U.S. Department of Transportation
Federal Highway Administration

Traffic Signal Operations and Maintenance Staffing Guidelines

Prepared by:

Dunn Engineering Associates, P.C.
in cooperation with
Kittelson and Associates, Inc.

Prepared for:

Federal Highway Administration
Washington, D.C.

March 2009

FHWA-HOP-09-006

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document. This report does not constitute a standard, specification, or regulation. The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

QUALITY ASSURANCE STATEMENT

The Federal Highway Administration (FHWA) provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-HOP-09-006		

4. Title and Subtitle	5. Report Date: March 2009
Traffic Signal Operations and Maintenance Staffing Guidelines	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Robert Gordon (Dunn Engineering), Cade Braud (Kittelson and Associates)	Project

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Dunn Engineering Associates 66 Main St. Westhampton Beach, NY 11978 and Kittelson and Associates 225 East Robinson Street, Suite 450 Orlando, Florida 32801	11. Contract or Grant No. Contract No. DTFH61-06-D-00005

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Federal Highway Administration Office of Operations 1200 New Jersey Ave, SE Washington, DC 20590	Final Report Jan 2008 – March 2009 14. Sponsoring Agency Code HOP

15. Supplementary Notes

Eddie Curtis, Contracting Officer's Task Manager, FHWA. The project team acknowledges, Paul Olson, FHWA Resource Center the Puget Sound Regional Operations Committee and the numerous practitioners that provided key information to develop this report.

16. Abstract

This report provides a guideline to estimate the staffing and resource needs required to effectively operate and maintain traffic signal systems. The results of a survey performed under this project, as well as a review of the literature and other surveys indicated that agencies achieving a high level of signal system performance do so under a wide variety of conditions such as agency size, geography, system complexity and traffic conditions that do not adhere to the typical level of documented resource requirements. Accordingly, a set of *performance-based criteria* were developed to define requirements. The performance-based criteria are focused on establishing realistic and concise operations objectives and performance measures.

17. Key Words	18. Distribution Statement
Signalized Intersections, Traffic Signal Timing, Staffing, Traffic Signal Operations, Maintenance, Management, Objectives, Performance Measures	No Restrictions.

19. Security Classification.	20. Security Classification. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	84	N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Table of Contents

EXECUTIVE SUMMARY

This report provides a guideline to estimate the staffing and resource needs required to effectively operate and maintain traffic signal systems. In 2007, the NTOC Traffic Signal Report Card (TSRC) assigned a grade of D nationally to how agency programs support the efficient operation and maintenance of traffic signals (5). The D grade indicates that relative to what is considered “good practice”, overwhelmingly an ad-hoc approach is taken, resulting in some positive outcomes, but generally agency programs are not as effective as they could be.

In surveys of practitioners and national experts completed by the FHWA, it was recognized that no clear definition of traffic signal operations has been developed and no consensus appears to exist as to what activities are required to support traffic signal operations. The lack of a concise definition of traffic signal operations provides some insight into why practices, staffing levels, objectives and performance measures are divergent in this area. Operating agencies clearly understand the requirements for adequate traffic signal maintenance. The results of several surveys indicate that many agencies tend to be primarily focused on maintenance activities, with most of their attention focused on keeping traffic signals operating (turning green, yellow and red) and little attention on making the operation efficient on a 24/7 basis. This has some safety implications and contributes to millions of hours of unnecessary traffic delays and congestion.

A working definition of traffic signal operations is the active prioritization of objectives and collection of information to efficiently manage traffic signal infrastructure and control devices to maximize safety and throughput while minimizing delays. The working definition of traffic signal maintenance is the preventative and responsive activities to preserve traffic signal infrastructure and control devices necessary for the safe and efficient utilization of arterial, collector and local roadways. The discussion of resource requirements in this report will refer to the definitions of traffic signal operations and maintenance as stated above.

Initially, it was envisioned that this report would verify and update the *resource requirements* (staffing levels and criteria or levels of staff experience and training) provided in a number of publications including the ITE Traffic Engineering Handbook and FHWA Traffic Control Handbook. The results of a survey performed under this project, as well as a review of the literature and other surveys indicated that agencies achieving a high level of signal system performance do so under a wide variety of conditions such as agency size, geography, system complexity and traffic conditions that do not adhere to the typical level of documented resource requirements. Accordingly, a set of *performance-based criteria* were developed to define requirements. The performance-based criteria are focused on establishing realistic and concise operations objectives and performance measures. The operations objectives and performance measures dictate the staffing and resource level required for their achievement.

Research indicated that while maintenance was, in general, timely, and that agencies used effective tools such as Synchro to develop signal timing plans, significant deficiencies resulted from a failure to systematically determine the need for signal retiming and to retime at appropriate intervals. This result is closely related to not clearly establishing and documenting specific operations objectives and programs to measure performance.

Key management and operations criteria and recommendations to attain effective traffic signal operations and maintenance include:

- Management controls. Staff qualifications and periodic updating of management plans. Management plans should include a mission statement, strategic plan, objectives and measures, periodic collection and review of performance data and remedy of deficiencies in signal timing and other system characteristics. Recommendations concerning communication paths with the public and other stakeholders are also described.

- Signal timing design. Signal timing performance should be reviewed at periods established by management plans but should not exceed 30 to 36 month periods. Signals should be retimed using an accepted methodology. A methodology for determining the number of daily timing plans required as well as weekend and special function timing plans should be utilized.

- Operations. Functional changes in requirements such as pedestrian needs, transit and preemption requirements, etc. should be periodically reviewed and addressed. Criteria are provided for the persistent monitoring of traffic systems.

- Maintenance. Since maintenance response time for failure repair after the agency has been notified of failure is generally good and the ability to automatically detect failures at isolated intersections is poor, a criterion to improve this capability was established. Recommendations for the up-time for detectors are provided.

The report provides recommended personnel staffing, training and experience levels.

ABOUT THIS DOCUMENT

The audience for this document is agency managers, practitioners and personnel seeking to gain an understanding of the resource requirements to effectively and efficiently operate and maintain traffic signals. The document is organized into two major sections Guidance and State of the Practice. The Guidance section is advisory and is intended to provide a methodology for identifying operations and maintenance objectives and performance measures as well as for estimating staffing and resource needs required to achieve the specific operations objectives. The guidance is supported by an in depth survey, conducted for this project, of a limited subset of agencies that participated in the 2007 NTOC Traffic Signal Report Card Self Assessment Survey. A review of literature, discussions with noted experts, and a synthesis of surveys conducted by the FHWA Resource Center Operations Technical Service Team during Traffic Signal Operations Reviews, which characterize the state of the practice.

The State of the Practice section documents literature reviewed, the survey conducted to gather information for this project and a synthesis of information collected from other surveys. The appendix provides the methodology executed to develop the conclusions that are presented as guidance.

1. GUIDANCE FOR OPERATIONS AND MAINTENANCE OBJECTIVES AND PERFORMANCE MEASURES

1.1 INTRODUCTION

The objective of this section is to provide a guideline to assist managers and practitioners to prioritize the operations and maintenance objectives and performance measures to evaluate staffing and resource needs required to effectively operate and maintain traffic signal systems. Ineffective operation and maintenance of traffic signals may have safety implications and contributes annually to millions of hours of unnecessary traffic delays, congestion, fuel consumption and air pollution. The issues associated with understaffing and under funding traffic signal system operation and maintenance, activities are indigenous to urban, suburban and rural areas.

Major contributors to the inconsistency found in traffic signal operations and maintenance budgets include:

- A lack of clear guidelines describing traffic signal operations and maintenance activities and the resources required to support these activities;
- The lack of documented objectives and performance standards;
- Funding mechanisms that are geared more towards project development than operations and maintenance.

Some effort has been made to provide a benchmark for, and to promote good traffic signal operations and maintenance practices through the National Traffic Signal Report Card and associated self-assessment survey. These efforts have been supplemented through traffic signal operations audits and traffic signal operations reviews conducted by the FHWA. In 2005, the National Traffic Operations Coalition (NTOC) assigned a national grade of D- to traffic signal operations and maintenance practices. In 2007, the National Traffic Signal Report Card (5) grade improved slightly to a grade of D. The agencies that improved their scores employed "more effective management techniques and are taking a more thoughtful approach to resource allocation." (6)

While the Traffic Signal Report Card evaluates conformance to what is considered "good practice" it does not define traffic signal operations or maintenance. Clearly defining traffic signal operations and maintenance are essential to beginning the discussion about staffing and resource needs to support these functions. The following working definitions are offered for traffic signal operations and maintenance as a result of surveys conducted by the FHWA Resource Center and a glossary of terms developed by the Transportation Research Board Regional Transportation Systems Management and Operations Committee.

Traffic signal operations is the active prioritization of objectives and active collection of information to efficiently manage traffic signal infrastructure and control devices to maximize safety and throughput while minimizing delays.

Traffic signal maintenance includes the preventative and responsive activities to preserve traffic signal infrastructure and control devices necessary for the safe and efficient utilization of arterial, collector and local roadways.

Under a given set of geometric conditions, and without budgetary, technological and knowledge constraints the expectation of a minimum delay or ideal traffic signal system might be achievable. The goal of achieving an ideal traffic signal system, while unachievable given current constraints, should nonetheless represent the desired level of traffic system operation. To bring reality to the situation the ideal traffic signal system must be constrained to obtain goals that are Specific, Measurable, Achievable, Realistic and Timely (SMART). This requires clearly asserting objectives that are realistic given the resources available.

Past approaches to development of resource and staffing criteria for operation and maintenance of traffic signals have often provided guidelines in terms of the number traffic signals that can be maintained and operated per number of personnel performing these tasks. These approaches do not adequately consider the how agencies view their role, operations objectives and desired level or needs for traffic signal management operations and maintenance. Responsible agencies differ, in many characteristics. Some of these key variables include:

- Number of signals and changes in number of signals
- Variations in knowledge, skills and abilities of maintenance and engineering personnel.
- Differences in functions that the systems and agencies must perform.
- Organizational structure of the responsible agency (sharing of resources with other functions) and budgeting structures.
- Geographic configuration of traffic flow network i.e. grid, arterial and the overall number and size of other facilities in the transportation network (freeways, interstate, transit, freight, land use etc.)
- Density of traffic signal network relative to population density.
- Congestion levels.
- Type of signal system (e.g. distributed or centrally controlled); distribution of signals on the network and need for interconnection.
- Procurement of maintenance (own forces vs. contract).
- Procurement of signal timing plans (own personnel vs. consultants).
- Institutional issues such as union issues (e.g. union vs. nonunion employees, particularly as they relate to contractors.)

With this large number of variables, and because agencies provide essentially the same types of services in many different ways, it is essential that agencies develop a set of operations and maintenance objectives that are consistent with the agencies traffic management philosophy. The objectives should be SMART and defined in terms of *performance, reliability and function (PRF) based criteria* (as compared with *resource based criteria.)*

The following five key elements have been identified to serve as a basis for developing objective based criteria:

- Management
- Design
- Operations
- Maintenance
- Training
- Section 1.2 defines these elements and describes the Objective Oriented Operation (OOO) requirements for these elements. The Management element describes a set of candidate objectives, a subset of which may be adopted by the agency. Section 1.3 provides detailed conclusions and recommendations developed during the study.

1.2 DEFINITION OF OBJECTIVE ORIENTED OPERATION (OOO)

A. Management

Traffic signal operation is one of the transportation industry's most visible services provided to the traveling public. Therefore, it is appropriate that top management and elected leaders be attentive to and supportive of good traffic signal operations. Outlining and documenting a management approach for traffic signal operations is very important. Committing the appropriate resources (staff, funding and attention), coordinating activities, communicating with the traveler and cooperating and integrating with others are all important management activities (5).

Management practices for OOO should include the following:

1. Supervision of traffic operations by a PE and/or PTOE.
2. Availability of a mission statement and annual review. The mission statement contains a set of agency objectives. A listing of representative objectives from which the agency objectives may be developed is shown in Table 1.1. A set of representative measures is also included in the table. The measures selected by the agency should incorporate the following features:

- The measures should span the traffic system and agency functions required without significant redundancy. Be sufficiently general to encompass the different requirements of all agencies.

- Be measurable or answerable using existing information, information which can be readily obtained or information that may take some effort to collect but which is vital to the determination of the capability of the traffic system relative to the OOO.

- Minimize the need for subjective judgment to accomplish evaluation.

3. Collect and analyze data for traffic system measures selected for the mission statement. Management plans should incorporate a documented methodology for this analysis including a recommended time interval for reviews. The time interval should reflect traffic conditions, the type of network and the data collection capability of the traffic system. The interval should not, however, exceed 30 to 36 months. Continuous automatic data collection and subsequent data mining may assist in developing the database for the analysis. These measures primarily serve to identify trends in performance to provide a comparative basis for year-to-year evaluations. Based on these measurements and other requirements, a plan for required physical upgrades of the signal system or changes in the approach to signal timing and phasing should be developed. While many measures may be considered, a limited set that can be readily measured are the most useful. For systems whose mission is to provide basic signal control, a representative set might include:

    - Delay.

    - Travel time.

    - Crash analysis (13,14)

    - Intersection level of service.

    - Approaches worse than Level of Service F (control delay exceeding 80 seconds per vehicle).

4. Development and analysis of traffic system reliability data on an annual basis.

5. Availability and annual review of a Concept of Operations. Changes in functional requirements such as the need for preemption, transit priority, diversion timing plans and evacuation signal timing plans should be included in the review.

6. Compliance with the Regional ITS Architecture requirements pertaining to traffic systems.

7. Availability and annual review of a strategic management plan. The plan should have both long-range and short-range components. It should provide for the review and updating of the traffic system plant, engineering, operating and maintenance personnel requirements and purchased services. It should review the design, operations,

maintenance and training items described below. The review should be approved by the director of the operating agency. The management plan should be shared with employees.

8. Capability should be available for easy communication with the motorist. Examples include a well-publicized telephone call-in capability and an email response capability on the agency's web site.

9. Regional traffic signal operations should be established to ensure that timing plans are coordinated with those of neighboring agencies. The management approach should also consider coordination with neighboring agencies to respond to incidents and to both planned and unplanned events.

TABLE 1.1

EXAMPLES OF OBJECTIVES AND MEASURES FOR TRAFFIC SIGNAL SYSTEMS

OBJECTIVE EXAMPLES	MECHANISM TO ACHIEVE OBJECTIVE	POSSIBLE MEASURE	POSSIBLE MEASUREMENT TECHNIQUE
MOBILITY, FUEL CONSUMPTION AND EMISSIONS			
1. Reduce delay and fuel consumption for normal traffic patterns. Signal retiming should improve delay and fuel consumption by a specific minimum amount each time retiming is performed.	a. Improved signal timing. b. Improved level of traffic system control (e.g traffic responsive, traffic adaptive) c. Real time adjustment of timing by operator. d. d. Improved maintenance response time.	a. Vehicle hours delay. b. Gallons fuel reduced. c. Monitoring and tracking of citizen complaints, (provide regional 311 or equivalent phone number for reporting)	a. Travel Time & delay runs. b. Traffic system data. d. Simulation (e.g. Corsim) independent of signal timing programs. Use of traffic system data for input e. Real time performance monitoring
2. Reduce delay and fuel consumption for incident conditions and special events. New signal timing plans to support these functions should improve delay and fuel consumption by a minimum of 2% when these plans are in effect.	a. Signal timing – items a, b, c in 1 above.	Same as 1.	Simulation.
	b. Support of incident management using CCTV and other information.	Same as 1.	Simulation with reduction in incident clearance time.
3. Reduce emissions.	Same as 1.	Kg of CO, NOX, SO_2, CO_2.	Derive from gallons saved.

