Traffic Signal Benchmarking and State of the Practice Report

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National Operations Center of Excellence

A Community of Transportation Professionals

FOREWORD

The National Operations Center of Excellence is pleased to present the *2019 Traffic Signal Benchmarking and State of the Practice Report*. This report presents the results of the *2018 Traffic Signal Benchmarking and Self Assessment Survey* and is the next evolution of the prior three National Traffic Signal Report Cards issued in 2005, 2009, and 2012. In addition to providing a summary of the status of transportation agency traffic signal program capability, the report provides key benchmarks related to traffic signal system attributes nationally. The Center would like to acknowledge the resources provided by the Federal Highway Administration for this report, and the Institute of Transportation Engineers with the support of Kittelson & Associates, Inc. for its preparation. We invite your comments so that we may consider them in future editions of the both the *Self Assessment* and report.

Patrick Son
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List of Acronyms

Acronym	Definition
AASHTO	American Association of State Highway and Transportation Officials
ATSPM	Automated Traffic Signal Performance Measures
CIP	Capital Improvement Program
EDC	Every Day Counts
FHWA	Federal Highway Administration
G-COST	Goals, Context, Objectives, Strategies, and Tactics
ITE	Institute of Transportation Engineers
NOCoE	National Operations Center of Excellence
RTSMO	Regional Traffic Signal Management and Operations
SHRP2	Second Strategic Highway Research Program
TSMO	Transportation Systems Management and Operations
TRB	Transportation Research Board
TSMP	Traffic Signal Management Plan

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Executive Summary

State and local agencies have collectively invested an estimated $122.4 billion in the planning, design and construction of signalized intersections. The estimated ongoing annual operating and maintenance expenditure is about $1.23 billion, with an annual additional capital program investment of $763 million for all traffic signals in the U.S. The *2019 Traffic Signal Benchmarking and State of the Practice Report* is part of the continuing effort to raise awareness of the importance of and investment in the management and operations of traffic signal programs with the public, policymakers, transportation agency leadership, management and staff. In addition, this report brings attention to the benefits of a strategic approach and investment to improve organizational capability to reduce the risk of poorly managed and operated traffic signals.

The *2019 Traffic Signal Benchmarking and State of the Practice Report* evolved from but is distinctly different from prior *National Traffic Signal Report Card* efforts. Previous traffic signal report cards, completed in 2005, 2007 and 2012; focused primarily on evaluating individual agency practices, relative to best practice(s). The outcome of the process was a national traffic signal management and operations score. The *2019 Traffic Signal Benchmarking and State of the Practice Report* provides information about national trends in traffic signal infrastructure, systems and technology and organizational characteristics. and the state of the practice in organizational management in the form of a report card grade. The report card grade is an average of the 144 responses to the *Self Assessment* survey; while benchmarking data is drawn from both the *Self Assessment* survey and 2019 deployment tracking survey developed by the USDOT Joint Program Office.

Systems and Technology	**C+**
Infrastructure	**B-**
Business Processes	
Design	**C+**
Operations	**C+**
Maintenance	**C+**
Management	**C**
Workforce	**C+**
Management and Administration / Leadership	
Culture	**C+**
Organization	**C+**
Collaboration	**C+**
Performance	**C**
OVERALL GRADE	**C+**

The 144 agencies that completed the *Self Assessment* represent approximately 24 percent of the estimated 327,860 signals in the United States in 2018 across State, county and local agencies. Prior *National Traffic Signal Report Cards* were released in 2005, 2007, and 2012 and assigned incrementally increasing national scores of D-, D and D+, respectively. Although the *2018 Traffic Signal Benchmarking Self Assessment* approached creating a grade from a different basis, **the equivalent 2019 National Traffic Signal Report Card score has improved to a national grade of C+.** This is a meaningful improvement; demonstrating agencies are using established processes to support management and operations of traffic signals to meet their own stated goals and objectives rather than relying on ad hoc methods is growing. The letter grade represents a snapshot of the risk to an agency of becoming non-performing in the different dimensions of capability or overall. **Individual results are anonymous.**

Benchmarking traffic signal infrastructure, current practice, and technology implementation is an essential tool to informing the investment decisions of policymakers, department managers, and transportation professionals, both now and into the future. The *2019 Traffic Signal Benchmarking and State of the Practice Report* explores the current state of these topics for agencies across the United States. Benchmarking describes the current complexity, extent, and processes that support traffic signal assets and is integral to informing investment decisions. This report examines how these agencies are organized, workforce trends, technology implementation, and current business processes, practices, and policies involved in the planning, design, operation, and maintenance of traffic signals. Therefore, this report includes an analysis of how effectively agencies are articulating goals and objectives and the level of organizational capability and maturity attained as an outcome of how agencies structure and organize themselves to manage the risk of becoming non-performing.

The *2018 Traffic Signal Benchmarking Self Assessment* leverages the latest thinking in transportation system management and operations and capability-maturity frameworks by expanding upon the Traffic Signal Capability Maturity Framework[1]. to assess the effectiveness of an organization's capability and practices relative to its programmatic objectives rather than a composite of best practices. The baseline concept was to enhance and expand upon the Traffic Signal Capability Maturity Framework to evaluate the organizational capability of agencies in lieu of updating the previous traffic signal management and operations self assessments.

Key observations extending from data collected through prior National Traffic Signal Report Cards, FHWA Resource Center Traffic Signal Reviews, workshops for Automated Traffic Signal Performance Measures under Everyday Counts Round 4 (EDC-4), and peer exchanges support the incorporation of the Traffic Signal Capability Maturity Framework into the benchmarking framework. Comments from these activities as well as anecdotal feedback from agency staff found that agencies were simply checking off some hypothetical best practices without connecting their activities to their own agency's traffic signal program goals and objectives. Although this created a useful foundation to characterize the state of traffic signal infrastructure and organizational capability, it was also obvious that change in approach was necessary.

At the beginning of this effort, the project team held a structured interview process with a dozen selected representatives of the target audiences from local, regional, and State agencies known for the leadership in traffic signal program management. The approach provided the interviewees with a summary of this project and, subsequently, a phone interview with scripted questions provided in advance.

The *Self Assessment* has two components, a) benchmarking: coarse identification of the state of infrastructure and program components, and 2) capability maturity assessment that is based on Federal Highway Administration Capability Maturity Frameworks to allow agencies to do the following:

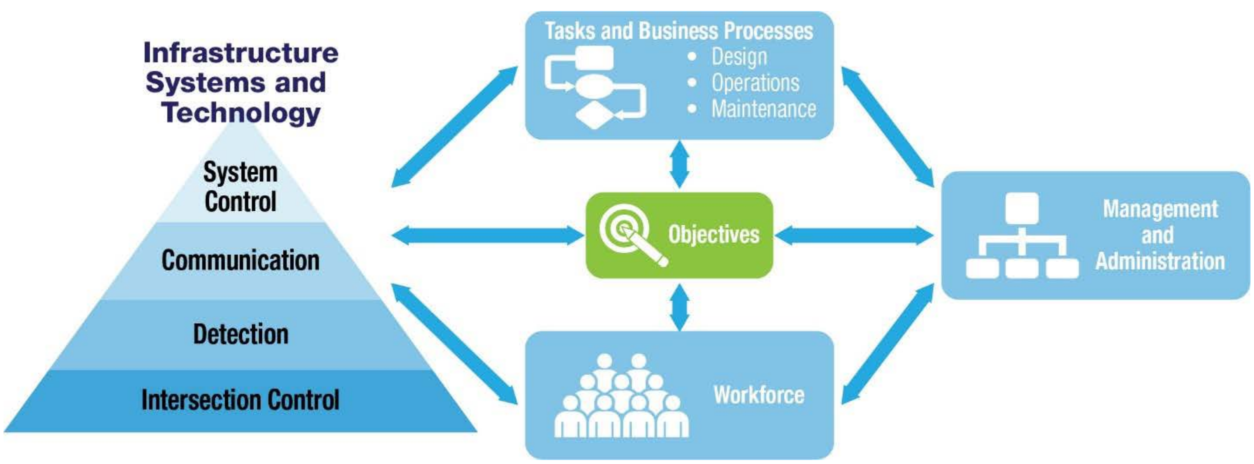
- Identify risks to sustaining the reliable delivery of the traffic signal program
- Develop consensus around the most critical traffic signal program needs
- Prioritize investments aimed at improving the reliability of the program
- Identify concrete actions to improve the reliability of the program to plan, design, and deliver TSMO

[1] FHWA. *Traffic Signal Management Capability Maturity Framework*, FHWA-HOP-16-028 (Washington, DC: FHWA, February 2016). Available at: https://ops.fhwa.dot.gov/publications/fhwahop16028/index.htm

The results of this *Self Assessment* and the associated *2019 National Traffic Signal Report Card* will provide for limited comparisons to the results of the earlier *National Traffic Signal Report Cards* at the individual agency and National levels. The primary reason is that the *Self Assessment* is based on an agency's rating of the organizational capability and maturity rather than self-rating against achievement of specific set of practices. The quantitative report card "score" should be viewed as a comparative indicator of an agency's practices.

Agencies around the country have different understanding and knowledge of their own capabilities and organizational maturity. As a consequence, the practical method to improve results is to develop strategies that can be implemented on an incremental basis from different starting points. By following a structured process, agencies can self-identify their current and desired levels of capability for each dimension.

A programmatic approach to traffic signal management and operations provides a framework to intentionally link transportation goals such as safety, mobility, reliability, and state-of-good-repair to organizational capability to clarify how limited resources can be used to focus on doing what is most important, generally defined a providing good basic service. The maturity of each area of the program can be assessed to determine the level of risks to sustained attainment of the programs objectives. The recommended approach is to organize as an agency service delivery for traffic signal systems around the Traffic Signal Program Model (TSMP) as shown in the diagram.

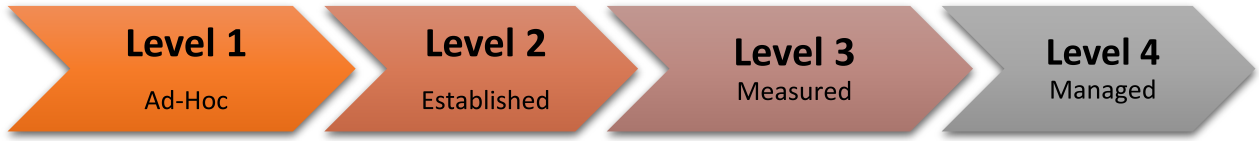


Source: FHWA

Traffic signal program objectives, shown at the center of the model, are the output of a process that continually evaluates context to extract attainable objectives from agency goals. Those derived objectives link and provide feedback to following other elements of the program: infrastructure, systems and technology; business processes, management and administration, and the workforce.

By combining the capability maturity assessment technique with the traffic signal program model, the presence of gaps in capability can be assessed as an indicator of risk. Gaps in organizational capability represent the risks to consistent and sustained attainment of objectives within any of the four program areas to the attainment of program goals and objectives.

As described in Chapter 2, four broad levels of maturity and capability have been defined Level 1 – Ad Hoc, Level 2 – Established, Level 3 – Measured, Level 4 – Managed.



Source: FHWA

By understanding the level of effort involved and benefits of achieving a maturity level, an organization can make a conscious decision about which maturity level best supports its current needs.

How to make the case to move forward now? By organizing agency functions around a Traffic Signal Management Plan (TSMP) to layout steps to define goal and key objectives to move ahead, specifically the following:

- Identify and champion a committee to discuss the need for and approach to developing the TSMP
- Agencies can jump-start traffic signal program planning by routinely completing the *Traffic Signal Benchmarking and Self Assessment Survey* and include meaningful measures that are directly connected to the programs objectives
- Kick off Traffic Signal Management Plan development process
- Create an action plan developed as an outcome of completing the *Self Assessment* and subsequent TSMP development process to provide a number of steps an organization might consider implementing to address risks that are related to a particular dimension and level of capability
- Develop an outreach strategy for policymakers and the public for the traffic signal program management plan

1 Introduction

This report presents the results of the *2018 Traffic Signal Benchmarking and Self Assessment* survey data supplemented by the *2018 Intelligent Transportation Systems Deployment Survey*[2] data. The *2019 Traffic Signal Benchmarking and State of the Practice Report* is part of the continuing effort to bring more attention to the importance and need for ongoing investment in traffic signal programs at state and local agency levels to improve the safety, efficiency and mobility of vehicles, pedestrians and bicycles at signalized intersections. Prior efforts in this area of study revealed a significant gap in management philosophy and practices to effectively coordinate traffic signal design, operations and maintenance processes, infrastructure and systems to sustain the delivery of high quality traffic signal operations[3]. The Institute of Transportation Engineers (ITE) worked collaboratively with the Federal Highway Administration (FHWA) and the National Operations Center of Excellence (NOCoE) to develop a self assessment survey to separately capture benchmarking and capability maturity data required to develop this report.

The report has four sections; this first section, provides an introduction, summary of *Traffic Signal Benchmarking and Self Assessment* and *Intelligent Transportation Systems Deployment Survey* responses and background information to contextualize the effort relative to prior National Traffic Signal Report Cards developed in 2005, 2007 and 2012. Section 2 presents the findings of the state-of-the-practice in traffic signal program management, the findings of which are based on the capability maturity assessment component of the *2018 Traffic Signal Benchmarking and Self Assessment* survey. Section 3 of the report provides infrastructure, systems and technology and organizational trends developed from a synthesis of 2018 *Traffic Signal Benchmarking and Self Assessment* survey and data received from agencies available from the 2018 *Intelligent Transportation Systems Deployment Survey*. Section 4 of the report provides case studies of two local agencies and two state departments of transportation to present profiles of high performing organizations relative to their benchmarking and organizational management self assessments.

These results present two perspectives that are consistent with the philosophy that the built environment is an outcome of the organizational practices of the state and local agencies that plan, design, construct, operate, and maintain our transportation infrastructure. The capability and maturity of organizational management is presented as the state of the practice, and is an aggregate measure of maturity in six distinct dimensions of capability. The self-rating of organizational maturity was used to establish the *2019 National Traffic Signal Report Card, State of the Practice* Score. The benchmarking component of the report is representative of the infrastructure, systems and technology and organizational trends that are the outcome of the state of the practice. Prior versions of the Traffic Signal Report Card did not draw a distinction between organizational practices and traffic signal infrastructure benchmarking but treated them through a single lens. The rationale for separating the analysis and discussion of organizational management from infrastructure and organizational trends, is to demonstrate that a strong relationship

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[2] U.S. DOT, *2018 Intelligent Transportation Systems Deployment Survey* (Washington, DC: U.S. DOT Intelligent Transportation Systems Joint Program Office, 2018).

[3] National Transportation Operations Coalition, *2012 National Traffic Signal Report Card*, National Transportation Operations Coalition: FHWA, ITE, AASHTO, ITS America, APWA, IMSA (Washington DC: Institute of Transportation Engineers, 2012)

exists between investments in organizational management and the ability of agencies to deliver good basic service in the area of traffic signal operations and maintenance. The case study examples in the last section of the report demonstrate the relationship between organizational capability and maturity, and the delivery of infrastructure, systems and technology to provide good basic service.

Self Assessment Response Summary

The *2019 Traffic Signal Benchmarking and State of the Practice Report* aggregates responses to the *Self Assessment* survey to develop a national score that is representative of the state of the practice in six dimensions of capability. Scores in each of the six dimensions of capability were averaged to develop an overall national score. A total of 144 responses to the *Self Assessment* represent State, county, and local agencies that operate various-sized traffic signal systems. Responses were received from two Canadian agencies because traffic signal operations and their associated funding mechanisms in Canada are similar to those in the United States and inclusion of Canadian responses is consistent with the methodology in previous report cards editions. Individual results are anonymous.

