Signal Systems Asset Management State-of-the-Practice Review

technical

memorandum

U.S. Department of Transportation
Federal Highway Administration

prepared for

Federal Highway Administration

prepared by

Cambridge Systematics, Inc.

April 2004

Notice

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■ Project Overview

Transportation Asset Management is a strategic approach to managing transportation infrastructure. It includes a set of principles and practices for building, preserving and operating facilities more cost-effectively and with improved performance, delivering the best value for public tax dollar spent, and enhancing the credibility and accountability of the transportation agency. Fundamental elements of asset management include:

1. Explicit identification of performance goals and measures;

2. Ensuring that programs, projects and services are delivered in the most effective way available;

3. Informed decision-making based on quality information and analytic tools;

4. Monitoring of actual performance and costs, and use of this feedback to improve future decisions; and

5. Identification and evaluation of a wide variety of options for achieving performance goals – spanning multiple assets as well as management, operational, and capital investment approaches.

Specific applications in support of asset management to date have emphasized maintenance and replacement decisions for the most costly elements of transportation infrastructure – pavements and bridges. Relatively little work has been done on how to apply the principles of Transportation Asset Management to operational decisions, or to develop specific approaches to making tradeoffs between operations investments and capital infrastructure investments. Given the increasing emphasis on enhanced operational capabilities and deployment of Intelligent Transportation Systems (ITS) technology, there is a need to investigate and improve the state-of-the-practice with respect to operations asset management.

The FHWA Office of Transportation Management has undertaken the Investigation of Signal System Assets Management Methodology and Process Elements project, Task Order Number CA81F042. The purpose of this project is to obtain a better understanding of operations-level asset management by examining the specific case of signal systems. Key products will include:

- A synthesis of existing signal systems asset management practices;
- A generic model of a signal system asset management system;
- A description of the elements of a signal system management system;
- Illustration of how a signals asset management system could be used to support signal system management, operation and improvement decisions; and
- Comparison of the signals asset management system concept to infrastructure-based and IT-based asset management systems.

The model signal systems asset management system will include the following three key aspects of signal system operations and management:

- **Physical –** the specific physical components that make up signal systems (e.g., signal heads, loop detectors, video cameras, controller boxes);
- **System –** the design features and operational characteristics of the traffic management function provided by the integrated set of components that make up the signal system; and
- **Personnel –** the staff resources available for operating and maintaining the signals and the institutional and management approaches used to provide these staff resources.

Therefore, the data collection effort was structured to explore each of these areas and to gain insights into how agencies balance investments in these three areas as they maintain and improve their signal systems.

This memo presents a synthesis of existing practice, based on collection of structured information from state and local agencies with signal system management responsibilities. One hundred twenty agencies were contacted and asked to fill out a data collection instrument placed on the web. The instrument was designed to collect basic information on the size and characteristics of each agency's signal system, and to provide an indication of the extent to which asset management principles (as described above) were being applied. Participation in the data collection was voluntary and 26 agencies responded during the fall and winter of 2003-2004. In-depth interviews with selected agencies will be used to supplement this information in order to provide input for development of the generic signal system asset management system model.

Agency Characteristics

Of the 26 agencies that responded to the interview about half (52 percent) were city agencies with the remainder split between States and Counties. These results are summarized in Figure 1. The data collection targeted mid-sized agencies (with 200 to 1,000 signals), which have a sufficient degree of complexity in their operations to merit a structured approach to asset management, but not such a large scale so as to create unique requirements or allow for major efforts that aren't representative of the majority of agencies. As shown in Figure 2, about half the respondents (12) reported jurisdiction over 300 to 500 signals while another seven reported having 501 to 1,000. Respondents were asked how many center-line miles of arterial road were under their jurisdiction. The majority of respondents (14) reported having less than 5,000 miles of center-line road, while five of the 14 had less than 1,000. Seven agencies did not respond. Responses are shown in Figure 3.

Staff levels for agencies were measured per hundred signalized intersections (SI). The average staffing reported was 0.32 staff/100 SI in operations management, 0.34 staff/100 SI in maintenance management, 0.50 staff/100 SI in operations staff and 1.45 staff/100 SI in maintenance staff. The majority of agencies had traffic engineers and electricians in house, while only half had electrical engineers, mechanical engineers or communications engineers on staff.

