Elements of a Comprehensive Signals Asset Management System

FHWA-HOP-05-006

final

report

U.S. Department of Transportation
Federal Highway Administration

prepared for

Federal Highway Administration

prepared by

Cambridge Systematics, Inc.

December 2004

www.camsys.com

final report

Elements of a Comprehensive Signals Asset Management System

FHWA-HOP-05-006

prepared for

Federal Highway Administration

prepared by

Cambridge Systematics, Inc.
100 Cambridge Park Drive, Suite 400
Cambridge, Massachusetts 02140

date

December 2004

Foreword

Transportation Asset Management is a discipline that helps agencies to make fact-based decisions about allocating scarce resources to improve transportation performance. It requires agencies to establish well-defined objectives and measures of performance, maintain pertinent information about their assets, analyze a wide range of options for preserving assets and improving service, and monitor performance to provide accountability and feedback into decision-making.

Transportation Asset Management has most commonly been applied to major infrastructure assets such as pavements and bridges. However, the same principles and methods can be valuable for guiding increasingly complex decisions about allocating resources within and across different transportation operations program areas.

The FHWA Office of Operations has embarked on a program of research to define specific transportation asset management methodologies for operations. This report, *Elements of a Comprehensive Signals Asset Management System*, takes an important first step in this effort. The report focuses on a single aspect of transportation operations – traffic signal systems – and explores how asset management can be used to improve critical decisions about resource allocation and deployment. The report also contrasts the emerging view of signal systems asset management with the more established practices for infrastructure and information technology asset management. This comparison provides an understanding of what can be adapted from these existing practices for use in operations, and where new research is required to fill gaps in methodologies that are specific to operations.

The intended audiences for this report are transportation agency executives and operations managers who are interested in improved techniques for enhanced decision-making and accountability.

Jeff Lindley

Director, Office of Transportation Management

Notice

Quality Assurance Statement

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-HOP-05-006		

4. Title and Subtitle
Elements of a Comprehensive Signals Asset Management System

5. Report Date
December 2004

6. Performing Organization Code

7. Author(s)
Frances D. Harrison, Daniel Krechmer, Jennifer Strasser, and Emily Sterzin

8. Performing Organization Report No.

9. Performing Organization Name and Address
Cambridge Systematics, Inc.
100 CambridgePark Drive, Suite 400
Cambridge, MA 02140

10. Work Unit No.

11. Contract or Grant No.
DTFH61-01-C-00181

12. Sponsoring Agency Name and Address
Office of Operations
Federal Highway Administration
400 Seventh Street, SW
Washington, DC 20590

13. Type of Report and Period Covered
Final Report
May 2003–December 2004

14. Sponsoring Agency Code

15. Supplementary Notes
FHWA COTR: Barry Zimmer, Operations Support Team
FHWA COTM: John Harding, Office of Transportation Management

16. Abstract
This document takes an initial step towards development of an operations asset management methodology through an investigation of traffic signal systems applications. It presents findings of a state-of-the-practice review of signal systems asset management and lays out the characteristics of signal systems that need to be considered in defining an asset management approach. The report then develops an architecture for a signal system asset management system, and presents an analysis illustrating how such a system could be used to evaluate tradeoffs across different options for addressing signal system deficiencies.

The report concludes with a comparison of the signal systems asset management approach to asset management systems currently in use for infrastructure assets and information technology assets. Elements of each of these two types of asset management systems can be used as models for the further development of the signal systems asset management methodology.

The architecture, analysis, and comparison presented in the report provide a solid basis for proceeding with further development of a signal system asset management approach. They also provide insights that are applicable to developing asset management approaches for other types of operations assets.

17. Key Words
Asset management, traffic operations, traffic signal systems, management systems

18. Distribution Statement
No restrictions. This document is available to the public through the National Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	62	

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

Table of Contents

List of Tables

List of Figures

1.0 Introduction

1.1 Project Background

Experience over the past 30 years with transportation asset management systems has focused primarily on collection of inventory and condition information, and the development of maintenance, rehabilitation, and reconstruction/replacement strategies for major infrastructure components (pavement, structures) and associated hardware (e.g., signs, guardrails, fences). Recently, the American Association of State Highway and Transportation Officials (AASHTO) adopted the new Asset Management Guide, which defines transportation asset management as "a strategic approach to managing transportation infrastructure" with a focus on "business processes for resource allocation and utilization with the objective of better decision-making based upon quality information and well-defined objectives." This definition is intended to broaden the scope of transportation asset management beyond the historical focus on preservation of physical facilities. As attention shifts towards operations as a critical means of addressing current congestion and safety problems, decision-makers need better methods to decide how to best allocate resources within and across operations program areas, and ultimately, between capacity expansion and operations.

The US Federal Highway Administration (FHWA) Office of Operations is undertaking a program of research to develop methodologies for operations asset management. An initial step in this research program is to conduct an investigation of a specific area of operations – traffic signal systems, and explore what an asset management system might look like to support resource allocation decisions within this area.

Asset management applied to operations can certainly borrow some of the approaches, tools, and techniques from infrastructure asset management, but operations is in many respects different from infrastructure. While operations programs do include physical assets that need to be maintained, repaired, and replaced, their performance is not measured by the condition of these assets, but by how well traffic moves, how much delay is experienced, and how many crashes occur. Therefore, factors such as equipment reliability and down-time, signal timing plans, and response time to incidents are key determinants of operations program performance. These factors are a function of three different aspects of operations programs – *physical equipment* that is deployed; the *systems* that connect, control, and manage this equipment; and the *people* that maintain and operate the equipment, keep it functioning well, and respond to problems. An operations asset management system concept needs to consider each of these elements and assist program managers to determine how to best manage them – individually and in combination – to achieve the best possible performance.

1.2 Document Overview

The purpose of this report is to define the elements of a comprehensive signal system asset management system (SSAMS). It builds on the results of a state-of-the-practice review of signal systems asset management, and lays the ground-work for investigating how a SSAMS could be used to evaluate alternative investment strategies. The document includes the following sections:

Section 2.0 provides an overview of asset management principles, which provide a framework on which to base the definition of a SSAMS.

Section 3.0 lays out the general operational and management characteristics of a signal system that need to be considered in designing a SSAMS. This is based on a state-of-the-practice survey of 26 agencies and follow-up in-depth interviews at Wisconsin DOT and the Minnesota DOT Metro District.

Section 4.0 presents an example of a "generic" signal system management organization and describes its operation and management characteristics as defined in Section 3.0.

Section 5.0 identifies key elements of a SSAMS that would support the functions of the generic signal system.

Section 6.0 presents an analysis of scenarios for signal system improvement illustrating how a SSAMS could be used to evaluate tradeoffs across different options for addressing signal system deficiencies.

Section 7.0 compares the SSAMS concepts developed in Section 5.0 to both infra-structure asset management and information technology (IT) asset management systems and identifies similarities and differences.

Section 8.0 summarizes findings and conclusions concerning the development and implementation of signal systems asset management.

2.0 Transportation Asset Management

The core principles of transportation asset management are summarized below. These principles provide a framework for establishing a SSAMS.

- **Policy-Driven –** Resource allocation decisions are based on a well-defined and explicitly stated set of policy goals and objectives. These objectives reflect desired system condition, level of service, and safety provided to customers, and typically are tied to economic, community, and environmental goals as well.
- **Performance-Based –** Policy objectives are translated into system performance measures that are used for both day-to-day and strategic management. Ideally performance measures should be applied to virtually all activities of the organization.
- **Analysis of Options and Tradeoffs –** Decisions on how to allocate funds within and across different types of investments are based on an analysis of how different allocations will impact achievement of relevant policy objectives. Alternative methods for achieving a desired set of objectives are examined and evaluated. These options are not constrained by established organizational unit boundaries – for example, solving a congestion problem could involve a capacity expansion or an operational improvement (e.g., signal coordination). The best method is selected considering the cost (both initial and long-term) and likely impacts on established performance measures. The limitations posed by realistic funding constraints must be reflected in the range of options and tradeoffs considered.
- **Decisions Based on Quality Information –** The merits of different options are evaluated using credible and current data. Where appropriate, decision support tools are used to provide easy access to information and to perform specialized analyses (e.g., simulation, optimization, scenario analysis, life-cycle cost analysis).
- **Monitoring to Provide Clear Accountability and Feedback –** Performance results are monitored and reported for both impacts and effectiveness. Feedback on actual performance indicates progress toward agency goals and objectives, and is connected to resource allocation and utilization decisions.

These principles provide a conceptual framework for transportation asset management. The specific business processes, tools, and techniques will vary depending on the specific domain within transportation. The next section examines the signal system operations domain, explores how transportation asset management principles are currently being applied, and identifies constraints and opportunities for further strengthening the application of these concepts.

3.0 Signal System Characteristics

In order to identify the key characteristics of signal systems that should be taken into account in the development of a SSAMS, the state-of-the-practice in signal system asset management was evaluated through a literature review, agency survey, and follow-up in-depth interviews. The detailed findings of the state-of-the-practice review were documented in an earlier report prepared for this project[1], and are summarized below.

3.1 STATE-OF-THE-PRACTICE REVIEW

The state-of-the-practice review targeted mid-sized agencies (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 are not representative of the majority of agencies. In order to identify the "mid-sized" agencies, a copy of the latest (2000) ITS Deployment Tracking Survey[2] database was obtained from Oak Ridge National Laboratories. This database covered agencies in the 75 largest U.S. metropolitan areas. Figure 3.1 shows the distribution of agency size included in this database. Of 428 total agencies included in the ITS Tracking Survey database, 41 percent (176) have less than 100 signals; 21 percent (89) have between 100 and 200 signals, 32 percent (137) have between 200 and 1,000 signals, and the remaining six percent (26) have over 1,000 signals.

Twenty-six mid-sized agencies identified from the ITS Tracking Survey database agreed to participate in this state-of-the-practice review. These agencies were asked to provide information about the following three aspects of signal system operations and management:

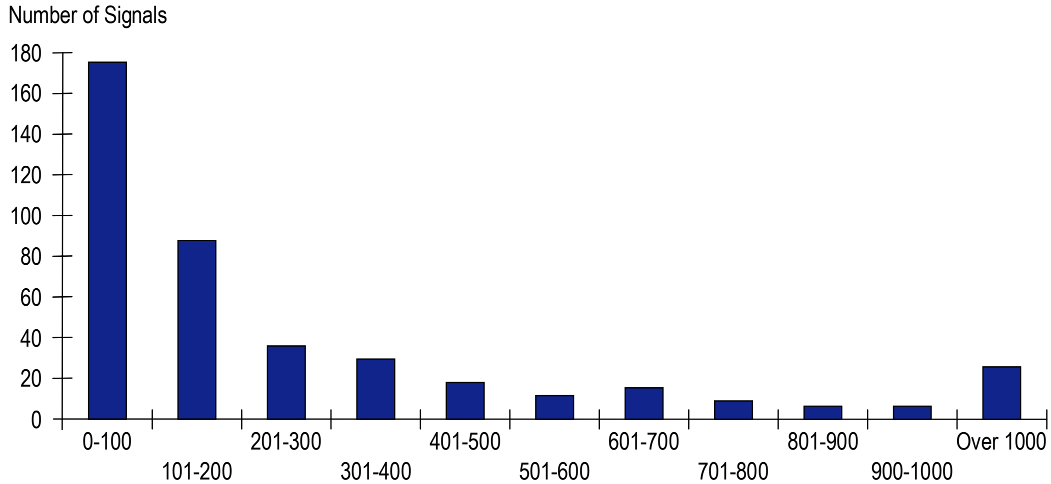
1. **Physical –** The specific physical components that make up signal systems (e.g., signal heads, loop detectors, video cameras, controller boxes);
2. **System –** The capabilities and configuration of hardware, software and communications infrastructure that connects and controls the signal system to provide the traffic management function; and
3. **Personnel –** The staff resources available for operating and maintaining the signals and the institutional and management approaches used to provide these staff resources.