Jurisdictional control of traffic signal management and operation is usually associated with the roadway designation of state, county, or local roadways. However, in states with home rule, state and county routes within incorporated areas are typically controlled by the incorporated jurisdiction. In addition, in many states there are interoperability agreements between State DOTs, and city/municipal agencies or counties, or all three in combination as well as a few instances where such agreements are through the metropolitan planning organization. The total number of responses by signal system size and the approximate percentages of overall signals represented in the collected data is shown in Table 1.

Table 1. Number of Responses by Signal System Size

Traffic Signals Managed	Number of Responses	Percent of Responses	Number of Coordinated Traffic Signals	Number of Isolated Traffic Signals	Total Number of Traffic Signals Represented	Percent of Total Number of Traffic Signals
Benchmarking Self Assessment Responses						
Less than 50	34	24%	350	338	688	1%
50 to 150	42	29%	2,117	1,642	3,759	5%
150 to 450 [1]	35	24%	6,928	3,112	10,040	13%
450 to 1,000	8	6%	3,337	1,265	4,601	6%
More than 1,000 [2]	25	17%	30,864	29,164	60,028	76%
TOTAL	144	100%	43,596	35,520	79,116	100%
Benchmarking Self Assessment Responses Supplemented by ITS Deployment Survey						
Less than 50	74	18%			1,614	1%
50 to 150	121	30%			11,721	7%
150 to 450	113	28%			32,111	18%
450 to 1,000	57	14%			37,259	21%
More than 1,000	44	11%			93,362	53%
TOTAL	409	100%			176,067	100%

Notes: [1]Includes one response from Canada; [2]includes one response from Canada.

The 2018 version of the self assessment specifically asked agencies how many isolated and/or coordinated traffic signals they operated or maintained. With this information and an updated total of 327,860 signals in the United States in 2018, it is estimated that the responses represent approximately 24 percent of all traffic signals in the United States.[4] For those questions where the *2018 Intelligent Transportation Systems Deployment Survey* provided supplemental information, the combination represents 54 percent of all traffic signals. Table 1 demonstrates that although agencies operating 150 or fewer traffic signals make up 53 percent of the total responses, they represent relatively few of the total number of traffic signals captured in the *Self Assessment*. Though no less critical than those in large jurisdictions, this can represent a challenge to coordinate service delivery across many smaller organizations.

Of the total responses to the *Self Assessment* in 2018, (144), 79.5 percent were from local agencies and 22 percent from State DOTs There were 31 State DOT submissions although some agencies chose to consolidate responses for the overall agency rather than provide individual submissions from district or regional offices of these agencies. The number of responses by agency type is shown in Table 2 and Figure 1.

Table 2. Number of Responses by Agency Type

	Number of Responses	Pct. Of Responses
Benchmarking Self Assessment Responses		
City/Municipality [1]	87	60%
County	24	17%
State [2]	31	22%
Other Jurisdiction	2	1%
TOTAL	144	100%
Benchmarking Self Assessment Responses Supplemented by ITS Deployment Survey		
City/Municipality	222	54%
County	107	26%
State [2]	78	19%
Other Jurisdiction	4	1%
TOTAL	411	100%

Notes: [1]Include 2 responses from Canada; [2]Represents responses from States with various districts or regions that operate their own signal systems.

Table 3 shows the number of responses the based on staff size within an agency. More than half the responses were from agencies with 10 or fewer traffic signal program staff. Less than 25 percent of responses were from agencies with more than 20 staff members working in the traffic signal program.

[4] Based on 1 traffic signal per 1,000 population with a U.S. population of 327,860 estimated by the U.S. Bureau of the Census as of June 6. 2018 when last self-assessment was submitted.

Table 3. Number of Responses by Staff Size

	Number of Responses	Pct. Of Responses
Benchmarking Self Assessment Responses		
5 or Less	49	34%
6 to 10	42	29%
11 to 20 [1]	18	13%
21 to 50	21	15%
More than 50 [2]	14	10%
TOTAL	144	100%

Notes: [1]Includes one response from Canada; [2]Includes one response from Canada.

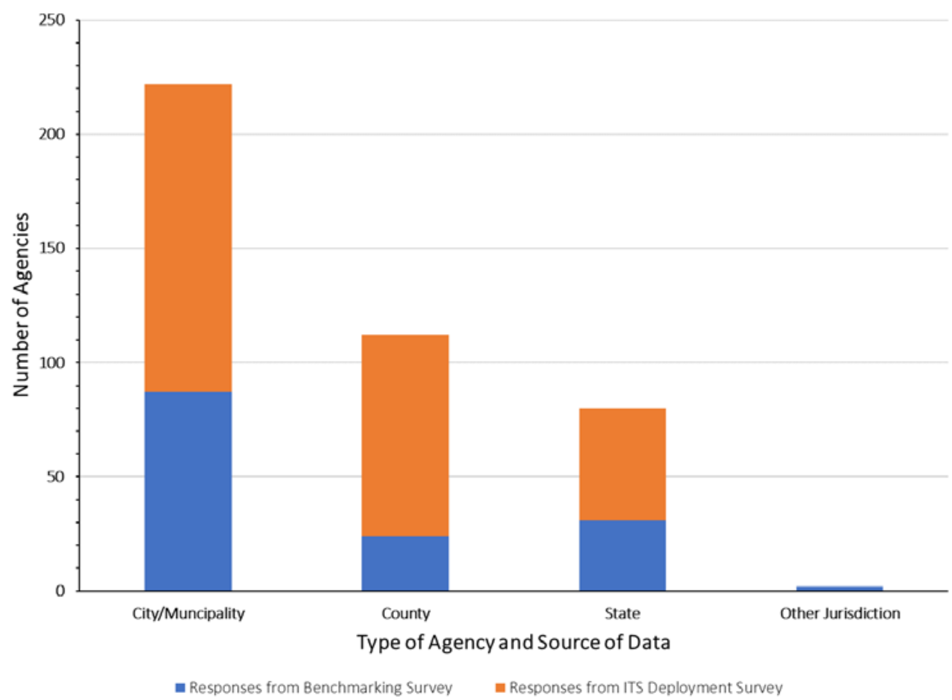

Figure 1. Chart. Number of Responses by Agency Type

There was at least one agency response (State or local) from 39 states. More specifically, responses came from 24 different states for city/municipality agencies, 14 different states for county agencies, and 21 different states for State agencies. Figure 2 shows the distribution of responses across the U.S. and Canada.

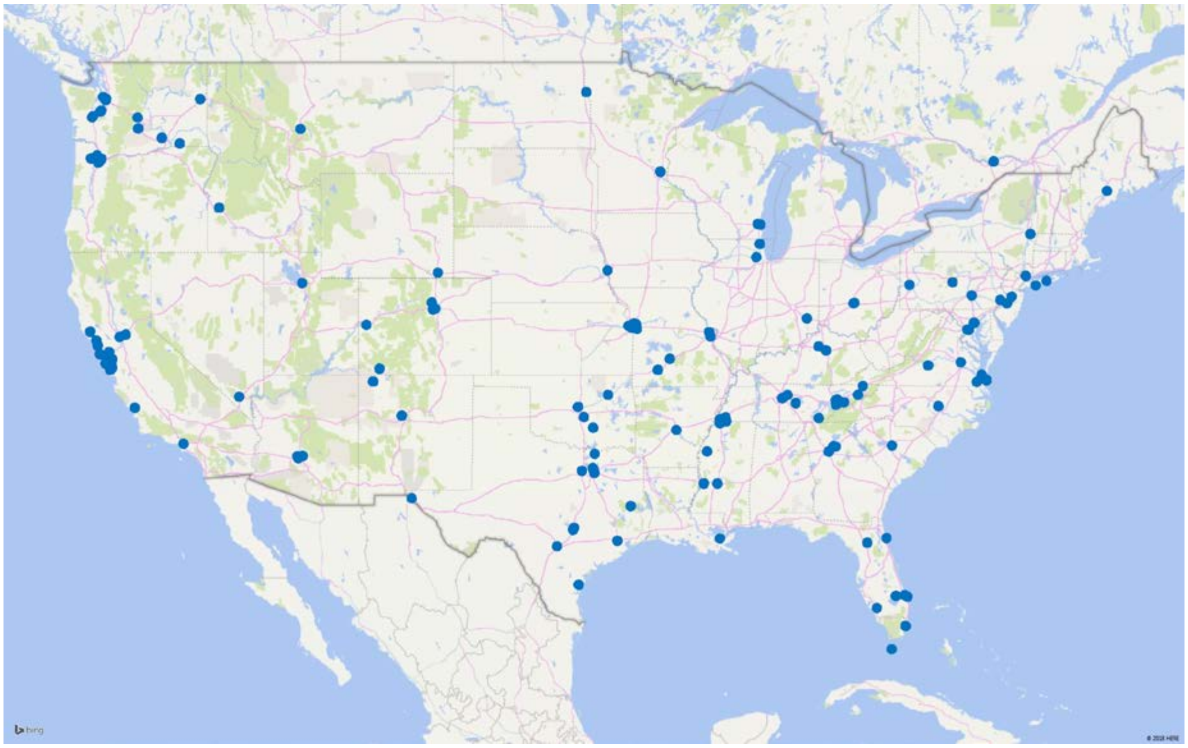

Figure 2. Map. Locations of Responses to Self Assessment and ITS Deployment Survey

Background

The *2019 Traffic Signal Benchmarking and State of the Practice Report* supports the goal to raise awareness of the importance of and investment in the management and operations of traffic signal programs with the public, policymakers, transportation agency leadership, management and staff. In addition, this report brings attention to the benefits of a strategic approach and investment to improve organizational capability to reduce the risk of poorly managed and operated traffic signals. Although not widespread, some agencies experience strong resource support when elected leaders recognize the economic and societal value of good traffic signal operations in proactively managing congestion and addressing safety for the public.

Traffic signals are owned and operated by State, county, and local transportation and public works agencies. As with all roadway infrastructure, public agencies have a fiduciary responsibility to manage and operate traffic signal systems in a manner that protects the estimated $122.4 billion public investment in these assets.[5] Delays experienced in highway travel have been steadily increasing since the last National Traffic Signal Report Card. INRIX analyzed congestion in 296 cities and large urban areas in the U.S. and found that congestion cost drivers in the US more than $305 billion in direct and indirect costs in 2017. Since traffic

[5] Example asset value of $351,358,545 for 941 traffic signals and associated infrastructure from the City of Portland, OR, USA, Bureau of Transportation, Asset Status + Condition Report, December 2017 factored up to the 327,700 traffic signals in the United States.

signals contribute an estimated 5 to 10 percent of all traffic delay on National Highway System roadways that is roughly $22.9 billion in urban areas alone. Additionally, delays on streets with traffic signals are greater than on freeways in urban areas, 61 percent in urban areas with more than 1 million population and 84 percent in urban areas under 1 million population. Although, as noted in an

Since the prior release of the *National Traffic Signal Report Card* in 2012, the SHRP2 program and benchmarking efforts in other discipline areas have created a portfolio of resources that have been actively-advanced through the Transportation Research Board (TRB), AASHTO, and FHWA. The AASHTO Systems Operations and Management Guidance was the first of these resources to apply the capability maturity model from the information technology field to transportation organizations. Traffic Signal System Capability and Maturity Framework (TSS-CMF) is another outcome which provides an organizational assessment in six dimensions of capability that are linked to the effectiveness of Transportation System Management and Operations (TSMO) programs. In addition, these concepts have been expanded into the objectives and performance-based management approach to traffic signal programs championed by FHWA.

Who Should Read This Report

The intended audience for the *2019 Traffic Signal Benchmarking and State of the Practice Report* is transportation professionals at the local, regional, and State levels involved in the management of traffic signal programs. These leaders within agencies are responsible for articulating and resolving program risks along with the management, budget development, planning, and workforce needs associated with metropolitan transportation programs. This includes risks and opportunities connected to other operations elements such as emergency response, pedestrian/bicycle mobility, and transit services. These are the people with program responsibility in many cases above the chief traffic engineers who may have a more limited span of

AASHTO Systems Operations and Management Guidance (www. aashtosomguidance.org). At the core of the guidance is the application of the capability maturity model (CMM) to identify key program, process, and institutional preconditions in transportation organizations. The concept underlying CMM is continuous improvement through improving capability. Agencies around the country are in different places in their abilities; this practical method develops strategies that can be implemented on an incremental basis from different starting points. CMM combines into one framework the key features of quality management, organizational development, and business process reengineering concepts that have long been used as strategic management tools. CMM is applicable to outcome-oriented product and service development, especially in areas impacted by changing technology like traffic signal management and operations.

Six critical dimensions of capability are closely associated with the more effective program activities including the following:

- *Business processes including formal scoping, planning, programming, and budgeting*
- *Systems and technology including use of systems engineering, systems architecture standards, interoperability, and standardization*
- *Performance measurement including measures definition, data acquisition, and utilization*
- *Culture, including technical understanding, leadership, outreach, and program legal authority*
- *Organization and workforce including programmatic status, organizational structure, staff development, and recruitment and retention*
- *Collaboration including relationships with public safety agencies, local governments, MPOs, and the private sector*

Each of the six dimensions is divided into sub-dimensions to support more specific targeting of the guidance.

The CMM approach evaluates the current strengths and weaknesses of an agency's current capability level in the key dimensions shown to be critical to improving effectiveness on a continuous basis. There are four distinct progressive levels in the guidance structure for each of the six dimensions representing levels of increased capability achieved by development of processes and organizational structure characterized by increasing integration, structure, formality, and collaboration. The importance of the guidance release is that it provides agencies with a tool that provides definition of issues that have long been tacitly understood as challenges—often informally discussed—related to transportation agency culture, organization, business processes, and workforce.

control. The organizational cross section includes State DOTs, metropolitan planning organizations, (MPOs) and local government agencies.

It is anticipated that an ancillary audience of peer association partner's members would benefit from this report such AASHTO, National Association of City Transportation Officials (NACTO), American Public Works Association (APWA), Intelligent Transportation Society of America (ITS America), Association of Metropolitan Planning Organizations (AMPO), and the National Association of Regional Councils (NARC) as well as their working committees at the agency level. Further, FHWA through their division offices, Resource Center, and the Every Day Counts program, will use the information from the *2019 Traffic Signal Benchmarking and State of the Practice Report*.

Using the Report

Benchmarking traffic signal infrastructure, current practice, and technology implementation is an essential tool to informing the investment decisions of policymakers, department managers, and transportation professionals, both now and into the future. The *2019 Traffic Signal Benchmarking and State of the Practice Report* explores the current state of these topics for agencies across the United States. Benchmarking describes the current complexity, extent, and processes that support traffic signal assets and is integral to informing investment decisions. This report examines how these agencies are organized, workforce trends, technology implementation, and current business processes, practices, and policies involved in the planning, design, operation, and maintenance of traffic signals. Therefore, this report includes an analysis of how effectively agencies are articulating goals and objectives and the level of organizational capability and maturity attained as an outcome of how agencies structure and organize themselves to manage the risk of becoming non-performing.

The results of this *Self Assessment* and the associated *2019 National Traffic Signal Report Card* will provide for limited comparisons to the results of the earlier *National Traffic Signal Report Cards* at the individual agency and National levels, primarily because it is based on an agency's rating of the organizational capability and maturity rather than rating themselves against achievement of specific practices. However, the *Self Assessment* will allow organizations to identify potential programmatic gaps that are related directly to an organization's capability to attain its most relevant goals and to benchmark agencies with different sizes and complexity against one another. The *Self Assessment* is not intended to suggest that all practices must or will be used in all cases. It is designed to serve as a tool to identify areas of strength and areas with opportunity for improvement in an agency's approach to traffic signal program management. The information published is intended to serve as a benchmarking tool to establish a baseline from which the need for and approach to improvements can be established, planned, and implemented. Improvements in practice to benefit the traveling public through proactive management lead to consistent system and organizational reliability.

Drawing on Experience to Inform the Current Approach

The *2018 Traffic Signal Benchmarking and Self Assessment* evolved from but is distinctly different from prior *National Traffic Signal Report Card* efforts. Previous traffic signal report cards, completed in 2005, 2007, and 2012; focused primarily on evaluating individual agency practices, relative to best practice(s). The outcome of the process was a national traffic signal management and operations score, reported within an executive summary and technical report.

