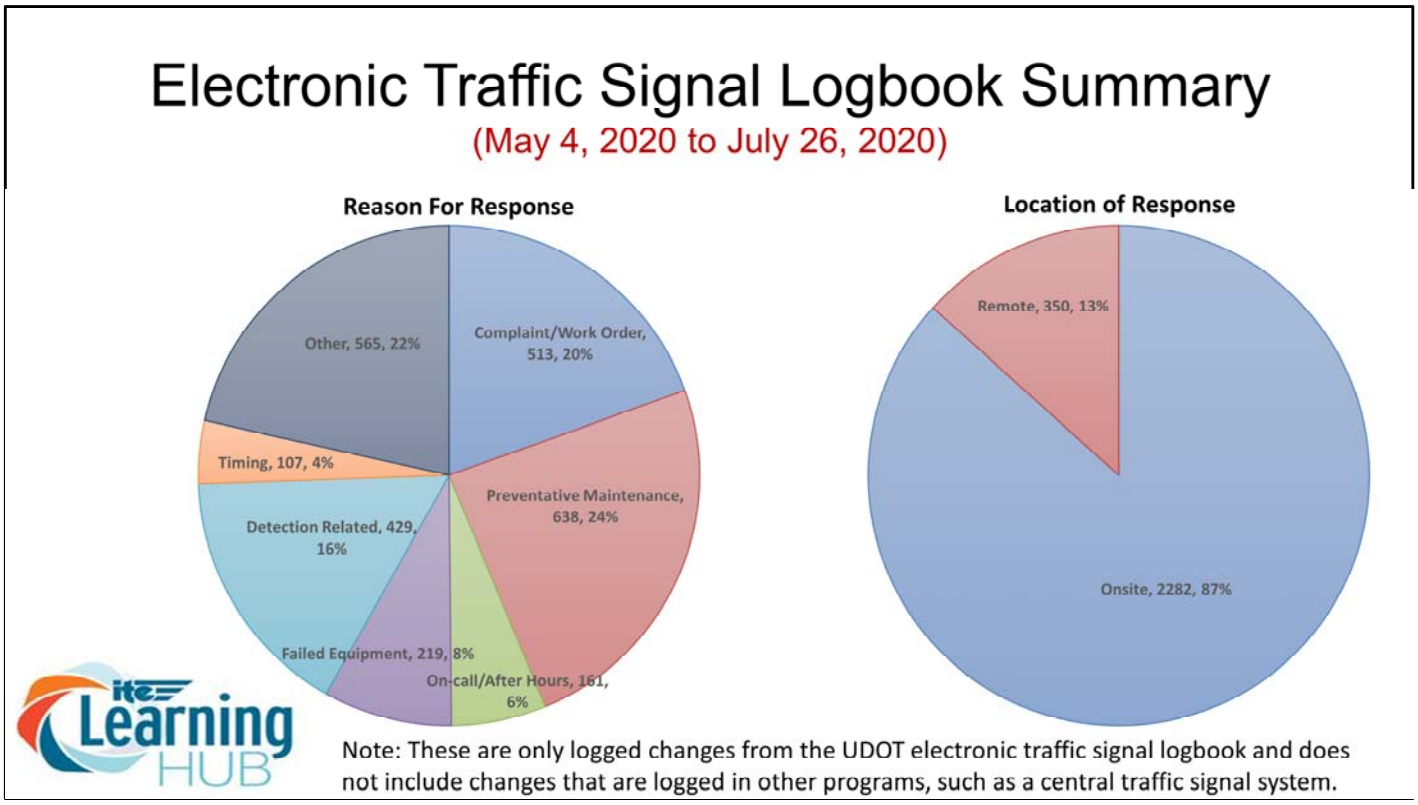
[Slide 46 Electronic Logook#9]
The MaxView log box will show the comments from our traffic signal central system program. We only record information in the electronic logbook if no other programs have recorded the information. **[click]**



[Slide 47 Electronic Logook#10]
The electronic locks box displays a history of who was previously at the cabinet, thus helping to increase accountability as we know you were there so complete the logbook.
[click]