OBJECTIVE EXAMPLES	MECHANISM TO ACHIEVE OBJECTIVE	POSSIBLE MEASURE	POSSIBLE MEASUREMENT TECHNIQUE
SAFETY			
4. Reduce crashes resulting from left turns, red-light running and signal outages. Improvement measures should result in a 1% reduction in accidents.	Improved maintenance response time. Implementation of countermeasures to reduce crashes due to left-turns and red-light running (13,14).	Crashes reduced.	Analysis inference techniques using response time maintenance records.
5. Reduce secondary crashes resulting from incidents. Improvement measures should result in a 2% reduction in secondary accidents.	Support of incident management using CCTV and other information.	Secondary crashes reduced	Analysis inference techniques using reduction in incident clearance time.
COMMUNICATION WITH PUBLIC AND PUBLIC PERCEPTION OF SERVICE			
6. Improved public perception of signal and management center operations by 1% per year.	• Achieve other objectives. • Regular reporting to public	Rating scale.	Survey.
	Monitoring and tracking of citizens complaints (provide regional 311 or equivalent phone number for reporting) Develop and provide outreach material describing how traffic signals function and the benefits of active operations. Develop website to disseminate information and reports, provide an online feedback and complaint database.	Number of calls, complaints	Monitor number of calls, time to respond to calls and outcome of complaints received.

OBJECTIVE EXAMPLES	MECHANISM TO ACHIEVE OBJECTIVE	POSSIBLE MEASURE	POSSIBLE MEASUREMENT TECHNIQUE
7. Provide traffic information to public and private traffic information services. Improved information quality and delivery by 1% per year	Make traffic, construction, special event, incident, weather data and CCTV signals available to traffic services, media, web sites.	Rating scale.	Survey.
ANCILLARY FUNCTIONS			
8. Serve as a diversion route for corridor operations. Goal established by stakeholders.	b and c in 1 above plus availability of diversion timing plans.	Same as 1 and 3.	Corridor simulations.
9. Provide preemption for emergency vehicles and railroads. Goal established by stakeholders.	Preemption equipment.. Use of equipment must be carefully restricted so as not to cause unreasonable delay to general traffic	Number of critical mission emergency vehicles provided preemption.	Some preemption systems provide logs of preemptions granted.
10. Provide transit priority. Goal established by stakeholders.	Priority equipment used for late vehicles.	Traveler hours reduced. Variation in delay reduced	Transit records coupled with simulation with delay and delay variation criteria.
11. Support emergency evacuations. Goal established by stakeholders.	Evacuation signal timing, phasing, and lane use plans.	Availability of plans.	
MANAGEMENT			
12. Data for planning and evaluation.	Mining of detector data	Employment of data by agency or MPO.	

OBJECTIVE EXAMPLES	MECHANISM TO ACHIEVE OBJECTIVE	POSSIBLE MEASURE	POSSIBLE MEASUREMENT TECHNIQUE
13. Improve internal efficiency of department operations.	Plans and procedures, training, concept of operations and operations procedures documents.	Development of review processes to consider traffic signal operations and maintenance from planning to design and construction.	Time to implement new timing plans.

B. Signal Timing Design

Traffic signal coordination is one of the most important aspects of good traffic signal operation on arterials. Signal coordination ensures that motorists are able to travel through multiple intersections at a prescribed speed without stopping or with an absolute minimum of stops (5).

Regardless of whether an individual signalized intersection is coordinated with other nearby signals or operates totally independently, there are issues that are critical to how well that intersection operates and serves the public. Reviewing and updating the intersection-specific timing and operational aspects of individual signalized intersections on a regular basis is extremely important, especially where changes in traffic volumes and/or adjacent land uses have occurred since the last review. The issues include reviewing and updating the phasing sequence, detectors, displays, timing parameters and other related operational aspects of individual signalized intersections within a jurisdiction (5).

Signal timing design practices should include the following:

1. Review of intersection performance data every three years to determine whether geometric improvements can remedy approaches exceeding 90% saturation for 200 hours per year on weekdays and 100 hours per year at other times.

2. Review of intersection performance data for phasing and type of signal control (actuation, etc.)

3. Review of signal timing performance using a documented methodology should be performed at periods established by management plans but should not exceed 30 to 36 month periods to identify the need for retiming (see Appendix C).[1] Where automatically collected data is available, it should be reviewed at 6 month intervals to determine the need for more rapid retiming. A methodology to establish the priority of retiming requirements should be used (for example see Appendix D).

4. Retiming of signals should be performed as part of this review cycle. Data should be collected as necessary to support the retiming process. Timing plan updates should be performed using an accepted methodology such as SYNCHRO, TRANSYT 7F, etc. Retiming should be completed and checked in the field within *3* months of identifying the need for retiming.

5. Retiming should be supervised by a PE/PTOE.

6. A methodology for determining the number of daily timing plans required as well as weekend and special function timing plans should be utilized. Factors such as saturated approaches, spillback from intersections and turning bays should be given

[1] These criteria may be modified where agencies utilize adaptive systems or ACS Lite type systems.

special attention. Strategies that facilitate flow during light traffic periods should likewise be given attention.

C. Operations

Agencies should support operational practices that have been shown in the past to be effective. Operations should include the following:

1. Supervision of traffic operations by a PE and/or PTOE. Supervision should include periodic review and assessment of continuing operations and counseling employees on improving operations. Other supervisory monitoring activities include periodic review of automatically collected data and physical observation of traffic operations.
2. The data collected in Signal Timing Design Items B.3 and B.4 should be reviewed to develop a plan for required physical upgrades of the signal system. System upgrades should be accomplished in accordance with the Strategic Management Plan (Item A.7.)
3. A plan for remedying reliability deficiencies identified in item A.4 should be developed. Correction of major deficiencies not requiring major capital expenditures should be performed within three months.
4. Changes in functional requirements such as the need for pedestrian treatment, preemption, transit priority, diversion timing plans and evacuation timing plans should be identified and a plan developed for their implementation.
5. Commitment to continuing education for the professional staff.
6. Traffic systems in urban or suburban areas that are of a medium size or larger should provide a capability to monitor real time field information at a central facility for the majority of signals. Manual monitoring should, as a minimum, be provided during weekday peak periods and at such additional times as conditions may require. Smaller systems should be periodically monitored during these periods. Monitoring should include equipment failures and unusual congestion conditions. The operator should select alternate signal timing plans when conditions such as incidents or special operations require. A criterion and process should be employed to establish appropriate monitoring periods.

D. Maintenance

Maintenance practices should include the following:

1. Response time - Response time depends on two factors - time to obtain an indication of failure and time to respond after receiving an indication of failure. The following requirements apply:

    - Time to obtain indication of failure – Since closed loop systems and other centrally monitored systems provide an indication of controller failure, rapid failure identification can be accomplished using such techniques if these systems are supervised. Criteria for the percentage of failures that are initially detected within the traffic agency (as compared to reports from police, other agencies or citizens) are:

        - For systems in excess of *400* intersections *70%* of failures should be detected by the operating agency. In a dense network of coordinated signals, critical failure detection by the agency should approach 100%.

        - For systems with *400* intersections or fewer, *50%* of failures should be detected by the operating agency. Detection should be considerably higher for a dense network

    - Time to respond after receiving an indication of controller or signal failure.

        - Within one hour during business hours.

        - Within two hours during non-business hours.

    The Traffic Signal Report Cards indicate that a significant number of agencies conform to this requirement.

    A procedure to identify the level of criticality for the intersection with respect to safety and congestion should be developed. Response priorities should be developed in accordance with this procedure.

2. Rates of critical failures (e.g. controller failures, deficient cabinet or signal wiring, short circuits, lightning strikes, etc.) should not exceed F failures per year per for each intersection. Where this rate is exceeded for a period of one year, an investigation to determine the root cause should be conducted. To establish the value of F, intersection failure rates should be reviewed and the value of F set at the highest 20% of intersection failure rates.

3. Spares for the current equipment in the field should always be available.

4. A minimum of 95% of the detectors in the system should provide the system functions to the accuracy required for the application at any time.

5. Qualifications for technicians for maintenance performed by the agency or by their contractor are described in Table 1.2. Although the specific technician position titles differ among agencies the table provides a spectrum of requirements for commonly used technician grades.

6 Periodic checks of database parameters and controller settings should be performed. Procedures for software program and database configuration control should be adopted and utilized. Backups for software and databases should be maintained.

Table 1.2

Recommended Qualifications for Maintenance Personnel

Requirement	Technician 1	Technician 2	Maintenance Supervisor
General Tasks	Replacement and repair of controllers, signals, wiring and other field equipment. Works under direction.	Skills include programming of traffic controllers, troubleshooting controllers and ancillary equipment. Requires minimal direction. Provides direction and training to Technician 1 level.	Full supervisory responsibility. Supervises Technician 1 and Technician 2 levels. Greater technical knowledge than Technician 2 is required. Administrative duties include ordering spares and supplies, contract administration, budgets, provision for training.
Education and Experience	• High school (minimum). • Knowledge of electrical standards, codes, practices and repair techniques. • Certification to IMSA Traffic Signal Level I within one year of employment.	Minimum of 2 years as Technician 1 plus: • Certification to IMSA Traffic Signal Level II. • Minimum of two years experience as Technician 1.	• Combination of training, education and experience for a total minimum of five years. • Certification to IMSA Traffic Signal Level II. • Additional training beyond IMSA Traffic Signal Level II.
Physical Requirements	• Must be able to work for long periods in inclement weather. • May be required to lift heavy objects, work from bucket trucks	Same as Technician I.	

E. Training

Training practices should include the following:

1. A plan to insure that the required number of qualified personnel will be available when required. The plan should prepare for retirements and other personnel losses.

2. Support for training programs to achieve personnel proficiency requirements including the education required for continued PE and PTOE certification.

3. Support for specialized training provided by suppliers and others relating to specific equipment or software currently in use or planned.

Formation and participation in a statewide or regional traffic signal management program should be considered. Regional traffic signal management programs allow agencies to formulate operations objectives that serve both the regional and local needs, facilitate consistent traffic signal operations throughout the region and provide a collective voice to improve the resources available for traffic signal operations and maintenance.

1.3 CONCLUSIONS AND RECOMMENDATIONS

As stated by the National ITS Architecture *Traffic Signal Operations is a strategy to manage the travel demand and flow of traffic on an arterial or roadway*, At the beginning of the project, the guidance to be provided was envisioned to be defined, in large measure, by the *resources* used to accomplish these functions. The results of the literature review and the survey did not show a sufficiently strong correlation between resources provided and performance to justify defining the guidance strictly in terms of resources.[2] During the course of the effort, it was determined that agencies have different approaches to the use of resources for the signal timing process and the primary guidance should be in terms of *performance* based criteria. This was termed Objective Oriented Operation (OOO).

OOO satisfies the objectives of the jurisdiction with regard to providing a quality of service that manages delay equitably and responds in a timely way to operations and maintenance requirements. It provides services consistent with the objectives of the agency, regional and national standards of performance. Given that there is no nationally accepted standard of performance, the performance requirements should be generally consistent with those identified by the NTOC Traffic Signal Report Card, as it our best current synthesis of what constitutes good practice.

[2] The respondents estimates of detailed resource information may be in considerable error and the subjective character of agency performance estimates contribute significantly to this lack of strong correlation.

The following conclusions and recommendations are largely based on the key items described for OOO in Section 1.2 and the staffing recommendations that are summarized later in this section and described in more detail in Section 2. It is recognized that agencies whose current capabilities differ significantly from these recommendations may require considerable time to reach this capability. It is, however, important that significant progress in this direction be made each year. If it is unlikely that agencies will achieve this capability in the future because their size is not compatible with the specialized requirements of OOO, it is recommended that other means, such as contract services or combining functions with another agency or jurisdiction be considered.

1.3.1 Management Approach

Agencies generally do not implement a systematic top-down approach to management. This type of approach requires a systematic, periodic, documented review, at least annually of the department's operations and the performance of the traffic signal system. Management deficiencies common to many agencies as determined by the study that should be resolved include the following:

- Availability of a mission statement including objectives.
- Availability of an annually reviewed and documented strategic management plan that describes the available system assets and operations, plans for improvement (including plans to update signal timing). The strategic management plan should also include plans for the correction of the types of deficiencies described in this section.
- Availability of a set of measures and periodic collection and evaluation of performance data relative to these measures. Mining and analysis of automatically collected data should be used to support this evaluation.
- Communication paths that are easy for the public to use.
- Resolution of issues and servicing of requirements involving other stakeholders. Typical requirements include signal preemption, transit priority, corridor coordination, coordination of signal timing with other agencies.

1.3.2 Functionality

Operations

Many agencies do not retime signal with sufficient frequency nor do they have a systematic approach to determine the number of timing plans and their operating periods. Recommendations to correct these deficiencies include the following:

- Signal timing performance should be reviewed at periods established by management plans but should not exceed 30 to 36 month periods. Signals should be retimed using an accepted methodology. A methodology for determining the number of daily timing plans required as well as weekend and special function timing plans should be utilized.

- Review of system performance data to determine necessary phasing changes or intersection improvements.

- Systematic review of the number of timing plans needed and the periods for which they should be employed.

- Changes in functional requirements such as the need for pedestrian treatment, preemption, transit priority, diversion timing plans and evacuation timing plans should be identified and a plan developed for their implementation.

Maintenance

Once a notification of a critical field equipment failure is received, response times to repair are generally satisfactory i.e. within one hour during business hours and within two hours during non-business hours. Service deficiencies often occur under the following circumstances

- Most isolated traffic signals are neither connected to a traffic control system nor is provision made for monitoring their failure status. As a result, notification of equipment failure is often considerably delayed. It is recommended that greater emphasis be placed on providing such feedback to the cognizant maintenance facility.

- Most traffic control systems provide notification of critical equipment failure. It is recommended that when the traffic operations center is not staffed, this information be provided directly to the maintenance facility if the agency has not already made provision.

- Traffic detector repairs are often not made with the same response time as for critical equipment failures. It is recommended that a minimum of 95% of the detectors in the system should provide the system functions to the accuracy required for the application at any time.

1.3.3 Staff Qualifications, Training and Experience

Staff Qualifications

Providing sustained excellence in traffic signal operations requires qualified and well-trained professionals throughout the operating agency. Traffic signal operations rely on expertise and support at all levels, from maintenance and engineering technicians to traffic engineers for signal operations and management. Specific job classifications vary between jurisdictions due to the size of the agency, number of signals operated and staffing levels. Regardless of the number of staff or the job classification, certain core functions must be performed to develop and sustain good traffic signal operations. These functions require specific knowledge, skills and abilities. The depth of knowledge needed varies by staff position and subject matter.

In order to stratify knowledge, skills and abilities and to provide an organizing structure for the analysis of training gaps, four generic categories of traffic signal professionals were defined. The following are descriptions of these categories or positions pertaining to traffic signal operations. It is important to note that the number of positions, titles and allocation of responsibilities can and should vary based on agency size and needs. For very small agencies, the traffic engineer for signal systems and the traffic signal design engineer may be a single individual. In some cases, these roles or some portions thereof may be performed by a traffic engineering technician. Therefore, the following descriptions are illustrative, and vary among agencies (11).

TRAFFIC ENGINEER

Traffic Engineer for Signal Systems:

This is typically a supervisory and advanced professional position responsible for directing the work activities pertaining to traffic engineering and operations, including the installation, monitoring, modification, maintenance and administration of all traffic signals and signal systems within the geographic boundaries of the jurisdiction. This position ensures that signal-related maintenance activities are adequately planned and executed and that there is an adequate inventory for signal related projects. The traffic engineer for signal systems is responsible for investigating and preparing specific recommendations for all traffic-related inquiries from both the public and governmental agencies and for providing overall traffic engineering expertise. This position plans, administers and supervises the installation, alteration, maintenance and repair of all types of traffic control devices. This position also develops and administers contracts for the installation or modification of traffic signal installations.

Signal Operations Engineer:

This is typically an advanced professional position responsible for**,** among other duties, managing, directing and supervising the planning, design, implementation, optimization and distribution of timing plans for traffic signal and signal system timing projects. This position reviews and approves plans for accuracy and clarity, conformance to standards, good engineering practices and reviews the provisions for the safety of the motoring public. Depending on the size of the agency, this position may be a supervisory position responsible for managing, directing and supervising assigned personnel on timing strategies, standards and practices for traffic signal and signal systems. The signal operations engineer may manage and supervise the development, approval, implementation and optimization of timing strategies at signalized intersections and signal system corridors. This position will coordinate, plan and evaluate computerized timing software packages. It also develops and recommends new strategies and tactics for traffic signal and signal system timing, including the development of performance criteria, methods of testing and an evaluation of performance.