The *2018 Traffic Signal Benchmarking and Self Assessment* leverages the latest thinking in transportation system management and operations and capability-maturity frameworks by expanding upon the *Traffic Signal System Capability Maturity Framework* (TSS-CMF)[6] to assess the effectiveness of an organization's capability and practices relative to its programmatic objectives rather than a composite of best practices. The baseline concept was to enhance and expand upon the TSS-CMF to evaluate the organizational capability of agencies in lieu of updating the previous traffic signal management and operations self assessments.

Key observations extending from data collected through prior *National Traffic Signal Report Cards*, FHWA Resource Center Traffic Signal Reviews, workshops for Automated Traffic Signal Performance Measures under Everyday Counts Round 4 (EDC-4), and peer exchanges support the incorporation of the TSS-CMF into the benchmarking framework. Comments from these activities as well as anecdotal feedback from agency staff found that agencies were simply checking off some hypothetical best practices without connecting their activities to their own agency's traffic signal program goals and objectives. Although this created a useful foundation to characterize the state of traffic signal infrastructure and organizational capability, it was also obvious that change in approach was necessary.

At the beginning of this effort, the project team held a structured interview process with a dozen selected representatives of the target audiences from local, regional, and State agencies known for the leadership in traffic signal program management. The approach provided the interviewees with a summary of this project and, subsequently, a phone interview with scripted questions provided in advance. Additional information from experience and references from the project team were identified as well. The interviews were summarized to draw out key points which were the following:

- Benchmarking an agency's program to other systems around the country would be beneficial
- The two primary transportation goals supported by traffic signal systems identified as safety and mobility
- Low rating of interest from a traffic signal program perspective in the area of connected vehicles, risk management, and, surprisingly, the use of ITS Architecture, standards, and specifications
- Very high-relevance noted for relationship to other transportation modes, policies, and funding; transportation management centers, case studies, performance management, technology, and the maturity of organizational practices and processes

In addition, the group noted that MPO-related information was difficult to find or unavailable. Interviewees cited difficulty in obtaining financial data due to multiple funding sources. Respondents stated that cybersecurity and technology information may be in an information technology department and hard to access.

The group indicated that they have satisfactory-to-not-enough personnel to handle their current system maintenance and operations. They voiced concern that staffing and skill sets have not grown at the rate commensurate with the expansion of the system and technology advances. As a result, they are finding difficulty being proactive. They further expressed a need for resources to help better explain outcomes to policymakers. There was also concern that there was little organizational depth to deal with retirements or staff turnover. Thematically, all the agencies indicated that they used consultant support on a project or on-call basis to free staff for other needs because they can't sustain positions in-house.

[6] FHWA. *Traffic Signal Management Capability Maturity Framework*, FHWA-HOP-16-028 (Washington, DC: FHWA, February 2016). Available at: https://ops.fhwa.dot.gov/publications/fhwahop16028/index.htm

These factors were combined to create the *2018 Traffic Signal Benchmarking and Self Assessment* that, as the title suggests, incorporated elements of both benchmarking and self assessment of organizational capability. In the first part of the *Self Assessment*, respondents were asked to respond to 43 fact-based questions about the nature of their organization, resources, workforce, infrastructure, collaboration, operations, maintenance, and management. The questions were a combination of yes/no, multiple choice, or fill in the blank with the number or percentage of applicable items.

This was followed by the agencies self-rating of their capability in five primary dimensions and eight sub-areas based on their program's status in 2018. Each dimension had a description of the activities that an agency would need to carry out to achieve either Level 1: Ad hoc, Level 2: Established, Level 3: Measured, or Level 4: Managed. Although the capability rating is based on specific attributes of an agency's traffic signal program, there is a qualitative aspect depending on the role of the individual completing the *Self Assessment* for a given agency. The *Self Assessment* can be used by local agencies, regional, or Statewide programs to identify gaps in practices and target areas for process improvement or investment. **It was not anticipated that any agency would give themselves the highest rating across all dimensions of capability.**

The *Self Assessment* was implemented as a tool as part of the Traffic Signal Benchmarking website (www.tsbenchmarking.org) and it was also made available for download as an Adobe PDF format file. The website was promoted through FHWA, ITE, and NOCoE communications portfolio and social media, and provided to other allied professional organizations like AASHTO APWA, National Association of County Engineers (NACE) and AMPO. The *Self Assessment* remains available online at the website as a tool for agencies to use on a recurring basis along with other supporting resources.

Introduction to Capability Maturity Model Approach

Section 2 of the report presents the results of the Capability Maturity Assessment as the State-of-the-Practice in Traffic Signal Program Organizational Management. The Capability Maturity Assessment was adapted from the Capability Maturity Model (CMM) developed by AASHTO (www.aashtosomguidance.org). This work provided agencies with a tool that provides definition of casually-discussed issues implicitly understood as challenges to improving transportation agency services such as organization, workforce, business processes, culture, and collaboration.

To continue the emphasis, this approach has been actively expanded by FHWA as a more focused program-level guidance application—Business Process Frameworks for Transportation Operations—covering such areas as planned special events, road weather management, traffic incident management, traffic management, and work zone management. More details can be found on the FHWA Operations website: http://www.ops.fhwa.dot.gov/tsmoframeworktool/index.htm).The Traffic Signal System Capability and Maturity Framework (TSS-CMF) was the first approach to provide an organizational assessment in six dimensions of capability that are linked to the effectiveness of TSMO specific to traffic signal programs. The *2018 Traffic Signal Benchmarking and Self Assessment* updates this approach based on the current concept of the traffic signal program model.

By understanding and using a capability maturity model approach, agencies can accomplish the following:

- Identify risks to sustaining the reliable delivery of the traffic signal program
- Develop consensus around the most critical traffic signal program needs
- Prioritize investments aimed at improving the reliability of the program
- Identify concrete actions to improve the reliability of the program to plan, design, and deliver TSMO

Consistent with the AASHTO Guidance, the *Traffic Signal Benchmarking and Self Assessment* describes capability for agencies in dimensions with same underlying theme although organized differently:

- **Systems and Technology** – Use of systems engineering, systems architecture standards, interoperability, and standardization
- **Infrastructure** – Standards and methods to evaluation condition and guide placement, visibility, recognition, necessity, and function of traffic control devices
- **Business Processes** – Formal scoping, planning, programming, and budgeting broken out for processes specific to design, operations, maintenance, and management
- **Workforce** – Staff development and recruitment and retention
- **Management and Administration / Leadership** – consists of the following subdimensions:
    - **Culture** – Technical understanding, leadership, outreach, and program legal authority
    - **Organization and Staffing** – Programmatic status, organizational structure, roles, and responsibilities
    - **Collaboration** – Relationships with public safety agencies, local governments, metropolitan planning organizations (MPOs), and the private sector
    - **Performance Measurement** – Measures definition, data acquisition, and data utilization

For each of the dimensions, the following four levels of capability related to program success and risk of failure are used in the framework as well:

- **Level 1: Ad Hoc** – Activities and relationships largely ad hoc, informal, and champion-driven, substantially outside the mainstream of other DOT activities
- **Level 2: Established** – Basic strategy applications understood; key processes support requirements identified and key technology and core capacities under development, but limited internal accountability and uneven alignment with external partners
- **Level 3: Measured** – Standardized strategy applications implemented in priority contexts and managed for performance; technical and business processes developed, documented, and integrated into DOT; partnerships aligned
- **Level 4: Managed** – Full, sustainable core DOT program priority, established on the basis of continuous improvement with top level management status and formal partnerships

As agencies around the country are in different places in their abilities, the practical method is to develop strategies that can be implemented on an incremental basis from different starting points. By following a structured process, agencies can self-identify their current and desired levels of capability for each dimension.

Agencies can jump start traffic signal program planning by completing the *Self Assessment* and supporting development of an action plan to improve capability, if desired. An action plan can be developed as an outcome of completing the assessment, providing a number of actions an organization might consider implementing to address risks that are related to a particular dimension and level of capability. However, in this *Self Assessment* tool, traffic signal systems is viewed as a subset of the larger TSMO program. The capability levels and the actions are more focused and defined from a traffic manager's perspective. The actions may require other agency functions or other agencies to be the responsible party, which is intended to foster multi-agency collaboration and dialogue about traffic signal systems at the regional level.

2 State-of-the-Practice in Traffic Signal Program Management Results

Approach

Three *National Traffic Signal Report Cards* were released in 2005, 2007, and 2012 and assigned incrementally increasing national scores of D-, D and D+, respectively. The prior *National Traffic Signal Report Cards* associated a 1- to 5-point value with each self assessment question which was then averaged across each section and across all questions for the total score. The scores were assigned letter grades and the national score was developed from an average of all responding agencies. The 2019 score was developed by using the self-rating of organizational maturity, the organizational assessment section of the *Self Assessment*, and assigning a mid-point score for each of the four levels (i.e., Level 1 – 65, Level 2 – 75, Level 3 – 85, Level 4 – 95). In a similar manner, the scores were then the assigned letter grades and the national score was developed from an average of all responding agencies.

National Results: Grade C+

The national grade is a composite score derived from the 144 responses to the *2018 Traffic Signal Operations Self Assessment* section on capability maturity for the 2019 report card. The responses were treated equally and were not weighted by system size, agency type, or population. While these criteria are important to characterizing and drawing conclusions about the current state of traffic signal operations, the overall score is presented as an indicator that can be applied on a National scale.

Although the *2018 Traffic Signal Benchmarking Self Assessment* approached creating a grade from a different basis, **the equivalent 2019 National Traffic Signal Report Card score has improved to a national grade of C+** as shown in Figure 3. This is a meaningful difference; demonstrating agencies are using established processes to support management and operations of traffic signals to meet their own stated goals and objectives rather than relying on ad hoc methods. The snapshot of a letter grade represents the risk to an agency of becoming non-performing overall or in the individual dimensions of capability.

The number of staff and number of traffic signals managed by an agency affects the score with agencies with five or less staff, or fewer than 50 signals were as or more likely to use ad hoc methods rather than established processes. With the overall improvement in the economy, agencies are not only looking at strategic investments, but more importantly methods and practices to improve performance.

Noteworthy Findings

Since the release of the *2012 National Traffic Signal Report Card* there has been a concerted effort within transportation agencies supported by various FHWA, ITE, SHRP2, TRB, and AASHTO resources to improve capability of traffic signal programs which has ***led to a letter grade improvement in the national score (77) to a C+***. This is consistent with the increasing emphasis on program management of the traffic signal function in agencies to provide value to decision-makers from a safety and operational perspective. The overall C+ Grade falls into the upper range of the responding agencies employing Level 2 Established practices and move towards a Level 3 Measured organization. This result means there is a basic understanding of strategy applications and support, requirements for important processes have been

Systems and Technology	**C+**
Infrastructure	**B-**
Business Processes	
Design	**C+**
Operations	**C+**
Maintenance	**C+**
Management	**C**
Workforce	**C+**
Management and Administration / Leadership	
Culture	**C+**
Organization	**C+**
Collaboration	**C+**
Performance	**C**
OVERALL GRADE	**C+**

Figure 3. Chart. National Traffic Signal Report Card 2019

identified, and the development of technology and core capacities is underway. However, there is limited internal accountability and uneven alignment with external partners. In addition, since the overall grade is above the midpoint, a number of agencies have moved to standardize and implement strategy applications in priority contexts and manage for performance. Further they have developed specific technical and business processes which are documented, and integrated into the agency, and aligned internal and external partnerships. The grade demonstrates that the work to improve traffic signal programs across the country is still a work in progress and there is an ongoing need for attention and resources for traffic signal management and operations.

The overall improvement is notable in agencies operating more than 450 signals that have an overall letter grade of B- (80). This is supported by comparing this score to the score by staff size with agencies with more than 20 staff that have a letter grade of B- (80) as well. Larger staff resources assigned to traffic signal programs as well as a balance of resources compared to the relative complexity and size of the traffic signal system lead to improved capability and performance. In addition, this suggests that the importance of document processes increases, as does the size of the program because of the complexity and risks involved. Even with challenging budgetary choices, agencies that operate larger signal systems are performing better than the National average. Resources for traffic signal operations appear to be prioritized in the allocation of funding in the larger operating agencies. This may be an indication of focus on organizational processes, flexibility in allocating staff resources, and resources aligned to the complexity and size of the system. The potential to impact—positively or negatively—significant numbers of the traveling public with the assets managed by these larger organizations is important, both from the need to improve further, but also from the risk of reverting to a previous less well-managed position.

Small cities and towns tend to operate fewer traffic signals even those that are suburbs in large metropolitan areas. ***Agencies operating less than 50 traffic signals scored a C (74)*** which is an improvement from past results and indicated overall that those agencies generally have established programs even though scores for individual agencies ranged from a D (65) to A- (91). This is definitely a step forward from 2012, although the reporting sample size is 60 percent of the prior self assessment. Fewer numbers of signals means less individual assets to manage; however, many smaller communities often have no specifically-dedicated traffic engineering staff. Staff responsible for traffic signals in small jurisdictions are more likely to have broad-based experience and are less likely to have specialized training in traffic signal operations. Public works rather than a transportation department typically manage traffic signals in these communities and must deal with a wide range of needs including routine service requests, water and sewer systems, and roadway maintenance.

Scores are remarkably similar across the United States and Canada and across jurisdiction types. Although there are high-performing signal systems, on the whole, the majority of systems across the United States and Canada have the potential for improvement toward performance management.

Highest scoring dimensions were infrastructure (80), maintenance business processes (79), and workforce (79) reflecting that there is more reporting, control, and standardization in these areas. The topic of these dimensions is focused on the knowledge, standards and procedures directly related to traffic control devices and associated infrastructure…something where transportation agencies have long-standing processes in place. Traffic signal maintenance scored high in the previous *2012 National Traffic Signal Report Card* as well, continuing to score high in the most recent assessment across all signal and staff size except agencies w/ 450-1000 signals. This may suggest challenges with annual operating funds for managing systems as they become larger at these agencies. Workforce appears to have scored relatively highly because competencies tend to be linked to the complexity of the signal systems.

Lowest scoring dimensions were performance measures (74), management business processes (75), and organization and staffing (76) independent of signal system or staff size which implies that more elements in these areas a performed on an ad hoc basis lowering the score relative to other dimensions. The low score in these dimensions relative to others, although higher overall values, is consistent with results reported in the previous *2012 National Traffic Signal Report Card* for the management and data collection categories. These topics are interrelated. Clearly-articulated objectives for a traffic signal program requires performance measurement to uniformly measure progress toward meeting goals whether they are related to local fluctuations in traffic, overall system performance, or to provide valuable input to the resource allocation process. This continues to be an area where agencies must focus their attention to improve performance to make the next steps forward toward performance management.

State agencies' scores perform slight better than cities in systems and technology (80 vs. 77), infrastructure (82 vs. 79), and design-related business processes (80 vs. 77). Otherwise, city, county, and state agencies were very similar on average. This is likely due to having processes and capital procurement plans with supporting fiscal resources win place.

There seems to be a sweet spot with ***agencies that have 11 to 20 staff that have an average score of 82 across all categories***; ahead of both larger agencies and smaller staffed agencies. This appears these agencies are staffed at this level consistent with the amount of traffic signal assets managed. ***Lowest dimension score (71) for systems and technology for systems w/ less than 50 signals*** reflect a more ad hoc approach at smaller agencies. More than half the reporting agencies in this category had fewer than 20 signals. This is not surprising as this size of agency would have limited experience on a regular and recurring basis for systems engineering, architecture requirements, or interoperability.