[Slide 48 Electronic Logbook Reports]
One of the neat features of the electronic logbook is being able to sort and analyze all of the logs for all of the intersections. We have a reporting tab and can sort the entire database for various items of information. The reporting feature is a good way to improve the management and quality of signal maintenance activities. If a technician needs additional oversight, it's quite easy to pull up all the logs for that person. Evaluating all of the logs is a good way for managers to monitor activities so to improve future training or monitoring certain brands of equipment. **[click]**



[Slide 49 Electronic Logbook Reports Summary]
Using an electronic logbook allows for the database to be sorted and analyzed. For example, from May 4th 2020 to July 26th 2020, the majority of the log entries are related to preventative maintenance activities, which is good. However, complaints/work orders amount to 20%, detection related issues are 16% and failed equipment is 8%. 13% of all the entries were remote, thus showing that the 350 remote entries would have never been logged anywhere unless we had this electronic logbook program in place. **[click]**

4. PREVENTATIVE MAINTENANCE (PM) & ASSET MANAGEMENT

- SIGNAL MAINTENANCE PM (PM)
- SIGNAL TIMING ROUTINE MAINTENANCE (RM)
- ASSET MANAGEMENT

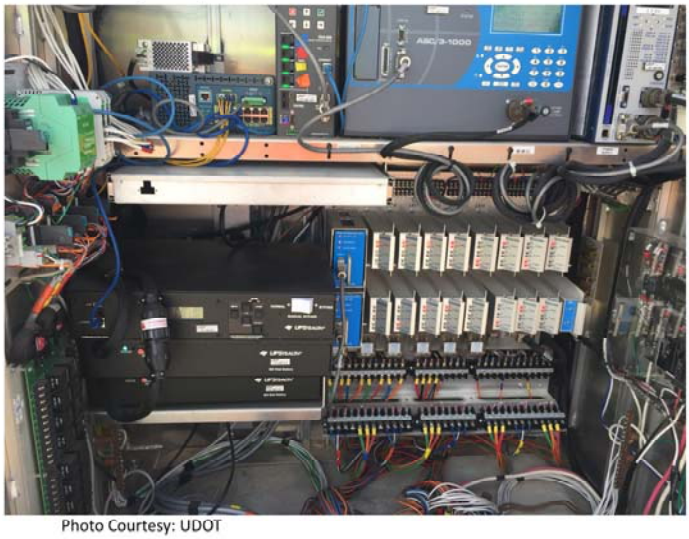
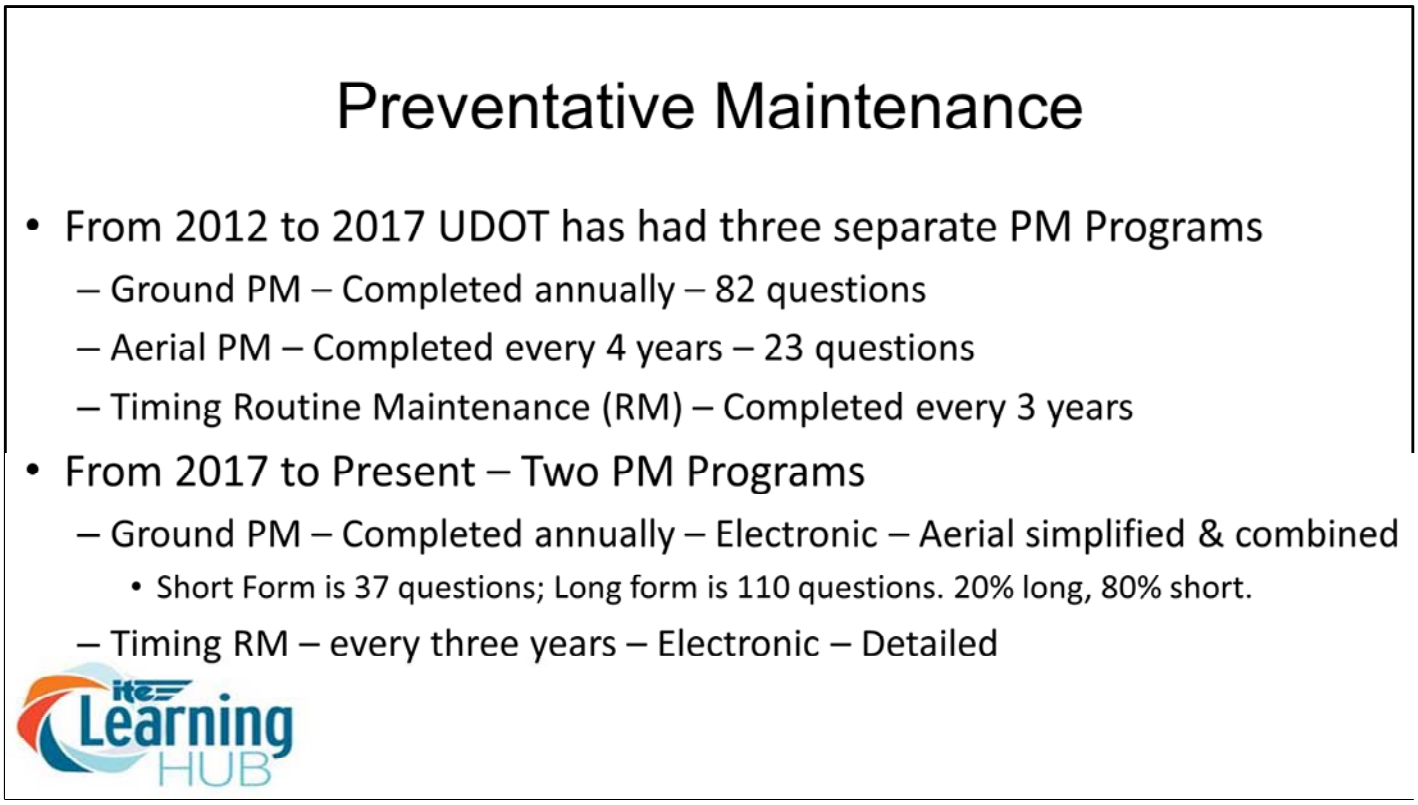