MAINTENANCE

Traffic Engineering Technician:

This position is typically responsible for advanced technical engineering support in the design of traffic signal control, communication systems and the operation of traffic signal systems. Depending on the size of the agency, there may be several traffic engineering technician positions with varying levels of expertise that correspond to designated technician levels. The position performs a variety of functions, including but not limited to the following:

- Provides technical assistance for traffic signal design, including phasing and calculation of timing plans;
- Uses computer-based software programs to develop optimized timing plans for individual intersections, corridors and/or networks;
- Maintains signal timing database;
- Maintains count database;
- Takes and responds to calls from the public pertaining to traffic signal operation;
- Conducts traffic signal studies;
- Conducts field reviews of signalized operations to identify problems and/or adjust timing plans; and
- Evaluates signal system operations in the field.

Signal Maintenance Technician:

This position is typically responsible for the installation, diagnostics and maintenance of all electronic equipment pertaining to traffic signal operation. Depending on the size of the agency, there may be several traffic signal maintenance technician positions with varying levels of expertise that correspond to designated technician levels. This position must have knowledge related to the application of sophisticated electronics and data communications technologies to traffic control applications, and be knowledgeable of new technologies applied to both new and old traffic control applications, including the variety of brands, models, types of equipment, systems and software that are available. Changes in traffic control technology and the greater use of telecommunications require increasingly more knowledge of electronics and greater computer literacy. The individual also requires sophisticated skills to troubleshoot and repair the latest generation of traffic electronic equipment.

Achieving OOO functionality requires a staff capable of providing the level of services required or capable of supervising qualified contract personnel. In many cases, besides the courses provided by equipment and software suppliers, there is little support for or encouragement of training. Professional training to achieve the recommended competence levels should be encouraged and supported. Required proficiency levels are summarized below.

- Agency management and supervision of signal timing and operations should be supervised by a personnel with a Professional Engineer and a Professional Traffic Operations Engineer qualifications.

- Maintenance technicians should conform to the requirements shown in Table 1.2

Staffing Levels

Achievement of OOO capability requires adequate staffing by qualified personnel. Staffing requirements are driven by the objectives (Table 1.1), performance measures selected and agency specific considerations described in Section 1.1. The following staffing guidelines are based on operating agencies interviewed under this project and other projects.

- A staffing level of 75-100 signals per engineer for agencies that operate a minimum of 150 signals will be appropriate to support the Constrained Ideal Traffic System. Smaller agencies will likely require fewer signals per engineer because economies of scale may be difficult to realize.

- A staffing level of 30-40 signals per technician for agencies that operate a minimum of 150 signals will be appropriate to support the Constrained Ideal Traffic System. Smaller agencies will likely require fewer signals per technician because economies of scale may be difficult to realize.

Giblin and Kraft (12) estimate that a per intersection annual average of 42 hours is required for preventive maintenance, 15 hours for response maintenance and 3 hours for design maintenance for a totals of 60 hours. With an estimate of 1627 hours per year of productive time available per technician, they estimate that one technician can service 27 intersections. More technician labor is required if the agency has a greater percentage of complex intersections.

2. STATE OF THE PRACTICE

This section describes the state of the practice regarding traffic signal operations and maintenance. Section 2.1 provides the results of the literature surveyed. Section 2.2 documents the results of the field survey conducted under this project as well as relevant results developed under a related survey performed by the Puget Sound Regional Council (7). Section 2.3 summarizes the operations and staffing resources required. Section 2.4 relates current agency practices to the requirements for achieving OOO capability

2.1 LITERATURE SURVEY

The following descriptions summarize key information relating to traffic operations and maintenance.

TRAFFIC CONTROL SYSTEMS HANDBOOK

This handbook provides an update to the 1996 Traffic Control Systems Handbook and covers traffic signal maintenance as part of Chapter 13, System Management. In this chapter, the authors describe the increased complexity of traffic signal systems since the previous Handbook update and how agencies have often erroneously estimated the maintenance requirements of these systems. The example given is that agencies assume that technology upgrades associated with traffic signal systems would result in fewer maintenance requirements and therefore under estimate budget and staffing needs as well as staff skill levels for them. The authors suggest that agencies perform a cost trade off analysis during the design of traffic signal system upgrades that considers the potential impacts on maintenance that follow.

The Handbook defines three types of traffic signal system maintenance activities: Functional, Hardware, and Software. Functional maintenance activities include updating traffic signal system databases and optimizing signal timing plans. The Handbook describes hardware maintenance activities as remedial, preventive, or modification. Remedial hardware maintenance includes the immediate replacement of malfunctioning or failed equipment. Preventative hardware maintenance includes scheduled intervals at which equipment is checked to minimize failure probability. Hardware modification relates to design flaws or changes identified after design that are needed to improve equipment characteristics.

For software maintenance, the Handbook describes debugging problems identified following system acceptance or the modification of the software to provide additional features.

The authors identify the possible results associated with inadequate traffic signal maintenance. These results include a potential for increases in accidents, degraded system performance, and increases in equipment malfunction or failures.

The Handbook also provides a summary of staffing surveys for various Traffic Management Centers (TMC) and their respective City/Area population, TMC, and traffic signal system sizes. The survey results are summarized here in Table 2.1.

Table 2.1

Comparison of Various Traffic Signal System TMCs in the U.S.

Location	City / Area Approx. Population	TMC Size	Number of Traffic Signals on System	Staff
Los Angeles, CA (ATSAC)	3,700,000	5500 sq ft	2912	7 transportation engineers, including 1 supervisor. 2 systems analysts, 1 graphics designer, 1 traffic signal electrician, 1 secretary
Miami-Dade County, FL	2,200,000	5000 sq ft	2020	13 employees
San Antonio, TX	1,100,000	6000 sq ft	765	1 engineer, 3 technicians
Las Vegas, NV: Las Vegas Area Computer Traffic System (LVACTS)	1,500,000 (Covers Clark County)	2500 sq ft	700	4 administrative positions. 4 traffic operations positions. 4 maintenance positions
Atlanta, GA	416,000	2300 sq ft	650	Traffic signal operations: 1 engineer, 1 senior operator, 2 operators. CCTV: 1 engineer, 1 technician
Albuquerque, NM	449,000	800 sq ft	450	4 employees (2 engineers)
Seattle, WA	600,000	1420 sq ft	432	One supervisor, two operators
Phoenix, AZ	1,300,000	1500 sq ft	400	1 supervisor, 4 technicians
Denver, CO	555,000	2800 sq ft	450	No dedicated staff for TMC. Approx 1.5 FTE, more during special events
Boston, MA	590,000	2500 sq ft	320	7-8 employees
Renton, WA	53,000	700 sq ft	96	Initially, one part-time staff member. Can accommodate up to two full-time staff members
Redmond, WA	48,000	800-1400 sq ft (currently under construction) for traffic management area. 1200-1700 sq ft for signal shop area	25 (under construction)	Control room: one supervisor, one operator Signal shop: up to five maintenance staff

2005 NATIONAL TRAFFIC SIGNAL REPORT CARD

The National Traffic Signal Report Card was developed to answer the question: How well does the nation support its traffic signal systems? The report consolidated responses of 378 agencies across the United States on this subject. The overall score and grade related to maintenance practices as well as key findings from this report are summarized below.

SUMMARY

Maintenance practices had an overall national score of 67, or D+. The minimum level of operation and critical maintenance for traffic signal systems scored high across the surveyed agencies which were mainly attributed to ensuring public safety and limiting potential for increased liability. However, despite meeting minimum requirements, other components of maintenance programs such as planning, management, and execution contributed to the overall low score.

The report defined key components of an excellent maintenance program. These components are:

- Adequate maintenance staffing (or contract staffing) for traffic signals with a recommended staffing level of 30 to 40 intersections per technician.

- Committing on-going funding to repair, replace, or upgrade signal controllers, detectors and other signal hardware.

- Including as part of the project scope of work, timely replacement or repair to sensors or detectors that are destroyed or disabled by roadway maintenance or utility activities.

- Providing and encouraging maintenance personnel to regularly attend technical training programs to familiarize themselves with the latest equipment and procedures associated with signal maintenance.

- Regular assessment of the condition of traffic signal control equipment, including verification that detectors are working properly, traffic signal controller timings are entered correctly, verification that signal displays are operational, visual assessment of the alignment of traffic signal and pedestrian displays to make sure they are visible to motorists and pedestrians, and a semi-annual comprehensive assessment of all operating conditions.

- Near real-time monitoring and emergency response, (7 days a week, 24 hours per day) for traffic signal system and intersection equipment using computer and communications facilities that provide reports to maintenance personnel within 5 minutes of detecting a failure.

- Use of a maintenance management system database that tracks equipment failure histories, so as to avoid repeated purchase of unreliable equipment, and for scheduling proactive maintenance, rather than reacting to failures after they have occurred.

- Policies or processes that define the time frame for responding to malfunctions and the agreed-upon criteria or prioritizing among multiple problems.

In order to achieve an excellent maintenance program and in turn improve scores and grades in future report cards, several needs were identified. These needs include more adequate maintenance resources, increased staffing levels, improvement training, more frequent signal hardware upgrades and timing updates, and more training for traffic signal technicians.

2007 NATIONAL TRAFFIC SIGNAL REPORT CARD

In the update to the 2005 National Traffic Signal Report Card, the report showed an increase in both score and grade related to maintenance practices. The report consolidated responses of 417 agencies across the United States and found the overall national score improved from 67 in 2005 to 70 in 2007 with a corresponding improvement in grade from D+ to C-. The key findings from this report are summarized below.

SUMMARY

The 2007 report provided more specifics on the key components of an excellent maintenance program than provided in the 2005 report by adding the following:

- Adequate policies and staffing (or contract staffing) to provide for timely response within one hour during normal business hours (within two hours outside of regular business hours) after a critical malfunction is reported.

- Regular preventative maintenance and operational reviews, including a comprehensive semi-annual maintenance review, quarterly operational reviews and annual conflict monitor testing, including formal documentation for some or all equipment.

- Complete configuration management information (for example, schematics, interconnection information and software documentation) and inventories of all traffic signal control equipment.

- Continuous malfunction monitoring notification of critical components that provide reports to maintenance personnel within five minutes of detecting a failure.

- Maintaining operation for at least 90 percent of an agency's detection system

The report findings showed that two-thirds of surveyed agencies had policies or processes to provide a traffic signal technician at intersections with a reported critical malfunction in the times specified above. In addition, 69% of the agencies reported regular preventative maintenance and operational reviews.

INTELLIGENT TRANSPORTATION SYSTEMS FOR TRAFFIC SIGNAL CONTROL (WWW.ITS.DOT.GOV)

The US DOT website provides a summary of deployment benefits, costs, and lessons learned for a number of different transportation subject matters. One of these subject matters involves traffic signal control. The website was reviewed for information on traffic signal operations and maintenance. The findings of this review are summarized below.

SUMMARY

The website described several important benefits related to proper traffic signal operations and maintenance. Examples were given of several case studies that showed optimizing signal timing as a low-cost approach to reducing congestion that ranges from $2,500 to $3,100 per signal per update. Updating traffic signal control equipment, in conjunction with signal timing optimization, was also shown in the case studies to have a positive benefit on reducing delays.

The website also provided several general rules of thumb for operations and maintenance of traffic signals. These include providing one traffic engineer for every 75 to 100 signals and one signal technician for every 40 to 50 signals and performing signal re-timings every 2-to-3 years at a minimum.

The website also described the practices needed to properly deploy traffic signal systems for maximum benefit. These practices include devoting sustained resources to the system and the professionals who design, operate, and maintain them, making wise investments in current signal hardware, timing updates, and maintenance resources, and providing training for signal technicians and engineers to ensure proper operation and maintenance of traffic signals and to preserve the investment in the hardware and timing updates.

TRAFFIC CONTROL SYSTEM OPERATIONS GUIDE (INSTALLATION, MANAGEMENT, AND MAINTENANCE)

This guide was prepared in 2000 by ITE and includes summaries of covers topics on traffic signal systems that include operations, staffing, and maintenance.

Operations

For traffic signal operations, the guide describes the monitoring devices used to determine how well traffic signal systems are operating. Among these devices are TV surveillance, detectors, dynamic message signs, and traffic signal controllers. The guide therefore stresses the need for regular care of these devices. The day to day operation is described as a number of basic tasks and procedures that include maintaining checklists, ledgers or system parameter inputs and changes, running daily summary reports, system back-up of data, and incremental improvements.

The guide also describes the use of modern computerized equipment to facilitate information processing. Over the years, the transition from paper filing systems to electronic filing systems has improved the speed and ability of operators to process information on traffic signal systems.

In addition to improved information processing, the guide describes the benefits of automated data collection. A key benefit to this includes less costly data collection efforts as compared to manual labor. The guide also describes how ITS has improved information gathering for traffic signal systems such as by providing data streams of different equipment (e.g. on-board systems of buses, and commercial truck fleets) into traffic control systems and using this information to monitor the performance of a street.

Data Synthesis, or Data fusion, is another key component of traffic signal system operations described by the guide. The data coming into the traffic control system must be in a form that is useful to the operator. It is also important for this data to be easily manageable and not require large amounts of time to reduce. Finally, the guide describes the importance data information dissemination. The information gathered through traffic signal operations is useful to a wide audience and is therefore shared with groups such as service representatives, road users, and transit patrons.

Outside of information gathering, data synthesis, and dissemination, the guide stresses the need for quality documentation of operator functions, maintenance procedures, and operating software.

Staffing

The guide also provides summaries of staffing levels from three sources: Hampton, VA, Menlo Park, CA, and NCHRP Synthesis 245. The City of Hampton surveyed 23 similar sized cities (approximate pop. 141,000) which found an average of one traffic engineer per 76 traffic signals and one traffic signal technician per 47.1 traffic signals. The NCHRP survey concluded that a traffic signal technician could maintain between 38 and 43 traffic signals. When evaluating staffing needs, the City of Menlo Park recommends one traffic signal engineer for every 100 traffic signals and one traffic signal technician for every 50 traffic signals.

From this information, the guide concludes that one single maintenance person can maintain 40-50 traffic signals or other field devices.

Maintenance

Common provisions for maintenance were also covered in this guide. The first provision covered in the guide was on the personnel required for traffic signal systems. This included a definition of five general personnel classifications including traffic signal mechanic, supervising traffic signal mechanic, traffic signal technician, traffic signal engineer, and traffic engineer. The guide also included basic guidelines for qualifications, training, and experience for each personnel classification. This guidance is as follows:

Personnel Experience Requirements

Title	Responsibilities	Experience Requirements
Engineer	Management, operations, and design; system checks; modifications to timing; supervision of daily activities	B.S. in Civil or Electrical Engineering (M.S. desirable), Engineer-In-Training (E.I.T.) or P.E., 1-3 years experience, IMSA certification
Supervisor	Supervise crews; schedule work activities; oversee maintenance, operations, and construction; issue work orders	IMSA certification, FCC license, CDL, journeyman skills level
Technician	Responsive and preventative maintenance, troubleshooting, equipment repair and installation	IMSA certification, CDL, electronics and electrical training or Associates degree
Mechanic	Troubleshooting, perform repairs and maintenance, installation of equipment	Controller and conflict monitor training, IMSA certification, master skills level

The guide also covers provision of various maintenance equipment including maintenance vehicles, test equipment and tools, replacement parts and supplies. For each of these categories, the guide offers an itemized list of equipment, estimated quantities and prices for average conditions. The guide also provides guidance on the preferred location of repair shops for traffic signal equipment as well as considerations for layout, size, organization, outfitting, staffing, and budget for these types of shops.

The importance of good maintenance records was also stressed within the guide. The records needed for effective maintenance are described as falling into maintenance service records, signal timing charts, and maintenance manuals and as-built plans. The maintenance service records include the two main types of maintenance performed by traffic signal departments which are preventive and responsive. Another type of maintenance record required of traffic signal departments described by the guide is design modifications. This includes the documentation of changes to the approved design and operation of existing system installation to corridor recurring problems, accommodate changes in prevailing conditions, or updates since installation.