---

[1] Signal Systems Asset Management – State-of-the-Practice Review, prepared for the FHWA Office of Operations, April 2004.

[2] http://itsdeployment2.ed.ornl.gov/its2000/default.asp.

Figure 3.1 ITS Deployment Tracking Survey
Distribution of Agencies by Number of Signals



The data collection instrument was designed to gain insights into how agencies balance investments in these three areas as they maintain and improve their signal systems.

Results of the agency survey 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 online which will allow further performance gains to be realized.

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.

Based on the data collected, the following conclusions can be drawn regarding the state-of-the practice in relation to the asset management principles stated in the previous section:

Policy-Driven and Performance-Based – 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.

Analysis of Options and Tradeoffs – 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.

Decisions Based on Quality Information – 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 to Provide Clear Accountability and Feedback – 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.

3.2 In-Depth Interviews

In-depth interviews were held with the Minnesota DOT Metro Division and the Wisconsin DOT Central Office Traffic Operations Group. These interviews supplemented the state-of-the-practice review, providing more detailed information on signal system management and operations that are necessary for defining the elements of a SSAMS. Key findings were as follows:

MnDOT Metro District

- **System Size –** The Metro District covers the Minneapolis-St. Paul metropolitan area and is responsible for 650 signalized intersections or about 50 percent of the signalized intersections under MnDOT jurisdiction in the State.
- **Organizational Responsibilities –** Signal maintenance and operations functions are provided by separate units. Signal maintenance functions include

routine maintenance and repairs. These functions are carried out by electricians, electronic technicians, and locators (responsible for identification of underground utilities). The unit responsible for signal maintenance is also responsible for lighting maintenance. Signal operations functions include signal timing, and signal system upgrades and replacements. These functions are carried out by traffic engineers, signal technicians, and construction inspectors. In addition, several departments outside of traffic operations perform specialized functions – for example, the road maintenance department performs annual preventive maintenance inspections on electronic signal components.

- **Monitoring –** MnDOT tracks personnel hours, vehicle usage, and materials usage for maintenance/repair activities and capital projects. Complaints from the public (primarily related to equipment failures) are monitored. Maintenance records are kept and reviewed to identify failure patterns. MnDOT has also begun to systematically evaluate each intersection's capacity and throughput.
- **Operations, Maintenance, and Repair Strategies –** Annual timing adjustments are made as needed based on intersection evaluation (and using guidelines for minimum cycle lengths); contractors are used to recommend and sometimes implement the new timing plans. Repairs are made in response to customer complaints/service requests. Repair guidelines are used to determine priorities for addressing these requests (e.g., equipment failure is highest priority). Analysis of failure patterns is used to identify replacement needs – by equipment type and location. Preventive maintenance is performed on all cabinets, filters, and bulbs twice annually. Contracts are let for cable and wire replacement, and "group relamping" activities (replacement of 3,000+ lamps at one time). Older signals are replaced (10 to 15 per year) – sometimes just the signal head (which has a shorter life) is replaced. The signal control system is maintained in-house.
- **System Upgrades –** New signals are added in response to traffic studies – the construction cost is shared with municipalities and with private developers. Most of the controllers have been modernized – many of these were accomplished as special projects. Upgrades to the signal control system are done by the vendor.
- **Budgeting –** There are separate budgets for maintenance and operations. The operations budget includes an allocation for preservation projects (rehabilitation and replacement of older equipment). Budget requests have been based primarily on historical trends, but a new maintenance management system is providing a better basis of information for forecasting of requirements from year to year. For major signal upgrades, intersections are prioritized based on safety considerations and volume.
- **Key Tradeoffs –** 1) Preventive versus responsive maintenance: preventive maintenance has been proven to be beneficial (e.g., the implementation of a

preventive maintenance plan back in 1987 led to a decrease of 50 percent in signal malfunctions) but it has been difficult to fund it adequately and therefore much of the maintenance is reactive; and 2) life-cycle implications of new investment: Adding new signals to the network and introducing new technology to improve performance (e.g., video detection) has "downstream," life-cycle impacts on maintenance and operations needs that are not anticipated or budgeted for. New ITS technology imposes up-front training requirements as well. Use of standardized equipment is preferred from an operations and maintenance perspective to ensure reliability and minimize training needs.

WisDOT

- **System Size –** WisDOT owns approximately 1,000 signals. Over 60 percent of these are in District 2, which includes the greater Milwaukee area. Others are maintained by the State through agreement.
- **Organizational Responsibilities –** WisDOT's signal operations and maintenance function is split between the Central Office and the Districts. The WisDOT Central Office in Madison has two electricians that provide oversight to maintenance personnel in the eight districts. The Central Office also has a shop that builds cabinets. On the operations side, the Central Office has a signal group with six traffic engineers who do capacity analysis and signal design. The Central Office also executes statewide contracts for servicing controllers. District 2, which contains the majority of state-owned signals is the base for most of the electrical staff in the State. District 2 also has two people dedicated to safety and signal operations. In other districts there is generally a "lead worker" in signal operations and an engineer who is in charge of signal studies, design, and analysis. Depending on the size of the district, this engineer may have other duties as well.
- **Monitoring –** WisDOT tracks service requests, including response and repair times. Timesheet information is used to track labor hours for signal maintenance and repair activities.
- **Operations, Maintenance, and Repair Strategies –** WisDOT staff respond to service requests, though budgetary constraints and staff reductions make it difficult to address non-emergency requests. About five percent of signals are rehabilitated annually. Monitor checks are also conducted annually and refurbishing and rewiring is done where necessary.
- **System Upgrades –** Needs are identified through the annual six-year program update process. Corridor or area planning studies also help to identify future investment needs. Signal requirements are often generated through Traffic Impacts Analysis related to new development. WisDOT reviews these analyses and may identify the need for new signals or signal upgrades. This process allows for systemwide impacts to be identified and clearly documents the need for improvements. If the improvement required is not in an

existing plan, the developer will pay the full cost. A cost sharing agreement will generally be negotiated between the developer and WisDOT if the improvement is already in the plan but not funded.

- **Budgeting –** Previous year's budgets are reviewed prior to the annual capital budgeting process and are generally used as a guideline. A similar process is used for operations and maintenance budgeting. Improvements to inventory tracking are being made to establish annual budgeting requirements. Both Central office and District activities are being tracked to help estimate personnel requirements for the upcoming year.
- **Key Tradeoffs –** Budget cuts have forced WisDOT into a more reactive (rather than preventive) approach to system maintenance. Labor is the most constrained resource, and impacts on introduction of new components (such as LEDs) on personnel requirements are considered.

3.3 Overview of Signal System Characteristics

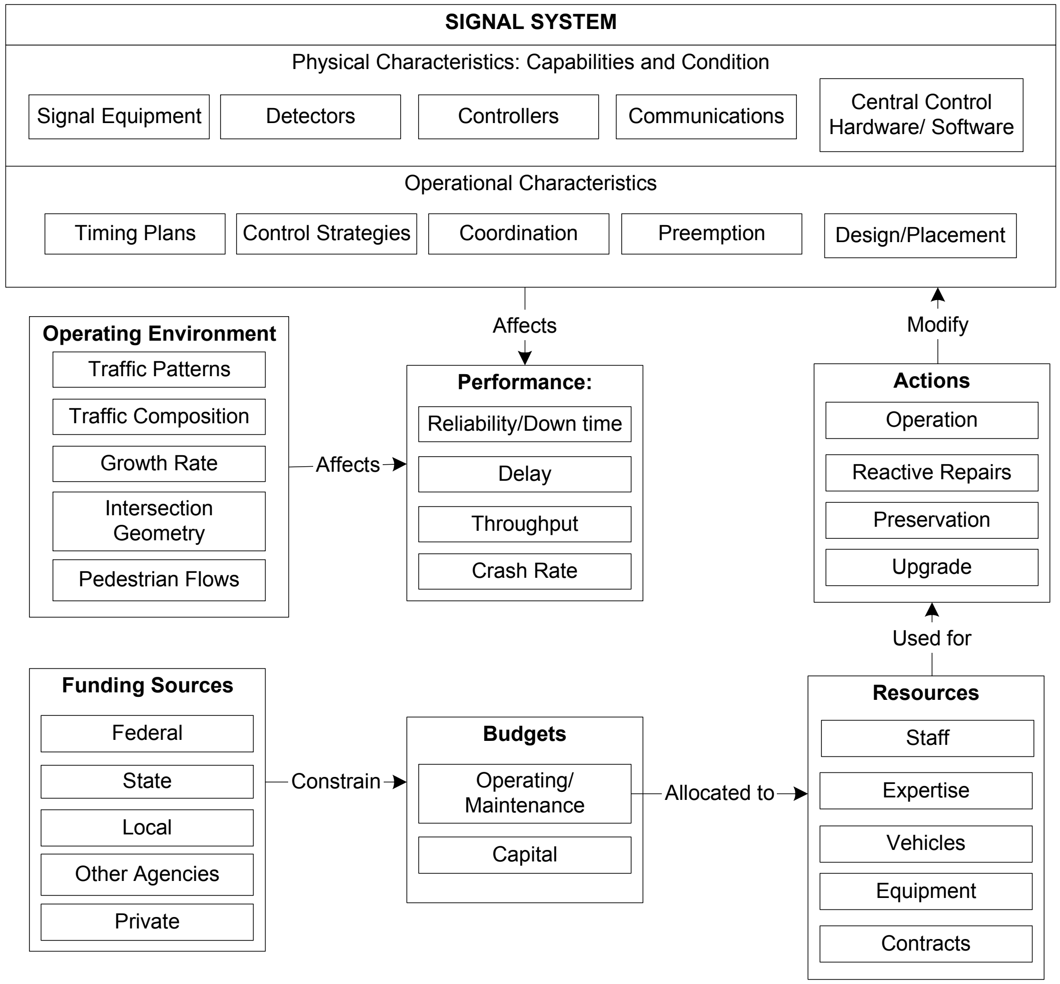
The information collected from the state-of-the-practice review and in-depth interviews has provided insights into the decision-making structure of signal system agencies. This section builds on these reviews, and identifies those characteristics of signal systems that need to be considered in order to determine the types of capabilities to be provided by a SSAMS.

Figure 3.2 provides an overview of the characteristics of a signal system that are relevant to the development of a SSAMS, and shows the logical interrelationships among these characteristics.