When the responses results are considered across the entire Self Assessment, the results are better than the 2012 results. Some of this may be due to the approach changing from a comparison against an idealized best practice to a progress indicator of an agency's practices in the context of their own program goals and implementation actions to meet objectives. Reliable resources for both staffing and funding remain challenging even in the improving economic environment; this dictates that many agencies' approach to traffic signal systems, especially smaller ones, do what is needed to support their established program. As a result, many agencies continue to lack the capability and resources to move up to the next level to proactively measure performance and actively manage their traffic signal program. Oftentimes, agencies see the performance management approach to traffic signal programs as an additional expenditure of effort and resources even though there is value created in the process that is important to policymakers. A programmatic approach to traffic signal management and operations connects community goals to realistic safety and operational objectives and defined, documented, and measured supporting strategies. This enables agencies to address congestion and fuel consumption and lessen the negative impacts to air quality to improve the quality of life within our communities.

With this report there does appear to be forward movement across the board in all areas of capability with some stronger improvement in some areas depending on system size and staffing of a reporting agency. Agencies that perform well in their self assessment have demonstrated that they employ recognized performance measures, driven by objectives-based best practices to manage and operate their traffic signal network. However, there still appears to be a separation between established, stated, measurable objectives and their measures, performance of signal operations tasks and timing practices; and incorporating those measures into an actively managed program. The traveling public pays the price in terms of congestion, air quality, carbon emissions, and fuel consumption.

Some agencies viewed as leaders over many years continue to lead the way in the approach to managing traffic signal operations. Other agencies have recognized the challenges they face and have stepped forward asking for support to create an organization for the future; both should be recognized and emulated. These progressive approaches and documented outcomes are helpful, real world activities that can demonstrate to other agencies the necessary tools needed to improve.

Results by Section

The following pages describe results for each of the five dimensions of capability and their subareas included in the *2018 Traffic Signal Benchmarking and Self Assessment*. Each section provides a general description and the characteristics for each progressive level as well as noteworthy findings are described. The text for each question can be found at the Traffic Signal Benchmarking website (www.tsbenchmarking.org/assessment/). Appendix A includes tables showing the results for each question by signal system size and agency type.

Systems and Technology

This dimension describes the appropriate processes for the implementation of systems such as local and central control, communication, and detection support attainment of operations and maintenance objectives and that they are efficiently implemented and are consistent with regional architecture standards, interoperability, and standardization needs. The system owner interacts with and affects users through implementation and management of technology. The description of the four levels of systems and technology capability are noted below with the national grade for this dimension.

Noteworthy Findings
The average numerical score for the systems and technology dimension is 78. The lagging performance agencies with fewer than 50 traffic signals and less the five staff is the most noteworthy finding drawn from information shown in Figure 4, Figure 5, and Figure 6.

- 62 percent of agencies with fewer than 50 signals function on an ad hoc basis as well as 49 percent of agencies with 5 or fewer staff. This signal system size group had the lowest average dimension score of 71. More than half the reporting agencies in this category had fewer than 20 signals. This is not surprising as this size of agency would have limited experience on a regular and recurring basis for systems engineering, architecture requirements, or interoperability.
- 31 percent of cities function on an ad hoc basis.
- 86 percent of agencies with 50 or more signals function on and established or better basis.
- 27 of 31 reporting State DOT offices function at established or better basis.

On a positive note, overall across all signal systems and staff sizes 46 percent of agencies function at Level 3 or Level 4 resulting in an aggregate grade for this dimension of C+ shown in Figure 7 with the associated capabilities.

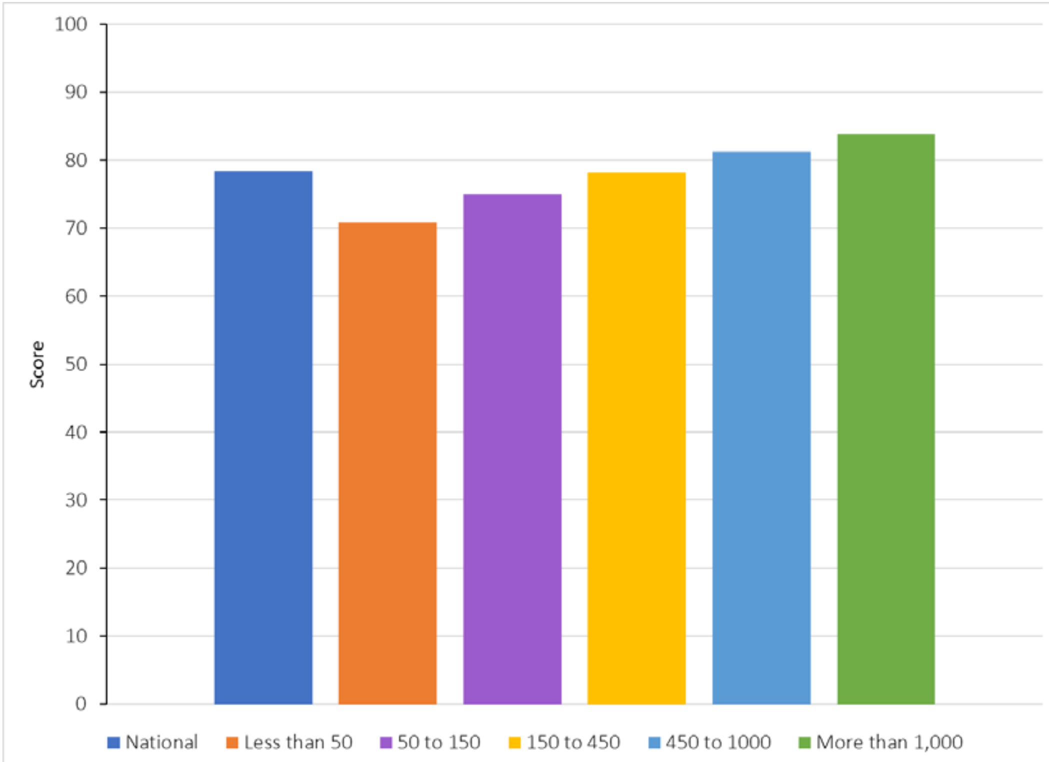

Figure 4. Chart. Systems and Technology Score Results by Signal System Size

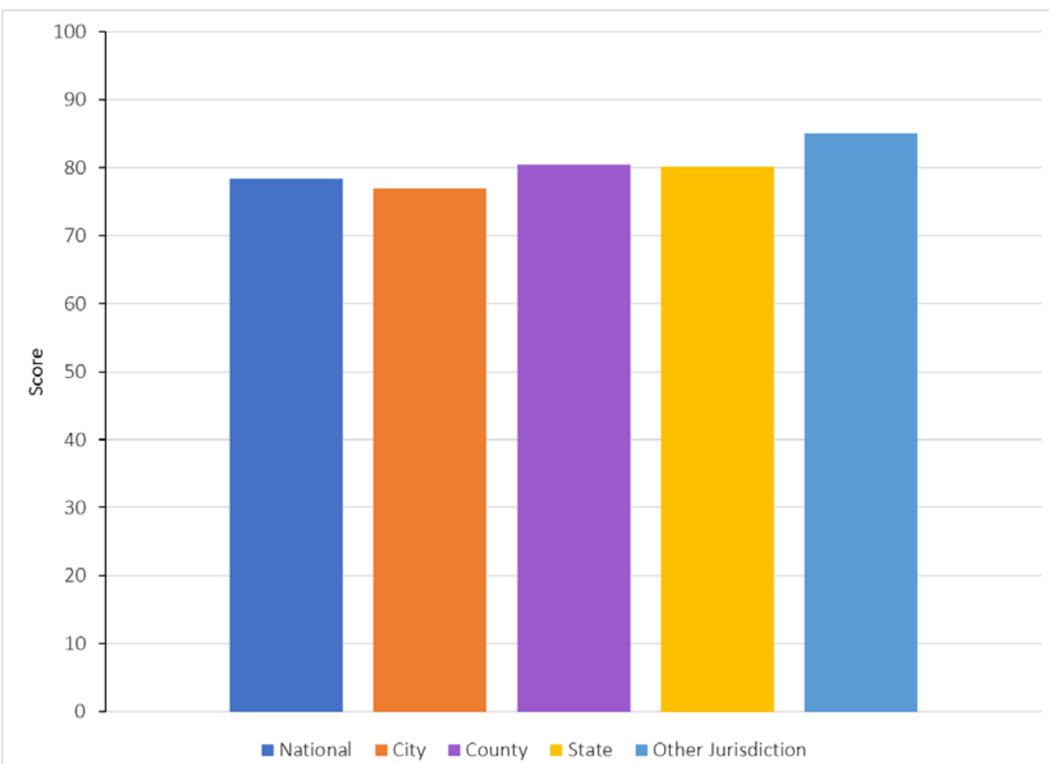

Figure 5. Chart. Systems and Technology Score Results by Agency Type

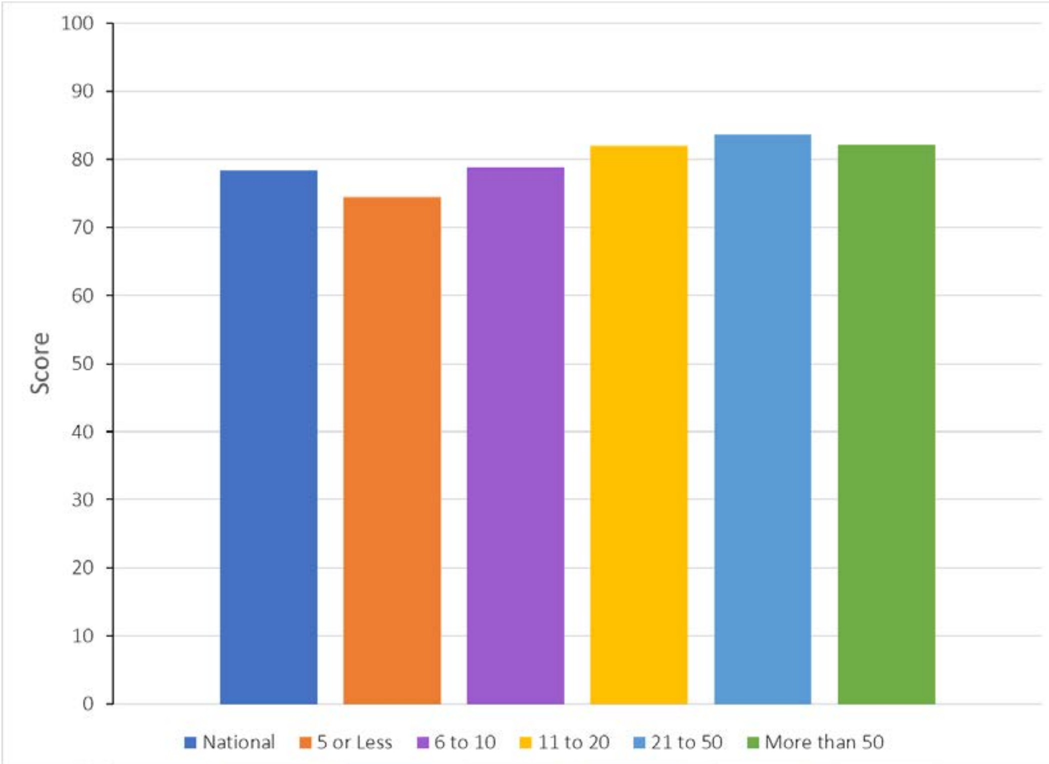

Figure 6. Chart. Systems and Technology Score Results by Staff Size

Grade	Capability		
C+	A	L 4	In addition to Level 3: • Systems and technology needs are continuously evaluated to validate the attainment of operations and maintenance objectives and to identify deficiencies and opportunities for improvement by investing in systems and technology. • Performance measures inform budget and resource allocation decisions. Asset management and system and technology investments are informed by performance measures.
	B	L 3	In addition to Level 2: • Processes are established to verify that systems provide the required functionality. • Measures are established to validate that systems and technology provide the required functionality to execute needed operations and maintenance strategies and attain objectives. • Traffic signal equipment is replaced/updated through regular upgrades that consider life cycle and functionality gaps.
	C	L 2	• Requirements to support procurement of system (e.g., local control central control, detection, communication) are established via systematic processes (systems engineering, architecture standards, etc.) that link operations and maintenance objectives and needs to requirements. • The appropriate function and performance of systems and technology is established and is based on the definition of operations and maintenance objectives and strategies. • System components are replaced based on life cycle and or when needed improvements in functionality are identified.
	D	L 1	• Requirements to support procurement of systems (e.g., local control central control, detection, communication) are not well-defined, ad hoc selection of systems and technology is typically based on the preferences of key individuals. • The appropriate function and performance of systems and technology is not well-defined and the capability to evaluate performance is limited and typically dependent on complaints. Visual observations and citizen complaints are used to determine the effectiveness of signal operation and maintenance. • System components are typically replaced when there is equipment failure.

Figure 7. Chart. Systems and Technology Grade and Associated Capability

Infrastructure

The Infrastructure dimension addresses capability in the use of standards and processes to evaluate the condition and guide placement, visibility, recognition, necessity, and function of traffic control devices and associated infrastructure such as foundations, poles, mast arms, and signal displays.

Noteworthy Findings

The average numerical score for the infrastructure dimension is 80; it is noteworthy that this was the highest score across different agency types, signal systems, and staff sizes. More specific information is presented in Figure 8, Figure 9, and Figure 10.