Photo Courtesy: UDOT

[Slide 50 PM & Asset Mgt]
In this section, we will discuss UDOT's preventative maintenance programs, as well as preventative maintenance and asset management. **[click]**



[Slide 51 PM Program]
From 2012 to 2017, UDOT had three separate Preventative Maintenance programs. Ground PM's, which would be completed annually. There were 82 questions on our ground PM form and we would change some of the questions each year so to make the program most meaningful. Every 4 years, we would complete aerial PMs, which would involve inspections in the air evaluating and tightening signal heads, brackets, wiring and cleaning of video detection (if exists). We have a separate signal timing group and they visit each intersection every three years and complete signal timing routine maintenance that involves checking all of the signal timing parameters for consistency to our policies, ensuring phasing is safe & good, time-of-day plans are consistent, etc.

In 2017, we realized that the workload was too much. The technicians were doing their best to keep their heads above water but were in all reality drowning. Most regions were getting the PM's completed, however, most were just checking boxes as they had previous punch lists a mile long of items that needed to be fixed that wasn't getting done. So, in 2017, we took a year off and only tested MMU's and focused our efforts in fixing all the items on the previous punch lists.

I learned a few good lessons:

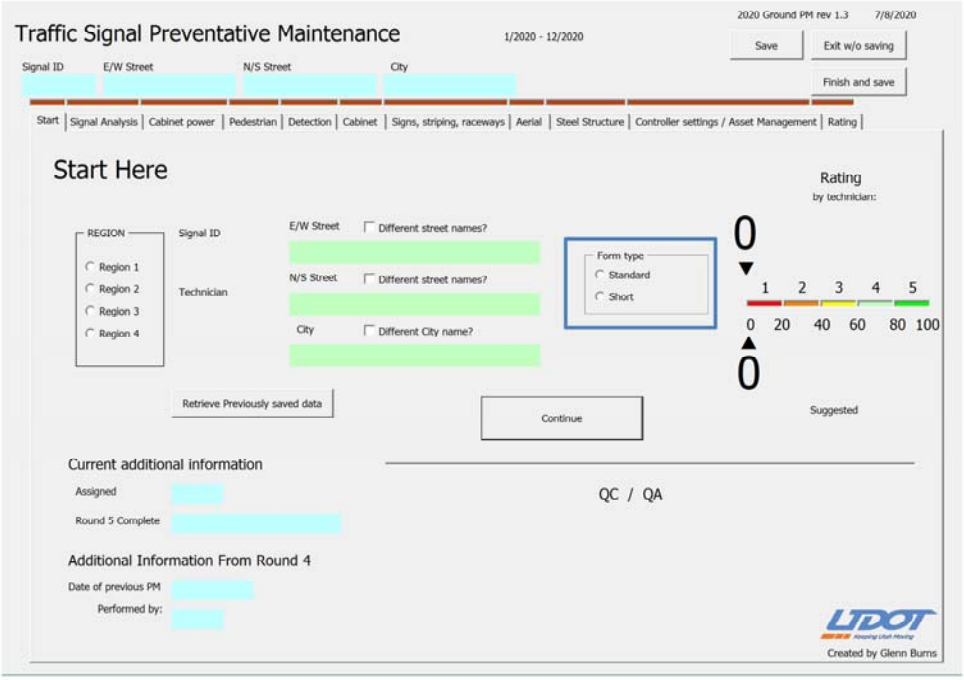
1) Make the PM program meaningful. Don't bite off more than you can handle and pause the program if you fall way behind so you can catch up. It's not a big deal if you don't keep on a rigid schedule.

2) Don’t just check boxes. Have a short and long form. Let the technicians choose which form to use with a goal to complete a long evaluation approximately 20% of the time. They know best which intersections need more attention and intersections that need just a quick lookover.
3) Change the questions periodically. There’s only so much time the techs have to get the work done. Each year we meet with the field supervisors, seek their input and revise, delete or add questions. **[click]**

Preventative Maintenance (PM) – Start Page

https://udottraffic.utah.gov/atspm - UDOT Traffic Signal Documents – Signal Maintenance PM 2020

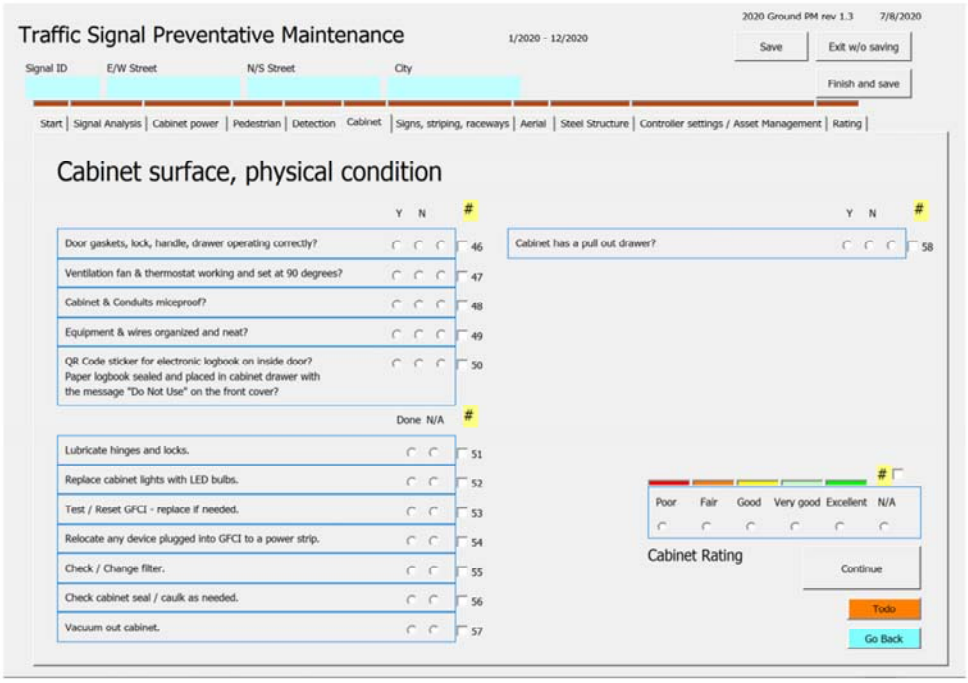
- 11 categories – all electronic
- Can choose between "standard & short" form
  - Standard: 110 questions
  - Short: 37 questions
- Each category given a subjective rating