Each of these characteristics is discussed below:

- **Physical Characteristics of the Signal System –** The signal heads, structures, controllers, detectors, communications system, and central control hardware and software. Each of these physical components has a set of *capabilities* and a *condition* that affects its functionality and performance. While not illustrated in the figure, it is also important to recognize that because these different parts make up a system, the interconnections and dependencies among components must be considered. A hierarchical view of a signal system is needed to indicate subsystems and their member signals and controllers. Such a view would also allow for decomposition of signal heads, controllers, structures, detectors, and communications equipment into their component parts.
- **Operational Characteristics of the Signal System –** These encompass signal timing plans, coordination of different signals in the system, control strategies (e.g., fully versus semi-actuated operation, use of adaptive control), preemption and priority strategies in place, and other aspects of signal system design such as detector placement.

Figure 3.2 Signal System Characteristics



- **Operating Environment of the Signal System –** A description of the context within which the signal system operates and the demands that it must satisfy, which includes the characteristics of the road network, intersection geometry, presence of rail crossings, the current volume, composition and distribution of traffic (including percentage of trucks and buses), the variations in traffic patterns (and the degree to which these patterns are predictable based on season, time-of-day or day-of-week), pedestrian flows, and patterns of development affecting traffic growth. Other environmental factors such as temperature range and weather patterns can also be important characteristics that impact system requirements and performance.

- **Performance Characteristics –** Measures of how well the signal system is meeting objectives. Signal systems are typically evaluated based on traffic flow efficiency, throughput, reliability (failure rates or down-time), travel time and delay, and safety record (crashes). Performance characteristics are affected by the combination of the operating environment and the physical and operational characteristics of the signal system.

- **Actions –** Actions change the operational or physical characteristics of signal systems. There are many different ways used to categorize actions, but the following four basic types can be distinguished because they may be planned, budgeted and carried out using distinct sets of business processes.
  - *Operation* of existing signals (retiming, adding protected turn phases, modification to preemption or priority strategies).
  - *Upgrades* to signal systems (establishing a traffic management center, adding signals, connecting signals or changing the architecture for signal interconnections, adding new detectors to side streets, upgrading controllers, implementing adaptive signal control strategies, implementing new detector technologies).
  - *Preservation* of signal systems including inspection/testing and repair, rehabilitation or replacement of existing signals or signal system components based on observed condition or functionality, age, failure rates, or identified safety concerns.
  - *Reactive or Remedial Repairs* to correct damaged or malfunctioning equipment (e.g., signal knockdowns, lamp burnouts, detection failures, controller malfunctions, traffic progression problems, or safety risks).
- **Resources** are used to carry out work in order to impact performance. Five types of resources are distinguished here:
  - The existing internal agency *staff resources*, including traffic engineers, electricians, and technicians.
  - *Expertise* is called out as a separate resource, since it can be purchased in the form of training to enhance the capabilities of existing staff.
  - *Vehicles* used to perform signal system maintenance and repairs.
  - *Equipment* used to perform signal system maintenance and repairs (e.g., electronic test equipment).
  - *Contracts* are used to carry out capital projects and major maintenance activities – thus, they are also included as a resource. (From a day-to-day operations perspective, contracts in place are viewed as a resource to draw upon to perform actions (e.g., emergency repairs). From a longer-term planning perspective, contracts might not be classified as a resource, but rather as one method for obtaining labor, expertise, vehicles, and equipment resources.)
- **Budgets –** Resources are paid for out of budgets. There are typically separate budgets for capital, operations, and maintenance, though some agencies have a combined operations and maintenance (O&M) budget, some fund major maintenance projects from the capital budget and some agencies allow certain types of capital projects to be funded with O&M monies.

- **Funding** for signal system work comes from Federal, state, and local sources. It is common for signals projects to be funded with monies from private developers and from other jurisdictions. The funding source is important to consider, since it typically constrains what resources the funds may be used to pay for.

The next section of this report presents a model of a "generic" signal system based on a description of the above characteristics. Then, this model is used to define key elements of a SSAMS.

4.0 Generic Signal System

4.1 Overview

This section presents a description of a fictitious signal system, operated by the traffic operations division of the City of "Anywhere USA," based on the key characteristics identified in Section 3.0. A medium-sized system is described, of sufficient scale to benefit from application of a systematic asset management approach, but not so large as to require highly sophisticated or unique approaches. This concrete example will be used to help define the capabilities, features, and procedures needed to do signal systems asset management, and to develop a high-level architecture for a SSAMS.

4.2 The Anywhere Signal System

Operating Environment

The City of Anywhere's traffic engineering division is responsible for a 640-mile arterial network with 405 signalized intersections. Anywhere is a medium-sized suburban community of 200,000 population, located within a metropolitan area of 1.2 million. Most intersections are currently operating at level of service C or better. However, traffic on the arterial system in the western portion of the City has been growing at the rate of three to four percent per year, which has created the need to add new signals to the network and adjust timing plans at many intersections each year.

Physical and Operational Characteristics of the Signal System

One hundred fifteen of the 405 signalized intersections are under closed loop control. The system has 20 master controllers, and 165 local controllers – five signals are flashing and have no controller. All of the controllers are based on NEMA TS-1 and are not NTCIP-compliant. The communication network consists of dial-up telephone lines from the traffic management center to various on-street master locations and either dedicated copper or fiber optic lines from master to local controllers.

Twenty intersections have loop detectors; 10 have video detectors. 170 signals allow preemption by emergency vehicles.

A traffic management center is in place, housing two personal computers running the central control software, video monitors, and communications devices.

Performance Measures

Objectives for the Anywhere signal system are to maintain or improve current traffic speeds in arterial corridors, to improve reliability of signals, and to reduce crashes at intersections where the crash rate exceeds the regional average. Performance measures that are tracked include: number of crashes at signalized intersections, mean time between failure (MTBF) for signal components, and mean time to repair (MTTR). In addition, intersection vehicle hours of delay are evaluated as part of intersection and corridor traffic studies.

Resources

Staff

The division has a manager, two traffic engineers, two maintenance supervisors, five electricians, 10 signal maintenance technicians, two utility locators, and two construction inspectors.

Outside contractors are used for major preventive maintenance activities (e.g., relamping), and to provide support for signal timing and intersection traffic control design.

Expertise

The two traffic engineers have their professional engineer's licenses. All other staff have associates degrees and have completed training programs for their areas of responsibility. Special training is provided to staff in conjunction with any upgrades to equipment or software.

Vehicles

The division has 10 hydraulic lift trucks.

Equipment

The equipment inventory consists of 20 two-way radios, 20 cellular telephones, electronic test equipment, a stock of spare parts, power tools, hand tools, and other standard maintenance equipment such as ladders, shovels, and brooms.

Budget

The annual capital budget is $3,000,000, which is used to fund system upgrades and larger preventive maintenance projects. The annual operations and maintenance budget is $2.1 million, which funds salaries, equipment, and materials.

Actions

Operation

Signal timing is reviewed for roughly half of the intersections each year, and adjustments are made as needed in response to changes in traffic patterns.

Traffic control software is used to monitor signal operations, update system parameters, and dispatch repair crews to address operating concerns.

Upgrades

Roughly three to four new signals are installed each year, after traffic analysis has demonstrated that they are warranted.

A corridor project is underway to re-design traffic control for 10 intersections, and includes upgrades to controllers, installation of new detectors, and connecting previously isolated intersections.

A five-year program to replace older plastic signal heads with aluminum die cast heads is underway.

System software is due to be upgraded within the next two years.

An advanced traffic management study is planned, to develop a strategy for upgrading software and controllers and implementing adaptive control at selected intersections.

Preservation

Signal equipment, controllers, and detectors are inspected twice per year, and repairs are made as needed. All electronic components are tested for proper functioning. Signal indication lenses are cleaned/relamped.

Sixty signal poles are painted each year; four to five are replaced.

Reactive Repairs

In the past year, the division responded to:

- Twenty reports of signal knockdowns or damage to signal structures due to vehicle collisions;
- Fifty reports of burned-out lamps or cut cables;
- Thirty reports of timing problems that were creating traffic backups; and
- Two complaints about signal visibility.

5.0 Elements of a Signal System Asset Management System

5.1 Overview

At its heart, asset management is about making best possible use of available *resources* to implement the most effective set of *actions* that maximize *performance* in a given *environment*, informed by quality *information and analysis*. The signal system model presented in Section 3.0 and the generic model in Section 4.0 identified:

- Objectives and performance measures for signal systems;
- The physical and operational characteristics of the signal systems that impact performance;
- The environmental characteristics to which signal systems must respond, that also have a major influence on performance;
- The types of actions that are undertaken to operate, repair, preserve, and upgrade signal systems; and
- The funding sources and resources used to carry out these actions.

This section focuses on the decision-making processes and explores how information and analysis tools can be used to support and improve them.

5.2 Signal System Decision Support Requirements

In order to define the elements of a signal system asset management system, it is necessary to begin with an identification of the decision processes that the system is intended to support:

- Daily Operations and Management,
- Identification of System Deficiencies,
- Development and Evaluation of Preservation and Improvement Options, and
- Resource Allocation and Budgeting.

This section describes the key elements of these decision processes and their inputs and outputs. It presents high-level diagrams of the SSAMS components that would be required to support these decision processes. The SSAMS architecture is described in more detail in Section 5.3.

Daily Operations and Management

Key Process Elements – Staff hiring and training, work prioritization and scheduling, staff deployment, response to urgent work requests and equipment failures, adjustments to operating parameters in response to special events or incidents.

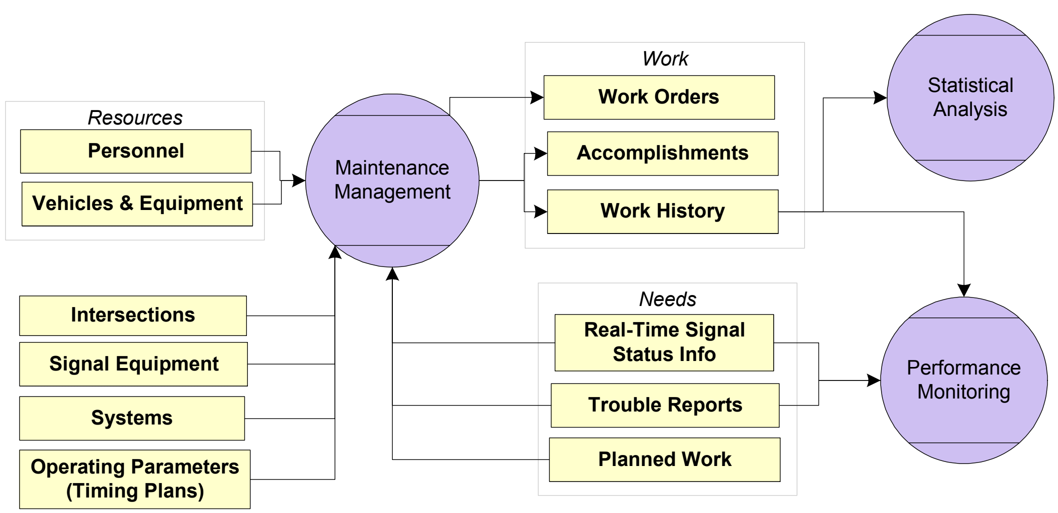
Inputs – Information about:

- Personnel, vehicle, and equipment resources (knowledge of staff capabilities and certifications; current availability of staff, vehicles, equipment and replacement parts);
- Signalized intersections (location, geometrics, traffic characteristics);
- Signal equipment and systems (specifications, maintenance and repair standards, equipment failure, and repair histories);
- Current signal timing parameters for each intersection or subsystem of intersections; and
- Needs (real-time system status, trouble reports from the public, and planned work).