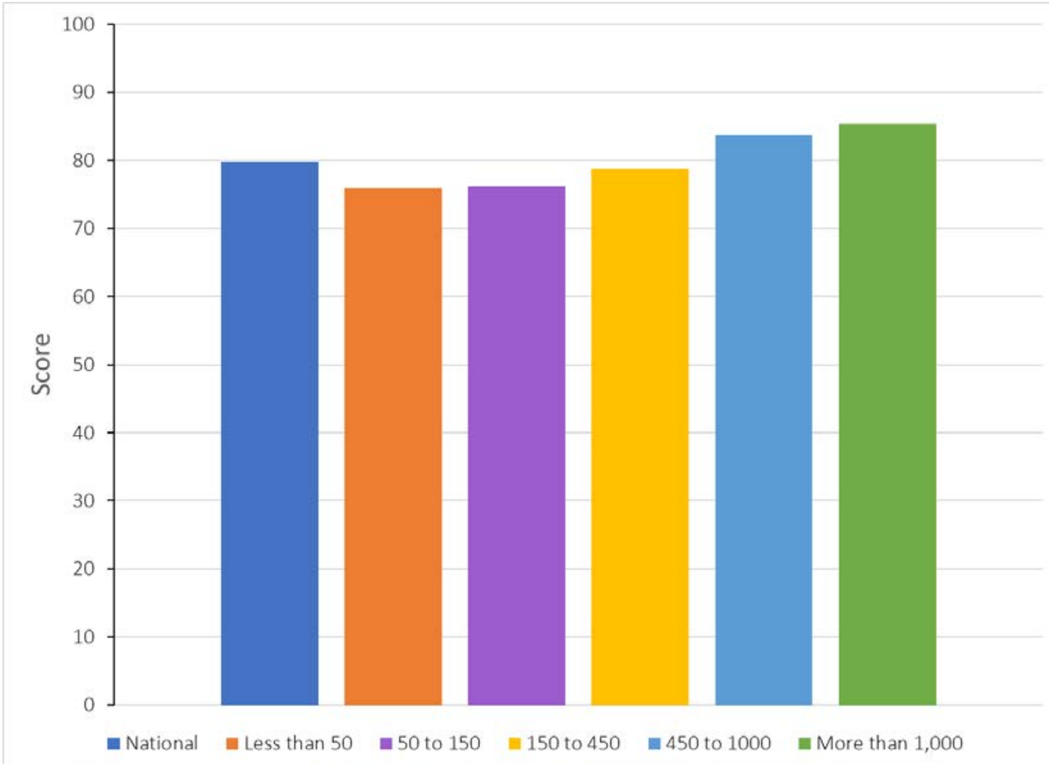

Figure 8. Chart. Infrastructure Score Results by Signal System Size

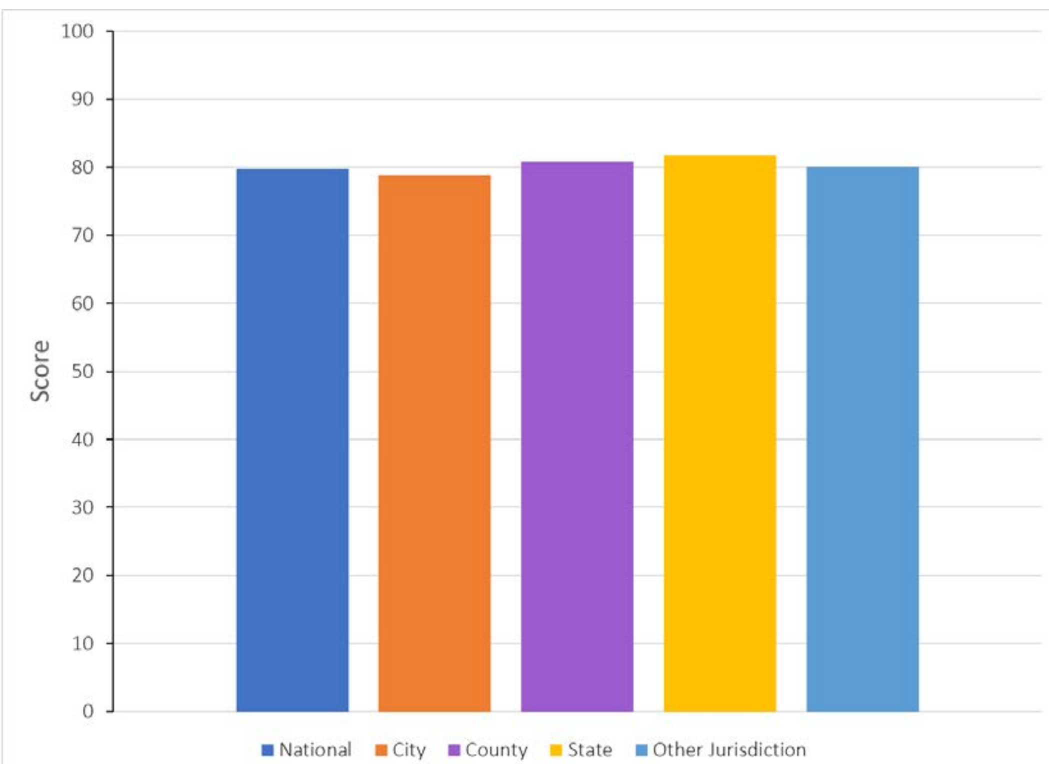

Figure 9. Chart. Infrastructure Score Results by Agency Type

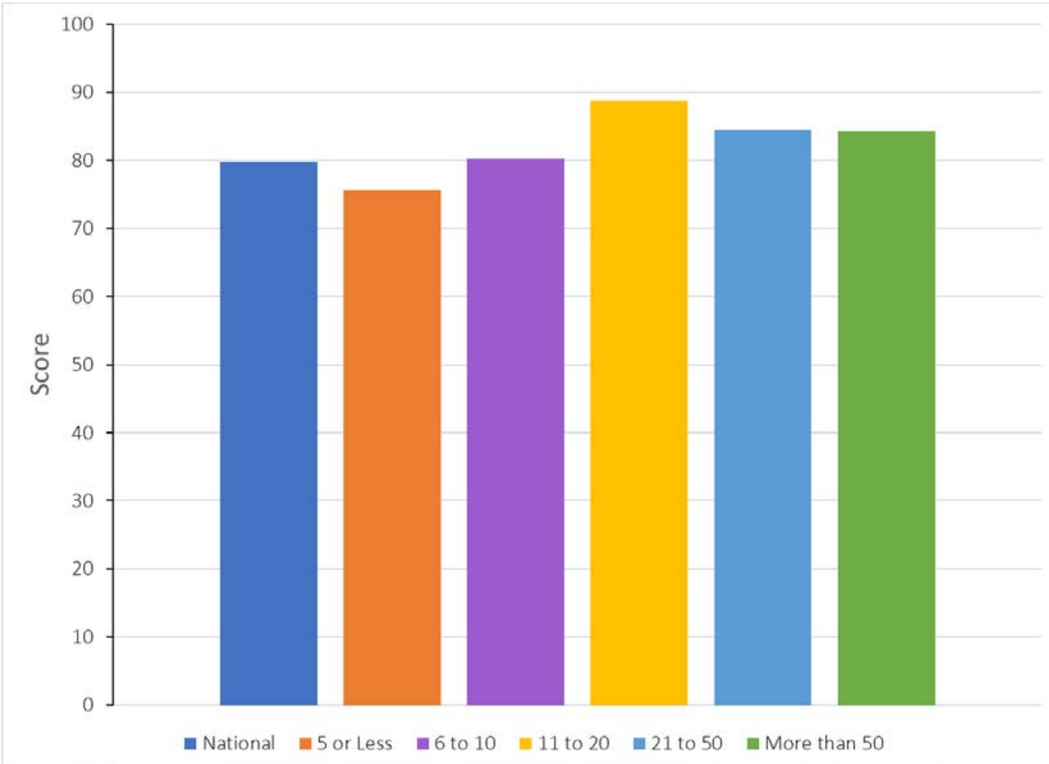

Figure 10. Chart. Infrastructure Score Results by Staff Size

This includes the following findings:

- State agencies scored higher than city agencies (82 vs. 79)
- Thirty-two percent of agencies with five or less staff function on an ad hoc basis, while only five percent with six or more staff do
- Thirty-three percent of agencies with fewer than 50 signals function on an ad hoc basis although 60 percent of agencies with more than 50 signals function on a measured or managed level
- Seventy-nine percent of cities and all reporting states function on an established or better basis

On a positive note, across all signal systems and staff sizes, 45 percent of agencies generally function at Level 3 Measured or Level 4 Managed. Although a relatively large percentage of agencies operate at a higher level, the resulting aggregate grade for this dimension is a B- as shown in Figure 11 with the associated capabilities.

Grade	Capability		
B-	A	L 4	In addition to Level 3: • Infrastructure measures are regularly evaluated to ensure consistency with required condition and functionality. Gaps in functionality and opportunities for enhancement are monitored to identify needed investments.
	B	L 3	In addition to Level 2: • Processes and measures are established to track the condition of infrastructure components to ensure the consistency of functionality with specifications. • Measures are established to ensure that infrastructure provides and maintains the required functionality (visibility, recognition, and understanding) to meet objectives and compliance with national standards.
	C	L 2	• Infrastructure specifications and requirements for functionality are based on established operations and maintenance needs which support component selection. • The capability to confirm that the current condition and function of signalized infrastructure components (e.g., poles, mast arms, span wire, wiring, signal heads) is consistent with well-established operations and maintenance requirements. • Infrastructure location and placement is recorded on As-Built plans that are readily accessible to support ongoing design, maintenance, and operations activities.
	D	L 1	• Infrastructure specifications and requirements for functionality are not well-defined; ad hoc selection of components is made based on preferences of key individuals. • The capability to confirm that the current condition and function of signalized intersection infrastructure components (e.g., poles, mast arms, span wire, wiring, signal heads) consistent with operations and maintenance requirements is not well-defined. • Infrastructure location and placement must be identified each time design, operations, and maintenance activities are initiated due to the lack of adequate recorded keeping.

Figure 11. Chart. Infrastructure Grade and Associated Capability

Business Processes

The business processes dimension—in the context of traffic signal program management and TSMO more generally—refers to activities such as scoping, planning, budget programming, agency project development processes, and those organizational aspects that govern various technical or administrative functions such as contracting and procurement, information technology, or agreements. In many cases, the business process elements go beyond the day-to-day activities and require broader institutional support and involvement to address. All of these processes are fundamental to the success of the four subareas of **design, operations, maintenance, and management** activities that support systems, technology, and infrastructure. Without the right procurement processes, sustainable funding, internal awareness, and support, there could be a limited capacity to implement more complex operations programs and activities. Figure 12, Figure 13, and Figure 14 present the score results for the business process subareas for staff size, signal system size and agency type.

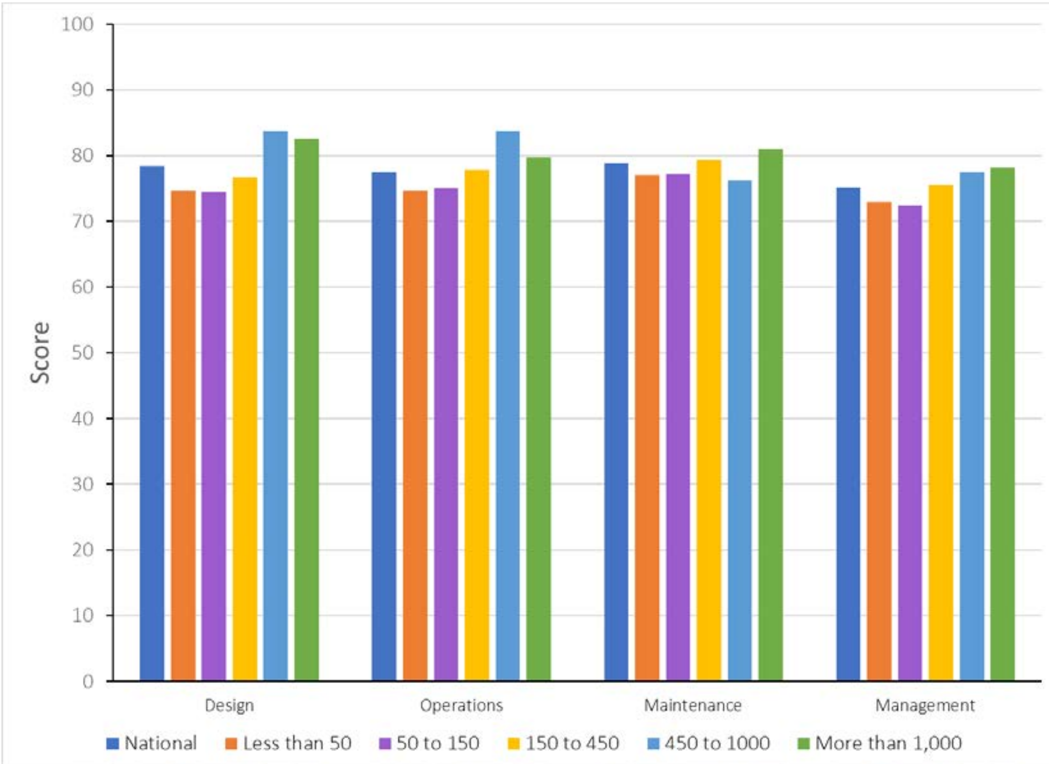

Figure 12. Chart. Business Processes Score Results by Signal System Size

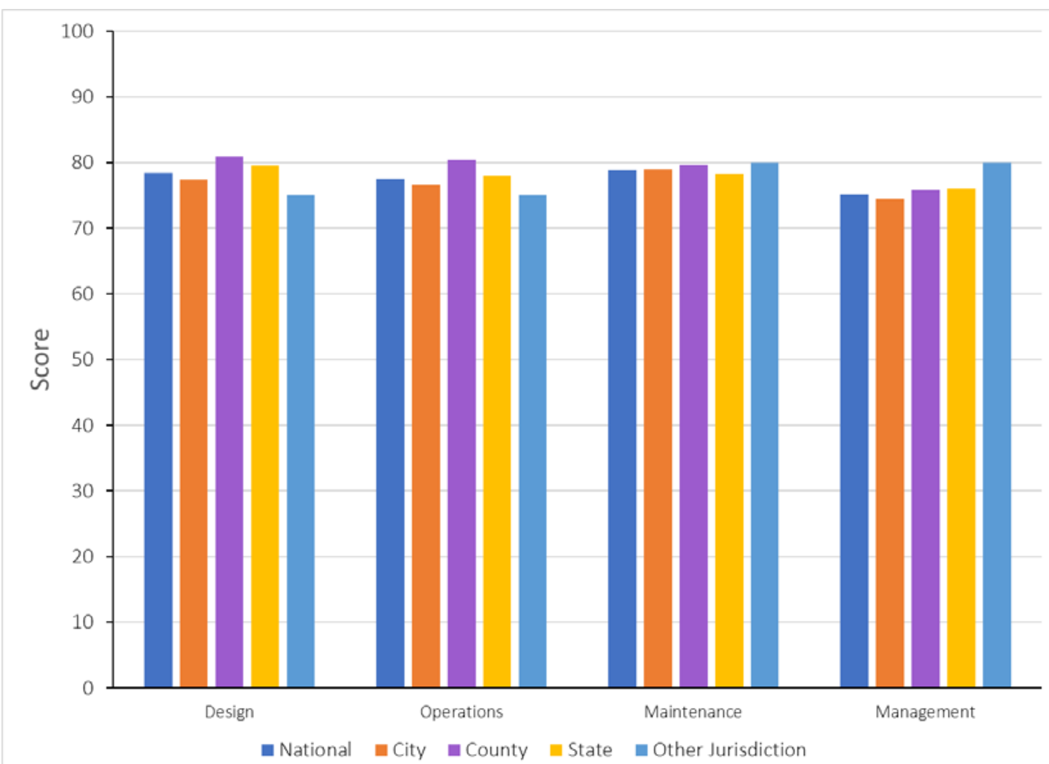

Figure 13. Chart. Business Processes Score Results by Agency Type

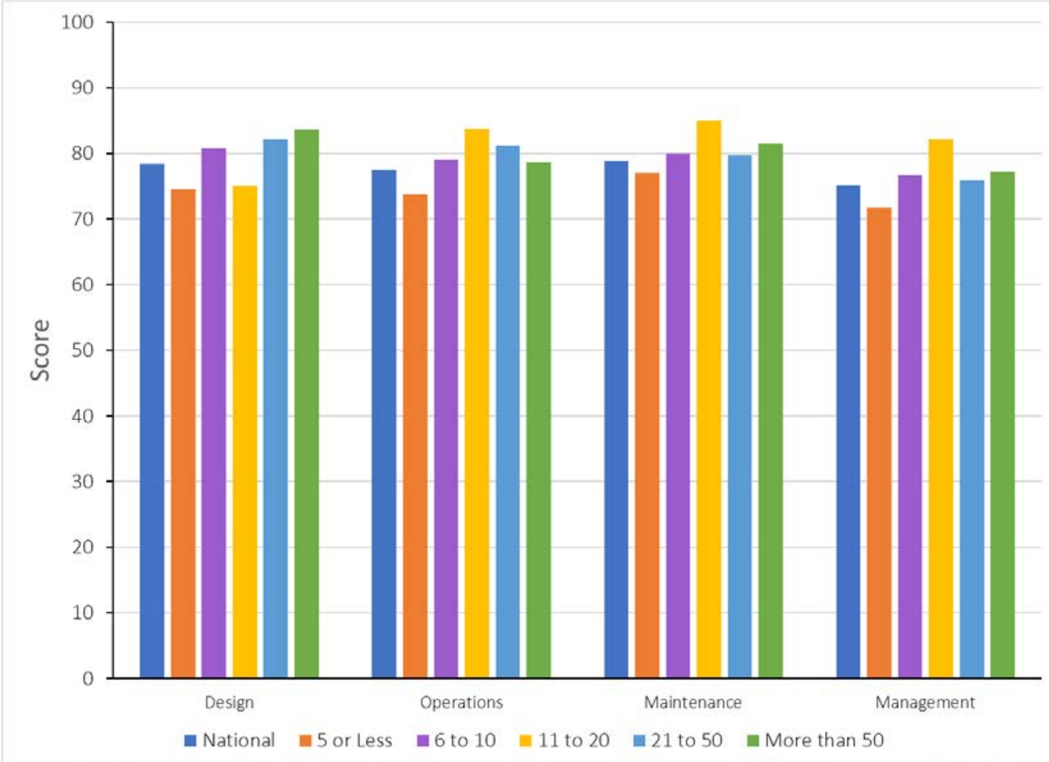

Figure 14. Chart. Business Processes Score Results by Staff Size

Design

Traffic signal design processes include the development of plans, specifications and estimates for traffic signals and associated infrastructure, related inspection during construction activities and final inspection and acceptance testing that conform to the applicable standards. In addition, design processes include related support for operations and maintenance activities as well as multimodal transportation.