The guide also provided information on estimated maintenance requirements associated with five common traffic signal configurations for example purposes. From these examples, the guide deduced that the "average" intersection requires a total of 60 hours of annual maintenance of which 70% is devoted to preventive maintenance, 25% to responsive maintenance, and 5% to design modification maintenance. The guide also concludes that signal mechanics have 1,627 estimated annual work hours to perform maintenance which translates to the capability of maintaining 17-27 intersections per year.

2.2 FIELD SURVEY

2.2.1 Overview

This section provides a summary of the survey responses received from various agencies on the FHWA sponsored Traffic Signal Operations and Maintenance Staffing and Resource Requirements questionnaire. The purpose of this questionnaire was to seek input on current traffic signal operations and maintenance practices and to use this information in the development of guidelines developed in subsequent project tasks.

The 2005 and 2007 National Traffic Signal Report Cards (NTSRC) highlight a number of better practices that are believed to contribute to effective traffic signal management, operations and maintenance processes. Table 2.2 summarizes recommendations from the report card gathered from a number of sources, for staffing and resource needs for traffic signal operations and maintenance. A survey was also conducted in conjunction with the development of this report and those survey results are presented in the following table as well.

Table 2.2

Comparison of Key Results from the National Traffic Signal Report Card

Criteria	NTSRC Recommendation	Project Survey Results
Traffic Signal O&M Maintenance Staffing	30 to 40 signals per technician	38 to 61 signals per technician (this includes the maintenance of ancillary devices as well such as CCTV, CMS, etc)
Signal Monitoring	Near real-time 24/7 monitoring of signals to provide reports to maintenance personnel within 5 minutes of automatic failure report.	24/7 monitoring of traffic systems not the rule. Most isolated intersections have no automated failure reporting capability
Critical Malfunction Response Time	Should not exceed one hour during business hours and 2 hours at other times.	Reporting agencies averaged 1.4 hours during business hours and 1.9 hours at other times.
Detection System Maintenance	Maintaining operation for at least 90% of an agency's detection system.	This goal appears to have been achieved for local actuation detectors but not for system detectors.

The section describes the survey distribution process and the feedback received from respondents. The report then compiles survey responses by the following subject areas:

- Classification of Signal System Characteristics
- Redundancy Characteristics of System
- Traffic Detection
- Timing plan characteristics

- Operations characteristics
- Maintenance practices
- Staff size and qualifications

2.2.2 Definition of Traffic Signal System Management, Operation and Maintenance

Transportation system management and operations is described by the Technical Corrections Act (6) as follows:

(A) IN GENERAL- The term ‘transportation systems management and operations’ means an integrated program to optimize the performance of existing infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services, and projects designed to preserve capacity and improve security, safety, and reliability of the transportation system.

(B) INCLUSIONS- The term ‘transportation systems management and operations’ includes—

‘(i) regional operations collaboration and coordination activities between transportation and public safety agencies; and

‘(ii) improvements to the transportation system, such as traffic detection and surveillance, arterial management, freeway management, demand management, work zone management, emergency management, electronic toll collection, automated enforcement, traffic incident management, roadway weather management, traveler information services, commercial vehicle operations, traffic control, freight management, and coordination of highway, rail, transit, bicycle, and pedestrian operations.

Concurrently with the survey conducted under this task, a related survey was conducted by the Puget Sound Regional Council (7). Results of the Puget Sound survey that are relevant to survey topics under this project are also included.

2.2.3 Survey Distribution and Respondents

The questionnaire that was distributed is included in the Appendix A of this memo. While the Traffic Signal Report Card survey provided a broad overview of operations practices and established a basis for comparatively evaluating agency performance, the survey was intended to provide an in-depth view of the practices of a limited number of agencies. It was desired to obtain responses from 10 agencies that could serve to assist in establishing the basis for superior practices, however it was only possible to obtain seven in-depth responses. The initial distribution list included a total of 34 agencies of different sizes, type, and locations. The survey was first distributed in July 2008 via email to each of the agencies. This first distribution was then followed up by subsequent reminder emails and telephone calls. Of the 34 potential respondents, a total of seven agencies provided feedback. The responding agencies and their signal system network characteristics are shown below in Table 2.3. Note that the agency names are not presented to protect the anonymity of the respondents the type of agency, state and population of the jurisdiction are germane to this discussion and are provided to characterize each survey response. Appendix B provides a tabulation of the survey responses.

Table 2.3
Survey Respondents and Traffic Network Characteristics

Agency	Agency Type	Service Area Population (Approx.)	State	Total Signals	Number of Signals in Each Network Type			Approx. % Growth in Signals/Year
					Grid	Arterial	Isolated	
A	Urban county	600,000	Florida	780	390	314	76	6%
B	City	800,000	Florida	1,001	135	415	451	Not Available
C	Urban county	800,000	New York	622	85	362	175	<1%
D	City near major city	40,000	Georgia	115	0	25	90	4%
E	City	350,000	Californi a	300	180	80	40	1%
F	County	900,000	Maryland	800	200	525	75	1%
G	DOT	N/A	Georgia	2800	350	1050	1400	3%

Table 2.4 shows a partial set of responses regarding the operational characteristics of these traffic signal system networks. Those agencies providing responses on this indicated that traffic volumes were growing in the range of 1% to 5% and the level of saturation experienced.

Table 2.4
Traffic Network Operations

Agency	Approx. % of signals operating under saturated conditions*		Total Signals
	Peak hour	At least one hour outside of peak hour	
A	30%	30%	780
C	3.2%	0.8%	622
D	15%	5%	115
E	60%	50%	300
F	40%	50%	800
G	15%	2%	2800

*Examples of saturated conditions include cycle failure (failure of a motorist to be serviced by the green phase subsequent to his arrival), long persistent queues and volume to capacity ratios that closely approach or appear to exceed 100%.

Traffic delays increase modestly until a volume to capacity ratio of approximately 0.9 is reached, at which point delay increases exponentially. Thus the capability of an agency's staff to identify saturation or near-saturation conditions (by on street observation, CCTV observations and data mining) and to remedy the situation strongly influences the level of delay that motorists will experience.

Additionally, it was found that these agencies operate traffic management centers. The hours of operation for these centers varied from nine (9) hours per day to 17 hours per day. Three of the agencies reported co-location in their traffic management centers with other operators such as Department of Transportations, State Police Departments, Transit, 911, and Emergency Operations.

2.2.4 Classification of Signal System Characteristics

The respondents were asked to provide an inventory of the field devices and operational strategies used with their traffic signal system. This included traffic signal controllers, traffic detectors, ancillary devices, and communication systems.

Traffic Signal Controllers

The type and age of the equipment has a bearing on some of the challenges that a municipal traffic engineer faces, the premise being that the greater the number of different types of equipment present in a signal system, the more difficult it is to operate and maintain. This additional difficulty results from the additional spares inventories required as well as the additional training and configuration management required. Similarly, it is likely that an agency that uses older technology will have differences in hardware and software that may result in different operations, making troubleshooting more difficult for the technician in the field. The traffic signal controller classifications used by the respondents are summarized in Table 2.5.

Table 2.5
Traffic Signal Controller Inventory

Agency	Standard Classification				Controller Age		
	Type 170	ATC/ 2070	NEMA TS1	NEMA TS2	<5 Years	Between 5 & 10 Years	> 10 Years
A	0%	0%	40%	60%	25%	67%	8%
B	6%	17%	69%	8%	27%	13%	60%
C	0%	0%	35%	65%	10%	55%	35%
D	0%	97%	0%	3%	100%	0%	0%
E	0%	60%	40%	0%	27%	40%	33%
F	0%	0%	0%	100%	0%	75%	25%
G	0%	100%	0%	0%	36%	64%	0%

The agencies operate all of their traffic signal controllers in time of day mode with the exception of Agency A which operates approximately 12% of their network using traffic responsive mode. The number of timing plans used varied from three to seven plans per weekday and from two to four plans per weekend day or special event. The agencies reported using other non-periodic timing plans as well such as during emergency evacuation plans, detour plans, heavy volume plans. Agency A also reported the operation of peak and off-peak seasonal plans that take into account fluctuations in traffic volumes at different times of the year. The Puget Sound Survey reported that traffic responsive operation was used by 15% of the agencies.

Four of the respondents reported retiming at three year intervals or less and one respondent reported retiming at five to seven year intervals. Two respondents retime on an as needed basis. One of these agencies uses aircraft and cameras to assist in determining the need for retiming.

Traffic Detection

The respondents also provided a breakdown on the traffic detection strategies employed at their intersections. This breakdown is shown in Table 2.6.

Table 2.6
Traffic Detection Configuration

Agency	Fully Actuated Configuration		Semi-Actuated Configuration	No Detection
	Advanced & limit line detection on main street, limit line detection on side street approaches	Advanced detection on main street & limit line on side street	No detection on main street, limit line detection on side street.	
A	1%	98%	1%	0%
B	75%	12%	0%	13%
D	100%	0%	0%	0%
E	30%	70%	0%	0%
F	5%	5%	75%	15%
G	2%	93%	5%	0%

Five of the agencies surveyed also provided estimates on the percentage of operable local actuation detectors. These agencies reported very high percentages (90% or greater). The agencies periodically check the operability of their traffic detectors through preventative maintenance programs, routine monitoring of central system software, and when complaints are made.

The survey results also showed that only one of the agencies is analyzing detector data on a regular basis. This data is being used to determine spot traffic flow conditions, real-time volumes, peak hours, and yearly daily traffic volume trends.

The Puget Sound survey reported that 28% of the agencies did not send real-time traffic information to a central computer or master controller.

Ancillary Devices

The ancillary devices also maintained by the responding agencies are provided in Table 2.7. These devices include emergency preemption/transit signal priority equipment, Closed Circuit TV (CCTV) cameras, Changeable Message Signs (CMS), and Uninterrupted Power Supplies (UPS).

Of the six agencies that reported using CCTV cameras operated by that agency, four reported on the use of these cameras to support on-line adjustment of timing plans, planning for signal timing/phasing, and incident management. One agency reported using CCTV monitoring to support on-line adjustment of timing plans and incident management and another agency uses CCTV only for incident management.

Table 2.7
Ancillary Devices (Number of Units)

Agency	Preemption/ Priority	CCTV	CMS	UPS
A	20	3	0	18
B	50	0	0	4
C	351	75	2	0
D	60	9	0	9
E	1	60	13	0
F	25	180	0	0 (near term plans includes installation of 250 UPS units)
G	70	2	0	100

The Puget Sound survey determined that 79% of the agencies used CCTV to monitor traffic and that 53% of these agencies used the cameras for incident management as well. 23% of the agencies used CMS.

Communication Systems

The survey sought information on the various types of communication systems being used by agencies with their traffic signal systems. These communication systems provide a data transfer link between traffic signals and in some cases provide a means for communicating remotely to a traffic management center. Table 2.8 provides a summary of the survey results showing the number of signals within each communication system type.

Table 2.8
Communication Systems (Approximate number of signals)

Agency	Total Signals	None (Isolated)	7-wire Cable	Twisted Wire Pair	Fiber Optics	Coaxial Cable	Wireles s
A	393	76	0	292	5	0	20
B	1000	450	0	30	193 directly; 319 remotely	0	8
C	620	175	10	20	100	305	10
D	104	34	0	0	70	0	0
E	250	60	0	170	7	0	13
F	800	0	0	800	0	0	0
G	2800	1950-2250	0	200	300-500	0	50

For the isolated traffic signals, the survey respondents indicated that only one agency uses automatic failure reporting at some locations. The respondents also indicated that portions of their traffic signal system operate with remote monitoring capabilities either as a closed loop system or through central control. The information provided on this capability is presented in Table 2.9.

Table 2.9
Number of Traffic Signals with Remote Monitoring Capabilities

Agency	Closed Loop	Central Control
A	0	314
B	550	0
C	47	405
D	80	0
G	750 (additional 150 isolated intersections report failures)	0

The number of traffic signals reported in the table above includes coordinated systems as well as isolated locations. The redundancy characteristics of the traffic signal systems were also reported on by the survey respondents. This included redundancy of central controls and both backbone and distribution communication systems. The redundant characteristics of the central controls included software/server based systems that can be transferred to backup systems as needed, spare data storage and communication servers, and regular off-site backup of system data.

The agencies reported accomplishing redundancy with their backbone and distribution communication systems by providing alternate paths in the case of communication breaks.

2.2.5 Staff Levels and Qualifications

The number of staff responsible for traffic signal operations and maintenance along with their required qualifications were also provided by the agencies participating in this survey. This information is presented in Table 2.10 and includes the number of personnel in each of the identified positions. Where data was available, the qualifications, training, and experience level is also provided.

Analysis of the Puget Sound survey data for agencies operating in excess of 150 signals found that the number of maintenance technicians ranged from 18.4 to 78.9 per thousand signals. The large differences may be attributable to varying definitions of labor categories and maintenance tasks.

The data in Table 2.10 was analyzed according to the following Knowledge, skills and abilities categories described in Section 1.3.3.[3]

Table 2.10
Staff Levels and Qualifications

Agency	Total Signals	Number of full time equivalent positions[2]			Qualifications, training, experience level
		Management / Traffic Engineer/ ITS Engineer	Traffic Signal Analyst/ TMC Operator	Traffic Signal Maintenance Tech./ Electronic Specialist	
A[1]	393	3.5	4.5	10	Require minimum of three years electrical experience, IMSA II, and IMOT certification for Traffic Signal Maintenance Technicians
B	1000	2	1	16	IMSA certification for technicians
D	104	2	1	6	Require Management to have P.E + 10 years of experience, Traffic Signal Engineer to have P.E., PTOE + 10 years of experience, Traffic Signal Analyst/Tech. to have 10 years of experience
E	250	5	9	5	No certifications required for engineers or technicians

[3] Categories correspond to the those defined in Row, S., Tarnoff, P.J. *Traffic Signal Training Assessment Summary Report 7*, Federal Highway Administration, July 2005.

Agency	Total Signals	Number of full time equivalent positions[2]			Qualifications, training, experience level
		Management / Traffic Engineer/ ITS Engineer	Traffic Signal Analyst/ TMC Operator	Traffic Signal Maintenance Tech./ Electronic Specialist	
F	800	5	7	14	No certifications required for engineers or technicians
G	2800	16	0	46	No certifications required for engineers or technicians

[1]Agency A also reported a public relations position that serves traffic signal operations and maintenance which is not reflected in the table.

[2] The survey results found that agencies use a variety of job descriptions to characterize the typical functions of these positions. Therefore, the table generalizes these positions into the three categories shown.

The survey also provided information on the average tenures of both engineering and maintenance staff. The average tenures of engineering staff was found to be between five (5) and twelve (12) years while the average tenure of maintenance staff was found to be between five (5) and twenty (20) years.

Table 2.11 shows a comparison of these results for the medium and larger signal systems. The analysis is approximate in that the categories in Table 2.9 do not directly correspond to the questionnaire categories.

Table 2.11
Comparative Staffing by Agencies

Agency	Number of Signals	Number of signals per staff	
		Traffic Engineer	Maintenance
A	383	85	35
B	1000	500	63
E	250	33	33
F	800	160	57
G	2800	175	61

The widespread variations in the engineering areas are at least partly attributable to the definitions of the positions by different agencies. Analysis of the Puget Sound data indicated that for agencies operating in excess of 150 signals, the number of maintenance technicians ranged from 18.4 to 78.9 per thousand signals. These large differences are most likely attributable to differences in labor categorizations, combined task assignments and variations in the definitions of maintenance tasks.

2.2.6 Maintenance Practices

The survey included a number of questions regarding maintenance of traffic signal systems. The feedback provided insights on the allowable and actual practices used by each agency when responding to maintenance requests. Feedback was also provided on the distance between traffic signals and maintenance facilities. The information provided is summarized in Table 2.12 and Table 2.13.

Table 2.12
Proximity of Traffic Signals to Maintenance Facilities

Agency	5 miles or less	Between 5 and 10 miles	Greater than 10 miles
A	76	57	257
C	481	125	20
D	100	15	0
E	170	120	10
F	200	500	100
G	175	250	2375

Table 2.13
Maintenance Response Times

Agency	Signal Failure Repairs during Business Hours		Signal Failure Repairs during Non-business Hours		Ancillary Equipment Failure Repairs		Communication System Failure Repairs during Non-business Hours
	Allowable	Actual	Allowable	Actual	Allowable	Actual	
A	2 hours	1 hour	4 hours	2 hours	48 hours	24 hours	48 hours
E	1 hour	1-2 hours	2 hours	1-3 hours	2 weeks	From 2 hours to 3 days	2-3 days
F	0.5 hours	0.5 hours or less	0.5-1 hour	1.5 hours or less	Dependent upon device	Dependent upon device	30 minutes
G	2 hours	2 hours	2 hours	2 hours	Typically one week	Typically one week	Typically one week

In addition, several of the responding agencies reported on the annual number of traffic signal controller failures. The information provided showed a range of failures from less than 1% per year to more than 10% per year.