Outputs – Work orders, work accomplishments, changes to staff, changes to operational parameters and equipment resulting from work, updates to ongoing system performance tracking information.

Figure 5.1 shows the SSAMS components to support this process. System functions are shown as circles; data components are shown as rectangles.

Figure 5.1 SSAMS Architecture
Daily Operations and Management Process



Identification of System Deficiencies

Key Process Elements – Identify problem areas which are contributing to poor performance – for example, equipment with high failure rates, intersections with recurring operational problems, high crash locations. Prioritize deficiencies based on severity of problems, impacts on customers and other established criteria.

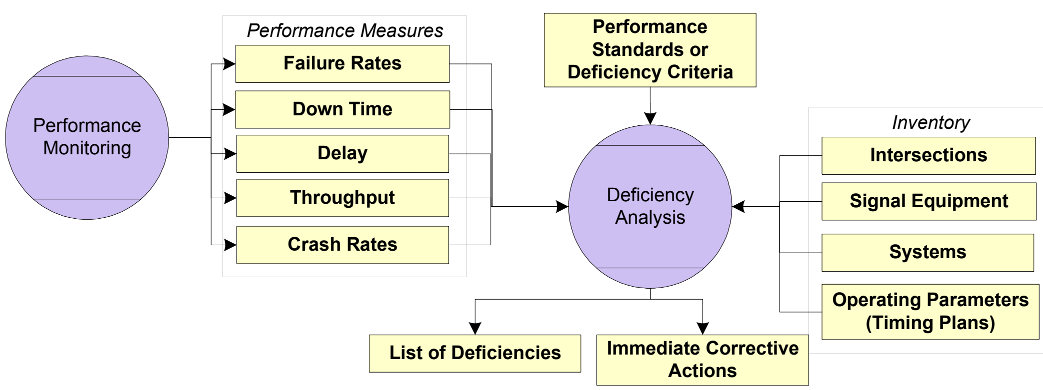
Inputs – Key inputs to deficiency analysis include:

- Performance standards or deficiency criteria;
- Measured or estimated system performance measures including crash rates from intersection crash data; component failure rates and signal down-time from analysis of repair records, trouble reports and/or archived signal system monitoring data; and user delay and throughput from traffic studies, archived real-time data, and simulation results); and
- Inventory information including intersection traffic characteristics or geometrics, signal equipment and system age, condition and capabilities, and current operating parameters of the signal system are also needed in order to identify where deficiencies exist. This information is needed in order to determine which intersections and which signal equipment meet the performance standards or deficiency criteria that have been established.

Outputs – Prioritized list of deficiencies, identification of immediate actions for correction.

Figure 5.2 shows the SSAMS components to support this process.

Figure 5.2 SSAMS Architecture
Deficiency Identification Process



Development and Evaluation of Preservation and Improvement Options

Key Process Elements – Development of *preservation* options includes specification of policies and standards for how often different types of maintenance work is to be done, and the conditions under which different types of remedial actions (repair, rehabilitate, replace) are to be taken.

Development of *improvement* options includes consideration of both operational improvements (e.g., signal re-timing) that can be accomplished without major capital investments, and upgrades (e.g., adding signals to the network, implementing a traffic management center, modernizing signal equipment and systems). All preservation and improvement options are analyzed with respect to life-cycle costs and likely contribution to improved performance. Life-cycle cost analysis is performed to understand the full costs of an option. These costs include initial capital costs and other implementation costs (e.g., staff training) and changes (both increases and decreases) in ongoing operational, maintenance requirements.

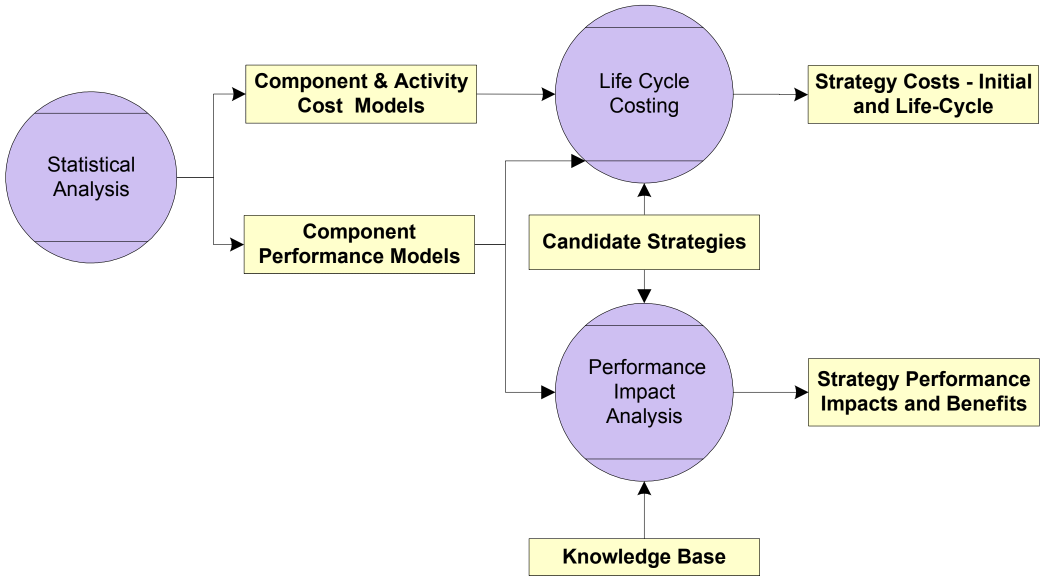
Inputs – Information needed for the development and evaluation of options includes:

- Candidate Strategies – preservation and improvement strategies for evaluation are developed based on engineering guidelines and expertise, equipment manufacturer's recommended maintenance practices, information on current technology options and specifications of available equipment, and understanding of available replacement options and their life-cycle cost profiles. These strategies must be specified in sufficient detail to allow for quantitative evaluation of costs, performance impacts, and benefits.
- Cost models for different work activities and signal system components (e.g., replacement costs, fixed and variable costs of different remedial actions, repair costs as a function of component age, use, and environmental factors). These may be derived from statistical analysis of work history and other local or national data sources.
- Performance models indicate how different physical components of the signal system deteriorate over time and how they perform at different stages of their life cycle. Example performance model indicators are average life, and mean time between failures. Sources may include agency and national information on equipment service life and component failure costs (or proxies for the degree of impact resulting from component failure).
- A "knowledge base" made up of information from a variety of sources can assist with understanding of strategy impacts. This may include research literature providing information on (or analysis of) the range in performance improvements that could be gained from different options, peer agency experience, vendor product information, and prior engineering studies or simulation results.

Outputs – Candidate strategies for consideration in resource allocation, with documented initial and life cycle costs, performance impacts, and benefits.

Figure 5.3 shows the SSAMS components needed to support the development and evaluation of preservation strategies and improvement options.

Figure 5.3 SSAMS Architecture
Preservation and Improvements Options Evaluation Process



Resource Allocation and Budgeting

Key Process Elements – Allocating a fixed budget across competing needs, making best use of available funding sources. Selecting the best mix of preservation and improvement work and associated investment in physical equipment maintenance/replacement, system refinement/upgrades, and personnel. Estimating resource requirements based on a set of target activities, assessing where to make cuts when funding is reduced, and where to make additions when funding is increased.

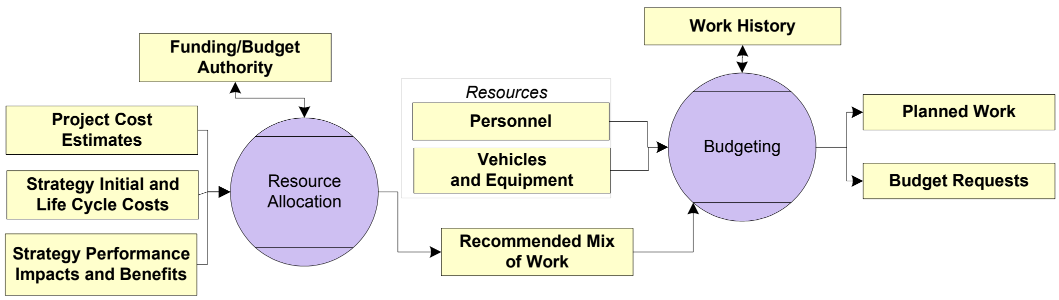
Inputs – Information needed for Resource Allocation and Budgeting includes:

- Funding/budget authority – available revenues by source, allocations by budget category;
- Resource requirements for different activity types, historical resource utilization, and unit costs by resource type;
- Estimated life-cycle costs and benefits of candidate strategies;
- Project cost estimates; and
- Work history information (for estimation of the costs of routine maintenance and operational activities).

Outputs – Planned work, budget request line items (including resource and cost estimates).

Figure 5.4 shows the SSAMS components required for the resource allocation and budgeting process.

Figure 5.4 SSAMS Architecture
Resource Allocation and Budgeting Process



5.3 KEY ELEMENTS OF A SSAMS

The key business processes that a SSAMS must support were described above in Section 5.2, and Figures 5.1 to 5.4 illustrated the associated data and analysis components for these business processes. Each of these SSAMS components is described below, and then their linkages and relationships to the key business processes are discussed.

Data Components

Intersection Inventory – Identification of the signal subsystems (groups of interconnected or coordinated intersections), and the physical locations of signal equipment at each intersection. May include documents (design drawings, traffic studies).

Equipment Inventory – Information about the equipment at each intersection (signal structures, signal heads, controllers, detectors).

Systems Inventory – Information about the communications and computer hardware and software deployed in the field and at the central management center (if any).

Personnel – Information about the personnel resources available to perform signal maintenance and operations tasks.

Vehicles and Equipment Inventory – Information about the vehicle fleet and equipment resources available to perform signal maintenance and operations tasks.

Operating Parameters – Information about the current timing plans in effect.

Work Orders – Scheduled work activities including location/component identification, resource assignments, and status.

Accomplishments – Completed work activities, summarized for performance tracking purposes.

Work History – Historical information about signal work completed – description of actions taken, components repaired and replaced, and resources utilized.

Real-Time Signal Status Information – Real-time information available from signal system management software on the operational status of different system components.

Trouble Reports – Historical information on trouble tickets including location/equipment involved, nature of problem, resolution, and response time.

Planned Work – List of planned and approved work activities to be scheduled.

Performance Measures – Measures of systemwide, corridor, intersection, and component-level performance, including equipment failure rates, signal downtime, traveler delay, throughput, and crash rates.

Performance Standards or Deficiency Criteria – Target or threshold levels of performance measures used to identify where deficiencies exist.

List of Deficiencies – List of intersections, signals or signal system components that should be considered for remedial actions in order to improve performance.

Candidate Strategies – Includes both candidate preservation and improvement strategies. Preservation strategies seek to preserve the original functionality of existing signal system components and are defined by maintenance, repair, rehabilitation, and replacement cycles. Improvement strategies include operational improvements such as signal retiming, upgrades to the system (e.g., implementing new controllers or system control software), and expansion of the system (e.g., connecting additional intersections).

Component and Activity Cost Models – Default signal system component repair, rehabilitation, and replacement costs needed for life-cycle cost analysis. These may be built up from models of standard resource requirements for different types of maintenance and repair activities and resource unit costs.