Noteworthy Findings

The average numerical score for the business processes - design dimension is 78 with 55 percent of city agencies rating themselves at an Established level as noteworthy.

- Only 13 percent of all reporting agencies indicated that their design processes were ad hoc, half to two-thirds of which were small systems or staff sizes.
- Twelve to 17 percent of agencies function in this subarea on a measured and managed basis.
- A quarter of the agencies with 50 to 150 signals or with six to 10 staff rate themselves as a managed organization for this subarea.
- All but one of 31 reporting State DOT offices function at Established or better basis.

Positively, the strong majority (87 percent) of agencies of different types and sizes function at an Established level or better, reflecting the standardization of design processes. The associated capabilities and resulting aggregate grade for this dimension subarea of a C+ is shown in Figure 15.

Grade	Capability		
C+	A	L 4	In addition to Level 3: • Traffic signal design activities are evaluated to identify deficiencies and proactively identify opportunities to make improvements that add value to design activities and processes.
	B	L 3	In addition to Level 2: • Objectives and strategies are well-defined and performance measures (output and/or outcome) are defined to support evaluation of design activities. • Reporting of program output and outcomes is a core business practice.
	C	L 2	• Design activities and processes are well-established and responsive to operations and maintenance objectives to ensure that what gets built can be operated and maintained. • Design standards are established and based on nationally-accepted guidelines or state and local standards that are routinely updated and that conform to national guidelines.
	D	L 1	• Design activities are not well developed and practices are ad hoc, driven by individuals with adequate or developing skills and expertise. Designs may largely be based on tradition rather than established design objectives. • Processes that guide the selection, location, and placement of traffic signal control devices are not well-defined and could be based on outdated guidance.

Figure 15. Chart. Design Processes Grades and Associated Capability

Operations

Business processes associated with operations include activities related to timing traffic signals for multimodal, system and intersection efficiency including elements such as signal timing parameters, phasing, coordination, software analysis tools, etc. under overarching safety considerations.

Noteworthy Findings

The average numerical score for the business processes-operations dimension is 78. Half of the reporting agencies indicated that their operations business processes are established. Further, 23 percent are at the Measured level, and another 10 percent are at the Managed level, which overall is positive. The Measured and Managed level agencies are relatively uniformly distributed with slightly more in the 50 to 150 signal system size and six to 10 staff size. It is somewhat surprising though, that with the emphasis on operations over the recent years that more agencies, especially states, have not moved farther ahead. The resulting aggregate grade for this dimension subarea of a C+ is shown in Figure 16 with the associated capabilities.

Grade	Capability		
C+	A	L 4	In addition to Level 3: • Operations objectives, strategies, and performance measures are fully integrated across the program. The relationship between activities, processes, systems, and performance is acknowledged by efforts to predict, detect, and proactively make improvements that add value to operations activities and processes.
	B	L 3	In addition to Level 2: • Measures and process to collect data and evaluate performance are established. • Measures (output and or outcome) are established to validate the attainment of objectives and effectiveness of strategies. • Reporting of program output and outcomes is a core business practice.
	C	L 2	• Established operations strategies and tools are used to develop and implement signal timing, based on appropriate objectives (e.g., smooth flow, equitable distribution of green time, manage queues) and context (e.g., traffic demand, user mix, network configuration). • Guidelines and strategies are well-established to support the design and evaluation of signal timing to provide consistency, manage results, and capture experience. • Efforts to make improvements to operations processes are limited, tend to be reactive, and have limited accountability.
	D	L 1	• Operations activities are not well-defined. The day-to-day approach to operations might be described as "fire-fighting." • Priorities and processes are ad hoc, driven by individuals with adequate or developing skills and expertise to implement operations strategies. • Little or no documentation exists to guide operations and processes. Updates to existing guidelines are rare and not tracked.

Figure 16. Chart. Operations Processes Grade and Associated Capability

Maintenance

Maintenance processes include both preventative and responsive activities. Preventative activities extend traffic signal infrastructure life, identify issue prior to malfunctions or failures and can reduce their frequency and severity while efficiently using staff and resources. Component failure(s) in a traffic signal causing a malfunction or unintended operations are when response maintenance activities are required to resolve the problem.

Noteworthy Findings

The average numerical score for the business processes-maintenance dimension is 79. Appropriate maintenance resources relative to the complexity and size of the signal system through staff or external contractors is necessary for well-functioning system. The Self Assessment results showed that 90 percent of the agencies maintenance processes function at Established or better level of maturity. Fifteen percent of city agencies reported that they functioned at a Managed level of maturity and 22 percent reported functioning at a Measured level of maturity. This is more than twice the number as reporting state agencies and may reflect the differences in monitored versus remote signals. The resulting aggregate grade for this dimension subarea of a C+ is shown in Figure 17 with the associated capabilities.

Grade	Capability		
	A	L 4	In addition to Level 3: • Maintenance objectives, strategies, and performance measures are fully-integrated across the program. • The relationship between activities, processes, systems, and performance is acknowledged by efforts to predict, detect, and proactively make improvements. • Processes are continuously improved by validating the effectiveness of day-to-day activities, systems, and technology and workforce capabilities with performance measures.
	B	L 3	In addition to Level 2: • Measures (output and or outcome) are defined for maintenance-related activities. • Measures (output and or outcome) are established to validate the attainment of maintenance objectives and the effectiveness of strategies. • Reporting of maintenance output and outcomes is a core business practice.
C+	C	L 2	• Established maintenance strategies, activities, processes are practiced to guide preventative, routine/scheduled, and emergency maintenance. • Guidelines, checklists, or other documentation is available or under development to support traffic signal maintenance to ensure the reliability of infrastructure, systems, and technology. • Efforts to make improvements to maintenance processes are limited, tend to be reactive, and have limited accountability
	D	L 1	• Maintenance activities are not well-defined, ad hoc, and are driven by individuals who are equipped with or developing the skills and expertise to implement maintenance strategies. • Little or no documentation exists to guide maintenance processes. Updates to existing guidelines are rare and are not tracked. • Processes to evaluate infrastructure condition are ad hoc and not well-defined. The systems, technology, and infrastructure components may be dated (potentially obsolete), with gaps in functionality and typically replaced upon failure.

Figure 17. Chart. Maintenance Processes Grade and Associated Capability

Management

Business processes for management activities involve the budgeting and programming of general operating and capital improvement program budgets, staffing considerations and supervision within this context, customer service to the public and elected leaders, and engagement with the media and stakeholders.

Noteworthy Findings

The average numerical score for the business processes - management dimension is 75. This dimension of organizational maturity continues to lag behind other areas with 36 percent of the agencies reporting that they function at an ad hoc level. This is especially notable with 150 or fewer signals (67percent) or 10 or fewer staff (75 percent) that make up a significant majority of this group. Fewer state agencies function at an ad hoc level (23 percent) than city (41percent) or county (38 percent) agencies. The associated capabilities and resulting aggregate grade for this dimension subarea of a C is shown in Figure 18. This rating lags other business process subareas is consistent less standardization of management practices in smaller organizations.

Grade			Capability
	A	L 4	In addition to Level 3: • Program businesses processes are continuously improved by validating the effectiveness of the day-to day-activities, systems and technology, and workforce capabilities with measures. • Asset management, funding processes, training, implementation of technology and innovation, and investments in innovation and technology are informed by evaluation measures. • Priorities and investments are referenced in the Agency strategic plan.
	B	L 3	In addition to Level 2: • A set of measures (output and/outcome) are defined for management-related activities as well as the overall program. • The capability and processes to validate and routinely report on the attainment of program objectives and strategies is developed or under development. • Asset management inventory is available.
C	C	L 2	• The potential loss of continuity resulting from the attrition of key staff is mitigated by documenting program goals and objectives in the form of a Traffic Signal Management Plan (TSMP). • The TSMP references National standards and guidelines to support agency practices. The TSMP considers and documents the need for collaboration among traffic signal-related activities. • Workforce competencies, asset inventories, procurement processes (e.g., systems engineering) are documented. An asset management system is available to track life cycle of equipment.
	D	L 1	• The clear articulation of the goals and objectives of the traffic signal program relies on one or more program champions as documentation to support the day-to-day activities in the areas of design, operations, and maintenance have not been fully-developed. • The loss of key staff due to attrition or retirement presents a risk to continuity of administration activities. • Little or no documentation exists to provide direction, vision, and goals to guide traffic signal program processes. • The relationship between workforce, systems and technology, asset management, and agency goals is reliant on key individuals. Updates to existing guidelines are rare and are not tracked.

Figure 18. Chart. Management Processes Grade and Associated Capability

Workforce

This dimension characterizes the people within the organization. They carry beliefs, attitudes and behaviors that are influenced by their education and training to produce knowledge. The workforce possess the skills and experience that are required to carry out tasks, interact with systems and technology and provide the information that is critical to the management and administration program area to prepare for and address resource needs. The elements of the workforce area include the positions and roles with in the organization as well as the employee's knowledge, skills and abilities. This dimension concentrates on the development, training and competency of qualified staff across all levels in the program including technical, engineering, and management positions.

Noteworthy Findings

The average numerical score for the work force dimension is 79. Information from Figure 19, Figure 20, and Figure 21 shows, encouragingly, overall across all signal systems and staff sizes, 84 percent of agencies function at an Established or better level of maturity. However, 50 percent of signal systems with fewer than 50 signals and 65 percent of agencies with fewer than five staff continue to lag behind larger agencies. Of note is that three of the 31 reporting State agencies indicated that they function in this dimension on an ad hoc basis. The aggregated grade from responding agencies for this dimension of capability is a C+ as shown in Figure 22 with the associated capabilities.