Figure 1. Respondents by Agency Type

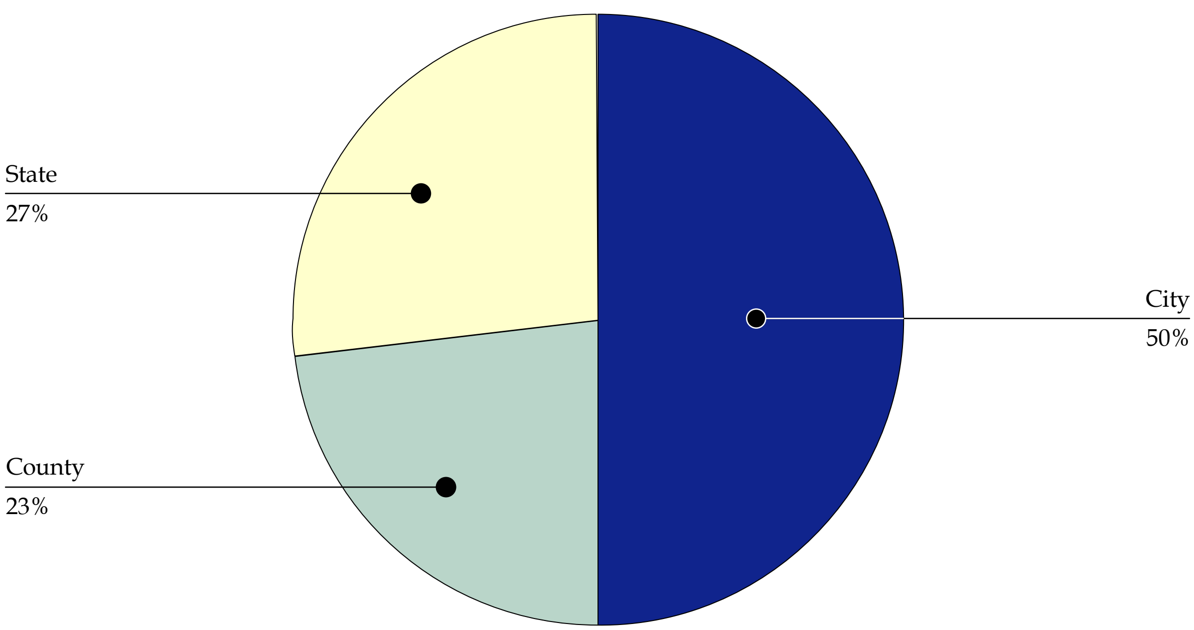


Figure 2. Respondents by Number of Signals

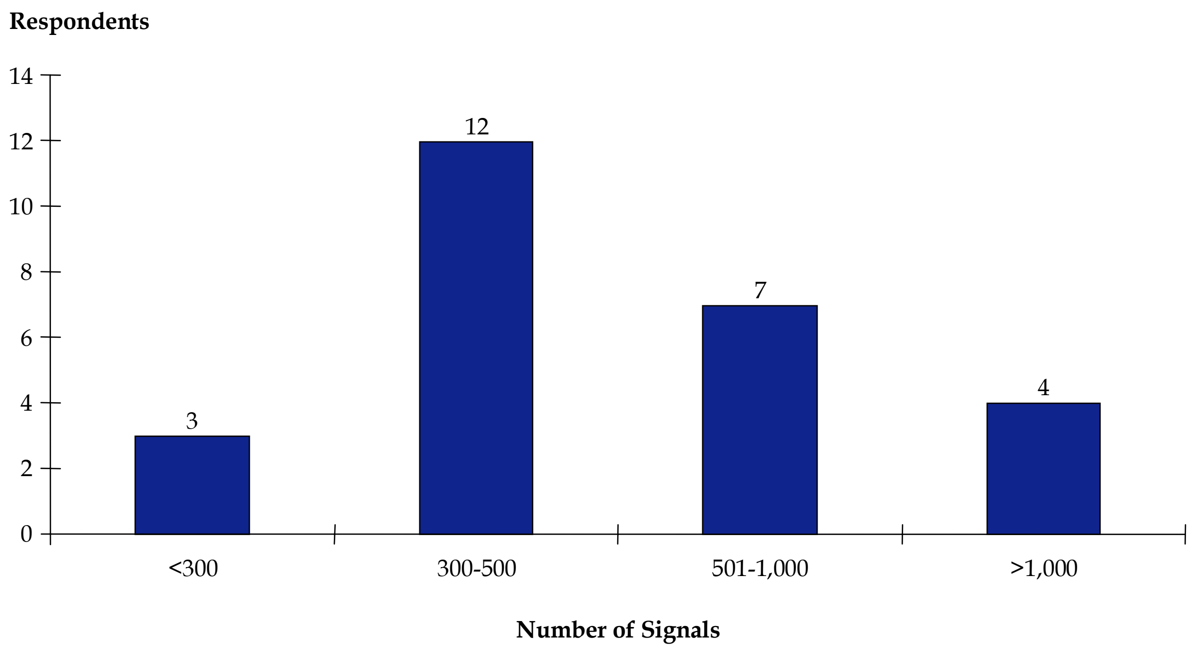
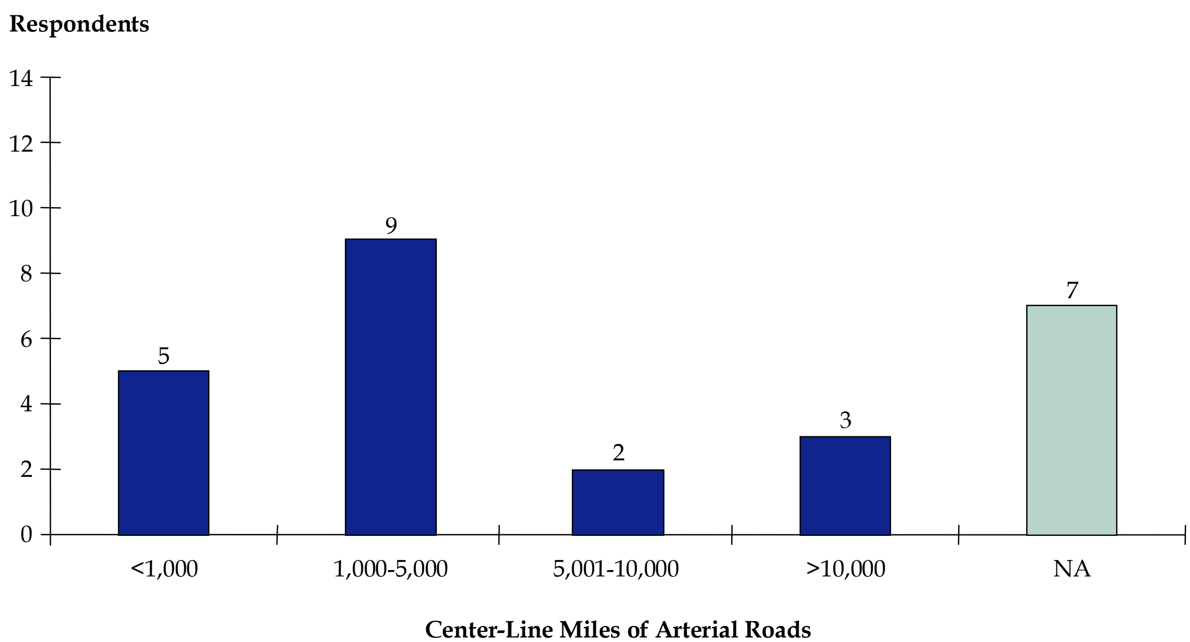


Figure 3. Respondents by Arterial Mileage



Agency budgets for signal systems are typically divided into the following three categories:

1. **Signal System Construction Budget –** Funds used for signal system improvements, such as the design and installation of new signals and the upgrade of current signal system capabilities. Respondents were asked to estimate their average annual signal systems construction budget (from all Federal, state, and local sources) for signal system improvements.

2. **Signal System Maintenance Budget –** Funds used for the labor and equipment required to conduct preventive and emergency maintenance, such as the repair or replacement of faulty signal equipment in the field. Respondents were asked to estimate their current annual signal systems maintenance budget (total from all funding sources) for signal systems maintenance, including contracted services.

3. **Signal System Operations Budget –** Funds used for the labor and equipment required to operate the signal system, such as the development and implementation of signal timing plans. Respondents were asked to estimate their current annual signal systems operations budget (total from all funding sources) for signal systems operations, including contracted services.

Figure 4 shows reported annual construction budgets. Responding agencies were split evenly between the categories with six reporting budgets of under $500,000 and six reporting budgets of over $2 million. The number of responding agencies in each annual construction budget category is presented in Table 1 according to agency size. As expected, larger systems tend to have larger construction budgets. In Figure 5, a similar distribution is reported for maintenance budgets, with six agencies reporting budgets of under $500,000 and six reporting budgets of over $2 million. The number of responding agencies in each annual maintenance budget category is presented in Table 2 according to agency size. Agency size does not seem to have as much of a correlation with maintenance budgets. Operations budgets, as shown in Figure 6, tend to be lower, with nine agencies reporting budgets of under $500,000 and only three reporting over $2 million. Again, the number of responding agencies in each annual operations budget category is presented in Table 3 according to agency size.