2.2.7 General Observations

The following additional observations were made based on a review of the survey responses.

Signal Operations

- There is a suspected relationship between the degree of traffic congestion in cities and counties and their staffing levels.

- Isolated signals generally do not have the capability to automatically report failures.

  - There is some use of changeable message signs (CMS) and increasing use of CCTV. Where available, CCTV is used for on-line adjustment of signal timing, planning for signal timing and phasing and incident management.

  - Although most signals have some form of detection, and in many cases the detector data is available at the TMC, this data is generally not mined or reviewed for intersection performance, or reviewed to determine the need for signal timing updates.

  - PE and/or PTOE certification is generally not required for signal system engineers (the survey sample may be too small to form a general conclusion.)

Maintenance

- Field maintenance of controllers is generally accomplished quickly (0.5-2 hours during business hours and 1-3 hours during non-business hours).

- Maintenance of detectors and other devices may not be performed for prolonged periods.

- On the average, controllers are from five to ten years old.

- Certification of maintenance technicians is required by some agencies but not by others. There is no consistent pattern.

- There is a wide variation in controller failure rate. Determining the causality of this variation might yield productive modifications to maintenance practices.

Management

- There is little general use of measures of effectiveness measures or performance reports.

- Future planning cycles generally range from three to five years.

- Provisions for feedback from the public vary considerably in ease of accessibility among agencies.

- Mission statements, concepts of operations and operations procedures are generally not provided by agencies.

- Training provisions are generally inadequate and not systematized.

- Funding inadequacy appears to play an important role in management and operational deficiencies.

2.3 OPERATIONS AND MAINTENANCE STAFFING AND RESOURCES

2.3.1 Introduction

A traffic signal system conforming to Objective Oriented Operation (OOO) provides performance, reliability and functional requirements necessary to achieve a high quality of operation at a reasonable cost. This section identifies the resources that are most likely to be needed to achieve OOO. The resources include sufficiently qualified personnel and the staffing levels required to implement the functions. An estimate is provided for signal retiming costs.

While an agency's ability to achieve operational objectives is related to budget and number of staff management approach, staff commitment, dedication and training are intangible elements that dictate how effectively an agency can operate and maintain a traffic signal system. The level of maintenance and operations is not only affected by the agency's perception of its importance but also by the public's perception. Under budgetary constraints, cutting programs for training and professional development provides short-term relief but undermines the long-term viability of the system's operation and maintenance.

2.3.2 Resource Requirements for Traffic Engineering

The person responsible for traffic system engineering (planning, system operations, equipment selection, signal timing) should have professional engineering (PE) registration and should preferably have professional traffic operations engineer (PTOE) certification. Other engineering personnel should either have these qualifications or be in the process of actively pursuing their acquisition.

Staffing Level for Traffic Engineering Personnel

Table 2.14 provides a summary of the engineering staffing levels developed by various references:

Table 2.14
Number of Signals per Traffic Engineer

Reference	Number of Signals per Traffic Engineer
Traffic Control System Operations: Installation, Management and Maintenance (12)	75-100
Survey performed under this project	Average: 185

Reference	Number of Signals per Traffic Engineer
Survey performed under Puget Sound Regional ITS Implementation Plan (7)	Average: 67. For agencies with over 150 signals the average s 93. Median: 62. For agencies with over 150 signals the median 81. 62% of the responding agencies felt that their staff size was inadequate.

Survey responses show wide variations in comparative staffing levels. To some extent, this reflects the phraseology used for the survey questions and varying interpretations by the respondents. Based on the table above, it appears that a staffing level of 75-100 signals per engineer for agencies that operate a minimum of 150 signals will be appropriate to support OOO. Smaller agencies will likely require fewer signals per engineer because economies of scale are difficult to realize. The engineering staff to support these functions should, as a minimum:

- Provide for the collection and analysis of traffic and accident data to determine the need for retiming, rephasing, and pedestrian treatment on a 30 to 36 month basis. Retiming should follow in a timely manner.
- Analyze traffic system reliability data annually to determine those locations where unusual equipment failure rates result in excessive delay and safety problems. Steps to remedy these conditions should be planned and implemented.
- Collect, analyze and report data yielding measures of effectiveness, in order to assess the quality of the traffic signal service being provided. Develop strategies to remedy deficiencies including traffic system and geometric upgrades.

2.3.3 Cost of Signal Retiming

The cost of signal retiming generally lies within the $2500-$3500 per intersection range (8,9). Table 2.15 provides a typical consultant's estimate of the time required per intersection to accomplish key activities associated with signal timing.

Table 2.15
Person Hours for Key Signal Timing Activities (10)

Task	Person Hours per Intersection
Project management	0.8
Weekday turning movement counts	19.8
Saturday turning movement counts	4.6
Field intersection inventory	1.5
Qualitative assessment	1.5
Signal timing analysis	7.5

Task	Person Hours per Intersection
Fine tuning	6.0
Final delivery	1.3

2.3.4. Resource Requirements for Maintenance Personnel

Qualifications

Personnel in agencies that perform their own maintenance should conform to the following as a minimum (agencies that contract maintenance services should require contractors with similar qualifications):

The technician in charge of signal maintenance should have the following qualifications:

- Combination of training, education and experience for a total minimum of five years.
- Certification to IMSA Traffic Signal Level II.
- Additional training beyond IMSA Traffic Signal Level II.

The number of subordinate positions depends on the number of signals for which the agency is responsible. Qualifications for two subordinate levels are described below:

Technician 2 - Minimum of 2 years as Technician 1 plus: certification to IMSA Traffic Signal Level II.

Technician 1-

- High school (minimum).
- Knowledge of electrical standards, codes, practices and repair techniques.
- Certification to IMSA Traffic Signal Level I within one year of employment

In addition, all technician levels must be able to work for long periods in inclement weather and may be required to lift heavy objects and work from bucket trucks.

Staffing Levels for Maintenance Personnel

Table 2.16 provides a summary of the maintenance technician staffing levels developed by various references:

Table 2.16
Signals per Technician

Reference	Signals per Technician
2005 Traffic Signal Report Card recommendation	30-40

Reference	Signals per Technician
Traffic Control System Operations: Installation, Management and Maintenance (12)	*40-50*
Survey performed under this project	Average: 51
Survey performed under Puget Sound Regional ITS Implementation Plan (7)	Average: 24 for all agencies, 29 for agencies with over 150 signals. Median: 21 for all agencies, 30 for agencies with over 150 signals

Variations in the data are significant. In particular, data for the smaller agencies tends to vary to a greater extent and to skew the averages. Based on the table above, it appears that a staffing level of 30-40 signals per technician for agencies that operate a minimum of 150 signals will be appropriate to support the Constrained Ideal Traffic System. Smaller agencies will likely require fewer signals per technician because economies of scale are difficult to realize.

2.4 Evaluation of Agencies Relative to CITS Criteria

This section relates agency practices to OOO criteria. Section 2.4.1 describes this relationship for the agencies interviewed under this project while Section 2.4.2 provides a general over view of current practices relative to these criteria.

2.4.1 Evaluation of Agencies Surveyed

The interview responses were evaluated using the OOO criteria described in the preceding sections. A scale of 1-5 (5 being the best) was used to rate the interview responses against certain of these criteria. Table 2.17 describes the specific criteria used in the evaluation. A score of 5 represents achievement of OOO criteria. The results of this analysis are shown in Table 2.18. That table, and the survey responses themselves, were used to develop the evaluations described below.

Table 2.17
Survey Evaluation Criteria

Management
1. Planning – Availability of planning procedures and documentation (mission statement, annual reviews, concept of operations, regional ITS architecture conformance, strategic plan) provides a rating of 5.
2. Data mining – Collection and analysis of traffic data on a 30-36 month basis to determine timing plan needs and evaluate system performance provides a rating of 5.

Operations
1. Monitoring at TOC – For the larger agencies, 24/7 monitoring is preferred (score of 5) while monitoring during weekday peak periods and at other critical times is awarded a score of 4.
2. Personnel qualifications – A score of 5 is awarded if the traffic engineering staff and timing plan preparation is supervised by a PE or PTOE.
3. Use of CCTV – The use of CCTV (and in some cases aircraft) is an estimation of the anecdotal capability to identify traffic signal timing problems. A score of 5 represents CCTV coverage of a minimum of one-third of the intersections
4. Number of timing plans – This is a measure of the agency's likely performance as well as the agency's intent to span the coverage of needs. The availability of 6 or more timing plans is awarded a score of 5.
5. Frequency of timing plan update – A score of 5 represents updates at two year intervals or less, 4 represents 2 to 3 year intervals and 3 represents 3-5 year intervals. Lower scores are awarded for longer periods.
Maintenance
1. Time to obtain indication of critical failure – Automatic failure reporting is necessary to achieve acceptable performance. To receive a score of 5, for systems in excess of 400 intersections, 70% of these failures should be detected automatically. For smaller agencies, 30% of the failures should be detected automatically. Lower scores are awarded for less detection capability.
2. Time to respond after receiving indication of critical failure – To receive a score of 5, a response within one hour during business hours and within two hours during non-business hours is required. Lower scores are awarded for longer response periods.
3. Maintenance technician qualifications and training – A score of 5 is awarded if IMSA or equivalent certification is required and training resources are available. Lower scores are awarded for lesser levels of certification and training provisions.

Table 2.18
Evaluation of Agencies Relative to Constrained Ideal Traffic System

	AGENCY								
	A	B	C	D	E	F	G	Total Responses	Average Score
Management									
1 Planning documentation	4	2	-	2	1	3	3	6	2.5
2 Collection, analysis and review of data	1	2	2	4	1	1	3	7	2.0
Operations									
1 Monitoring at TOC	4	3	4	2	4	5	1	7	3.3
2 Personnel Qualifications	1	1	1	1	4	1	1	7	1.4
3 Useof CCTV	2	1	3	5	5	5	1	7	3.1
4 Number of timing plans	5	5	5	5	3	2	3	7	4.0
5 Frequency of timing plan update	4	2	-	5	3	-	5	5	3.8
Maintenance									
1 Notification of critical failures	5	1	2	1	5	5	1	7	2.9
2 Time to respond after notification	5	5	-	4	4	5	4	6	4.5
3 Training and qualifications of maintenance staff	5	5	-	3	2	3	3	6	3.5

2.4.2 Overview of Current Practices

Management, Operations And Signal Timing

Within the limitations of their resources, agencies generally strive to provide operations and maintenance services to the extent possible. Most of the agencies interviewed, however do not manage in a top down fashion, i.e. they do not generally systematically collect and analyze data and make systematic reviews of traffic system performance using established measures have procedures.

Among the agencies interviewed, the number of timing plans employed and the frequency of timing plan updates, while somewhat deficient, probably do not constitute the most serious deficiency. The agencies do not generally analyze detector data collected by the traffic systems for the purpose of determining the number of timing plans needed and the time periods for which they are required. These values appear to be established by anecdotal or judgmental means (that appear to be influenced by the increasing use of CCTV and, in one case, by surveillance aircraft.) This statement is supported by a the following similar observation in Tarnoff and Ordonez (1) *"…more than 98% of the jurisdictions rely on engineering judgment to determine the best times of day for new plans. It must be emphasized that in many cases this approach is highly appropriate. However it is possible that within the 109 agencies that responded to this question, there are situations where a more quantitative approach should be used."*

While the problem may, in part, be caused by the lack of qualifications on the part of the engineering staff, the deficiency principally appears to stem from:

- The lack of a management plan for the review and evaluation of detector data and the determination of deficiencies, need for new timing plans, number of timing plans and for the time periods for which the plans should be employed.

- The lack of guidance material and analysis tools for developing these requirements.

Maintenance Practices

While the response to field failures when the agency is notified of a failure is generally satisfactory, the following deficiencies are apparent among the responding agencies:

- No capability is generally provided for control equipment at isolated intersections to report failures. Thus agencies whose operations include a significant percentage of isolated intersections are not able to detect these failures in a timely way.

- Many agencies substandard personnel qualification criteria and training programs.

2.4.3 Relationship of Agency Practices to Objective Oriented Operation (OOO)

Table 2.19 compares characteristics of currently operating traffic systems with OOO criteria. The first column of Table 5.1 summarizes the general features that may be used to characterize a traffic control system. These are described in more detail in Section 3. The remaining columns classify how systems of different quality generally address these characteristics. Column A summarizes the CITS approach. It is generally characterized by strong management planning and control that in turn leads to the use of systematic processes for signal timing operation, and management of the entire signal system operation. It generally corresponds to a NTOC Report Card rating of A. Column B describes systems that range in performance from below CITS requirements to just above minimally acceptable operation. These systems generally correspond to Report Card Ratings of B or C. Column C describes systems that do not generally provide acceptable responsiveness to the transportation needs of the community and correspond to Report Card ratings of D or F.

TABLE 2.19

COMPARATIVE KEY CHARACTERISITICS OF TRAFFIC SYSTEMS

Characteristic	A. Constrained Ideal Traffic System (CITS)	B. Generally Above Average Systems that do not Meet CITS Criteria	C. Traffic Systems with Below Average Performance
Management			
- Supervision by PE and/or PTOE	Always.	Usually.	Usually.
- Planning reviews and documentation (mission statement, management plan, concept of operations, operating procedures)	Reviews and updates of items needed on annual basis.	All items may not be available. Reviews and updates non-periodically.	Most items not available.
- Performance monitoring and annual review to determine deficiencies and needs	Comprehensive and systematic monitoring program and review processes.	Monitoring may be limited to key areas or routes and may not be performed periodically.	Little systematic attention, usually reactive to crises.
- Communication path to public, surveys	Well publicized and easy to use, proactive outreach.	Responds to public contact but does not proactively seek.	Minimal attention.
- Conformance with Regional ITS Architecture and interaction with other stakeholders	Proactive participation	Responds to requests generated by others	Minimal participation

Characteristic	A. Constrained Ideal Traffic System (CITS)	B. Generally Above Average Systems that do not Meet CITS Criteria	C. Traffic Systems with Below Average Performance
Timing Plan Design			
- Signal timing reviews and updates	30 to 36 month updates using a documented methodology. May be reviewed more frequently if automatically collected data is available and processed.	3 to 5 year updates.	Greater than 5 years, often in response to crises or other stakeholder requirements.
- Number of timing plans	Methodology used to determine number of daily plans needed. Sufficient number of plans provided to support daily needs, special events, weekends, diversion plans, transit needs, Spillback and saturation given special attention.	Number and duration of plans determined by traffic engineer's experience.	Relatively few plans available.
Operations			
- Real time traffic condition monitoring	Adequate surveillance capability available for development of measures. CCTV at key intersections.	Surveillance capability only able to provide partial measures. Little CCTV.	Little operative surveillance capability except for detectors used for local actuation. No CCTV.
- Equipment failure monitoring	Failure monitoring available and operative for all signals featuring traffic progressions. Failure monitoring available and operative for most isolated signals.	Failure monitoring generally available and operative for signals featuring traffic progressions, but not for isolated signals.	Failure monitoring sometimes available and operative for signals featuring traffic progressions, but not for isolated signals.
- Plan for upgrades	Periodic review of data to determine need for geometric and signal system upgrades with emphasis on bottleneck and saturation relief.	Reviews usually non-periodic or as required by other stakeholders.	As required by other stakeholders.
- Traffic management center operational periods	Weekday peak periods and at other times as warranted by traffic conditions. For moderate and major metropolitan areas this usually includes all day for weekdays except for evening and early morning periods.	Weekdays but certain key periods may not be covered. Varies for other key periods.	Traffic systems usually monitored periodically but not continually.
- Changes in functional requirements (e.g. preemption, transit priority, etc.)	Periodic review and implementation.	Non-periodic review or response to other stakeholders.	Response to other stakeholders.