[Slide 52 PM Start Page]
This is our electronic preventative maintenance program. Please note that the technician can choose between the standard **[click]** form which is a 110 questions, or the short form that is 37. The PM forms are completed by the field technician and sent to their supervisor electronically for review and approval. The supervisor will then send it to the region signal engineer who will review and approve it and then archive it to the UDOT PM database. The electronic forms makes it a lot easier to sort and analyze. If you're interested in a free download of the electronic forms, the URL is shown on top. **[click]**

Preventative Maintenance (PM) – Cabinet Page

https://udottraffic.utah.gov/atspm - UDOT Traffic Signal Documents – Signal Maintenance PM 2020

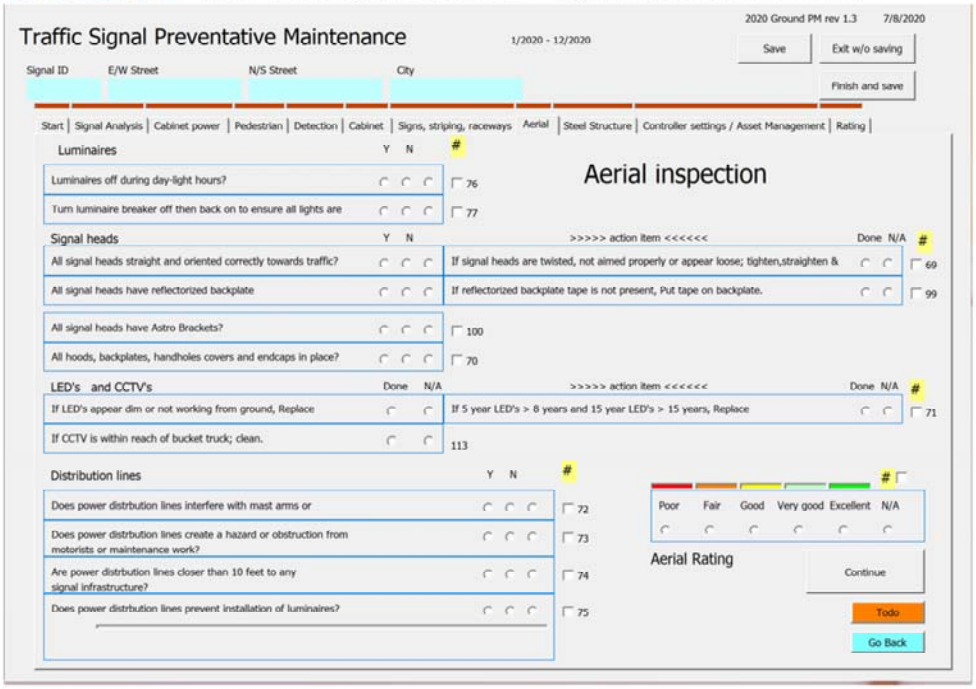


[Slide 53 PM - Cabinet]

The electronic PM form brings you through a series of questions. This slide is showing you some of the questions regarding the traffic signal cabinet. There are yes/no or n/a questions and a place for each question to leave a comment (if desired). For each series of questions, the technician is asked to subjectively rate the condition of the signal for the subject category (in this case, the cabinet) on a scale of 1-5, 1 being poor and 5 being excellent. The subjective score ratings are used to rate the condition of the overall intersection at the end, but are also useful in deciding how best to appropriate and spend the budget on equipment upgrades. **[click]**

Preventative Maintenance (PM) – Aerial Inspection

https://udottraffic.utah.gov/atspm - UDOT Traffic Signal Documents – Signal Maintenance PM 2020