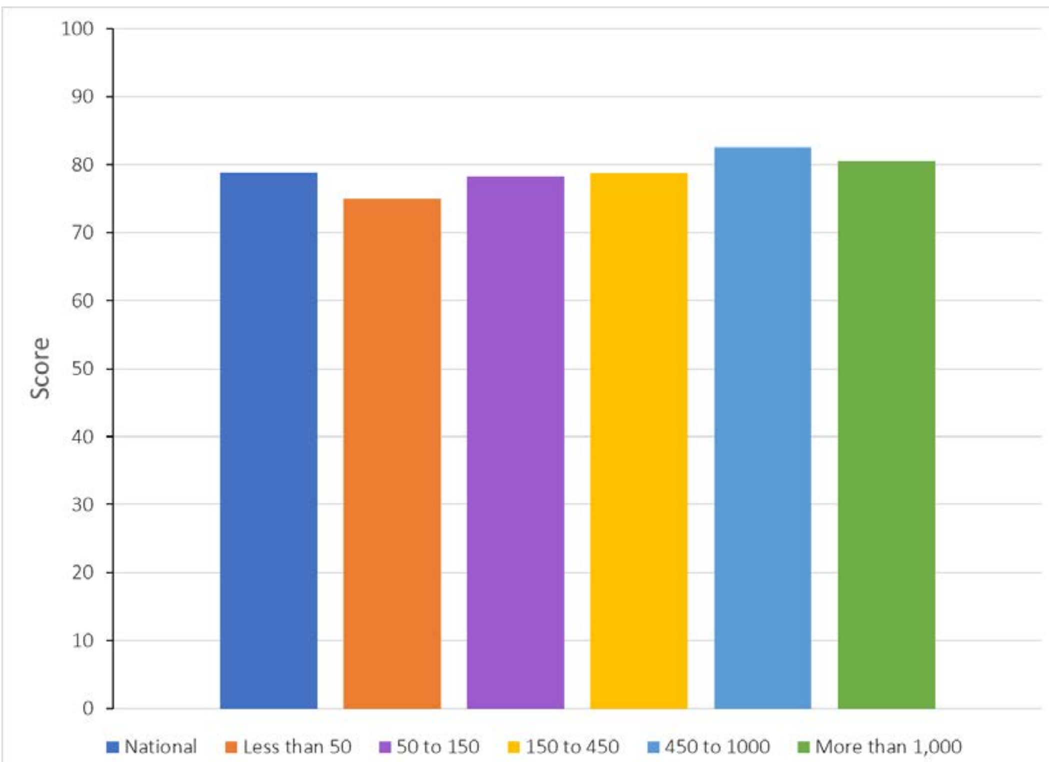

Figure 19. Chart. Workforce Score Results by Signal System Size

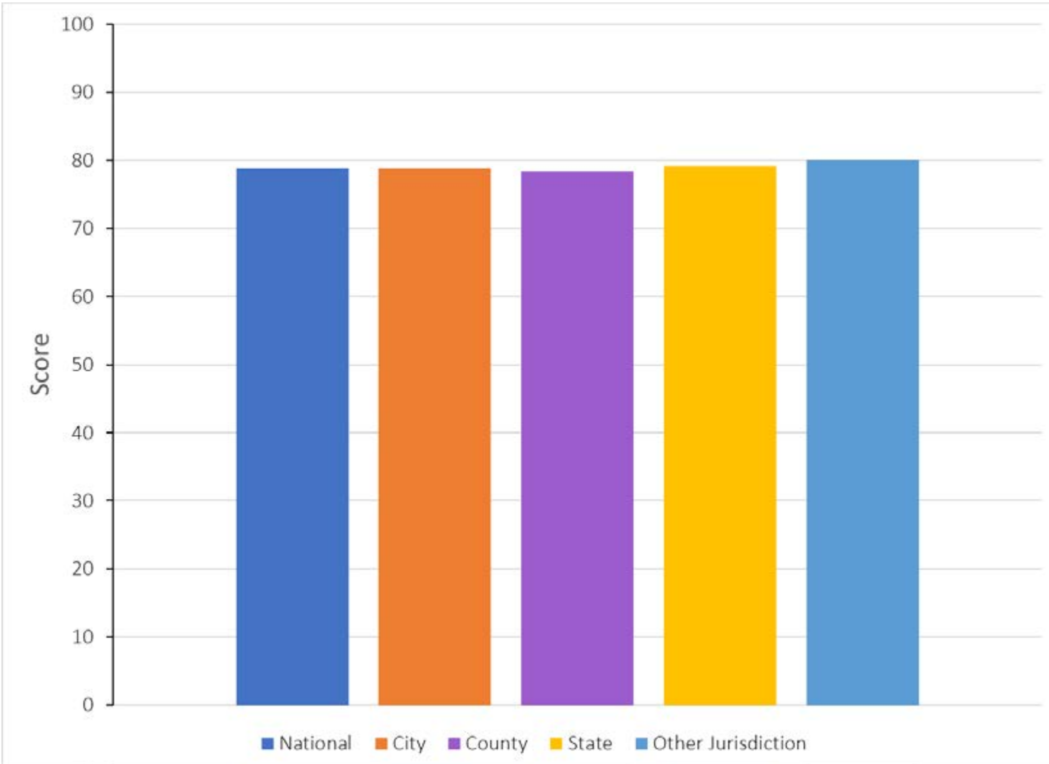

Figure 20. Chart. Workforce Score Results by Agency Type

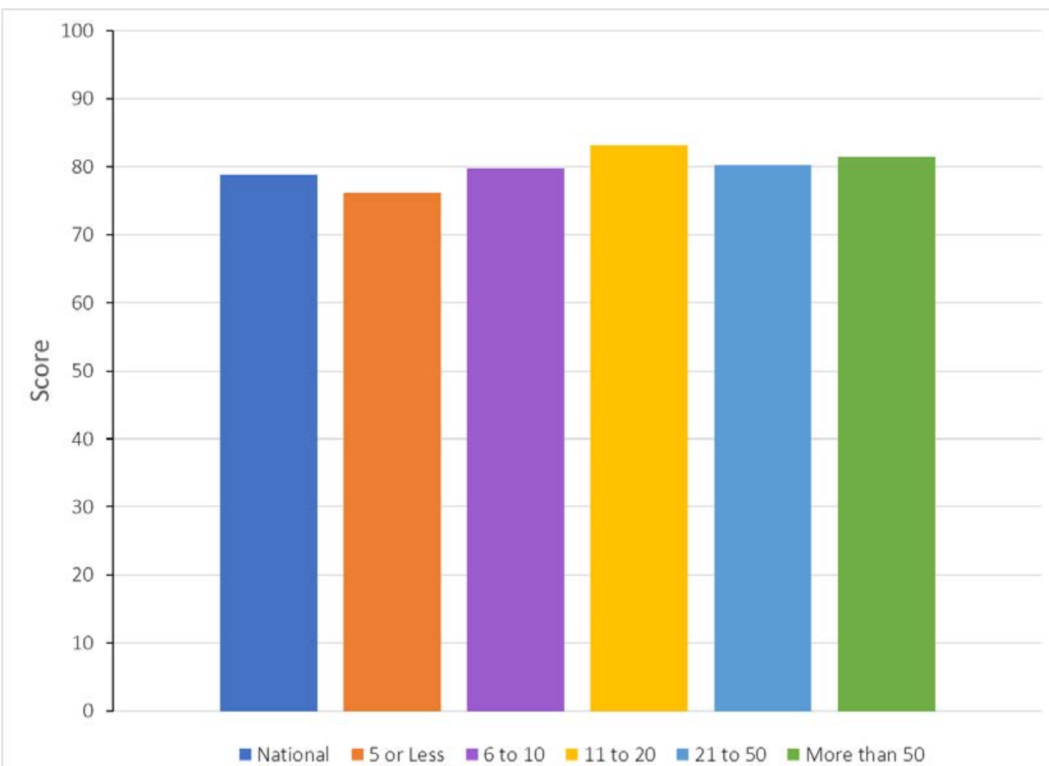

Figure 21. Chart. Workforce Score Results by Staff Size

Grade	Capability		
	A	L 4	In addition to Level 3: • Workforce competencies are evaluated to ensure consistency with industry standards and program needs, and routinely updated to improve competencies. • Appropriate program performance measures are evaluated to identify and address potential gaps between staff capability and program needs. Training and certifications are prescribed to address gaps.
	B	L 3	In addition to Level 2: • Workforce competencies are linked to current and planned program needs in each area of the traffic signal program and monitored for consistency. • Training and certifications are tracked to ensure that staff capability is consistent with program needs.
C+	C	L 2	• Workforce competencies are established and job descriptions are documented to support alignment of staff capability with design, operations, and maintenance strategies. • Workforce development is supported fiscally with structured internal and/or external training and certification as appropriate to maintain the competency of the workforce.
	D	L 1	• The workforce maintains minimum levels of capability to complete required tasks. Workforce competencies/position descriptions are not well defined. • Training is ad hoc and lacks formal structure. Funding to support training, development of core skills and certification is limited.

Figure 22. Chart. Workforce Grade and Associated Capability

Management and Administration / Leadership

The management and administration/leadership dimension encompasses the overall direction, outreach, and resources of an agency program in the subareas of culture, organization and staffing, collaboration, and performance measurement. Those organizational aspects govern various technical or administrative functions such as human resource management, contracting and procurement, information technology, partnering commitments, sustainable funding, internal awareness, support, and agreements. This dimension involves ensuring that adequate resource levels are sustained to support program functions, internal and external interactions to report outcomes, collaboration to achieve program goals, establishment and/or evolution of organizational culture, and the satisfaction of the programs customers and stakeholders. Routine assessments of the programs capability and maturity as well as the development of an action plan that is oriented around identifying and addressing potential risks to attainment of program goals and objectives is a function of the management and administration area of the program. In many cases, the management and administration/leadership dimension goes beyond the day-to-day operational activities to those requiring broader institutional support and involvement to address. All of these processes related to **culture, organization and staffing, collaboration, and performance measurement** are fundamental to the success of traffic signal programs within agency management activities. Figure 23, Figure 24, and Figure 25 present the score results for the management and administration/leadership subareas for staff size, signal system size, and agency type.

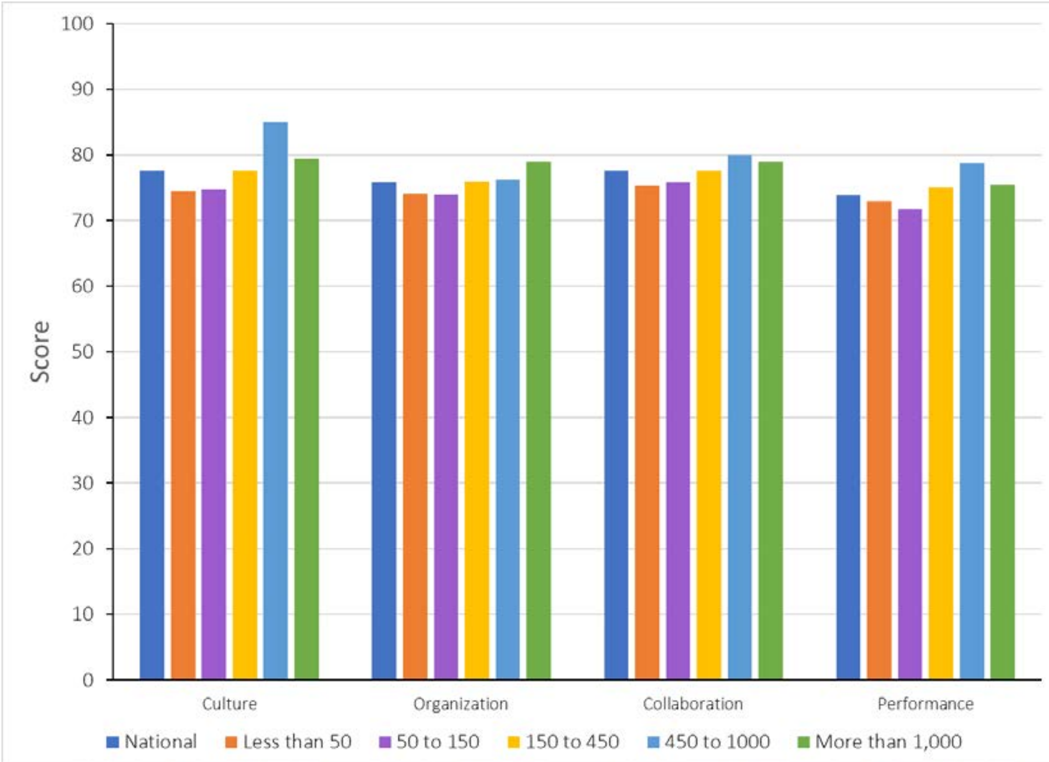

Figure 23. Chart. Management and Administration/Leadership Score Results by Signal System Size

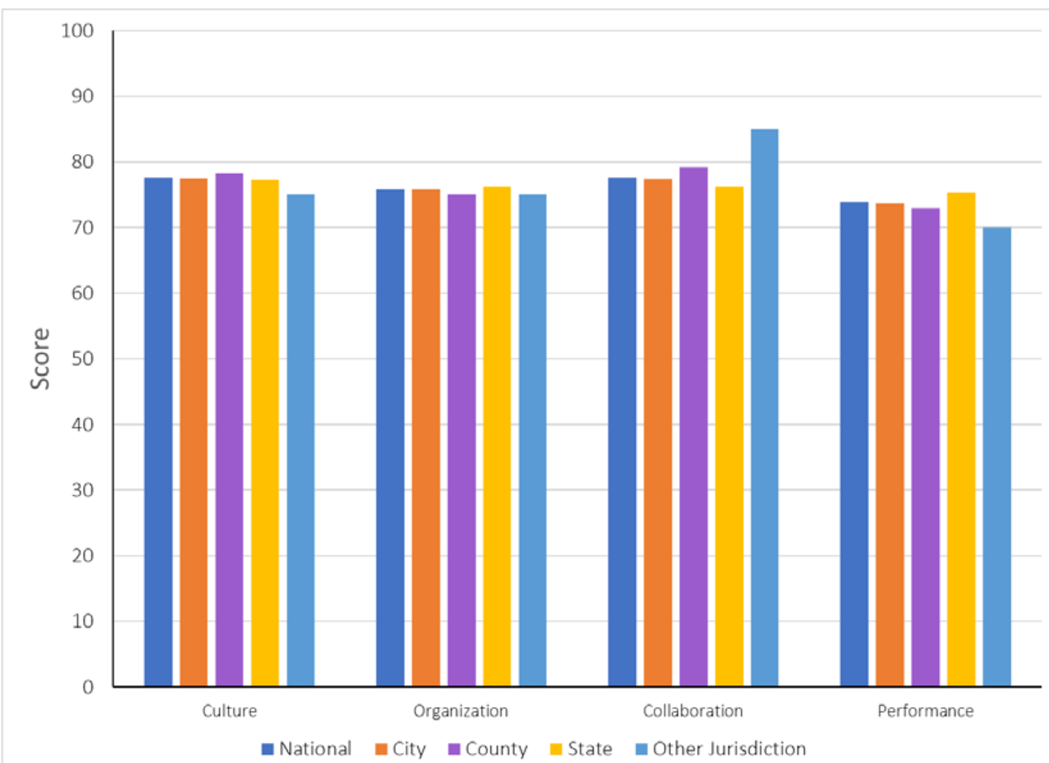

Figure 24. Chart. Management and Administration/Leadership Results by Agency Type

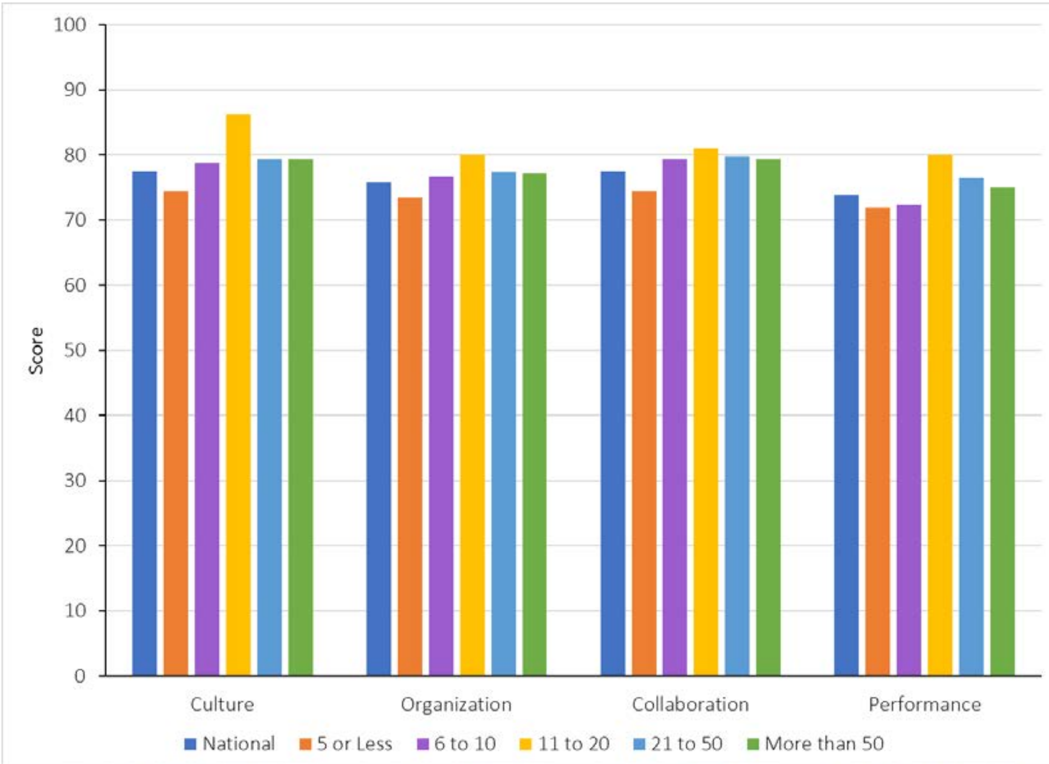

Figure 25. Chart. Management and Administration/Leadership Score Results by Staff Size

Culture

The culture of an organization emanates from beliefs, attitudes, and behaviors of the workforce that are influenced by their personal experience(s), education and training. Culture is the combination of values, assumptions, knowledge, and expectations of an organization in the context of its institutional and operating context, and as expressed in its mission and values.

Noteworthy Findings

The average numerical score for the management and administration/leadership sub-dimension on culture is 78. Encouragingly, overall, across all signal systems and staff sizes, 81 percent of agencies function at an Established or better level of maturity; and 32 percent function at either the Measured or Managed level. However, 46 percent of signal systems with fewer than 50 signals and 68 percent of agencies with fewer than five staff continue to lag behind larger agencies. Of note is that three of the 31 reporting state agencies indicated that they function in this dimension on an ad hoc basis. The resulting aggregate grade for this dimension subarea of a C+ is shown in Figure 26 with the associated capabilities.

Grade	Capability		
	A	L 4	In addition to Level 3: • Performance measures are continually evaluated to identify opportunities to improve the program. • Opportunities to improve customer satisfaction are identified and planned. • The program is included in the overall strategic plan of the agency, region, and State. • The program budget and resource needs are managed. Opportunities to improve fiscal support is continuously evaluated and reflected in investments. • Infrastructure and systems are managed and based on life-cycle monitoring; opportunities to enhance functionality is continuously evaluated.
	B	L 3	In addition to Level 2: • Performance measures are established to validate the objectives of the program. • Customer satisfaction is evaluated and reported. • The value of the program is demonstrated by reporting progress on program measures of effectiveness. • Budgetary and resource needs and priorities are established and monitored. • An asset management plan is Established and includes measures to evaluate infrastructure and systems.
C+	C	L 2	• The direction of the program is established and documented in a plan. • Customer needs are established and processes exist to address issues. • Consistent message established articulating the program's value, activities, and needs. • Budgetary and resource needs are established, planned, and constrained based on objectives, workforce, strategic needs, and limitations. • Infrastructure and systems life-cycle planning is under development or established.
	D	L 1	• The overall program lacks direction; goals and objectives are not well-defined. • Customer needs are difficult to evaluate. • The traffic signal program is a low priority within the overall transportation program. • The need for programmatic investments is not well-defined nor are budgetary and resource needs.

Figure 26. Chart. Culture Grade and Associated Capability

Organization and Staffing

This subarea is about the appropriate combination of coordinated organizational structure and functions, roles and responsibility, and levels of qualified staff with clear management authority and accountability that supports effective execution of the management and administration of an organization.

Noteworthy Findings

The average numerical score for the management and administration/leadership subdimension on organization and staffing is 76. Overall, across all signal systems and staff sizes 48 percent of agencies function at an established level of maturity. Further, 22 percent of State agencies, 25 percent of county agencies and 26 percent of city agencies function at the measured or managed level. However, 71 percent of signal systems with fewer than 150 signals, 68 percent of city agencies, and 61 percent of agencies with fewer than 5 staff continue to lag behind larger agencies functioning on an ad hoc basis. Four of the 31 reporting state agencies indicated that they function in this dimension on an ad hoc basis. The associated capabilities and resulting aggregate grade for this dimension subarea of a C is shown in Figure 27.

Grade	Capability		
	A	L 4	In addition to Level 3: • The organizational structure is evaluated and managed to maximize the capability for needed coordination. • The roles and activity of business units are evaluated to identify and take advantage of opportunities for improvements. • Staffing levels are routinely evaluated and modified as needed to maximize the output and outcomes of the program. • Staff succession, retention, and rotation within the organization is managed.
	B	L 3	In addition to Level 2: • Measures are established to validate the effectiveness of coordination among business units. • Measures are established to verify that the activities and processes of each business unit support attainment of objectives. • The output of organizational units is measured and reported. • Staff succession, retention and rotation within the organization is monitored.
C+	C	L 2	• Requirements to support procurement of system (e.g., local control central control, detection, communication) are established via systematic processes (systems engineering, architecture standards, etc.) that link operations and maintenance objectives and needs to requirements. • The appropriate function and performance of systems and technology is established and is based on the definition of operations and maintenance objectives and strategies. • System components are replaced based on life cycle and or when needed improvements in functionality are identified.
	D	L 1	• The organizational units responsible for design, operations and maintenance are siloed, coordination is ad-hoc and not well-developed. • The roles of organizational units may lack clear definition, resulting in redundancy or voids in needed activities (e.g., asset management, procurement, monitoring, reporting). • Staffing levels are not consistent with needs. • Staff retirements, promotions, and rotation within the organization or attrition is ad hoc.