Characteristic	A. Constrained Ideal Traffic System (CITS)	B. Generally Above Average Systems that do not Meet CITS Criteria	C. Traffic Systems with Below Average Performance
Maintenance			
- Time to obtain indication of failure	For systems in excess of 400 intersections, 70% of failures should be detected by the operating agency, for fewer intersections, 30% of failures should be detected by the operating agency.	Generally does not achieve CITS capability	Generally does not achieve CITS capability
- Time to respond after receiving an indication of controller or signal failure	Within one hour during business hours. Within two hours during non-business hours	Within two hours during business hours. Within four hours during non-business hours.	May be longer than for Column B.
- Maintain detector operation	Minimum of 95% of detectors operational.	May not achieve 95% operability.	Considerable percentage of detectors often inoperable
- Maintenance Personnel qualifications	Meet qualifications stated in Section 4 or well managed contractor support	Objective is to meet CITS qualifications.	Personnel with lesser qualifications or poorly managed contractor support.
- Preventive Maintenance	Formal program	May have formal program	Usually no program. May correct potential problems if observed as a result of inspection for other issues.
Training			
Personnel planning	Plan to assure that the number of required personnel will be available	General staffing plan for budgeting purposes	General staffing plan for budgeting purposes
Support for Training	- Support for training programs to achieve proficiency requirements - Support for specialized training	- Support to achieve proficiency requirements varies significantly - Support for specialized training	Support for specialized training

References

1. Tarnoff, P.J. and J. Ordonez, *Signal Timing Practices and Procedures,* Institute of Transportation Engineers, March, 204.

2. Gordon, R. L. *Systems Engineering Processes for Developing Traffic Signal* Systems, NCHRP synthesis 307, Transportation research Board, 2003.

3. Gordon, R.L. and Tighe, W., *Traffic Control Systems Handbook*, FHWA Report FHWA-HOP-06-006, Federal highway Administration, October, 2005.

4. Pline, J.L., *Traffic Engineers Handbook*, Institute of Transportation Engineers, 1999.

5. *National Traffic Signal Report Card – Technical Report* 2007, National Transportation Operations Coalition.

6. *H.R. 1195: SAFETEA-LU Technical Corrections Act of 2008.*

7. *Puget Sound Regional ITS Implementation Plan*, Puget Sound Regional Council, August 7, 2008.

8. *Intelligent Transportation Systems for Traffic Signal Control,* U.S. Department of Transportation.

9. Hood, W. Private communication.

10. Fee Estimate – Millennia Mall Retiming and Scope and Schedule-Millennia Mall Retiming (Bid submitted to the City of Orlando, FL in October 2005 by TEI Engineering).

11. Row, S. and P. J. Tarnoff, *USDOT, FHWA Traffic Signal Training Assessment –Summary Report*, Institute Of Transportation Engineers, University of Maryland, June 29, 2005.

12. Giblin, J.M. and W.H. Kraft, *Traffic Control Systems Operations – Installation, Management and Maintenance,* Institute of Transportation Engineers, 2000.

13. Antonucci, et al, NCHRP Report 500, *Guidance for Implementation of the AASTO Strategic Highway Safety Plan, Volume 12:A Guide for Reducing Collisions at Signalized Intersections,* Transportation Research Board, Washington, D.C., 2004.

14. *Making Intersections Safer:A Toolbox of Engineering Countermeasures to Reduce Red-Light Running,* Federal Highway Administration/Institute of Transportation Engineers, 2003.

Appendix A
Questionnaire

TRAFFIC SIGNAL OPERATIONS AND MAINTENANCE STAFFING AND RESOURCE REQUIREMENTS GUIDELINES

QUESTIONNAIRE

May 16, 2008

Background:

The 2005 Traffic Signal Report Card assigned a grade of D- nationally to traffic signal operations and maintenance practices. It is generally assumed that deficiencies in traffic signal operations and maintenance are the direct result of insufficient funding and staffing to optimally accomplish these tasks. While significant variability may exist among agencies in terms of system size, complexity, geography, demographics, locality, state, regional and local transportation priorities, politics and so forth; it is feasible that detailed guidance about staffing and resource based on functionality can be developed. The current guidance available is very general and not achievable for most jurisdictions.

The ITE Traffic Engineering Handbook and Traffic Control System Operations: Installation, Management and Maintenance publication are often referred to when establishing staffing and resource requirements for traffic signal operations. These documents suggest labor requirements of 20 to 25 hours per intersection for traffic signal retiming and estimates as a rule of thumb that one traffic engineer is needed to properly operate and maintain every 75 to 100 signals and one technician to operate and maintain every 40 to 50 signals. As a rule of thumb these estimates are adequate; however the current transportation environment requires much more detailed estimates.

The lack of a credible guideline for traffic signal operations and maintenance staffing and resource needs has resulted in the inefficient operation and maintenance of traffic signals on a national scale. Ineffective operation and maintenance of traffic signals has serious safety implications and contributes to thousands of hours of unnecessary traffic delays and congestion on both local and major arterial systems and road networks. An improved understanding of the relationship of performance to operations and maintenance resources expended is desired.

The objective of this FHWA sponsored project is to develop a guideline to assist agencies in developing a staffing and resource plan to effectively operate and maintain traffic signal systems. Science Applications International Corporation (SAIC) and its sub-consultants, Dunn Engineering Associates and Kittelson Associates have been tasked by FHWA to conduct a study to establish these requirements. As part of this study we are conducting a series of in depth interviews to identify the operational and maintenance requirements for an ideal traffic system that must conform to real world constraints and resource limitations. The interviews are structured according to the questionnaire that follows. We appreciate your participation to help us accomplish this objective.

Please provide the following information on the system and on the traffic signal operations that your agency is responsible for.

A. Traffic Network Characteristics

1. Number of signals in each type of network

Type of Network	Grid	Arterial	Isolated
Number of Signals			

2. % AADT growth per year

3. % signals operating under saturated conditions during peak hour

4. % signals operating at saturated conditions for at least one hour in excess of peak hour

5. Type of jurisdiction (major city with large number of grid signals, suburban jurisdiction with low population density, county with widely spaced intersections, state DOT with wider expansive distance between intersections (e.g. 50 miles or more)

6. % growth in signals/year

B. Classification of Signal System Characteristics

Please provide number or percentage of signals in each category (those items marked * relate to signals that actually operate under the conditions described).

1. Adaptive (e.g. SCOOT, SCATS, OPAC, RHODES)*

2. Closed loop with data development tools (e.g. ACS Lite) including isolated signals are controlled by this type of system*

3. Closed loop or central control (UTCS type) including isolated signals that are controlled by this type of system*

4. Other type of interconnected system*

5. Isolated signals with automatic failure reporting*

6. Isolated signals without automatic failure reporting

7. Proximity of signals to maintenance facility

    a. Number of signal within 5 miles of maintenance facility

    b. Number of signals between 5 and 10 miles of maintenance facility

    c. Number of signals greater than 10 miles from maintenance facility

8. Controller Classification

    a. Number of 170 family controllers

    b. Number ofATC/2070 family controllers

    c. Number of NEMA TS1 controllers

    d. Number of NEMA TS2 controllers

9. Age of field equipment

    a. Number of controllers less than 5 years old

    b. Number of controllers between 5 and 10 years old

    c. Number of controllers greater than 10 years old

10. Indicate number of ancillary devices present

    a. Preemption/priority

    b. CCTV

    c. Changeable message signs

    d. UPS

11. Communications – Indicate number of signals controlled by following

    a. 7 wire cable

    b. Twisted wire pair

    c. Fiber optics

    d. Coaxial cable

    e. Wireless

    f. Non-owned communication service (identify)

C. Redundancy Characteristics of System

1. Redundancy of central controls
2. Redundancy in backbone communications to field
3. Redundancy in distribution communications to field

D. Traffic Detection

1. Type and extent of detection

	Number of Each Detector Type				Number of Detectors Actually Operating
	Inductive Loop	Video Processor Detector	Radar, Microwave	Other	
Local actuation detectors					
System detectors					

2. Are detectors periodically checked for operability (in the case of video processor detectors are they checked under poor lighting and weather conditions)
3. Is detector data analyzed on a regular basis? How is the data used?
4. CCTV
    a. How many cameras are available
    b. Is CCTV monitoring used to support
        1. On line adjustment of timing plans
        2. Planning for signal timing/phasing
        3. Incident management

E. Timing Plan Characteristics

1. Number of daily timing plans
2. Other periodic timing plans (e.g. weekends, special events)
3. Non-periodic timing plans (e.g. diversion, emergency evacuations)

F. Operations Characteristics

1. Frequency of timing plan updates, phasing plan checks, warrant reviews
2. Is a staffed TMC used, if so what is the operating period
3. Co-location with other traffic operations or police agencies

G. Maintenance Practices

1. Allowable time to repair signal failure during business hours
2. Allowable time to repair signal failure during non-business hours
3. Allowable time to repair ancillary equipment (detectors, preemption equipment, etc.)
4. Allowable time to repair communications
5. Availability (Up-time) for central equipment
6. Identify routine maintenance practices
7. Actual time to repair signal failure during business hours
8. Actual time to repair signal failure during non-business hours
9. Actual time to repair ancillary equipment (detectors, preemption equipment, etc.)
10. Controller failures per year

H. Resource Issues

1. Budgets and personnel (including consultants). Please provide operating, maintenance and capital (only for signal system) budgets for following items. Please provide person hours for each of the items

    a. Management budgets and personnel hours for each of: supervision, planning, system engineering
    b. Operations budgets and personnel hours for each of (TOC operations, signal timing including data collection)
    c. Maintenance
        1. Maintenance of signals (department budgets, contract budgets, personnel)
        2. Maintenance of other equipment (detectors, preemption equipment, etc.)(department budgets, contract budgets, personnel)
    d. Training
        1. Does the agency have a formal training plan?
        2. Does the agency provide the cost for training?
        3. What training resources are available locally?
        4. Is IMSA certification required for maintenance personnel
        5. Is PTOE/PE certification required for engineering personnel
        6. Percentage of operating budges spent for training.
        7. Type of operations training
        8. Percentage of maintenance budget spent for training.
        9. Type of maintenance training
    e. Growth – Do O & M budgets increase with signal growth on an annual basis?

2. Practices and Constraints. Please identify the practices that are used that pertain to the following items and please identify whether the practices are discretionary or are required by the agency:

    a. Use of owned or leased communication facilities
    b. Use of own staff or contract maintenance
    c. Use of own staff or consultants for engineering

I. Staffing Issues

1. Pay as compared with peer agencies in the region (higher, approximately the same, lower)
2. What is the average tenure of engineering employees?
3. What is the average tenure of maintenance employees?
4. What is the number of vacant engineering and maintenance positions

J. Management

1. Is a mission statement available
2. Is a concept of operations available
3. Are operations procedures available

K. Staff Capability Level

Position	Number of Personnel in Position	Qualifications – Training/experience level
Management		
Traffic Signal Engineer		
Traffic Signal Analyst/Technician		
ITS Engineer		
Traffic Signal Maintenance Technician		
Electronic Specialists		
TMC Operators		
Public Relations Coordinator		

L. Objectives and Performance Measurement

1. Please complete Table 1

2. Are summary performance reports prepared and reviewed periodically

M. Planning Issues

1. What causes the staff size to change

2. Is your funding stream reliable

3. How far into the future do you plan

4. What upgrades or updates do you plan

5. Do you have planning documentation that is available for review? Examples include business plans, resource models, maintenance check lists, concept of operations

N. Communication to the Public

Do you provide information on incidents, construction, special events and congestion through:

1. Changeable message signs

2. Website

3. Media

4. Other

O. Feedback from the Public

1. Do you seek feedback from the public on its perception of agency performance through such means as surveys or other proactive techniques. If so please identify the technique

2. Do you have a telephone hotline or a website that facilitates feedback from the public.

TABLE 1 OBJECTIVES AND MEASURES

POSSIBLE OBJECTIVE	DOES OBJECTIVE PERTAIN TO YOUR AGENCY (Y/N)	ESTIMATE OF RELATIVE IMPORTANCE (5 is very important, 1 is not important)	EXAMPLE OF MEASURE FOR OBJECTIVE	MEASURES USED BY YOUR AGENCY
1. Reduce delay and fuel consumption for normal traffic patterns.			a) Vehicle hours delay. b) Gallons fuel reduced.	
2. Reduce delay and fuel consumption for incident conditions.			Same as 1.	
3. Reduce emissions.			Kg of CO, NOX, SO_2, CO_2.	
4. Reduce accidents resulting from signal outages.			Accidents reduced.	
5. Reduce secondary accidents resulting from incidents.			Same as 4.	
6. Improved public perception of signal and management center operations.			Rating scale.	
7. Serve as a diversion route for corridor operations.			Same as 1 and 3.	
8. Provide preemption for emergency vehicles and railroads.			a) Number of emergency vehicles provided preemption. b) Negative impact on general traffic.	
9. Provide transit priority.			a) Traveler hours reduced. b) Improvement in schedule c) Adherence.	
10. Support emergency evacuations.			Availability of plans.	
11. Provide traffic information to public and private traffic information services.			Checklist for information supplied.	
12. Data for planning and evaluation.			Employment of data by agency or MPO.	
13. Improve internal efficiency of department operations.				

Appendix B
Survey Responses

Appendix B - Survey Responses (Cont.)

Agency	A	B	C	D	E	F	G
Redundancy Characteristics of System							
Redundancy of central controls	Software/Server based, can be transferred to backup if necessary	0	2 servers, 1 spare communications server			Backup data hourly, and off-site. New system will be full redundant hot swap	none
Redundancy in backbone communications to field	Majority of center to field communication by PSTN	0	Some alternate paths	starting to implement Ethernet backbone with re-routing		That is beyond our control. There is limited redundancy due to County's budget	none
Redundancy in distribution communications to field	Limited, utilize radio communications for longer duration & significant failures of twisted pair	0	Some alternate paths			Minimal	none
Traffic Detection							

Type and extent of detection	A: Number of Each Detector Type: Inductive Loop	A: Video Processor Detector	A: Radar, Microwave	A: Other	B: Number of Each Detector Type: Inductive Loop	B: Video Processor Detector	B: Radar, Microwave	B: Other	C: Number of Each Detector Type: Inductive Loop	C: Video Processor Detector	C: Radar, Microwave	C: Other	D: Number of Each Detector Type: Inductive Loop	D: Video Processor Detector	D: Radar, Microwave	D: Other	E: Number of Each Detector Type: Inductive Loop	E: Video Processor Detector	E: Radar, Microwave	E: Other	F: Number of Each Detector Type: Inductive Loop	F: Video Processor Detector	F: Radar, Microwave	F: Other	G: Number of Each Detector Type: Inductive Loop	G: Video Processor Detector	G: Radar, Microwave	G: Other
Local actuation detectors	2200	125	0	0	98%	1%	1%			0	<20	0	Everything else	10			60%	40%			All other	100	35		14000	500		
System detectors	260	15	0	0						0	0	0					100%				1500				200	500		