Component Performance Models – Default signal system component performance models specifying key parameters such as average life, mean time between failures, condition, or failure/malfunction rates at different ages.

Strategy Initial and Life-Cycle Costs – Estimated costs of a given preservation or improvement strategy – both initial and continuing costs over the component life cycle, typically broken down by cost component.

Strategy Performance Impacts and Benefits – Estimated performance impacts and benefits of a candidate preservation or improvement strategy – both initial and recurring.

Knowledge Base – Compendium of documents and data sets with support information on equipment specifications, activity costs, component life, research reports, etc.

Funding/Budget Authority – Information on available budget authority by category.

Budget Requests – Budget line item descriptions and costs.

Project Cost Estimates – Engineering estimates of capital projects for budgeting purposes. These may be different from the cost estimates that are derived from Life-Cycle Cost Analysis.

Functional Components

Maintenance Management – Produce work orders, schedule resources and equipment, maintain repair records, record resource utilization.

Statistical Analysis – Conduct analysis of historical repair record data to derive estimates of component life, failure rates, repair costs by age, etc.

Performance Monitoring – Provide periodic snapshots, summaries or real-time reporting of performance data used by managers and operational staff to identify needs and prioritize activities.

Deficiency Analysis – Identify deficiencies for signal system components, intersections, and/or subsystems based on established criteria.

Life-Cycle Cost Analysis – Estimate present value of outlays for a life-cycle activity profile of construction, rehabilitation/repair, maintenance and operating costs. Standard work activity definitions and associated resource requirements support this cost analysis function.

Performance Impact Analysis – Provide analysis of the performance impacts and benefits of alternative actions.

Resource Allocation – Select the best set of candidate actions to maximize performance or benefits subject to resource constraints. Account for interrelationships among personnel, equipment, and system-related items so that resources are balanced appropriately.

Budgeting – Estimate resource requirements and costs for a set of activities in support of budget development.

While not explicitly shown in the SSAMS architecture, a Query and Reporting capability is required as an integral part of all of the functional components.

Relationship between Business Processes and SSAMS Components

The SSAMS functional components defined above assist signal system management and operations personnel to make strategic, tactical, and operational decisions. They are not intended to fully automate decision-making, just to provide better information and analysis tools to support it.

Daily Operations and Management Process – Three SSAMS functions were identified for use within the day-to-day operations and management process:

Maintenance Management, Performance Monitoring, and Statistical Analysis. Maintenance Management takes information about available resources (personnel, vehicles, and equipment), and schedules work activities. Needs for work are generated from planned work, trouble reports and (if available), real-time information from the signal system itself. Information about the work that is done, age/condition of the signal inventory components that were worked on, and resources consumed is recorded by the Maintenance Management function. This information feeds into a Statistical Analysis function that supports business processes for evaluation of preservation and improvement strategies. Real-time status information and information on resolution of trouble reports used for Maintenance Management also feeds into the Performance Monitoring function, which is used to identify and target deficiencies.

Deficiency Identification Process – The Deficiency Analysis function takes information from the Performance Monitoring function, and provides a systematic capability to identify locations/components meeting user-specified criteria (e.g., high crash rates, high failure rates, older style equipment, etc.). Inventory information is integral to this process, providing capabilities to analyze deficiencies by intersection, corridor, or subsystem.

Development and Evaluation of Preservation and Improvement Options Process – This process involves development and evaluation of system preservation, operational improvement, upgrade and expansion options for addressing the identified deficiencies, and maintaining signal equipment and systems in a cost-effective manner from a life-cycle perspective. For preservation options, the Life-Cycle Costing Analysis capability is used to evaluate candidate life-cycle activity profiles (maintenance, rehabilitation, and replacement) for different components. For improvement options, Life-Cycle Costing Analysis is used to get an understanding not only of the initial capital costs of these improvements, but also the full costs throughout the life, ensuring that maintenance and operational implications of new systems and equipment are considered. The Performance Impact Analysis capability yields estimates of the impacts of different preservation and improvement options on physical condition and operational performance of the signal system over time. It also produces estimates of benefits to system users (e.g., reduced delay) and managers (e.g., reduced maintenance costs). This may be provided at a "sketch-planning level," or may incorporate more detailed simulation modeling techniques. The Impact Analysis capability is also supported via queries of the Knowledge Base. Together, life-cycle cost and performance impact analysis provide the information needed to compare and contrast preservation and improvement strategies – how they will impact performance, and what each will cost over its life cycle. This information can be used for tradeoff analysis across different investment options.

Resource Allocation and Budgeting Process – This work process includes a resource allocation function to systematically evaluate different work mixes and determine how to make the best use of limited resources, and a budgeting function that assists with the development of budget line items given a chosen mix of work. The resource allocation function uses information on benefits and costs of alternative preservation and improvement strategies produced by the Life-Cycle Costing and Performance Impact Analysis functions. The budgeting function uses information on existing resources and work history to support development of trend-based estimates of resource requirements. It also makes use of a costing capability to support development of budget line items associated with specific planned work activities.

Relationships of SSAMS Components to Physical, Systems, and Personnel Elements of Signal Systems Asset Management

Specific data components in the SSAMS architecture have been defined to describe characteristics of the three key aspects of signal systems asset management – physical equipment, systems, and personnel. The functional components of the SSAMS ensure that the key relationships among equipment, systems, and personnel are considered so that appropriate tradeoffs can be made. For example:

- The Maintenance Management function draws upon physical, system, personnel, and other resource information (vehicles, equipment) to schedule work, which may include repairs to the equipment, changes to system operating parameters, or upgrades/patches to system software. This function uses and also produces information on the resource utilization of different maintenance and operations activities.
- The Performance Monitoring function includes information pertaining to both the physical and systems aspects of signal system management – e.g., equipment failure rates and system down-time.
- The Life-Cycle Costing function supports consideration of future personnel requirements for maintenance and operations in the evaluation of system and/or equipment upgrades. This function also supports analysis of how increases in preventive maintenance may reduce system failure rates, and also reduce the demand for reactive maintenance, thereby improving the predictability of daily work.
- The Resource Allocation function supports maintaining an appropriate balance across personnel, equipment and system investments – so that, for example, line items for training costs for new equipment are linked to the line items for equipment acquisition.

The components of a Signal System Asset Management System defined above can vary in scope and sophistication depending on agency size and signal system characteristics. Given the varied nature of required decision support functions, and the types of systems that may already in place – for maintenance management, budgeting, signal control, and simulation/optimization, the SSAMS is not envisioned as a new monolithic system but rather as a set of capabilities provided by a variety of tools in an integrated fashion.

In order to provide a concrete illustration of how the SSAMS decision support capabilities would be used, the next section presents an analysis of signal management and improvement scenarios, involving tradeoffs across physical, system, and personnel elements of signal systems.

6.0 Improvement Scenarios

6.1 Overview

This section presents signal system improvement scenarios which address common signal system deficiencies as indicated by the state-of-the-practice review (summarized in Section 3.0). These scenarios are used to explore how the elements of the SSAMS defined in Section 5.0 might be used to identify and prioritize improvement needs, and compare alternatives for addressing them with respect to goals, objectives, and performance measures.

Three different scenarios are described, representing conservative, moderate, and aggressive signal system improvements that address the identified deficiencies. For each scenario, a rough analysis of costs and benefits are provided for each scenario. Then, tradeoffs across the different scenarios are discussed.

The following references were used to assist in identification of scenario elements, and produce estimates of their costs and benefits. Note, however, that the emphasis of this analysis was not on presenting an accurate assessment of the benefits and costs of alternative strategies, but rather on illustrating the kind of tradeoff analysis that would be supported by a SSAMS.

- *Traffic Signal System Improvement Program*, 2003 Update, Denver Regional Council of Governments, Adopted July 16, 2003.
- *Traffic Signal Operation Self Assessment*, developed by the National Transportation Operations Coalition of the Institute of Transportation Engineers, 2004.
- NCHRP Synthesis 307, *Systems Engineering Processes for Developing Traffic Signals Systems*, prepared by Dunn Engineering Associates, 2003.
- Vancouver Area Smart Trek – Initiative 5 – Traffic Signal Systems (http://www.vastrek.org/initiatives/TS.htm).

6.2 Signal System Improvements

Table 6.1 presents a listing of signal system improvements that was developed to assist the process of constructing scenarios. The table classifies each improvement as "operations," "preservation," "upgrade," or "reactive repair" for consistency with the signal system characteristics illustrated in Figure 3.1. Note that this list is not intended to be exhaustive, but rather illustrative of the major types of improvements that are considered by signal system operating agencies.

Table 6.1 Signal System Improvement Options and Impacts

Description	Category	Alternatives	Impacts
1. Signal re-timing, timing coordination	Operations	Adjust as needed based on complaints and observation, resources-permitting. Review and adjust timing for priority intersections, identified based on location (e.g., primary corridors), land-use changes, other changes affecting traffic patters. Review and adjust timing for each intersection once every three to five years.	Decrease user delay. Increase throughput. Reduce fuel consumption.
2. Implement weekend/holiday timing plans	Operations	Implement for centrally controlled signal systems only. Phase in for isolated signals. Implement for all signals.	Decrease user delay. Reduce fuel consumption.
3. New equipment/ hardware/software, for improved coordination and control	Upgrade	Alternatives would consist of different sets of locations for implementation of one of the following types of upgrades: • Simple time-based coordination (TBC), • Interconnected control (IC), • Traffic Responsive Control (TRC), and • Adaptive Control (ATC). A wide range of design and technology choices exist within each of these categories (e.g., detector types, controller types, software, communications equipment, etc.).	Decrease user delay. Increase throughput. Reduce fuel consumption. Reduce operational requirements (all but TBC allow for downloading of timing plans and adjustments, remote monitoring of intersection and equipment status) – though some technology choices will also add to staff training requirements or require specialized services to maintain Reliability (varies based on technology choice).
4. New equipment for preemption/priority	Upgrade	Vary number of railroad crossings with preemption. Vary extent of system with emergency vehicle preemption, and the types/numbers of vehicles to be equipped. Vary extent of transit routes covered by transit preemption/priority.	Decrease probability of rail-vehicle collisions (for railroad crossing preemption). Improve response time for emergency vehicles (for emergency vehicle preemption). Decreased passenger travel time and improved transit reliability (for transit priority).
5. Signalize additional intersections	Upgrade	Vary lead time for implementation for locations meeting signal warrants – prioritize based on funding availability, urgency of need.	Decrease crash rates/prevent crashes. Decrease user delay. Increase throughput. Reduce fuel consumption.
6. Replace bulbs with LEDs	Upgrade	Replace in conjunction with upgrades. Proactively convert older equipment only. Proactively convert entire system (vary number of replacements per year).	Reduced energy costs. Reduced signal failures/down-time. Reduced staff maintenance time requirements due to increased life.
7. Modernize controllers	Upgrade	Replace older controllers (varying criteria based on age, reliability, functionality, compatibility).	Improve reliability/reduce down-time. Reduce operational requirements.
8. Modernize detectors	Upgrade	Replace older loop detectors with newer technologies – e.g., video, ultrasonic (varying criteria based on age, requirements).	Improve monitoring capability. Reduced traffic disruption for maintenance.
9. Modernize signal heads	Upgrade	Replace older signal heads with longer lasting design (vary criteria, number of replacements per year).	Improve reliability/reduce down-time. Reduced staff maintenance time requirements due to increased life.