Figure 4. Respondents by Construction Budget

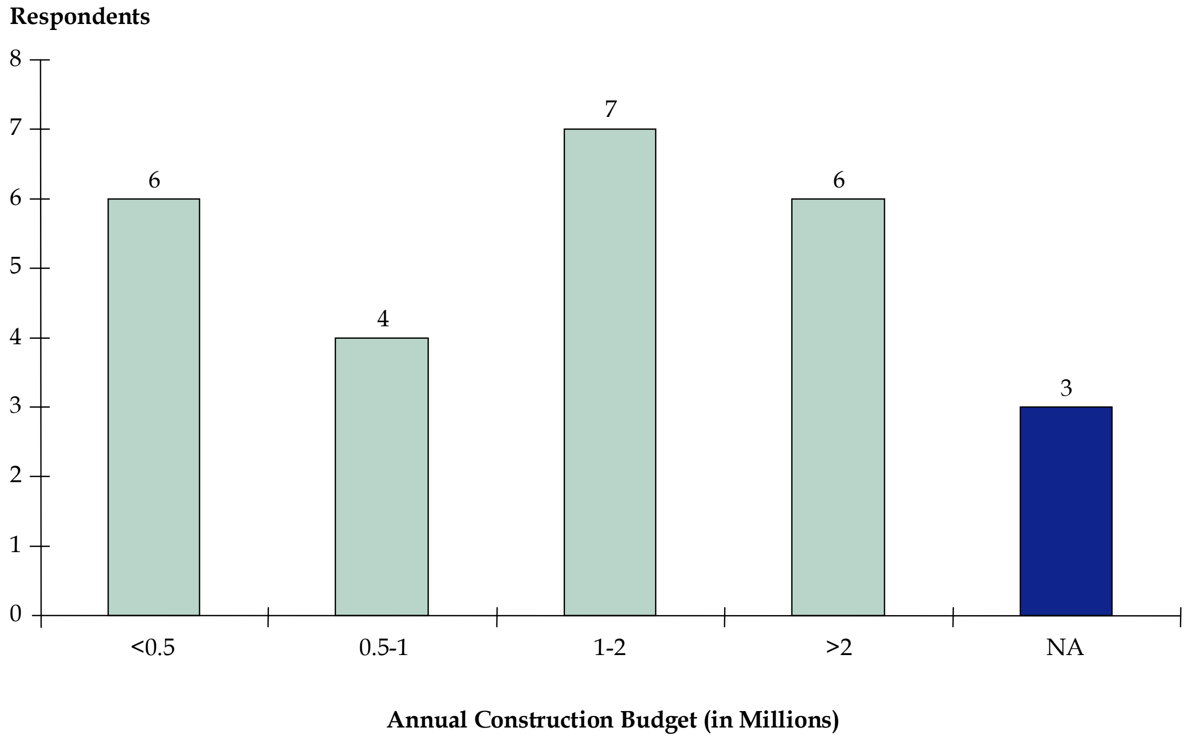


Table 1. Construction Budget by Signal System Size

Number of Signals	<0.5	0.5-1	1-2	>2	NA
<300	2	1	0	0	0
300-500	2	2	4	2	2
501-1,000	1	1	3	2	0
>1,000	1	0	0	2	1

Figure 5. Respondents by Maintenance Budget

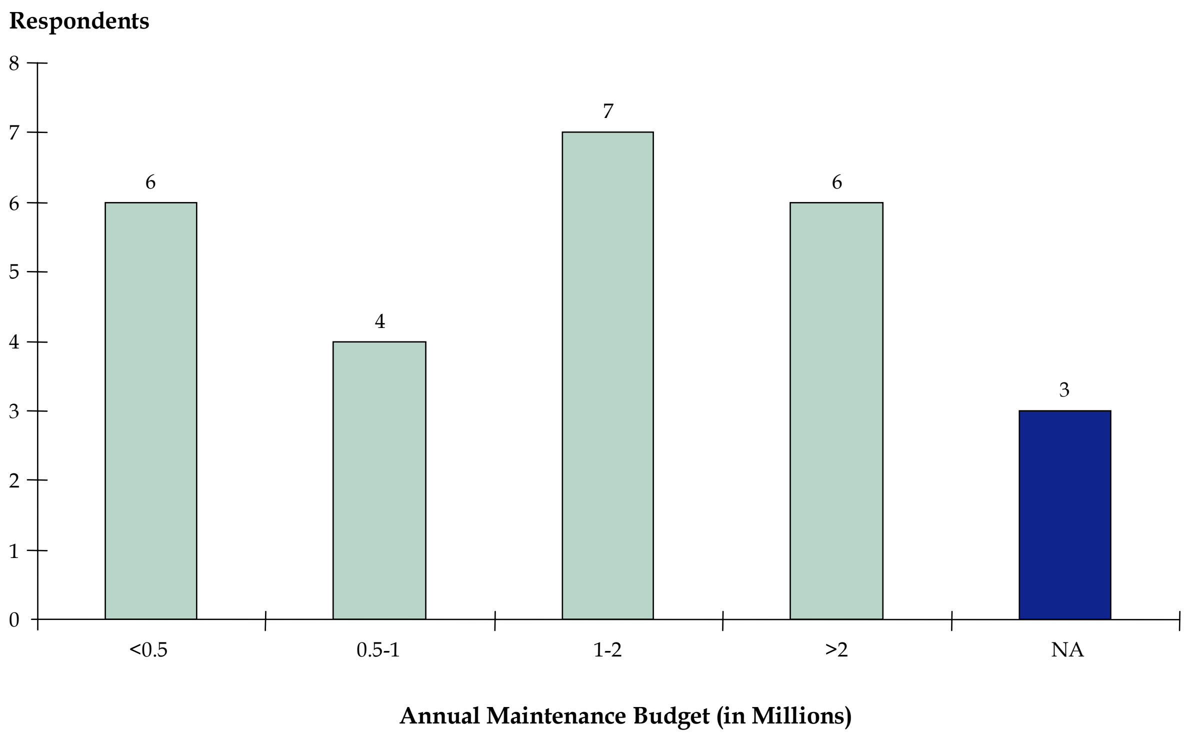


Table 2. Maintenance Budget by Signal System Size

Number of Signals	<0.5	0.5-1	1-2	>2	NA
<300	1	0	0	2	0
300-500	2	1	4	4	1
501-1,000	2	2	2	0	1
>1,000	1	1	1	0	1

Figure 6. Respondents by Operations Budget

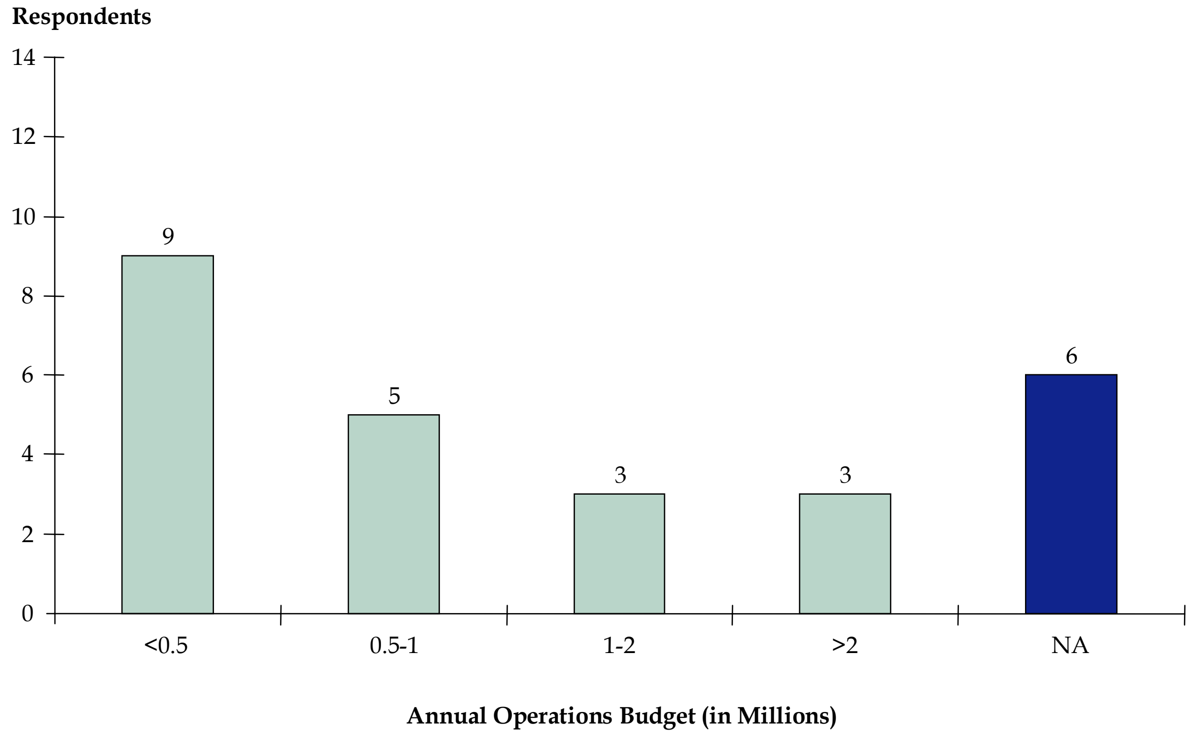


Table 3. Operations Budget by Signal System Size

Number of Signals	<0.5	0.5-1	1-2	>2	NA
<300	1	0	0	2	0
300-500	4	3	2	0	3
501-1,000	3	1	1	1	1
>1,000	1	1	0	0	2

■ Use of Software Tools

The use of software tools can provide an indication of the extent to which agencies are applying the asset management principles outlined at the start of this memo. Making informed decisions based on quality data depends on having a systematic approach to collecting, storing, analyzing and using information.