Agency	A	B	C	D	E	F	G
Number of Detectors Actually Operating:							
Local actuation detectors	2300	95%	All but approx. 50	95%		All other	14300
System detectors	275					400	less than 100
Are detectors periodically checked for operability (in the case of video processor detectors are they checked under poor lighting and weather conditions)	Through PM's and routine monitoring of Central System Software features	on yearly pm's and maintenance visits	Yes, annually	Yes for inductive loops	When complaints are made	No due to limited staffing resources	Through PM and Trouble calls
Typical detector configuration							
% of intersections that operate Fully Actuated: Advanced & limit line detection on main street, limit line detection on side street approaches	1%	75%		100%	30%	5%	This is not a standard design for GDOT maybe 2% of signals have this detector configuration
% of intersections that operate Fully Actuated: Advanced detection on main street & limit line on side street.	98%	12%			70%	5%	93%
% of intersections that operate Semi-Actuated: No detection on main street, limit line detection on side street.	1%	0%				75%	5%
% of intersections that opeate with no detection	0%	13%				20%, CBD areas - 2 large ones	0%
Is detector data analyzed on a regular basis? How is the data used?	Not Applicable	No	To look at on the spot traffic flow, real time volume, peak hours, and yearly trends in ADT's	No	No. Detector data is not used.	Not at this time due to old system	no
CCTV							
How many cameras are available	2 CCTV, 8 dial-up	0	75	7	60	180	2
Is CCTV monitoring used to support:							
On line adjustment of timing plans	yes		Yes	Yes	Yes	Yes	N/A
Planning for signal timing/phasing			Yes	Yes	Yes	Yes	N/A
Incident management	yes		Yes	Yes	Yes	Yes	Some
Timing plan characteristics							
Number of daily timing plans	4 to 6	three to five	7	Six (am, am off-peak, midday, midday off-peak, pm, pm off-peak)	4	Typical 3 dial operations AM, PM and Off peak	varies typically 4, AM, Noon, PM, Free
Other periodic timing plans (e.g. weekends, special events)	2 to 4	two to three	2	Holiday plans around shopping areas; special event plans around Ampitheater, occasional marathon or bike race special plans	Yes	Weekend peak and off peak as well as special plans	Developed on a case by case basis
Non-periodic timing plans (e.g. diversion, emergency evacuations)	15	0	1	Heavy volume plans available for implementation when necessary	Yes	Emergency evac plans and do detour plans daily	None
Operations characteristics							
Frequency of timing plan updates, phasing plan checks, warrant reviews	Major every two – three years	5-7 years	As required	Signals retimed every 2 years, no warrant reviews	Goal is every 3 years	timings are reviewed daily from our airplane and cameras. We do not do warrants the studies group do	1-3 years - varies
Is a staffed TMC used, if so what is the operating period	6am – 9pm	7:30 am - 4 pm	6 am to 6 pm weekdays	traffic engineer works out of TMC, but not with specific staffing hours	0700-1900, and during special events	20 hours a day 7 days a week. 05:00 – 00:30	
Co-location with other traffic operations or police agencies	None	No	Yes, state freeway management system, state police	Yes	No	yes Transit in same room as Traffic, we are all co-located in PSCC with 9-1-1 and EOC	

Appendix B - Survey Responses

Agency	A	B	C	D	E	F	G
Traffic Network Characteristics							
	Grid / Arterial / Isolated	Grid / Arterial / Isolated	Grid / Arterial / Isolated	Grid / Arterial / Isolated	Grid / Arterial / Isolated	Grid / Arterial / Isolated	Grid / Arterial / Isolated
Number of signals in each type of network	390 / 314 / 76	135 / 415 / 451	85 / 362 / 175	0 / 25 / 90	180 / 80 / 40	200 / 525 / 75	350 (CBDs) / 1050 / 1400
% AADT growth per year	Varies by roadway; Annual Count Report published on website - http://www.lee-county.com/publicworks/Traffic/2007%20Count%20Report2.pdf.		1%	Approx. 2-4%	3%-5%	N/A	Not measured statewide
% signals operating under saturated conditions during peak hour	Approximately 30%		3.20%	Approx. 15%	200	40	15% Estimated Statewide
% signals operating at saturated conditions for at least one hour in excess of peak hour	Approximately 30%		0.80%	5%	150	50	2.00%
Type of jurisdiction	County	Major City	County (responsible for City suburbs, some state signals, and rural signals	mid-size suburban city	Major City		Statewide - Georgia
% growth in signals/year	6%		<1.0%.	Approx. 4%	1%	5-10 new signals per year	3%
Classification of Signal System Characteristics							
Adaptive (e.g. SCOOT, SCATS, OPAC, RHODES)*	Operate approximately 12% in Traffic Responsive.	0	None	0	None		None deployed within GDOTs Jurisdiction (Cobb County has a SCATS system)
Closed loop with data development tools (e.g. ACS Lite) including isolated signals are controlled by this type of system*	None	0	Aries - 47 signals	0	None		None
Closed loop or central control (UTCS type) including isolated signals that are controlled by this type of system*	314	550	Transcore - 405 signals	70%	Siemens' ACTRA system		750 Statewide
Other type of interconnected system*	None		Hardwire - 7 signals	0		800	None
Isolated signals with automatic failure reporting*	None		None	0	None		150
Isolated signals without automatic failure reporting	76	450	Non-system - 175	30%	Approx. 60		1250
Proximity of signals to maintenance facility							
Number of signal within 5 miles of maintenance facility	76		Approx. 481	about 100	Approx. 170	200	175
Number of signals between 5 and 10 miles of maintenance facility	57		Approx. 125	about 15	Approx. 120	500	250
Number of signals greater than 10 miles from maintenance facility	257		Approx. 20	0	Approx. 10	100	2375
Controller Classification							
Number of 170 family controllers	none	50	None		0		0%
Number ofATC/2070 family controllers	none	150	None	112	Approx. 180		2800
Number of NEMA TS1 controllers	40%	625	222		Approx. 120		0
Number of NEMA TS2 controllers	60%	75	405	3	0	800	0
Age of field equipment							
Number of controllers less than 5 years old	150	275	Approx. 60	115	80		1000
Number of controllers between 5 and 10 years old	400	125	Approx. 345	0	120	600	1800
Number of controllers greater than 10 years old	50	600	Approx. 222	0	100	200	0
Number of ancillary devices present							
Preemption/priority	20	50	351	Approx. 60	1	25 locations have Fire house or Rail Road	70
CCTV	3	0	75	9	60	180	2
Changeable message signs	None	0	2	0	13	No static VMS, 5 portables	0
UPS	18	4	None	9	0	Zero now but beginning a program to install 250	100
Communications – Number of signals controlled by following							
7 wire cable	None	0	10	0	0		0
Twisted wire pair	292	30	20 on Aries	0	170	800	200
Fiber optics	5	193 directly; 319 remotely	100	70	7		300-500
Coaxial cable	None	0	305	0	0		0
Wireless	20	8	10	0	13		50
Non-owned communication service (identify)	Leased-line	0	37	DSL service - 1 (connects to closed loop fiber system); dial up phone connecting to fiber system - 2; dial up phone to isolated system - 1			none
* relate to signals that actually operate under the conditions described							

Appendix B - Survey Responses (Cont.)

Agency	A	B	C	D	E	F	G
Redundancy Characteristics of System							
Redundancy of central controls	Software/Server based, can be transferred to backup if necessary	0	2 servers, 1 spare communications server			Backup data hourly, and off-site. New system will be full redundant hot swap	none
Redundancy in backbone communications to field	Majority of center to field communication by PSTN	0	Some alternate paths	starting to implement Ethernet backbone with re-routing		That is beyond our control. There is limited redundancy due to County's budget	none
Redundancy in distribution communications to field	Limited, utilize radio communications for longer duration & significant failures of twisted pair	0	Some alternate paths			Minimal	none
Traffic Detection							

Type and extent of detection	A: Number of Each Detector Type – Inductive Loop	A: Video Processor Detector	A: Radar, Microwave	A: Other	B: Number of Each Detector Type – Inductive Loop	B: Video Processor Detector	B: Radar, Microwave	B: Other	C: Number of Each Detector Type – Inductive Loop	C: Video Processor Detector	C: Radar, Microwave	C: Other	D: Number of Each Detector Type – Inductive Loop	D: Video Processor Detector	D: Radar, Microwave	D: Other	E: Number of Each Detector Type – Inductive Loop	E: Video Processor Detector	E: Radar, Microwave	E: Other	F: Number of Each Detector Type – Inductive Loop	F: Video Processor Detector	F: Radar, Microwave	F: Other	G: Number of Each Detector Type – Inductive Loop	G: Video Processor Detector	G: Radar, Microwave	G: Other
Local actuation detectors	2200	125	0	0	98%	1%	1%			0	<20	0	Everything else	10			60%	40%			All other	100	35		14000	500		
System detectors	260	15	0	0						0	0	0					100%				1500				200	500		

Agency	A	B	C	D	E	F	G
Number of Detectors Actually Operating:							
Local actuation detectors	2300	95%	All but approx. 50	95%		All other	14300
System detectors	275					400	less than 100
Are detectors periodically checked for operability (in the case of video processor detectors are they checked under poor lighting and weather conditions)	Through PM's and routine monitoring of Central System Software features	on yearly pm's and maintenance visits	Yes, annually	Yes for inductive loops	When complaints are made	No due to limited staffing resources	Through PM and Trouble calls
Typical detector configuration							
% of intersections that operate Fully Actuated: Advanced & limit line detection on main street, limit line detection on side street approaches	1%	75%		100%	30%	5%	This is not a standard design for GDOT maybe 2% of signals have this detector configuration
% of intersections that operate Fully Actuated: Advanced detection on main street & limit line on side street.	98%	12%			70%	5%	93%
% of intersections that operate Semi-Actuated: No detection on main street, limit line detection on side street.	1%	0%				75%	5%
% of intersections that opeate with no detection	0%	13%				20%, CBD areas - 2 large ones	0%
Is detector data analyzed on a regular basis? How is the data used?	Not Applicable	No	To look at on the spot traffic flow, real time volume, peak hours, and yearly trends in ADT's	No	No. Detector data is not used.	Not at this time due to old system	no
CCTV							
How many cameras are available	2 CCTV, 8 dial-up	0	75	7	60	180	2
Is CCTV monitoring used to support:							
On line adjustment of timing plans	yes		Yes	Yes	Yes	Yes	N/A
Planning for signal timing/phasing			Yes	Yes	Yes	Yes	N/A
Incident management	yes		Yes	Yes	Yes	Yes	Some
Timing plan characteristics							
Number of daily timing plans	4 to 6	three to five	7	Six (am, am off-peak, midday, midday off-peak, pm, pm off-peak)	4	Typical 3 dial operations AM, PM and Off peak	varies typically 4, AM, Noon, PM, Free
Other periodic timing plans (e.g. weekends, special events)	2 to 4	two to three	2	Holiday plans around shopping areas; special event plans around Ampitheater, occasional marathon or bike race special plans	Yes	Weekend peak and off peak as well as special plans	Developed on a case by case basis
Non-periodic timing plans (e.g. diversion, emergency evacuations)	15	0	1	Heavy volume plans available for implementation when necessary	Yes	Emergency evac plans and do detour plans daily	None
Operations characteristics							
Frequency of timing plan updates, phasing plan checks, warrant reviews	Major every two – three years	5-7 years	As required	Signals retimed every 2 years, no warrant reviews	Goal is every 3 years	timings are reviewed daily from our airplane and cameras. We do not do warrants the studies group do	1-3 years - varies
Is a staffed TMC used, if so what is the operating period	6am – 9pm	7:30 am - 4 pm	6 am to 6 pm weekdays	traffic engineer works out of TMC, but not with specific staffing hours	0700-1900, and during special events	20 hours a day 7 days a week. 05:00 – 00:30	
Co-location with other traffic operations or police agencies	None	No	Yes, state freeway management system, state police	Yes	No	yes Transit in same room as Traffic, we are all co-located in PSCC with 9-1-1 and EOC	

Appendix B - Survey Responses (Cont.)

Agency	A	B	C	D	E	F	G
Maintenance practices							
Allowable time to repair signal failure during business hours	2	<60 min		ASAP	1 hour	30 minutes	Techs are on 24 hours call, Regular shift is 8 hours, time to repair is 2 hours both on and off shift
Allowable time to repair signal failure during non-business hours	4	< 2 hours		1 hr	2 hours	30 minutes to 1 hour	2 hours, techs earn comptime outside of working hours
Allowable time to repair ancillary equipment (detectors, preemption equipment, etc.)	48			no policy	2 weeks	Pre-empt is more important try to fix it that day. Det and stuff can be a year or more depending on funding	1 week
Allowable time to repair communications	48			no policy	2-3 days	30 minutes when possible	depends on the type of media typically 1 week
Availability (Up-time) for central equipment	24/7			100%		99.9999%	24/7
Identify routine maintenance practices				no policy			
Actual time to repair signal failure during business hours	1			depends on the problem, crews respond immediately upon call	1-2 hours	30 minutes or less	2 hours from onsite time
Actual time to repair signal failure during non-business hours	2			on-call techs will arrive within an hour, time to fix depends on problem	1-3 hours	Under an hour and half	2 hours from onsite time
Actual time to repair ancillary equipment (detectors, preemption equipment, etc.)	24			varies	2 hours - 2-3 days	Depends on equipement	typically 1 week
Controller failures per year	Estimated average is 4 per /year			3 this year	10-20 per year	Routine failures due to storms	10 -20%
Resource issues							
Budgets and personnel (including consultants).							
Management budgets and personnel hours for each of: supervision, planning, system engineering	$230,000					Theses functions come from inside our general fund budgets and most are not specifically funded. We have to alter people's work assignments and find ways to complete things	Unable to quantify budget amount. This accounts for all districts, maintenance, conlutant and loop contracts
Operations budgets and personnel hours for each of (TOC operations, signal timing including data collection)	TOC approximately $190k, Signal timing approximately $125,000.					We do have 1 ATMS engineer but he is paid from several general and CIP funds. The TMC general budget is about $800,000 that mostly covers salaries, vehicle charges and benefits	allocated by district
Maintenance							
Maintenance of signals (department budgets, contract budgets, personnel)	$897,000					This work is performed by in house staff in TMC and our Signal Shop. The TMC general budget is about $800,000 that mostly covers salaries, vehicle charges and benefits	
Maintenance of other equipment (detectors, preemption equipment, etc.)(department budgets, contract budgets, personnel)	$100,000					This work is performed by in house staff in TMC and our Signal Shop. The general budget from several accounts for equipment is about $400,000 to maintain stuff	
Training							
Does the agency have a formal training plan?	Yes	Yes		unavailable	No	No	No
Does the agency provide the cost for training?	yes	Yes		unavailable	No	Yes minimal budget less than $5,000	Training is usually provided by the vendors or consultants and typically incorporated into material contracts
What training resources are available locally?	IMSA	Community college and university courses		unavailable	None	ITE, IMSA,	No
Is IMSA certification required for maintenance personnel	Yes	Yes		No, but most have	Desired, not required	No	No
Is PTOE/PE certification required for engineering personnel	No				For principal engineers and higher	No	No
Percentage of operating budges spent for training.	1%			unavailable	0%	Less than 1%	1%
Type of operations training				unavailable	None	On job training	Vendor training
Percentage of maintenance budget spent for training.	1%			unavailable	None	None	1%
Type of maintenance training				unavailable	Internal, on as needed basis	On job training	Vendor training
Growth – Do O & M budgets increase with signal growth on an annual basis?	Generally as funds are available	No		roughly	No	Not by much, it is hard to get maintenance dollars. New construction is easier	No Relationship
Practices and Constraints							
Use of owned or leased communication facilities	Discontinuing	Discretionary		allowed		We use all our own copper and fiber. We have 30 data circuits we lease but those will go away as we expand our new signal system	owned
Use of own staff or contract maintenance	Use of own staff	Discretionary		all in-house	Required	Both	blended several maintenance contracts exist
Use of own staff or consultants for engineering	Limited use of consultants	Discretionary		some of each	Discretionary	Both	Blended some signal timing is done in house some is contracted out

Appendix B - Survey Responses (Cont.)