Description	Category	Alternatives	Impacts
10. Preventive Maintenance on signal poles/ structures	Preservation	Painting (at varying time intervals or age/ condition thresholds). Inspection and Replacement/Rehabilitation (at varying intervals or age/condition thresholds).	Increase useful life. Reduce risk of failure and associated emergency response needs.
11. Preventive Maintenance on Signal Heads	Preservation	Inspection and maintenance/replacement (at varying time intervals or age/condition thresholds).	Increase useful life. Reduce risk of failure and associated emergency response needs.
12. Preventive Maintenance on Controllers and Detectors	Preservation	Inspection and maintenance/replacement (at varying time intervals or age/condition thresholds).	Increase useful life. Reduce risk of failure and associated emergency response needs.
13. Make staff available to respond to problem reports	Reactive Repairs	Handle emergency requests only with existing staff. Add staff or contract out for improved response time and accommodation of non-emergency requests.	Improved customer service. Reduced delay. Improved safety.

From the state-of-the-practice review, the types of signal improvements rated as high priority by more than 40 percent of respondents included:

- Replacing/repairing equipment;
- Upgrading communications equipment;
- Adjusting or upgrading existing signals;
- Integrating signals within the agency's jurisdiction (as opposed to coordination with other jurisdictions); and
- Increasing operation and maintenance staff.

No direct questions on deficiencies were included in this review, but the following three can be inferred from these stated needs:

- Signal down-time due both to older equipment and limited staff;
- Signals operating with suboptimal timing plans, resulting in avoidable customer delay and excess fuel usage; and
- Isolated Signals (not under closed loop operation), which increases maintenance costs (since timing adjustments cannot be downloaded from a central location), and makes coordination more difficult.

The next section describes how the elements of a SSAMS would help to identify these deficiencies. Then, Section 6.4 presents scenarios that address these deficiencies drawing upon the alternatives in Table 6.1.

6.3 USING THE SSAMS TO IDENTIFY DEFICIENCIES

Signal Down-Time

Information on signal down-time would be derived from Trouble Reports, Work History Records, or, where they exist, from signal management software that automatically tracks equipment status (Real-Time Signal Status Information – archived or summarized). The Performance Monitoring functional component of the SSAMS takes information from Trouble Reports, Work History Records, and Real-Time Status Information from the signal system itself, and provides input to the Deficiency Analysis component. Ideally, the Deficiency Analysis capability would allow for analysis of patterns in failures that would help the SSAMS user to understand causes of failures and identify and prioritize appropriate actions. Information of interest would include:

- Map of signal malfunction or failure rates by subsystem/location;
- Signal component failure rates and mean time between failures by component type/model and age category;
- Signal malfunction or failure rates by cause (e.g., bulb, controller, power outage);
- Estimated number of vehicles affected by each signal failure cause – to help establish priorities for targeting preventive maintenance;
- Mean time to repair for different types and models of signal components; and
- Mean time to repair for different types of repair (e.g., by type or level of expertise required) – to identify where staff resources need to be supplemented.

Suboptimal Timing Plans

Information on which signals may need retiming can be derived from periodic floating car speed studies, reported complaints (the SSAMS Trouble Reports data component), or direct observation. In addition, Work History records that show when signals at each intersections were last timed, together with information from traffic monitoring systems on AADT growth (or development tracking systems) can be used to identify locations where analysis is warranted. Intersection crash data would also be of value to identify where safety issues related to signal timing may exist. Centralized access to information on current timing plans (in the SSAMS Operating Parameters data component) provides useful input to this process as well.

Isolated Signals

The SSAMS Intersection Inventory component tracks which signals are interconnected. This Intersection Inventory should include designations of functional system, priority corridors, and other defined roadway classifications that would help in prioritizing locations for extending existing or implementing new closed-loop systems. It should also (perhaps in conjunction with a Geographic Information System) allow for access to information on signal separation distances, and traffic volumes and turning movements. This would allow the SSAMS Deficiency Analysis component to perform automated screening based on defined criteria to identify where additional coordination should be investigated.

6.4 SCENARIOS

Overview

Three scenarios were developed to address the deficiencies discussed above: conservative, moderate, and aggressive. The conservative scenario emphasizes lower-cost actions and upgrades to address the most pressing deficiencies. The aggressive scenario takes a longer-term view, and pursues technology upgrades that will reduce the ongoing maintenance and operation cost of the system, and provide increased functionality and control that can be used to deliver improved performance. The moderate scenario takes the middle ground between the other two scenarios. All of the scenarios are for investments over a five-year period.

Improvements

Table 6.2 summarizes the improvements included in each scenario, organized according to the deficiencies that they address.

Table 6.2 Signal System Preservation and Improvement Scenarios

	Conservative	Moderate	Aggressive
Signal Down-Time	• Conduct annual inspections on all signals that have not been replaced or upgraded for the past seven years, and repair or replace any components that appear to be at the end of their life. • Replace bulbs with LEDs at 30 locations, in conjunction with replacement of signal faces that are at the end of their life. • Delay work on proactive inspections in order to respond to emergency requests.	• Inspect each signal once every other year and repair or replace any components that appear to be at the end of their life. • Convert half of the system to use LEDs (300 bulbs). • Upgrade controllers and communications equipment in the most heavily traveled corridor (25 locations). • Add another signal maintenance technician in order to improve response time to signal malfunction reports.	• Conduct annual inspections of each signal and repair or replace any components that appear to be at the end of their life. • Convert entire system to use LEDs (600 bulbs). • Replace 100 older plastic signal heads with aluminum die-cast heads. • Upgrade controllers and communications equipment at 50 locations along designated major corridors. • Commit to a one-hour response time policy for any signal malfunction based on real-time tracking and external reports – negotiate a contract to provide this service.

	Conservative	Moderate	Aggressive
Suboptimal Timing Plans	• Conduct detailed retiming studies for 50 intersections each year, selected based on frequency of complaints and known changes in traffic patterns (due to new developments).	• Conduct screening-level review signal timing for each intersection once every other year to determine the need for timing adjustment. • Conduct detailed retiming studies for 75 intersections each year.	• Conduct screening-level review signal timing for each intersection twice per year to determine the need for timing adjustment. • Conduct detailed retiming studies for 150 intersections each year.
Isolated Signals	• Add 10 new intersections to existing closed-loop systems.	• Upgrade equipment at/between 50 additional intersections to bring them under closed-loop control.	• Upgrade equipment at/between 100 additional intersections to bring them under closed-loop control and connect them to TMC.

Scenario Costs and Benefits

The SSAMS business processes for evaluation of candidate preservation and improvement options involves looking at each of the improvements in Table 6.2, and estimating both benefits and costs. A detailed calculation of benefits and costs is beyond the scope of this project, but Tables 6.3 and 6.4 provide sample formats for the output of such an analysis, as a concrete illustration of what a SSAMS would produce.

Table 6.3 Scenario Costs

	Conservative	Moderate	Aggressive
Capital Costs			
Capital Equipment	$57,100	$493,500	$1,342,000
Annual Costs			
Engineering/Design Costs	$132,500	$290,000	$710,000
Scheduled Annual Maintenance and Operations Staff Labor Costs	$128,000	$130,700	$112,100
Emergency Annual Maintenance and Operations Staff Labor Costs	$10,400	$9,300	$8,000
Maintenance Contract Costs	$0	$0	$150,000
Present Value	**$1,138,800**	**$2,210,400**	**$5,255,300**

Note: Present value was calculated for a five-year analysis period, using an eight percent discount rate. All capital costs were assumed to be incurred in the first year.

Assumptions used to calculate costs were as follows (these would be part of the Life-Cycle Costing and Budgeting components of the SSAMS):

- Average annual salary for maintenance and operations technicians: $30,000;
- Average cost to convert a signal to use LED: $485;[3]
- Average per intersection cost of a contract for traffic study and signal retiming: $350;[4]
- Average cost per location to upgrade controller and communication equipment: $2,500;[5]
- Average labor cost per signal inspection: $200; and
- Average equipment replacement/parts costs per signal inspection: $60.

Scenario benefits are assessed with respect to a set of performance indicators, as shown in Table 6.4.

Table 6.4 Scenario Benefits

	Conservative	Moderate	Aggressive
Reduced annual vehicle hours of delay due to improved signal timing.	5% [405,000]	8% [648,000]	15% [1,215,000]
Reduced annual gallons of fuel consumption due to improved signal timing.	3% [420,000]	5% [700,000]	9% [1,260,000]
Average annual reduction in the number of hours of signal down-time.	2%	13%	25%
Annual reduction in electricity costs.	14% [$3,200]	45% [$10,600]	90% [$21,300]
Decrease in the average number of crashes.	4% [113]	6% [169]	12% [339]

---

3 *NYSERDA LED Traffic Signal Life Cycle Cost Analyzer*, New York State Department of Transportation, 2001. Accessible via: http://www.lrc.rpi.edu/programs/lightingTransformation/led/NYSTrafficSignals.asp.

4 Pearson, R. *Traffic Signal Control*, Institute of Transportation Studies, University of California, 2001. Accessible via: http://www.calccit.org/itsdecision/serv_and_tech/Traffic_signal_control/trafficsig_report.html.

5 Ibid.

Assumptions used to calculate benefits were as follows (these would be part of the Improvement Analysis component of the SSAMS):

- Average annual electricity costs per signal[6]
  - With conventional bulbs: $117.
  - With LED: $11.
- Average accident reduction per intersection retimed: 10 to 15 percent.[7]
- Mean time between failures for signal controllers
  - Greater than or equal to 10 years old: six months.
  - Less than 10 years old: one year.
- Mean time between failures for bulbs
  - Conventional, less than five years old: one year.
  - LED, less than or equal to seven years old: five years.
- Reduced vehicle hours of delay per re-timed signal: 15 percent.[8]
- Reduced fuel consumption per re-timed signal: nine percent.[9]

Key Tradeoffs Across the Scenarios

The comparison of costs and benefits across the three scenarios shown in Tables 6.3 and 6.4 allows the decision-maker to tradeoff the additional costs of the Moderate and Aggressive scenarios against the performance gains that they are expected to achieve. As shown, the Moderate scenario requires $1,071,600 more than the Conservative scenario, but results in improved reliability, and significantly reduced costs to motorists – in terms of both time savings and fuel cost savings. It also lowers the ongoing utility costs of the system. The Aggressive scenario costs an additional $3,044,900 over the Moderate scenario, but yields even greater levels of system reliability, motorist cost savings, and utility costs.

---

6 NYSERDA, 2001.

7 Institute of Transportation Engineers. *Issue Briefs – Traffic Signals*, Federal Highway Administration, April 2004. Accessible via: http://www.ite.org/library/IntersectionSafety/signals.pdf.

8 Institute of Transportation Engineers. *Improving Traffic Signal Operations – A Primer*, Federal Highway Administration, 1995. Accessible via: http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE/13466.pdf.

9 McCracken, J. *Demonstration Project 93 – Making the Most of Today's Technology*, Federal Highway Administration, 1996. Accessible via: http://www.tfhrc.gov/pubrds/winter96/p96w7.htm.