Respondents were asked which of the following types of software tools they use for signal system management. These tools collectively address physical, system and personnel aspects of signal systems asset management:

- **Inventory Tracking for Field Equipment –** Tools that store inventories of traffic signals, signs, controllers, cabinets, and other related field equipment. Inventory information typically includes identification, location, and classification, and date acquired/constructed. Condition information may also be tracked for some inventory items based on periodic inspections. This software type applies to the physical aspect of signal system asset management.

- **Inventory Tracking for Spare Parts –** Tools that contain an inventory of spare parts (equipment and materials) on hand that are needed to maintain traffic signals, signs, controllers, cabinets, and other related field equipment. These tools typically track the usage of spare parts and/or store a list of parts required for each piece of equipment. This software type applies to the physical aspect of signal system asset management.

- **Hardware/Software Version Control –** Tools used to track signal system management software in terms of what versions of software and hardware components are being used, when and what changes are made in software code, licensing information, and software compatibility requirements with signal system/communications hardware. This software type applies to the system aspect of signal system asset management.

- **Maintenance/Work Order Management –** A maintenance management system enables the agency to plan, schedule and track maintenance work for inventoried signal system assets, such as traffic signals, signs, controllers, cabinets, and other related field equipment. This type of software tool can generate work orders based on work requests or preventive maintenance schedules. Work completion is entered back into the system so that information about maintenance costs by element and component (labor, equipment, materials) can be tracked and summarized. Some systems include other related capabilities for maintenance planning and budgeting. This software type applies to the physical and personnel aspects of signal system asset management.

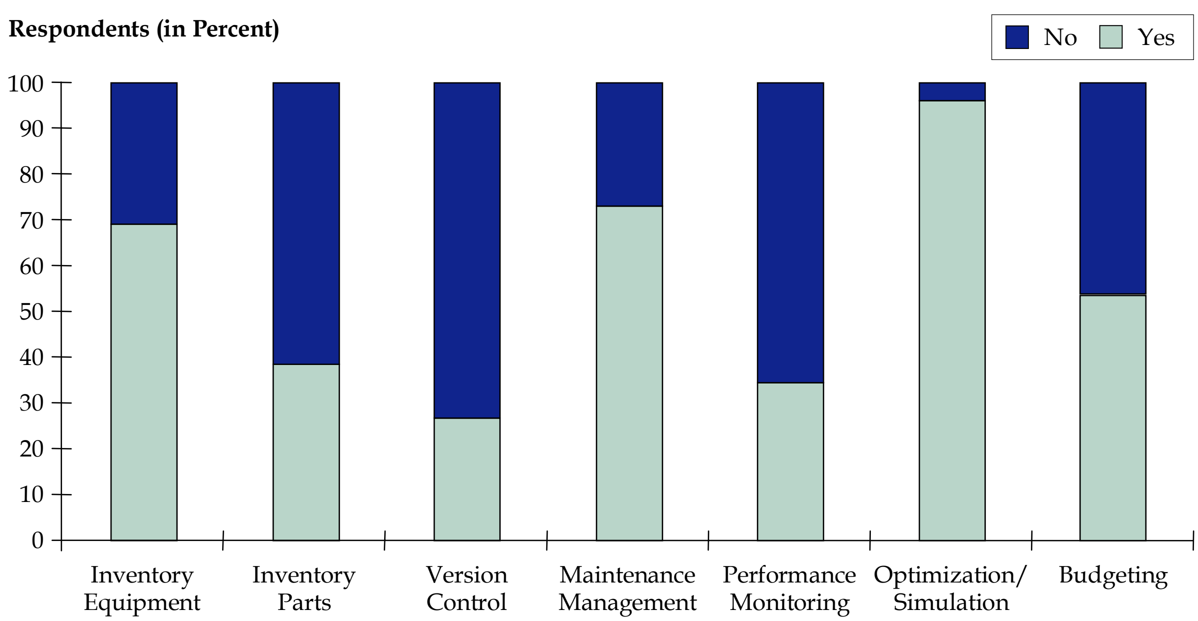
- **Performance Monitoring –** A performance monitoring system enables the agency to track the operational status of each inventoried signal system asset. Typically, this tool reports the current condition of system components in the field. This software type applies to the system aspect of signal system asset management.

- **Signal Timing Optimization/Simulation –** Using current traffic data, signal functionalities, and roadway geometry data, this software tool enables the agency to optimize traffic flow at signalized intersections by generating signal timing plans. This software type applies to the system aspect of signal system asset management.

- **Budgeting –** This software tool enables the agency to develop capital, maintenance and/or operations budgets. Software can range in complexity from a simple spreadsheet that is used to track planned versus actual expenditures by category to more sophisticated software that allows for trend analysis, projection of future costs or analysis of alternative budget scenarios (based on links to inventory information). As noted above, some maintenance management systems include a budgeting capability. This software type applies to all three aspects of signal system asset management.

Figure 7 shows the percentage of respondents using each type of software tool. Signal optimization/simulation software is used by nearly all responding agencies, and a majority of agencies have implemented systems for inventory and maintenance management. This indicates that the starting point for effective management of physical assets is generally (but not universally) in place – software that allows agencies to track what they own. The relatively high level of use of maintenance management software provides an indication that tools are in use providing capabilities to manage these physical assets effectively, anticipate and plan for preventive maintenance needs and to monitor actual costs over time. Maintenance management software also allows agencies to better understand the personnel requirements associated with different types of work activities.

Figure 7. Respondents Using Signal Management Software



The consistent use of signal optimization/simulation software indicates that agencies are making use of analytical tools to optimize system performance, which is consistent with asset management practice (ensuring effective delivery of services). Greater use of performance monitoring tools (which are typically an integral part of signal management and control software) would strengthen asset management capabilities in the systems area by providing a feedback loop. Performance monitoring capabilities are likely to improve over time as agencies pursue upgrades to signal system technology.

Table 4 lists the types of software used under each category. A wide variety of software is used, ranging from standard MS Office products such as Access and Excel to highly specialized systems. There is a mix of "home grown" systems and commercial software. Several agencies are using software tools that incorporate functions from several of the different software categories in an integrated fashion. Packages such as Hansen, VHB's Infrastructure 2000, and CarteGraph provide inventory, parts tracking, maintenance management/work orders, cost-tracking, and budgeting capabilities. Performance monitoring tools cited are part of signals or broader ITS management and control software packages; some of these tools (e.g., Siemens i2tms) include links to signal timing optimization software.