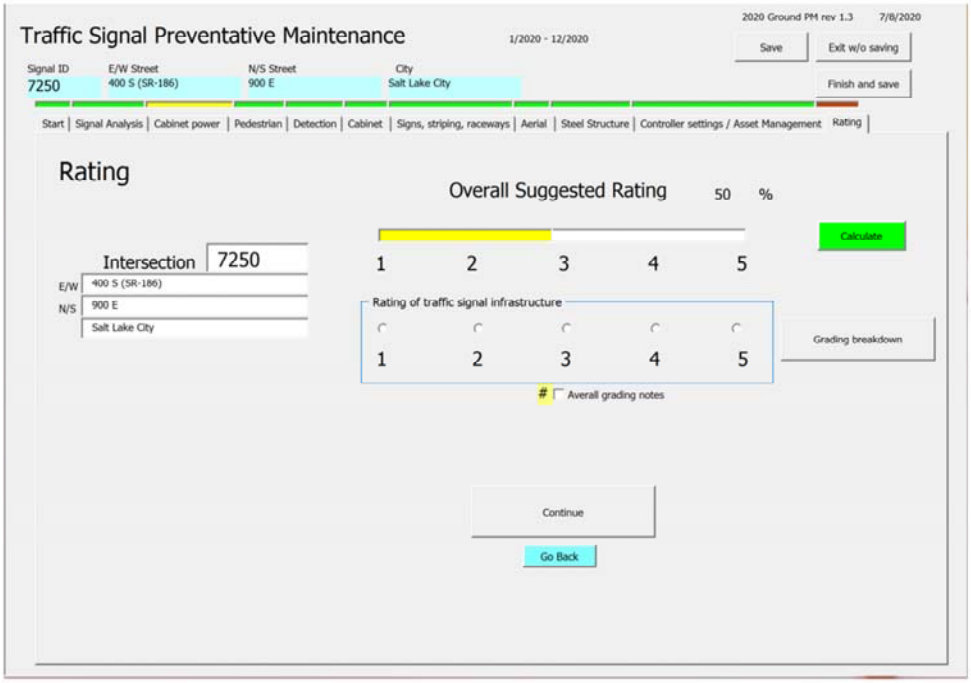


[Slide 54 PM Aerial]

This slide shows the aerial inspection that was integrated into the yearly preventative maintenance program, as previously it was a separate program that we just didn't have time for. In essence, the technician is asked from the ground level to observe the signal heads, LED's and ensure everything looks correct. **[click]**

Preventative Maintenance (PM) – Subjective Rating

https://udottraffic.utah.gov/atspm - UDOT Traffic Signal Documents – Signal Maintenance PM 2020