In addition to the benefits shown in the table, other performance indicators that are more straightforward to calculate and could be used to contrast the scenarios include:

- At the end of the five-year period, percent of signalized intersections on major corridors that are under closed-loop control at the end of the five-year period – for these scenarios, 31 percent, 41 percent, and 53 percent, respectively;
- At the end of the five-year period, percent of signalized intersections on major corridors that have controller, communications, and detection equipment with capabilities for Traffic Responsive Control – for these scenarios, five percent, 11 percent, and 17 percent, respectively;
- At the end of the five-year period, percent of signals that have been converted to use LEDs – for these scenarios, 15 percent, 50 percent, and 100 percent, respectively;
- Percent of signals that have been retimed within the five-year period – for these scenarios, 37 percent, 56 percent, and 100 percent, respectively; and
- Number of intersections per maintenance technician over the five-year period (ITE recommends 30 or fewer, considering both in-house and contract forces) – for these scenarios, 41, 37, and 30, respectively.

This sample analysis has illustrated application of the principles of asset management to signal systems, using the framework developed for a SSAMS in Section 5.0. A similar type of analysis could be constructed to examine tradeoffs across different activity types – for example, an aggressive program of signal retiming versus a focus on reducing signal down-time through equipment upgrades. Several scenarios could be defined, each with the same budget level but a different mix of work in order to explore what resource allocation yields the highest level of benefits.

After defining the SSAMS capabilities in Section 5.0, we observed that many of these are provided by systems already in place – e.g., for maintenance management and signal control. However, a number of the required capabilities – e.g., for life-cycle costing, are not commonly available. Because many of the required elements of a SSAMS are similar to elements of relatively mature asset management systems for infrastructure and for information technology (IT), the next section explores these types of asset management systems. It contrasts their capabilities to those required for signal systems asset management, and suggests ways in which future development of a SSAMS might build upon techniques and methods that are already in operation today.

7.0 Comparison of SSAMS to Other Asset Management Systems

7.1 Overview

The previous sections of this report have developed a concept for a SSAMS, and illustrated how a SSAMS might be used to analyze alternative signal system improvements. This section contrasts the SSAMS architecture with two types of asset management systems that are further advanced in terms of maturity and level of implementation: infrastructure-based asset management systems, and systems for management of information technology (IT) assets. Because signal systems consist of both physical assets and IT-type assets, this comparison allows us to understand how asset management systems that are already in place can provide models for further development of the SSAMS concept.

7.2 Comparison with Infrastructure-Based Asset Management Systems

Pavement and bridge infrastructure management systems are most mature with respect to implementation experience and sophistication. Therefore, this section bases the comparison to signal systems on these types of infrastructure management systems. However, much of the discussion would be valid for other classes of transportation infrastructure (e.g., tunnels).

Nature of Assets Being Managed

There are some fundamental similarities between major infrastructure and signal systems assets – both include physical assets that deteriorate over time, and require maintenance, rehabilitation, and replacement. Both have the purpose of serving a transportation function, and therefore measurement of their performance is typically related to impacts on the traveling public.

However, there are many characteristics of pavements and bridges that are distinctly different from signal system assets. These include:

- Considerably Longer Service Lives – For example, between 75 and 100 years for bridges; between 40 and 60 years for pavement structures (with surface replacements required every 10 to 15 years). This implies an emphasis on deterioration modeling and determination of optimal maintenance and rehabilitation intervals throughout the life.

- Higher Replacement Costs – Costs to reconstruct a road or replace a bridge are orders of magnitude higher than costs to replace a signal.
- More Static in Nature – Once constructed, pavement and bridges are static entities, and do not (with the exception of drawbridges) require ongoing monitoring and adjustments like signal systems do.
- Lower Incidence of Failure – Pavements and bridges are less subject to malfunctions or failures that cause them to cease providing the function for which they were designed. On the other hand, a failure of a central system controller or a power failure can cause a network of signals to stop working.
- Infrastructure asset components consist of materials such as concrete, asphalt, and steel; signal systems are made of electronic components including communications and computer hardware and software. Accordingly, infrastructure asset management emphasizes materials properties, physical condition and structural capacity; whereas signal systems management pays more attention to technology, operational features, characteristics, and performance.
- Fewer Systemwide Interdependencies – Whereas pavements and bridges are self-contained entities, decisions about signal systems must consider interrelationships across different system components - for example, coordination of timing, and upgrades that ensure compatibility of equipment.

Data and Information

Asset management systems are based on quality information to support fact-based decisions aimed at improving performance. At a high level, many of the data components identified in the SSAMS architecture are the same as the data components for an infrastructure asset management system. Both types of asset management systems require:

- Inventory information indicating the asset location and characteristics;
- Condition information about each asset (or proxy measures such as age or failure rate);
- Definitions of work activities and their cost components;
- Work history information to track maintenance, rehabilitation, and replacement by date, asset, component type, and work type;
- Information on reported problems or needs, in order to drive maintenance activities and track performance measures that assess service quality/ response time;
- Cost and performance model parameters derived from condition and work tracking information (and/or external sources, rules of thumb) for use in life-cycle cost analysis;

- Information on personnel and equipment resources *available* as input to maintenance work planning and scheduling functions;
- Information on personnel and equipment resources *used* as input to development and updating of work cost models; and
- Information on identified deficiencies, work candidates, and scheduled work (including funding sources).

At a more detailed level, there are clear differences in the type of information used for major infrastructure asset management and signals asset management:

- Inventory data for signal systems is more heterogeneous than that for pavement and bridges, covering distinct sets of information for intersections, different types of equipment, and systems components.
- Information about the characteristics of electronic equipment and systems is fundamentally different from characteristics of pavements and bridges. The former includes model numbers, serial numbers, vendor information, and functional specifications whereas the latter includes materials composition, and design and structural properties.
- Field inspection data providing time-series information on condition is a fundamental element of major infrastructure asset management. While inspections are required for effective signal systems asset management, there is less emphasis on condition tracking over time and greater emphasis on recording work activities performed and needs identified as part of the inspection process.
- As a rule, real-time information on status and failure is not currently part of major infrastructure management systems (though this may be changing with current advances in sensor technology and road weather information systems), whereas newer signal systems do have these capabilities. The time scale from identification of a problem to resolution of that problem is much shorter in the case of signal systems than for major infrastructure. Therefore, there is less need for persistent information on performance.
- Information for signals asset management must include tracking of the interdependencies across different system components to a much greater extent than pavement and bridge management systems. For pavement and bridge management, identifying location on a route network is sufficient information to support an understanding of how different projects relate to one another (e.g., coordination of work along a corridor in order to minimize work zone cost, prioritization of bridge improvements based on detour lengths). For signal systems, analysis of technology upgrades is done for groupings of interrelated components. Therefore, it is important to keep track of the different subsystems, and understand how different pieces of equipment within each subsystem relate to one another – if one is replaced, do the others need replacement also?

- While pavement and bridge management systems do require information on traffic, this information is used either to understand loading characteristics, or to derive user costs associated with different preservation and improvement strategies. Signal systems asset management requires a more detailed understanding of traffic characteristics (e.g., turning movements, speeds, variations in traffic by time-of-day, day-of-week, and season) and changes in these characteristics over time – these are used to select appropriate control strategies and determine detailed operating parameters.

Condition and Performance Measures

Because signal systems and major infrastructure are both transportation system components, investments in both of these asset classes are evaluated based on benefits to system users. For pavements, impacts on users include comfort, safety, speed, fuel consumption, and vehicle wear-and-tear, which are a function of the road surface characteristics. For bridges, travel time for certain vehicle classes is also considered (e.g., based on the need for weight or height restrictions or bridge closures). Failure risks are also sometimes taken into account. For signal systems, delay/travel time and safety are the primary considerations.

For major infrastructure assets, the impacts on users are driven to a large extent by the physical condition of the asset. Therefore, infrastructure asset management systems tend to emphasize tracking of physical condition, and typically include methods for deriving aggregate condition indices from a variety of physical measurements (e.g., cracking, roughness, and rutting in the case of pavements), or from individual subelement condition measures (e.g., condition of deck, piers, abutments, bearings, etc., for the case of bridges).

For signal systems, impacts on users are driven primarily by operational characteristics: timing plans, synchronization of signals along a corridor, type of control (e.g., traffic-responsive, adaptive, etc.), and response time to failures. Physical condition of the components of the signal system do impact these operational characteristics, by affecting failure rates. However, given the shorter service life of components, age can typically be used as a reasonable proxy value for condition, which de-emphasizes the need for development of the condition inspection methods and condition indices that are such a prominent feature of infrastructure management systems.

A final comment about condition and performance measures is that for both infrastructure and signal systems assets, performance indicators can be constructed based on progress towards defined service or work accomplishment targets that have been established. Examples of these types of indicators for signal systems were provided at the end of Section 6.4 (e.g., "percent of intersections on major corridors that are under closed-loop control"). For major infrastructure assets, similar types of performance indicators are used – for example – "percent of bridges that are load-posted," or "average percent of pavement miles resurfaced per year."

Analysis Capabilities

Key analytical capabilities of an infrastructure asset management system are:

- Condition inspection data validation, data reduction, and reporting;
- Performance Monitoring – Calculation of composite condition indices and performance measures derived from condition indices, traffic, and inventory characteristics;
- Deterioration Modeling – Application of deterioration models to predict treatment life and/or derivation of deterioration model parameters based on historical condition data and expert judgment;
- Cost Modeling – Estimation of work costs based on variables such as asset element quantity, condition and type, and location;
- Deficiency or Needs Analysis – Identification of needs – location, work type, and costs – based on application of user-defined deficiency or need criteria;
- Economic Analysis (Benefit/Cost and Life-Cycle Cost Analysis) – Estimation of the benefits and costs of a treatment or a sequence of treatments over an extended time horizon, and use of discounting methods to provide a comparison of the time streams of benefits and costs for different alternatives;
- Optimization – Algorithms to determine maintenance and rehabilitation strategies that minimize long-term agency costs (or agency and user costs);
- Work Simulation – Application of treatment decision rules, deterioration models, and cost models to simulate work over a defined time horizon, subject to user-specified budget constraints; and
- Resource Allocation/Prioritization – Application of simple ranking formulas or incremental benefit/cost methods to select the best set of projects or the best resource allocation to higher-level groupings (based on asset subcategory, geographic area, or subnetwork) – that can be accomplished for a given budget level.

In addition, the following capabilities are included in infrastructure maintenance management systems, which are considered by some agencies as integral to infrastructure asset management:

- Complaint Tracking/Trouble-tickets – Recording of problem reports received from the public or observed by agency staff, and tracking their resolution;
- Maintenance Quality Monitoring – Recording of information on maintenance condition (e.g., clogged drains), typically on a sample basis;
- Maintenance Budgeting and Planning – Allocation of resources by maintenance activity or element, based on level-of-service approach, historical needs, or activity-based approach;

- Work Scheduling – Creation of work schedules for planned activities that consider resource requirements and availability;
- Work Management – Generation of work orders that specify the scope, procedure, equipment, personnel, and materials; and tracking the completion of these work orders and the labor, materials, and equipment hours utilized; and
- Resource Management – Tracking of vehicle, equipment and materials inventories, and aggregate utilization.