Table 4. List of Software from Part 2 – Question 3

Name of Inventory Tracking Software for Field Equipment:
Access Database – PYRAMIDS
AFMS – In-house Oracle Database (Signals and Lighting)
CarteGraph
Custom SmartWare II DOS-based inventory databases, custom Windows-based object-oriented database ("MONOLITH"), and ESRI GIS mapping (shape files)
Great Plains – Dynamics accounting software (Microsoft)
i2tms – integrated traffic management system (Siemens)
Infrastructure 2000 (Vanasse Hangen Brustlin)
Maintenance Management System
MS Access
MS Excel
MS Office
Operations Management System (in-house operations budgeting and tracking software)
Paradox
RCMC (in house)
Name of Inventory Tracking Software for Spare Parts
AFMS – In-house Oracle Database
CarteGraph
Great Plains – Dynamics
Infrastructure 2000 Vanasse Hangen Brustlin
MS Excel
MS Office
RCMC in-house
Name of Hardware/Software Version Control Software
CarteGraph
Computran UTCS Protocol 90
Infrastructure 2000 (Vanasse Hangen Brustlin)
MS Office
Translink
WAPITI W4IKS, HCII rev 14/45A

Table 4. List of Software from Part 2 – Question 3 (continued)

Name of Maintenance/Work Order Management Software

- AFMS – In-house Oracle Database (Signals and Lighting)
- CarteGraph
- CASSWORKS
- FileMaker
- FoxPro and MS Access to a database
- Hansen Information Technologies
- Infrastructure 2000 Vanasse Hangen Brustlin
- Maintenance Management System
- MS Access
- MS Excel
- MS Word
- Paradox
- RCMC
- TNI/PDA – Allows for wireless Internet connectivity to fill out and submit electronic work orders

Name of System Performance Monitoring Software

- Computran UTCS Protocol 90
- i2tms
- JHK2000 and Naztec
- MONARCH/SCOOT
- Multi-Arterial Signal System
- PYRAMIDS and TNI/PDA – Both allow controller notification of problems
- TransCore Series 2000

Name of Signal Timing Optimization/Simulation Software

- CORSIM
- HCM Cinema
- HCS 2000
- NETSIM
- No-stop
- Paramics
- Passer II
- Signal2000
- SimTraffic
- SYncgri TS-PP
- Synchro
- Synchro and SimTraffic
- SynchroPro
- TEPAC 2000
- Transyt-7F
- TSIS
- TS-PPD

Table 4. List of Software from Part 2 – Question 3 (continued)

Name of Budgeting Software
MS Excel
Operations Management System
FileMaker
Banner
RCMC
Maintenance Management System
SAP
County's budget software
ADVANTAGE TOOL
Utah State Budgeting Software

Collection and Uses of Data

Data on Physical Components

Respondents were asked what types of data they maintain about major components, including signal heads, detectors, controllers, structures and communications equipment. The types of information listed on the data collection instrument included component characteristics, serial numbers, maintenance requirements, maintenance costs and history, repair and failure history and age/condition. The results are shown in Table 5.

Table 5. Information Maintained on Signal System

	Signal Heads	Detectors	Controllers	Structures	Communications Equipment
Characteristics of Components (equipment models, functions, etc.)	46%	46%	62%	35%	50%
Serial Numbers of Components	12%	12%	31%	80%	12%
Maintenance Requirements	12%	15%	27%	80%	15%
Maintenance Costs/History	42%	38%	46%	35%	38%
Repair/Failure History	38%	31%	50%	35%	38%
Age/Conditions	19%	27%	46%	23%	31%

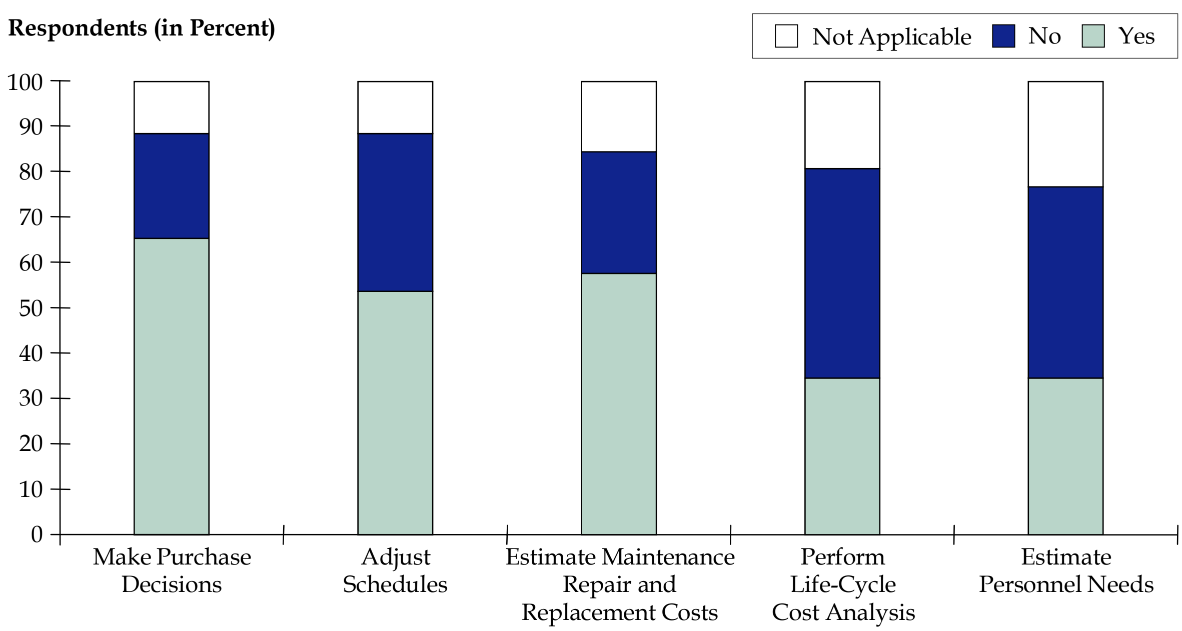
Note: Highlighted numbers are greater than or equal to 50 percent.

Most respondents reported keeping some type of information on one or more signal system components, with the largest number reporting that they maintain information on signal heads and controllers. However, there was significant variation across agencies with respect to the type of data they maintain. As illustrated in Table 5, only five elements (component/data type combinations) were maintained by 50 percent or more of the respondents.

The results indicate that while many agencies do have inventory and maintenance management systems, relatively few keep track of information such as failure rates, repair histories, maintenance costs and maintenance requirements that are needed to pursue a more proactive approach to management of physical assets. Without this type of information, it is difficult to develop effective preventive maintenance strategies. It is also difficult to build accurate predictive capabilities to demonstrate the likely impacts of different investment levels or packages of improvement options.

Respondents were asked whether they use the component information they maintain for a) equipment purchase decisions, b) adjusting preventive maintenance schedules, c) estimating maintenance, repair and replacement costs, d) analyzing life-cycle costs, and e) estimating personnel needs. As shown in Figure 8, one-third or more of the respondents said that they used the information for each of these areas. The most commonly cited uses of component information were for equipment purchase decisions and cost estimation. The least common use of the data was for life-cycle cost analysis (which would depend on a richer set of cost-tracking data than most agencies keep) and estimation of personnel needs (which would depend on using maintenance management/work tracking capabilities to analyze personnel requirements associated with preventive and responsive work on components).

Figure 8. Respondents Using Component Condition/Status Data for Decision-Making



Data on System Performance

Investments in signal systems are made in order to provide safe and efficient movement of traffic. Therefore information about system performance – in terms of crashes, throughput, delays, stops, travel time/speed are important metrics for evaluating the effectiveness of signal system investments, and for providing valuable input needed for effective management and operation of signal systems.

Respondents were asked whether they collect system performance data, which items they collected and how. Results are shown in Figure 9 and Table 6. As shown in Figure 9, the most commonly collected performance data items were intersection crashes and fatalities (through established police reporting procedures and agency crash records systems) volumes/throughput and speeds (through automated and manual traffic counts, video monitors, special studies and signal system control/management software), and inquiries/complaints (through a variety of automated and manual tracking systems, some of which are integrated with maintenance management software). Just under half the respondents report collecting data on intersection delays; those that did used a variety of methods including traffic monitors, special studies, and simulation tools. Very few collected information on queue lengths, stops, and signal downtime. Agencies that did collect information on queue lengths and number of stops used a similar set of methods as those used for information delay. Sources of information on signal downtime included the signal system management software, work orders, and manual log books.