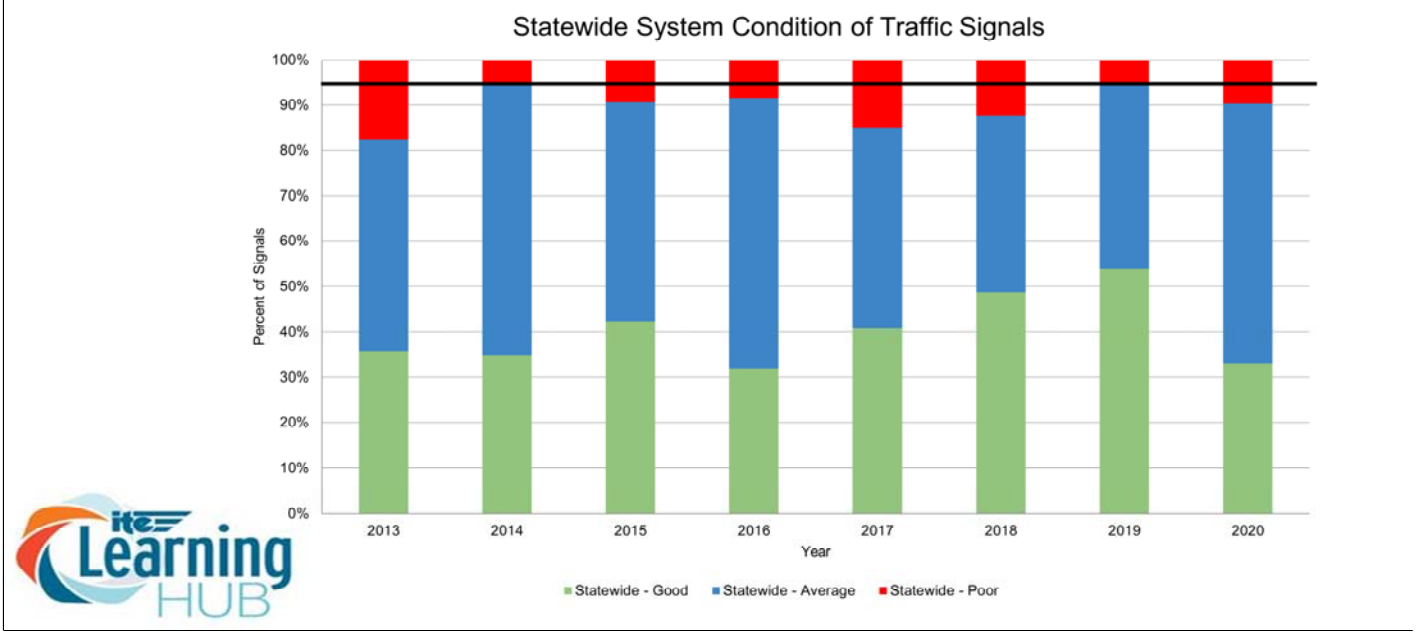


[Slide 55 PM Subjective Rating]

At the end of the PM, the technician is asked to rate the quality of the signal infrastructure, which is one of the traffic signal performance measures that we track over time. The form provides a suggested weighted rating, however, the tech can use the recommended rating or choose their own overall grade. **[click]**

Preventative Maintenance – Subjective Rating Score

(Goal: Good & Average - 95% or Better)

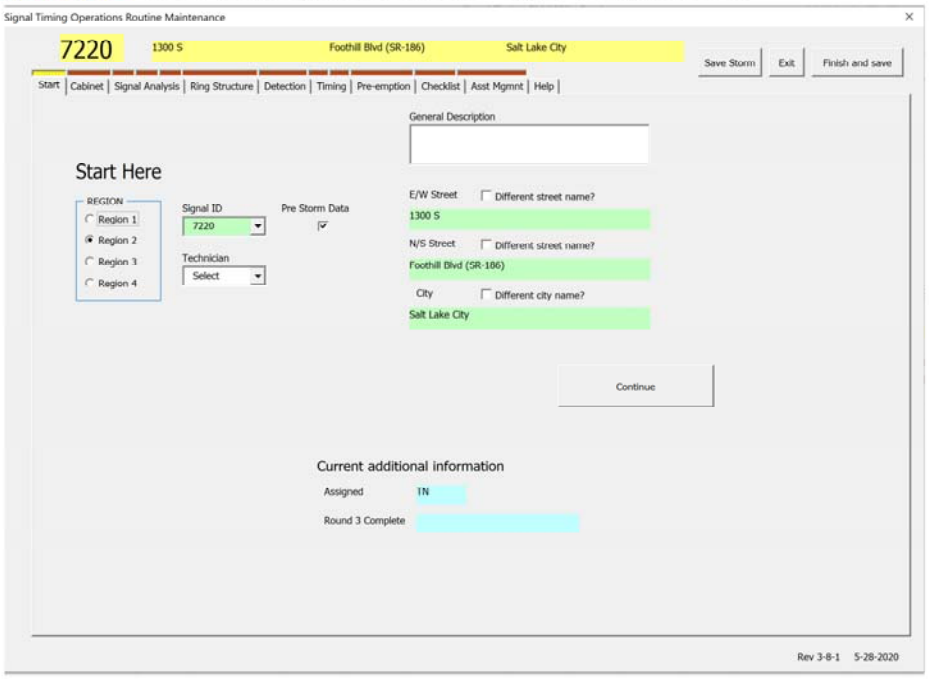


[Slide 56 PM Score]

We take those subjective ratings on a scale of 1-5 and track them overtime to measure the overall condition of the traffic signal system. Green is showing the signal to be in good condition, blue is average and red is poor. Our goal is to have 95% of the signals in the average & good category. This performance measure was used to request an increase in funding for a separate budget for signal rebuilds. Because of this metric, we now receive an extra $2.5 million for signal rebuilds each year. **[click]**