Analytical capabilities for signal systems were defined in the SSAMS architecture shown in Figure 5.1. At a high level most of these capabilities overlap with analytics for infrastructure asset management and maintenance management that were listed above. Maintenance management functions tend to be generalizable across different asset classes, so those defined above for infrastructure maintenance are fairly well aligned with those for signal system maintenance (though activity definitions and resource requirements vary).

At a more detailed level, there are several significant differences in emphasis and content of analytic capabilities:

- Infrastructure management requires more complex capabilities for deterioration modeling, preservation optimization, and work simulation; given the longer service lives, the high replacement costs, and the significant benefit to be gained through properly timed maintenance and rehabilitation treatments.
- Life-cycle cost (LCC) modeling is an important analytical component of both infrastructure management and signal systems asset management, but the analysis requirements are different. LCC analysis for infrastructure depends on more sophisticated interrelated models of condition deterioration, treatment cost and user cost, and an understanding of how infrastructure maintenance needs vary as a function of condition. The complexity in LCC analysis for signal systems lies more in setting up the problem. The analysis must be structured to handle interrelated groupings of components with different service lives, and to consider alternatives that have the same benefits (a fundamental premise of LCC analysis). Representation of uncertainty and provision for sensitivity analysis is important in both infrastructure and signal systems LCC, but it can be argued that signal systems LCC is by nature less amenable to deterministic models, and better suited to probabilistic approaches.
- Deficiency or needs analysis for infrastructure assets is more easily based on inventory characteristics and condition information determined from inspections, compared to different sets of standards or requirements. For signals, the relevant characteristics for identification of deficiencies are not as easily determined by observation. Probability of failure must be estimated based on age and/or historical failure rates of similar components. Operational

effectiveness needs to be determined based on detailed traffic studies and application of specialized analysis tools.

- Because of the real-time nature of signal system management, the shorter service lives, and the relatively rapid changes in technology that affect decisions, analytical functions for signal systems asset management need to be more nimble and less data hungry than those for infrastructure management. They must rely on easily assembled or automatically generated data, and use simple models that are easily adjusted. They must provide support for decisions that occur on very different time scales – including development of five- to 10-year upgrade strategies, annual budgeting, and day-to-day deployment of personnel to tasks.

7.3 Comparison with IT Asset Management Systems

Overview of IT Asset Management Systems

Because IT Asset Management is not as widely understood within the transportation community as infrastructure management, this section begins with a brief overview of what an IT asset management system is, and what it is used for.

The basic IT Management problem can be expressed as: "how to make most effective use of hardware, software, IT personnel, and available capital budget to meet the changing needs of the user population." This problem involves both an ongoing maintenance and operations component, and an upgrade component. The operations component seeks to maintain service, minimize system downtime and maximize responsiveness to the users. The upgrade component must balance across competing user needs and consider system-level capacity/ bandwidth needs and objectives for technology standardization.

IT Asset Management systems are used by managers of medium to large computer networks to track equipment (e.g., personal computers, servers, printers, routers, hubs) from acquisition to disposal. Information that is tracked includes hardware and software characteristics, configurations, licensing information, locations on the network, assignment to groups and specific users, and usage patterns. Much of this information is obtained through automated "discovery" and scheduled auditing functions that operate across the network. Some IT Asset Management systems also include support for hardware and software procurement processes, and provide linkages into enterprise resource planning and procurement systems.

IT Asset Management Systems perform or support the following types of functions:

- Tracking deployment of software patches and antivirus software to different computers on the network;
- Identification of efficient strategies for deployment of new equipment or redeployment of existing equipment;
- Analysis of upgrade needs and options based on current utilization patterns;
- Planning for server consolidation, system upgrades, and software upgrades (e.g., checks to see if computers have sufficient memory and processing power to run a new application);
- Cost analysis of alternative software licensing options;
- Provision of inventory information as backup for negotiations with hardware/software vendors (e.g., to obtain quantity discounts);
- Management of hardware and software procurements;
- Management of software leases, (e.g., ensuring on-time returns, locating leased equipment);
- Monitoring of compliance with license and warranty contracts – Comparison of the number of software licenses purchased with the number of installed copies, and the number of installed copies in active use;
- Monitoring of compliance with established IT standards;
- Providing Help Desk staff with easy access to configuration information needed to address service requests or problem reports;
- IT budget planning, cost allocations and payment management;
- Reporting on equipment inventory and usage;
- What-if analysis for alternative upgrade/replacement strategies, and evaluation of technology standardization strategies; and
- Scheduling of maintenance and repairs with consideration of the best timing given warranties in effect.

Nature of Assets Being Managed

Signal systems include computer hardware, software, and network equipment, so there is some overlap in the types of assets being managed between the two systems. However, IT asset management systems typically cover large numbers of computers, whereas the overall asset inventory of a signal system is less dominated by computer equipment. In addition, the major features of IT management systems – automated discovery of inventory, configuration, and usage information – depends on all of the computer equipment being networked together. This is not necessarily the case for signal system computer equipment.

Data and Information

Information on model numbers, licenses, warranties, configurations, and specifications is included in IT asset management. This information is also required for both the computer equipment and other electronic equipment of a signal system.

Condition and Performance

IT asset management systems emphasize measures of efficiency in use of computing resources, and compliance with license agreements and IT standards. IT asset management systems track utilization of existing equipment and software. Analogous capabilities for signal systems are provided in systems with integrated traffic monitoring functions that track traffic flow efficiency, typically in support of adaptive control algorithms.

IT asset management system information can also be used to derive statistics on progress towards objectives such as the percent of computers that have been upgraded to the latest operating system release.

IT asset management and signal systems asset management share service-oriented objectives of minimizing down-time. IT asset management systems include real-time monitoring capabilities to automatically detect status of devices on the network that are analogous to the features of modern signal management systems. Thus, both signal systems and IT systems asset management track operational performance from a real-time perspective.

However, IT asset management systems are not typically focused on monitoring failure rates for different types of components or maintaining persistent performance metrics on equipment down-time. This is due to the fact that most IT asset management systems are operated in a corporate environment which has a different accountability focus than a public agency environment.

Analysis Capabilities

Analysis capabilities that are shared by IT asset management systems and the SSAMS architecture include:

- Query and reporting features on equipment inventory characteristics and operational performance;
- Deficiency Analysis Capabilities – To identify equipment that does not conform to standards (which may be based on age, version numbers, or release numbers);
- Costing Analysis Capabilities – To support budgeting and comparison of different upgrade alternatives, and
- Maintenance Management Capabilities – For work scheduling, and management of the resolution of problem reports.

7.4 Conclusions

All three asset management approaches compared in this section – for signal systems, infrastructure assets and IT assets share the core principles presented in Section 2.0, and seek to maximize the efficiency and effectiveness in the use of available resources to address performance goals. From a birds-eye view, the basic functions of these three asset management approaches are the same – maintaining an inventory, monitoring performance, identifying deficiencies, evaluating options, and allocating resources. However, a closer look reveals distinct differences in emphasis and methods across asset management approaches for these three asset classes. These are due to differences in the characteristics of the assets themselves, and in the system users' decision-making context.

The specific requirements of signal system asset management include a mix of the capabilities covered by infrastructure and IT asset management. Similarities between signal systems and IT assets exist most obviously because signal systems include IT assets – computer hardware, software, and communications equipment, and other signal system components (e.g., controllers) have similar management requirements. The specific data content of IT asset management systems can therefore be used to further define data requirements for the IT assets of signal systems. The real-time monitoring and discovery functions of IT asset management systems are beginning to appear in signal system management software. Signal system asset management can also benefit from the kinds of quick-response what-if capabilities of IT asset management – for understanding the implications of equipment replacement and upgrades, and for understanding the relationships among hardware, software, and personnel requirements (analogous to the physical, system, and personnel elements of signal systems).

There are many aspects of infrastructure asset management that address requirements of a SSAMS. First, there are certain components of a signal system (e.g., structures/poles) that can be handled with deterioration modeling and life-cycle costing analyses that have been developed for the infrastructure domain. More broadly, the practice of tracking performance not only from a business/resource utilization perspective, but from a user or customer point of view is ingrained in infrastructure management, and is needed for signal systems asset management (and for all public sector transportation assets) as well. Calculation of the impacts of signal system improvements on users requires many of the same methods used in infrastructure asset management, and in fact some of the performance measures are identical (safety, travel time). Finally, both signal systems and infrastructure require significant taxpayer dollars to preserve and improve, and asset management systems must provide accountability for resource allocation decisions. Therefore, the discipline and methods used in infrastructure asset management for systematically identifying deficiencies, evaluating alternatives, and using well-defined prioritization methods for allocating resources are needed for signal systems as well.

8.0 Summary

This report has summarized information gathered for a state-of-the-practice review of signal systems asset management, and used this information to develop a generic signal system model. This model defines key characteristics of signal systems that are relevant to defining an asset management approach and the elements of a signal systems asset management system, or SSAMS. In order to provide a working example for future analysis and testing of SSAMS concepts, a signal system for "Anywhere, USA" was defined based on the characteristics of the generic signal system model.

Identification of the key elements of a SSAMS was based on the definition of five key business processes for signal systems asset management: daily operations and management; deficiency identification; development and evaluation of preservation and improvement options; and resource allocation and budgeting. These processes were derived by applying the core principles of transportation asset management to the generic signal system model. The inputs and outputs of each of these processes were identified, which led to the design of a high-level architecture for a SSAMS, including data and analysis components.

This high-level architecture represents an initial step towards identifying the needs of signal systems asset management. The state-of-the-practice review suggests that some of the data and functional elements of this architecture are in place – for example, maintenance management systems are in use; real-time system performance monitoring is available in some agencies; simulation tools are supporting evaluation of options. However, there are clearly gaps in practice that could be assisted by a stronger base of interconnected information and supporting analysis tools – for example, to make a better case for preventive maintenance, to clearly understand and plan for the long-term costs of system upgrades, and to evaluate different options for improving performance with consideration of the relationships among personnel, equipment, and system elements of signal systems management.

The high-level architecture was used to create example scenarios to illustrate how a comprehensive operational asset management system would analyze problem situations and provide decision support to managers. These scenarios illustrated analysis of the benefits and costs of conservative, moderate, and aggressive approaches to addressing common signal system deficiencies. This analysis demonstrated the value of systematic definition and evaluation of alternative approaches, with consideration of multiple factors – user benefits, short-term capital needs, ongoing personnel requirements, and other operating costs.

The investigation concluded with a comparison of the SSAMS architecture with the functions and data components of infrastructure asset management and IT asset management systems. This comparison found that further development of a SSAMS could benefit from incorporation of elements from both of these other types of asset management systems. IT asset management systems can provide models for the type and structure of data that is required for management of IT assets and electronic equipment. They can also provide insight into capabilities for operational decision support, in which the interrelationships across hardware, software, and personnel elements of a system need to be quickly understood. Infrastructure asset management can provide a solid model for how to structure resource allocation decisions in a public sector transportation environment. It can also offer specific techniques for deterioration modeling and life-cycle cost analysis that can be adapted for use in a signal systems asset management system.

Federal Highway Administration
U.S. Department of Transportation
400 7th Street, S.W. (HOP)
Washington, DC 20590

Toll-Free "Help Line" (866) 367-7487

www.ops.fhwa.dot.gov
Publication No. FHWA-HOP-05-006