Figure 9. Performance Data Collected by Respondents

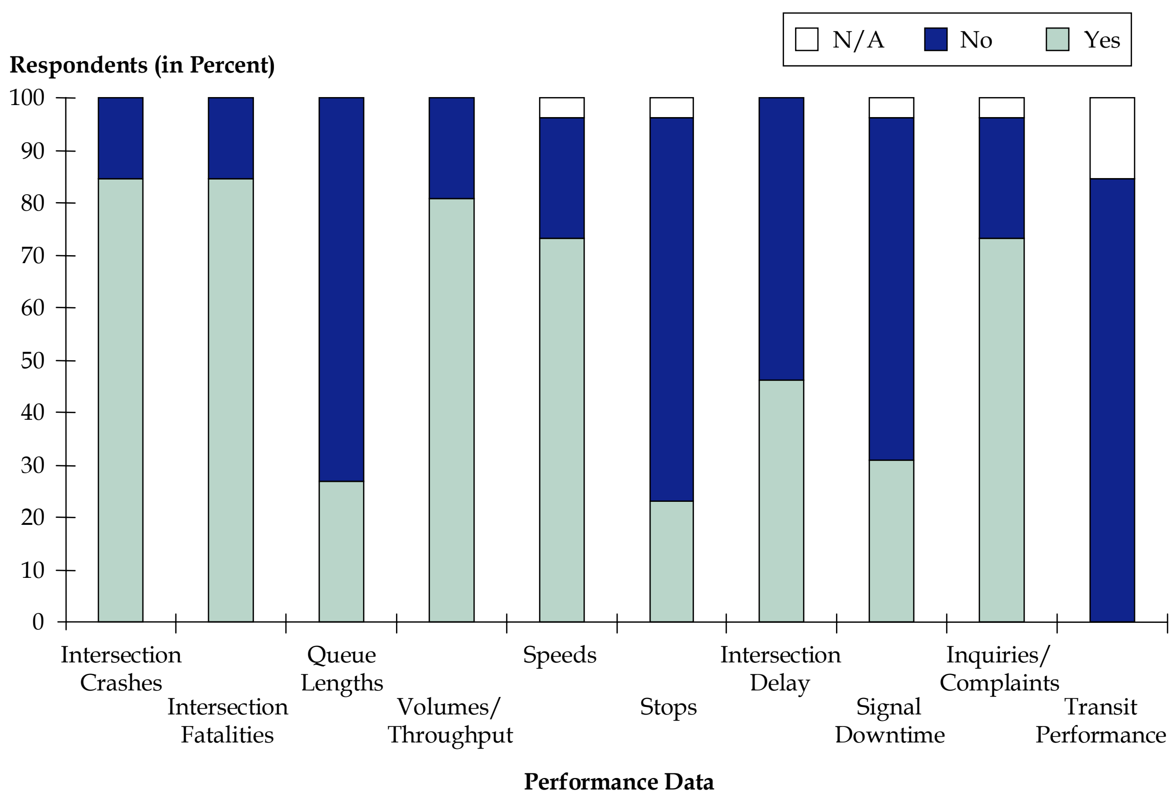


Table 6. Performance Data Collection Methods

Methods of Data Collection
Intersection Crashes
Police/crash Reports
Accident report system
Statewide accident database
Intersection Fatalities
Police/crash Reports
Accident report system
Statewide accident database
Queue Lengths
Analysis model output
Studies performed as needed
Loop Detectors
Volumes/Throughput
PETRA by JAMAR
Mechanical and manual traffic counts
24-hour, bi-directional
Studies performed as needed
From signal systems
Loop detectors
ADT and peak-period turning movement counts
Video
Speeds
Radar speed studies
PC Travel by JAMAR
Video
Tube and manual speed studies
Studies performed as needed
From signal systems
Loop detectors
Number of Stops
PC Travel by JAMAR
Analysis model outputs
Studies performed as needed
Driving/time runs
Intersection Delay
Observation
PETRA
Analysis model output
HCM/Synchro
Studies performed as needed
Loop detectors
Calculated through TMC data collection devices

Table 6. Performance Data Collection Methods (continued)

Methods of Data Collection
Signal Downtime
Maintenance/work order records
Technician's log book
Studies performed as needed
Computerized signal control system
Central Software
Number of Constituent Inquiries/Complaints
Manual and Action Center Request
Complaint office
In-house filing system (paper)
Customer Service Response by Motorola
Customer Contact System used by our front office
SAP
County Database
MS Excel spreadsheet
Hansen Information Technologies
Cassworks
Manually record all citizen complaints/requests in a database
Log
Maintenance/work order records
Transit Performance
NA

Figure 10 summarizes the reported uses of performance data for decision-making. The most common uses are 1) identifying needs for signal coordination; 2) identifying need for traffic control changes; and 3) identifying improvement needs. Over half the respondents also reported using performance data for real-time signal timing adjustment, periodic signal timing adjustment and planning equipment replacement.

Signal Improvement Priorities

Questions were asked about improvement priorities in order to understand the types of options and tradeoffs that respondents are considering in order to improve the performance of their signal systems. The signal systems asset management approach should provide methods for analyzing these options and tradeoffs.

Figure 10. Respondents Using Performance Data for Decision-Making

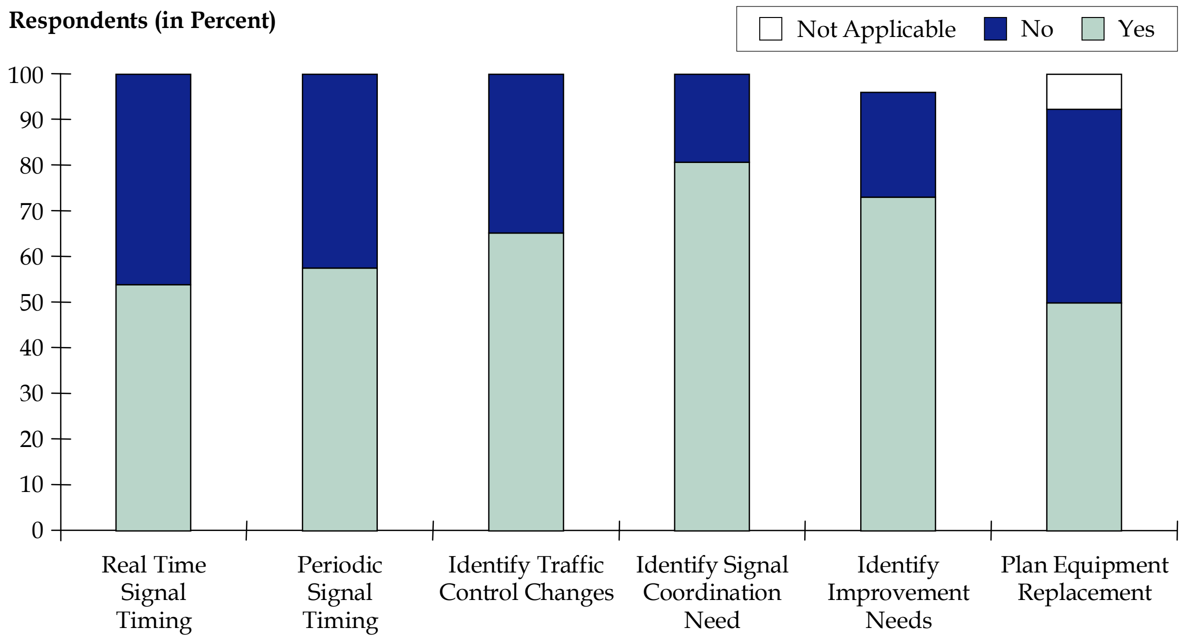


Figure 11 summarizes respondents' priorities for signal improvements in the systems area. The highest priority types of improvements (cited by 40 percent or more of respondents) were adjustment/upgrade of existing signals, integration of signals within their own jurisdictions, improvement of system capabilities and establishing/upgrading a Traffic Management Center.