Timing Routine Maintenance (RM) – Start Page

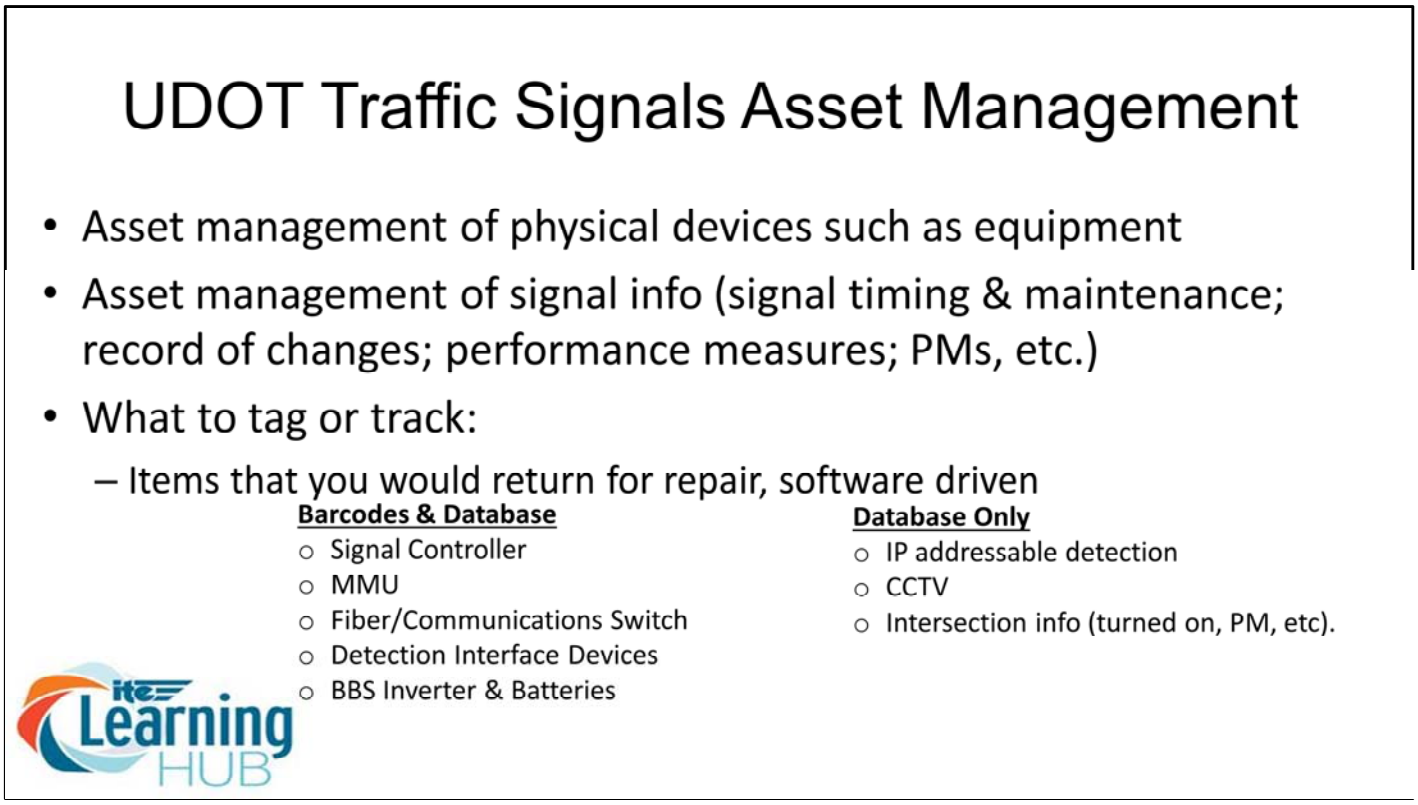
https://udottraffic.utah.gov/atspm - UDOT Traffic Signal Documents – Signal Timing RM 2020



[Slide 57 RM Start]

Every three years, our signal timing team conducts timing routine maintenance at each intersection. They also use an electronic form for this evaluation, that is available on our ATSPM website for free download. This form is all electronic and requires approvals similar to the PM form – by the supervisor and then by the signal timing engineer.

[click]



[Slide 58 Asset Management]
Lastly, I'm going to conclude with a few thoughts with asset management. Asset management involves both knowing the physical devices or equipment you have, as well as managing your assets. My experience has shown that the physical tracking of equipment is quite difficult to do and keep current. We have failed at it several times and keep at it the best we can. Our failures have taught us a few things to do, which is centered around having a good program to track and store your assets, as well as keeping the list of items you track small and manageable. In summary, we will track items that we would return to the vendor if they were to break, or items that are software driven. All other items are not tracked. Thank you for your time. **[click]**