Agency	A	B	C	D	E	F	G
Staffing Issues							
Pay as compared with peer agencies in the region (higher, approximately the same, lower)	Unavailable	lower		approx. the same	Approx. the same	Slightly above peers, but not high enough	State is lower, staff is typically lost to consultants or other jurisdictions
What is the average tenure of engineering employees?	12yrs			5-10 years	>10 years	10 years	10 years
What is the average tenure of maintenance employees?	6.5yrs			5-20 years	>10 years	10 years	5 years
What is the number of vacant engineering and maintenance positions	0 engineering, 2 maintenance	3		0	0	2	o vacant due to elimination by govenor to compensate for budget shortfall. 5 vacancies statewide prior to budget cut
Management							
Is a mission statement available?	Yes	Yes		no	No	Yes	GDOT overall and TMC overall nothing specific to traffic signals
Is a concept of operations available?	For operations center, under development	No		no	No	No	no
Are operations procedures available?	Yes	Yes		no	No	No	there are documented processes to collect counts, operate TMCs and develop signal timing

Agency	A		B		C		D		E		F		G	
Staff capability level														
Position	Number of Personnel in Position	Qualifications – Training/experience level	Number of Personnel in Position	Qualifications – Training/experience level	Number of Personnel in Position	Qualifications – Training/experience level	Number of Personnel in Position	Qualifications – Training/experience level	Number of Personnel in Position	Qualifications – Training/experience level	Number of Personnel in Position	Qualifications – Training/experience level	Number of Personnel in Position	Qualifications – Training/experience level
Management	1.5		1				1	PE, 10+ years	2		1			8 Districts, 8 District Traffic
Traffic Signal Engineer	1.5		1				1	PE, PTOE, 10+ years	2		3			8
Traffic Signal Analyst/Technician	2		0				1	10+ years	5		These are the TMC techs			43
ITS Engineer	0.5		0				0		1		1			none assigned to traffic signals
Traffic Signal Maintenance Technician	7-techs, 3-Sr techs	3yrs Electrical exp min. IMSA II signals, IMOT	12				6	varies	5		14			Same as signal analyst technician
Electronic Specialists	None		4				0							3
TMC Operators	2.5		1				0		4		7			0
Public Relations Coordinator	1		0				0							0

Agency	A	B	C	D	E	F	G
Objectives and Performance Measurement							
See Table 1							
Are summary performance reports prepared and reviewed periodically?		minimally		annually		No	B & A conducted after retiming, monthly and annual reports are prepared
Planning Issues							
What causes the staff size to change?	Growth	resignations		pretty constant		People leaving, vacations, hiring freezes	budget cuts
Is your funding stream reliable?		Yes		yes		Yes	consistent
How far into the future do you plan	3-5 yrs	5 years		2-5 years		We try to plan 5 years out, but our budget cycles are only 2 years	3-5 yrs
What upgrades or updates do you plan?	Updates to control equipment, major PM's updates to operations center, routine signal timing updates	ITS upgrades		roadway improvements		New signal system is what we are working on for the next 6 years	TS Controllers, Tactics software with adaptive capability is envisioned
Do you have planning documentation that is available for review? Examples include business plans, resource models, maintenance check lists, concept of operations	Yes	Master Plan on local MPO website		No		Con Ops and Require	Progarm plan for deploying 2070 controllers
Communication to the Public							
Do you provide information on incidents, construction, special events and congestion through:							
Changeable message signs	Portable Message Signs used as necessary			No	Yes		0
Website	Yes			Yes	Not yet		none
Media				Yes	Not yet		none
Other						TARS sites	none
Feedback from the Public							
Do you seek feedback from the public on its perception of agency performance through such means as surveys or other proactive techniques. If so please identify the technique		Mail out surveys		Surveys	The City's website is used. Citizens can enter questions, complaints, and comments to staff.	Our feedback comes from every day calls and letters. We also get feedback from the media that we work with	No
Do you have a telephone hotline or a website that facilitates feedback from the public	Yes, SOC phone # and Rrequest for action program	Yes		yes, both	See above	No telephone hot line due to very limited staff in TMC. Divisions have phone numbers and email where people can contact us	Trouble calls each district tracks it's own calls

Appendix C
Frequency of Signal Retiming

The need for signal retiming or rephasing may result from the following:

- Change in population level and car ownership in the region
- Change in land use that changes traffic demand.
- Change in traffic patterns resulting from changes in the highway network.
- Change in traffic operations such as corridor management plans.
- Change in motorist driving patterns resulting from increased emphasis on corridor management, use of transit or car-pooling.

Many agencies have reported a wide range of benefits and benefit to cost ratios resulting from signal retiming. Because of differences in evaluation methods and periods between retiming it is difficult to provide a general benefit figure except to say that it usually exceeds the cost of retiming by many times and usually results in a significant reduction in delay and fuel consumption.

Figure 1 (1) shows a general concept for assessing the benefits of signal retiming as a function of time. The figure shows that after three years the benefits begin to increase significantly.

Swayampakala and Graham (2) studied the benefits of retiming signals at varying time intervals for a number of intersections in several cities in North Carolina. They calculated delay using SYNCHRO runs based on collected turning movement counts. The benefit is computed as the saving in delay less the cost of retiming. Figures 2, 3 and 4 show the results of the research. Retiming intervals in the figures are shown in months. The results vary widely from location to location. No pattern can be observed with different rates of change in traffic volumes.

Swayampakala and Graham conclude that the suggested time period for signal retiming is 24 to 30 months. Parsonson (3) recommends a one to three year time interval.

The NTOC survey data responding to the question "Does your agency conduct a comprehensive review of area-wide or corridor signal timing at least every 3 years or sooner if justified" was analyzed. A score of 5 corresponds to retiming every 3 to 5 years. The scores are as follows:

Score	Percentage
5	12
4	24
3	25
2	19
1	18

Thus, a relatively small number of agencies retime the signals at 3 to 5 year intervals or sooner. A 30 to 36 month time period for the constrained system would therefore appear to capture most of the benefits indicated by prior research, while still setting an achievable goal for operating agencies.

REFERENCES

1. Sunkari, S. “The Benefits of Retiming Traffic Signals”, ITE Journal, April 2004, pp 26-29.

2. Swayampakala, R.K. and J.R. Graham, “Optimum Time Intervals fir the Traffic Signal Re-Timing Process, presented at the 2004 Annual Meeting of the Transportation Research Board.

3. Parsonson, P. “Signal Timing Improvement Practices.” In Synthesis of Highway Practice, No. 172, TRB, pp 1-10.

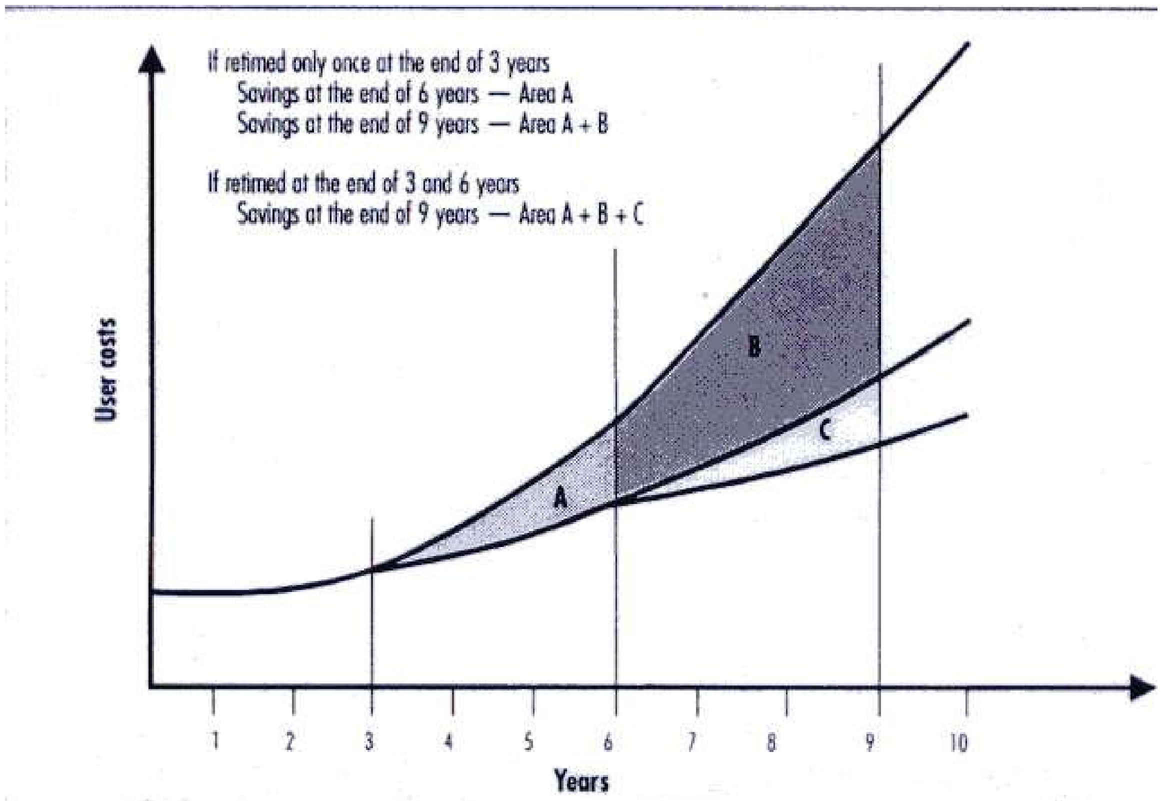

Figure 1
Savings in User Costs Due to Signal Retiming

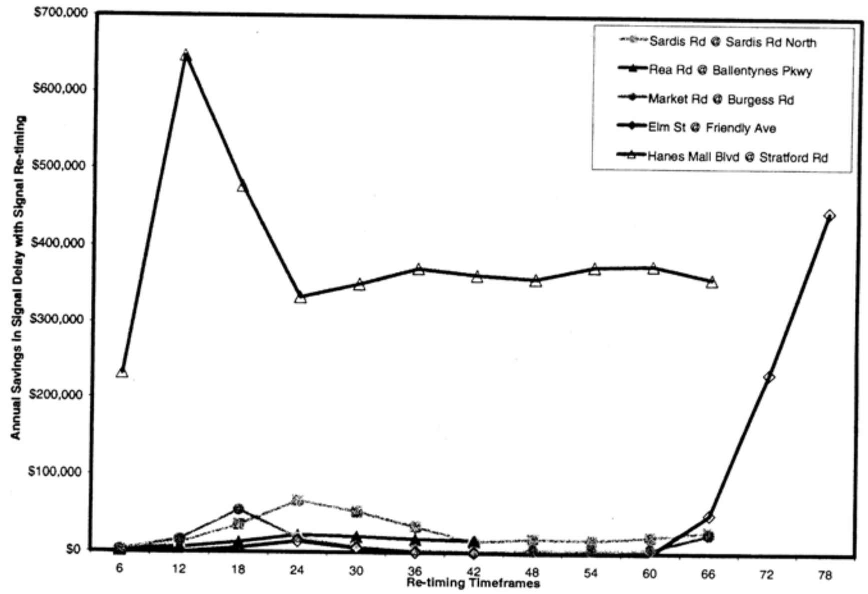

FIGURE 2 Annual Savings vs. Re-Timing Intervals
Intersections with Significant Rate of Change in Traffic Volumes

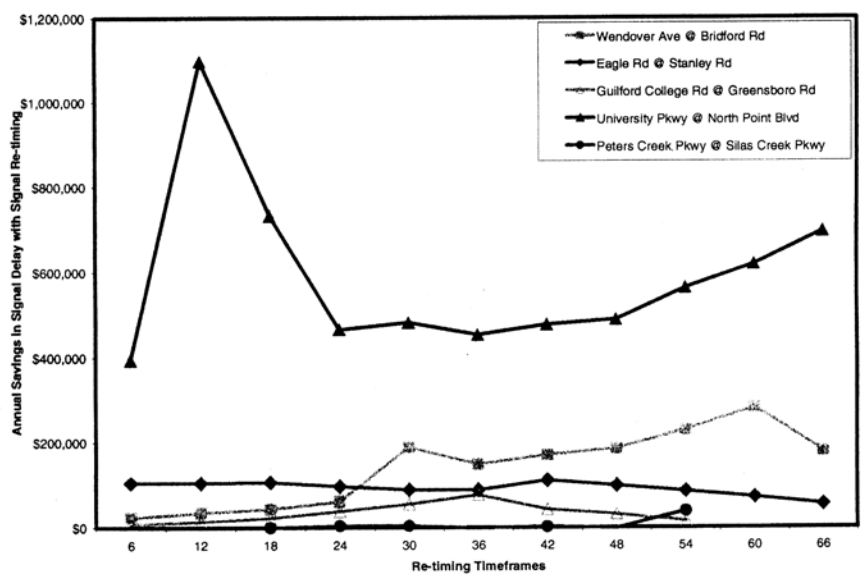

FIGURE 3 Annual Savings vs. Re-Timing Intervals
Intersections with Moderate Rate of Change in Traffic Volumes

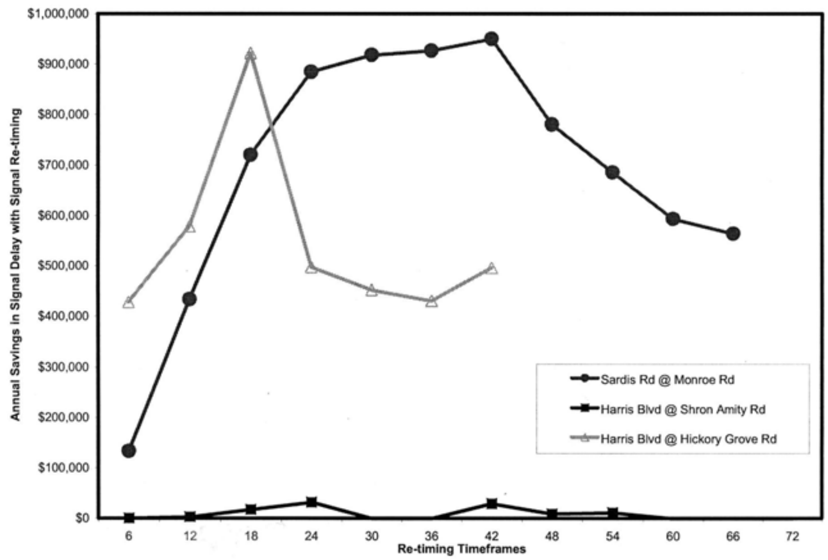

FIGURE 4: **Annual Savings vs. Re-Timing Intervals**
Intersections with Minimal Rate of Change in Traffic Volumes

Appendix D

North Central Texas Council of Governments Ranking Model

This appendix is largely abstracted from the reference.

The NCTCOG ranking model is based on the existing traffic conditions. The variables used in the model and their weights are discussed in this section.

Variables

Total delay

Delay is the most frequently used measure of effectiveness for signalized intersections. Delay can be quantified in many different ways: stopped time delay, approach delay, travel time delay and time-in-queue delay (McShane and Roess, 1998). Travel time delay is used in this research. Travel time delay of an individual vehicle is the difference between the measured travel time and the travel time at the desired speed. Measured travel time is taken as an average of travel time in both directions of travel. The desired speed is taken as the posted speed. In this model, delay is used on an aggregate basis, and it is calculated below:

DPV = delay/vehicle/intersection

= (measured travel time - desired travel time)/ (number of intersections) (1)

Total delay/ intersection = DPV x ADT (2)

Where ADT is the average daily traffic.

Number of Stops

The number of stops is taken as the average of the number of stops counted in both directions of travel along the corridor. To get the aggregate value, this average value per intersection is multiplied by the ADT.

Number of stops per intersection =

(Number of stops/number of intersections) x ADT (3)

System type

There are three types of existing systems. A value of one indicates that all intersections are part of an existing interconnected system with communications. A value of two indicates that some but not all intersections are part of an existing interconnected system with communications. A value of three indicates that there is no system (currently an isolated operation).

Weightings

The weighting for each factor is allocated by an expert group. The weightings are presented in Table 1.

Table 1

Variables and Weightings

Variable	Weighting
Total Delay (DELAY)	50
# of stops (STOPS)	30
System type (SYSTEMTYPE)	20

Calculation of Rank Order

Using the weightings applied by the NCTCOG, the following equation is developed.

Total Score(s) = (Delay /Max(Delay))•50 + (Stops/Max(Stops))•30 + System_Type•20   (4)

Where System_Type = 1.0 for type 1 (all signals interconnected)

0.5 for type 2 (some signals interconnected)

0 for type 3 (all signals isolated)

Quantitative variables DELAY and STOPS are normalized by dividing by the maximum value from all of the candidate corridors, which precludes any single variable dominating the total score because of its magnitude relative to the other variables. After normalization, each variable is expressed on a zero-to-one scale and the weights are an expression of the relative importance of each criterion.. The maximum value of a variable in the given data is used for normalization.

REFERENCE

Pulipati, S.B., “Regional Prioritization of Corridors for Traffic Signal Retiming, University of Texas Arlington.

Traffic Signal Operations and Maintenance Staffing Guidelines

U.S. Department of Transportation
Federal Highway Administration
Office of Operations
1200 New Jersey Ave., SE
Washington, DC 20590
Toll-Free "Help Line" 866-367-7487
FHWA-HOP-09-006