Figure 12 summarizes respondents' priorities for physical signal improvements. The highest ratings were given for replacement/repair of signal equipment, reduction in responsive repair costs and upgrade of communications.

Figure 13 summarizes priorities in the personnel category. The highest priority was on increasing the number of operations and maintenance staff followed by improving the match between staff skills and work needs. The low rating for contractor responsiveness is a function of the fact that only a few of the responding agencies use contract services for operations or maintenance. Four agencies outsourced work to private contractors for repairs, two for maintenance and none for operations.

Looking across the three categories (physical, system and personnel), the highest overall priorities (over 50 percent of respondents gave a high rating) are for equipment repair/ replacement and increasing staff.

Figure 11. Respondent's Signal Improvement Priorities (System)

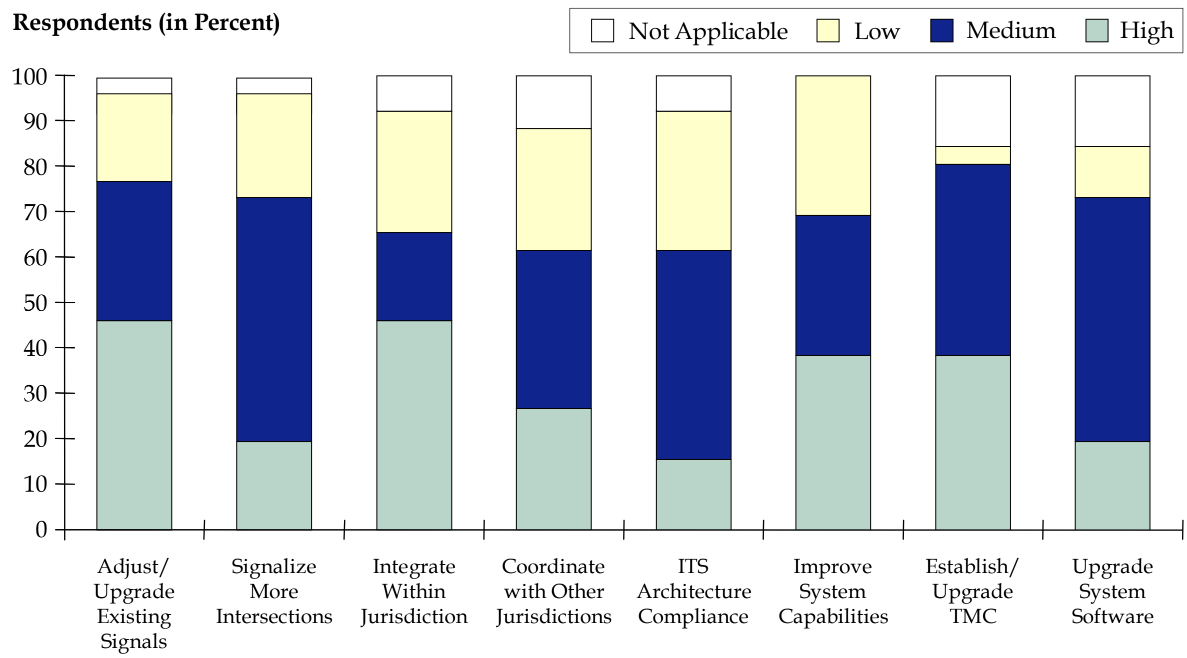


Figure 12. Respondent's Signal Improvement Priorities (Physical)

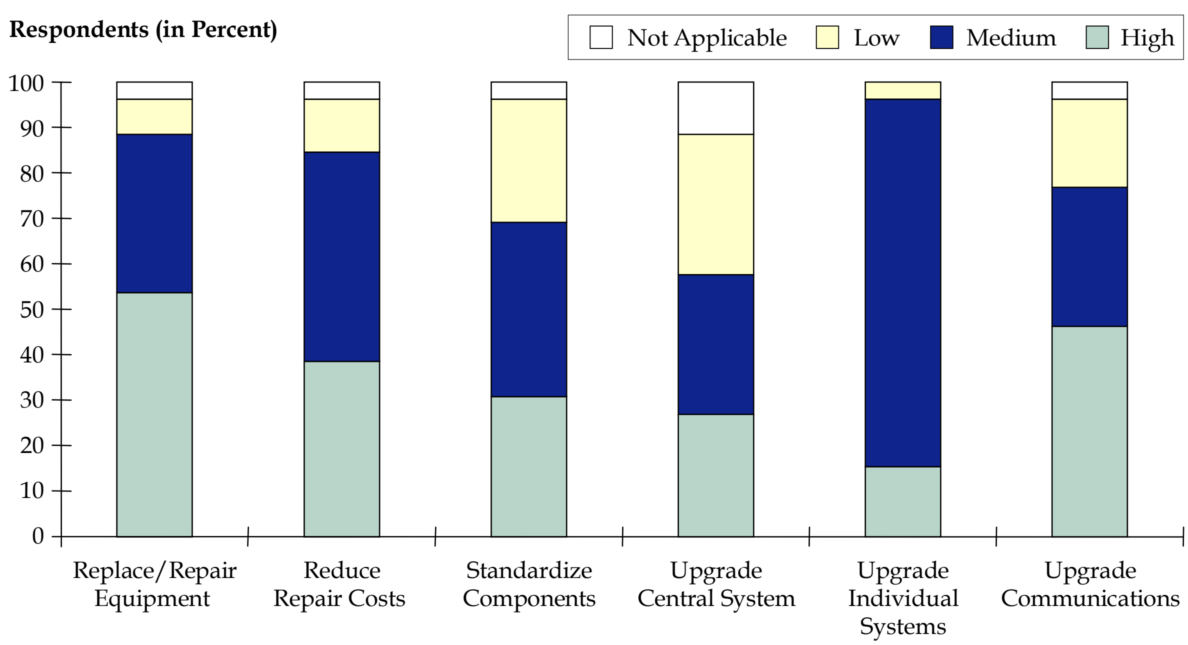
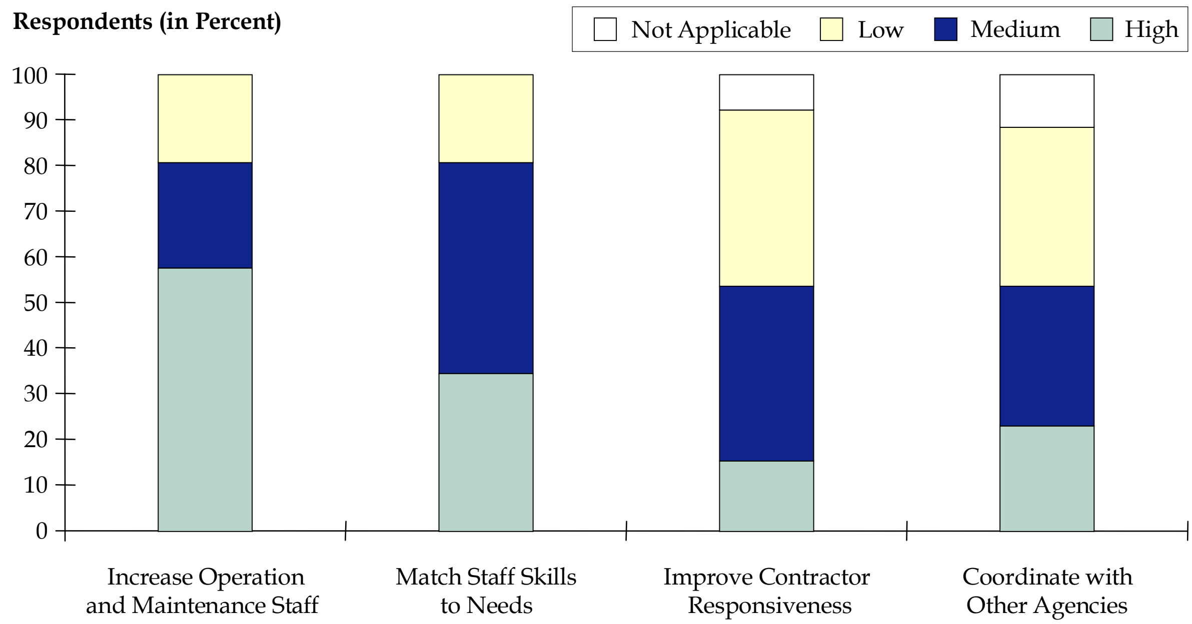


Figure 13. Respondent's Signal Improvement Priorities (Personnel)



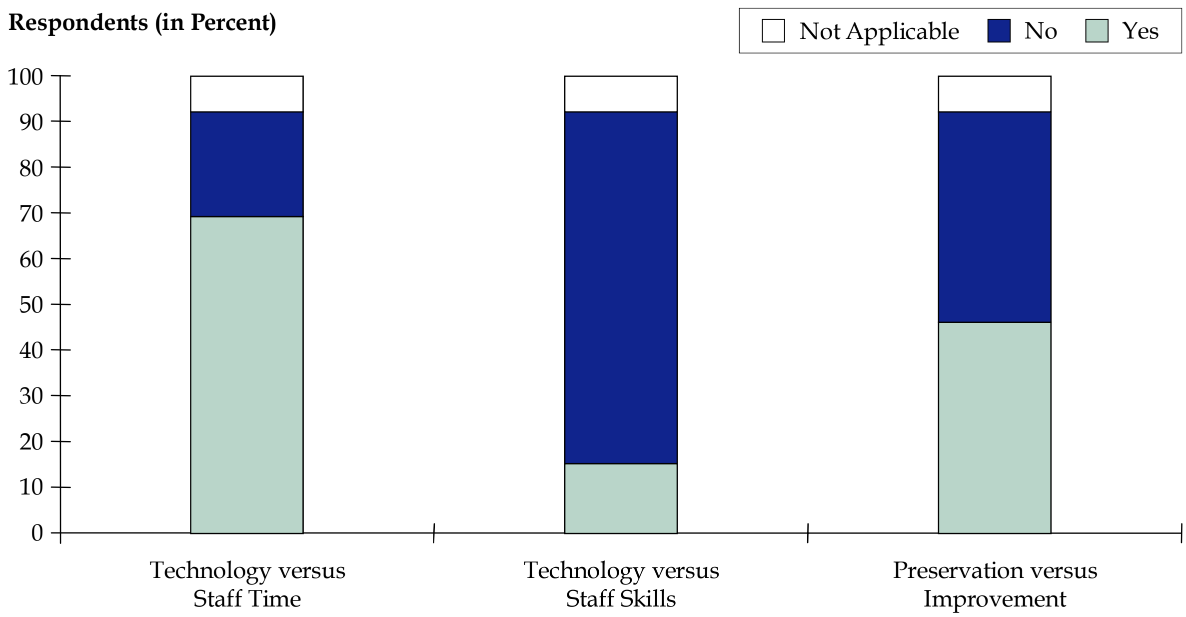
Tradeoffs

Respondents were asked to indicate the types of tradeoffs they considered in signal management decisions. These results are shown in Figure 14 and indicate that most of the agencies do consider investments in new technology as a way to free up staff time for other activities. Almost half of the agencies also reported that they have well-defined criteria or methods for deciding how to allocate available resources between maintaining existing physical signal infrastructure (e.g., equipment replacement) versus improving the capabilities of the system (e.g., upgrades to improve performance or system expansion).

Conclusions

Results indicate that agencies are tracking and managing the physical, systems and personnel components of their signal systems at varying levels of sophistication, as appropriate to the scale and complexity of their systems. Tools and techniques are in place to optimize system performance for the road user; most agencies track performance of intersections or groups of intersections with respect to safety and delay; and use this information to identify improvement needs. As agencies upgrade signal management technologies, new real-time capabilities for performance monitoring and control will come on-line which will allow further performance gains to be realized.

Figure 14. Respondents Making Tradeoffs



With respect to the physical aspect of signal systems, most agencies have basic inventory tracking and maintenance management systems, but relatively few maintain data on failure rates and historical repair costs that would be needed to make a case for doing more preventive (versus reactive) maintenance. This type of data would also be needed to develop predictive capabilities in support of performance-based budgeting approaches. Given the agencies' concerns with respect to budgetary and staff limitations and their desire to reduce repair costs, improved capabilities to both prioritize investments and to demonstrate what could be achieved with additional resources would be valuable.

Agencies are considering tradeoffs between technology and staff resources, and the application of asset management principles will increase the sophistication of this analysis. The detailed case studies conducted in the next phase of the project will help identify asset management tools and practices that will meet agency needs.

Based on the data collected, some preliminary conclusions can be drawn regarding the state-of-the-practice in relation to the asset management principles outlined at the start of this memo. These include:

- **Explicit identification of performance goals and measures –** Signal system goals and objectives focus on two major areas. One is performance of the system equipment in terms of reliability and function. The other is the level of service provided to the end-user in terms of throughput and safety. These areas are related in that unreliable equipment impacts the road user. Performance measurement for signal systems appears to be well understood and mature with respect to end user measures, particularly at the site-specific (as opposed to systemwide) level.

- **Ensuring that programs, projects and services are delivered in the most effective way available –** The use of signal timing/optimization software, signal control software and maintenance management software are supportive of this principle. Further evolution in the development of preventive maintenance strategies is needed.

- **Informed decision-making based on quality information and analytic tools –** Some agencies have implemented integrated management systems to link inventory data, maintenance management, and customer request management. Some are making use of signal management systems which support real-time monitoring and control. Simulation models are being used to improve signal optimization and maintenance management systems are providing improved information on equipment status. However, many agencies operate in a reactive mode and both staff and analytical tools for data reduction and analysis are scarce.

- **Monitoring of actual performance and costs, and use of this feedback to improve future decisions –** Maintenance management systems, traffic monitoring systems and real-time signal control and performance monitoring systems all offer the potential for a rich set of monitoring information that can be used to improve both day-to-day operations and longer-term strategic investment decisions for signal systems. Currently these systems are being used but not to their potential or in support of investment decision-making due to lack of data, lack of resources (staff to process and analyze the data), and the inability to integrate information across systems in relation to one set of goals and objectives.

- **Identification and evaluation of a wide variety of options for achieving performance goals –** Based on agency ratings of priorities, it appears that practitioners do consider a variety of alternatives for signal system maintenance and improvement – spanning physical upkeep of existing components, upgrades to components, implementing new traffic management capabilities, additional coordination within and across jurisdictions, adding signals, adding staff, and building staff capabilities. However, resource limitations constrain the set of feasible options for improving system performance.

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