Figure 27. Chart. Organization and Staffing Grade and Associated Capability

Collaboration

The development and implementation of traffic signal operations programs requires a collaborative approach internal to the agency and externally to public safety agencies, local governments, metropolitan planning organizations (MPOs), and the private sector. The effectiveness of most strategies is dependent on improving the coordinated performance of each partner.

Noteworthy Findings

The average numerical score for the management and administration/leadership subdimension on collaboration is 78. Continuing the challenge with smaller organizations, 74 percent of signal systems with fewer than 150 signals, 70 percent of city agencies, and 67 percent of agencies with fewer than five staff continue to lag behind larger agencies functioning on an ad hoc basis. Overall, across all signal systems and staff sizes, 50 percent of agencies function at an Established level of maturity. The resulting aggregate grade for this dimension subarea of a C+ is shown in Figure 28 with the associated capabilities.

Performance Measurement

Performance measurement is essential as the means of determining program effectiveness, evaluating methods, determining how changes are affecting performance, and guiding decision-making. In addition, traffic signal program-related operations performance measures demonstrate the extent of transportation issues and can be used to make the case for the traffic signal program within an agency, for decision-makers and the traveling public, as well as to demonstrate to them what is being accomplished with public funds on the transportation system.

Noteworthy Findings

The average numerical score for the management and administration/leadership subdimension on performance measurement is 74. This subdimension lags behind across multiple disaggregate areas. Again, smaller organizations underperform in this area with 67 percent of signal systems with fewer than 150 signals, two-thirds of city agencies, and one-half of agencies with fewer than five staff continue to lag behind larger agencies functioning on an ad hoc basis. Overall, across all signal systems and staff sizes, only 36 percent of agencies function at an Established level of maturity. Eight of the 31 reporting state agencies indicated that they function in this dimension on an ad hoc basis for performance management which can be viewed as a risk relative to the FHWA's recent emphasis on operations performance measures. The associated capabilities and resulting aggregate grade for this dimension subarea of a C is shown in Figure 29.

Grade	Capability		
	A	L 4	In addition to Level 3: Internal: • The program evaluates projects to identify opportunities to improve the quality of projects by enhancing coordination with other units (e.g., Planning, Safety, Construction, Active Transportation). External • The traffic signal program strategically coordinates with partners to achieve shared goals and objectives. • Appropriate local, State, and federal resources are leveraged to integrate activities, processes, and systems in support of regionally shared goals and objectives.
	B	L 3	In addition to Level 2: Internal: • The capability to monitor projects and activities that may benefit from coordination with the traffic signal program is established. External • The capability to evaluate the need for and effectiveness of coordination with external partners and Integration of systems is established. • The program monitors the outcome of regional planning activities to ensure appropriate consideration of needs.
C+	C	L 2	Internal: • Coordination between the program and other units (e.g., Planning, Safety, Construction, Active Transportation) is Established and consistent with objectives. External • Relationships with external public and private partners is Established. Memorandums of Understanding or formal agreements are developed as needed to facilitate collaboration. Special events, incidents, and emergencies are appropriately planned for and coordinated. • The program is appropriately established within regional and State transportation planning activities.
	D	L 1	Internal: • Coordination between the traffic signal program and other units (e.g. Planning, Safety, Construction, Active Transportation) is ad hoc, not well-defined and dependent informal relationships. External • The program does not routinely coordinate with other public or private organizations (e.g., MPOs, police, emergency services, schools, colleges, special event facilities) to plan, coordinate, or respond to activity or share information to support, day-to-day operations (e.g., cross jurisdictional coordination), management of special events, incidents, unplanned events, or unusual occurrences. • The traffic signal program is not routinely considered in local, regional, or state transportation planning activities.

Figure 28. Chart. Collaboration Grade and Associated Capability

Grade	Capability		
	A	L 4	In addition to Level 3: • Performance measures inform decision-making and planning for all workforce, business process, and systems and technology needs. • Performance measures inform budget and resource allocation decisions. Asset management and system and technology investments are informed by performance measures.
	B	L 3	In addition to Level 2: • Documented measures and methods direct evaluation of day-to-day activities, projects, etc., and the performance of the system. • Performance measures are collected and reported to demonstrate accountability but may not directly feed into budgeting and resource allocation decisions. The feedback loop may not be well- connected to external regional and state transportation programs.
C	C	L 2	• Outcome and output measures and methods are established to evaluate the effectiveness of the program and the performance of the system. • Limitations in systems and technology, business processes, or workforce capability may result in data collection that is discontinuous, potentially project-oriented, and may hinder the ongoing evaluation of program effectiveness.
	D	L 1	• The routine evaluation of program areas (e.g., design operation and maintenance) and the performance of the system relative to goals and objectives is not clearly-defined and ad hoc. Program needs may not be supported by workforce capability or systems and technology.

Figure 29. Chart. Performance Management Grade and Associated Capability

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3 Traffic Signal Program Benchmarking

Introduction

Benchmarking allows transportation organizations to compare trends among their existing staffing, resources, equipment, infrastructure, systems and standard practices against other similar organizations. The benchmarking component is quantitative; gathering data about the physical infrastructure of signalized intersections and the supporting program to characterize current capability, value, and the extent of the built infrastructure. This allows organizations to identify potential programmatic gaps that are related directly to an organization's ability to attain its most relevant goals rather than to benchmark agencies with different sizes and complexity against one another.

Each subsection provides a general description of the topic area and summarizes select responses from the benchmarking questions from the Self Assessment. Where supportive, the benchmarking responses are compared to the organizational assessment to draw conclusions related to the maturity of organizations.

Work Force and Fiscal Resources

Table 4 presents the average number of full-time equivalent (FTE) staff responsible for traffic signal operations, management, and maintenance in different categories by traffic signal system size. The results showed that, as expected, the largest number of staff are engineers and signal technicians. As signal system size increases, more staff are in roles of non-technical engineering manager, engineering manager, and IT/IS engineers representing the increasing complexity of the organization and system. There are more staff in the other technicians category in the largest agencies. The smallest agencies are less likely to have a traffic engineering specific manager as the work is typically folder under a public works department. Additionally, there are more non-engineering managers at the smallest agencies.

Table 4. Average Number of Staff Performing Traffic Signal Work by System Size

Signal System Size	Non-technical Manager	Engineering Manager	Engineers	Other Professionals	Signal Technicians	Other Technicians	Administrative	IT/IS Engineers	Other	Total
Less than 50	1.0	0.7	1.0	0.2	1.0	1.1	0.5	0.5	0.3	6.3
50 to 150	0.3	1.0	1.3	0.3	3.2	1.6	0.6	0.7	0.9	9.8
150 to 450	0.9	1.2	2.4	1.7	6.4	1.9	1.5	0.8	4.1	20.9
450 to 1,000	0.0	2.3	19.9	2.7	9.7	2.6	1.2	1.5	3.8	43.5
More than 1,000	2.7	3.3	15.7	3.1	41.5	13.1	3.0	1.6	8.9	92.9
AVERAGE	1.1	1.6	6.2	1.5	12.0	3.7	1.5	0.9	3.3	31.8

Table 5 shows the average annual source of 1) operating and maintenance and 2) capital funding for traffic signal management operations for different funding categories by traffic signal system size and agency type. Further, the total spending was $296,856,806 on operating and maintenance programs and $184,235,500 on capital projects for traffic signal programs by the 144 agencies responding to this question.

Table 5. Source of Operating/Maintenance and Capital Funding by System Size and Agency Type

	Average Operating/Maintenance Funding					Average Capital Funding				
	Local	Regional	State	Federal	Other	Local	Regional	State	Federal	Other
Signal System Size										
Less than 50	$89,059	$970	$23,331	$0	$0	$54,015	$7,353	$109,625	$95,406	$5,000
50 to 150	$375,372	$0	$65,114	$0	$33,333	$166,073	$13,750	$6,154	$113,750	$33,333
150 to 450	$458,930	$18,970	$429,922	$105,471	$200,000	$501,806	$0	$255,294	$209,706	$210,000
450 to 1,000	$216,429	$0	$185,714	$0	$0	$271,429	$142,857	$214,286	$71,429	$0
More than 1,000	$1,482,666	$150,250	$6,559,074	$1,606,667	$225,000	$689,568	$0	$1,097,358	$3,080,908	$3,308,200
AVERAGE	$514,524	$32,060	$1,292,039	$314,522	$105,000	$320,627	$12,857	$296,063	$650,911	$794,044
Agency Type										
City/Municipality	$552,584	$1,725	$75,847	$125,000	$75,000	$235,075	$9,524	$35,038	$114,852	$816,250
County	$988,111	$159,091	$570,432	$94,818	$0	$982,000	$0	$4,167	$395,833	$0
State/Province	$0	$21,586	$5,253,000	$1,002,000	$225,000	$18,507	$33,333	$1,237,887	$2,329,727	$616,400
Other Jurisdiction	$1,273,000	$0	$80,000	$0	$0	$1,275,000	$0	$225,000	$480,000	$0
AVERAGE	$514,524	$32,060	$1,292,039	$314,522	$105,000	$320,627	$12,857	$296,063	$650,911	$794,044

Infrastructure, Systems, and Technology

The questions in the infrastructure, systems and technology section focused on documenting the type of specific infrastructure assets and tools to support them. This includes information such as asset management systems, the number of traffic signals owned or operated, the number and types of traffic signal controllers, communications, detection, and cameras. In addition, information was gathered on whether cybersecurity measures were taken by the responding organization and organization's plans for deploying connected vehicle applications. These questions are related to both the systems and technology, and infrastructure CMM dimensions.

The pie charts in Figure 30a and Figure 30b on the use of asset management were developed from 74 affirmative responses from the *Self Assessment*. The result show that roughly half of the agencies use asset management systems. However, when broken out by each type of jurisdiction, almost three-quarters of state agencies report using asset management systems in comparison to lesser usage by city and county agencies. When examined form the context of signals system size, 70 percent of the agencies with more than 150 signals use asset management systems while only 34 percent of agencies with less than 150 signals do. There is a clear break point in the number of assets managed and breadth of the organization related to the use of asset management systems.

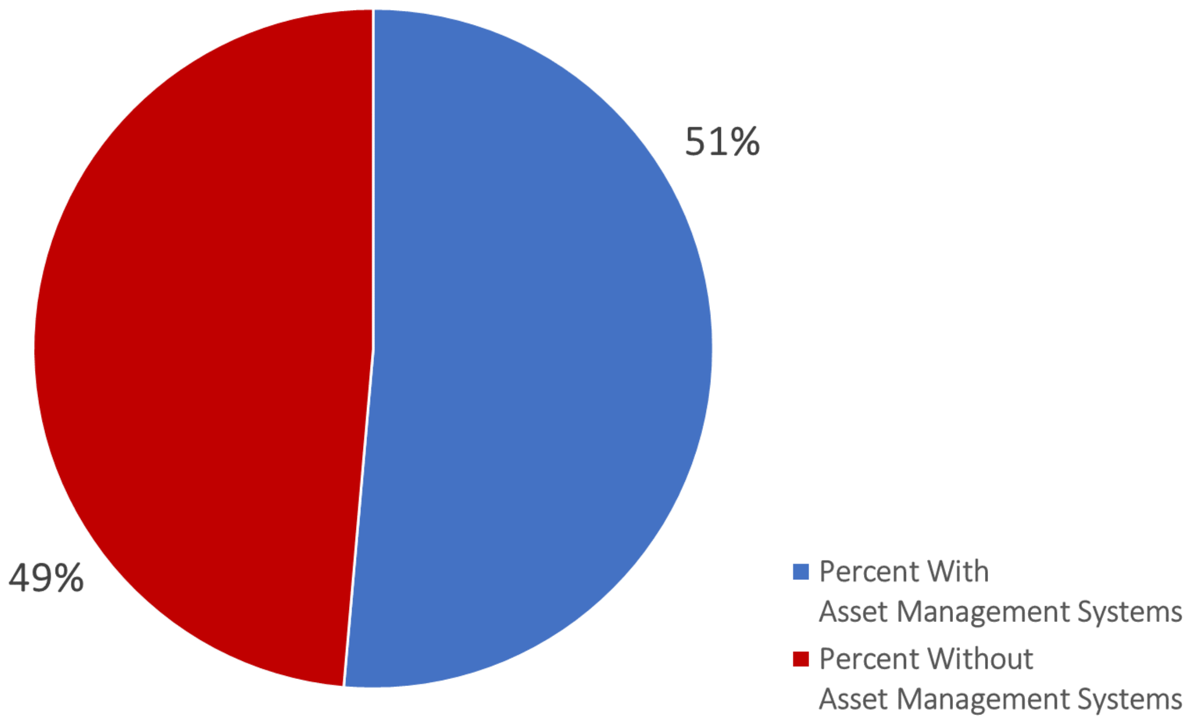


Figure 30a. Chart. Percent of Agencies Reporting Use of Asset Management System

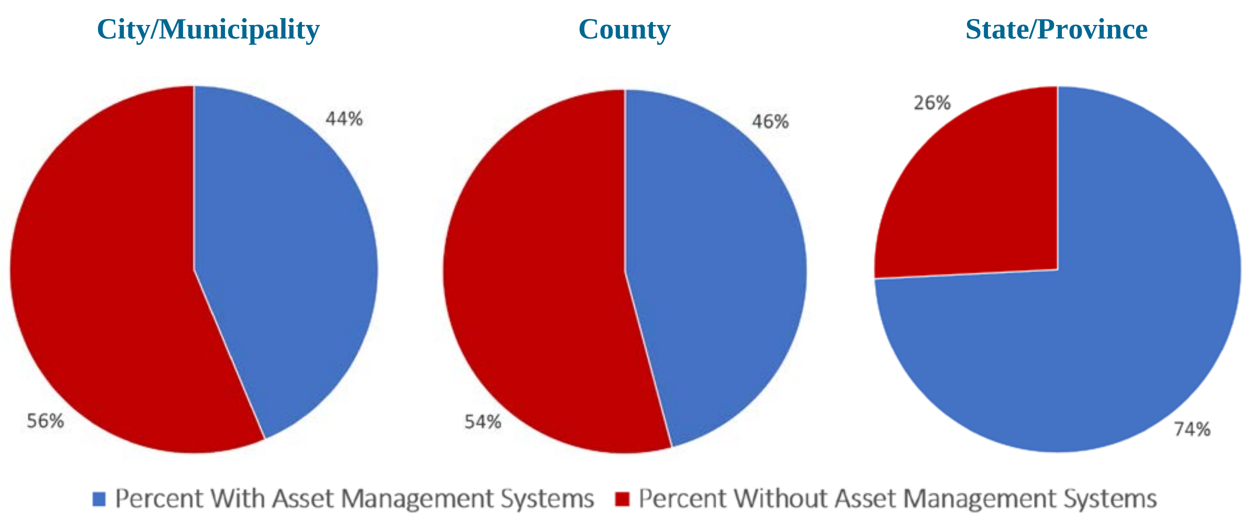


Figure 30b. Chart. Percent of Agencies with Asset Management System by Agency Type

Of the 99 agencies that reported traffic signal controller age, this represented 58 percent of the *Self Assessment* responses. Based on these responses **the national average age of traffic signal controllers is 9.4 years.** Figure 31 breaks out controller age by agency type. This shows that cities and counties have traffic signal controllers that are, on average, at least 1.4 years older than state agencies.

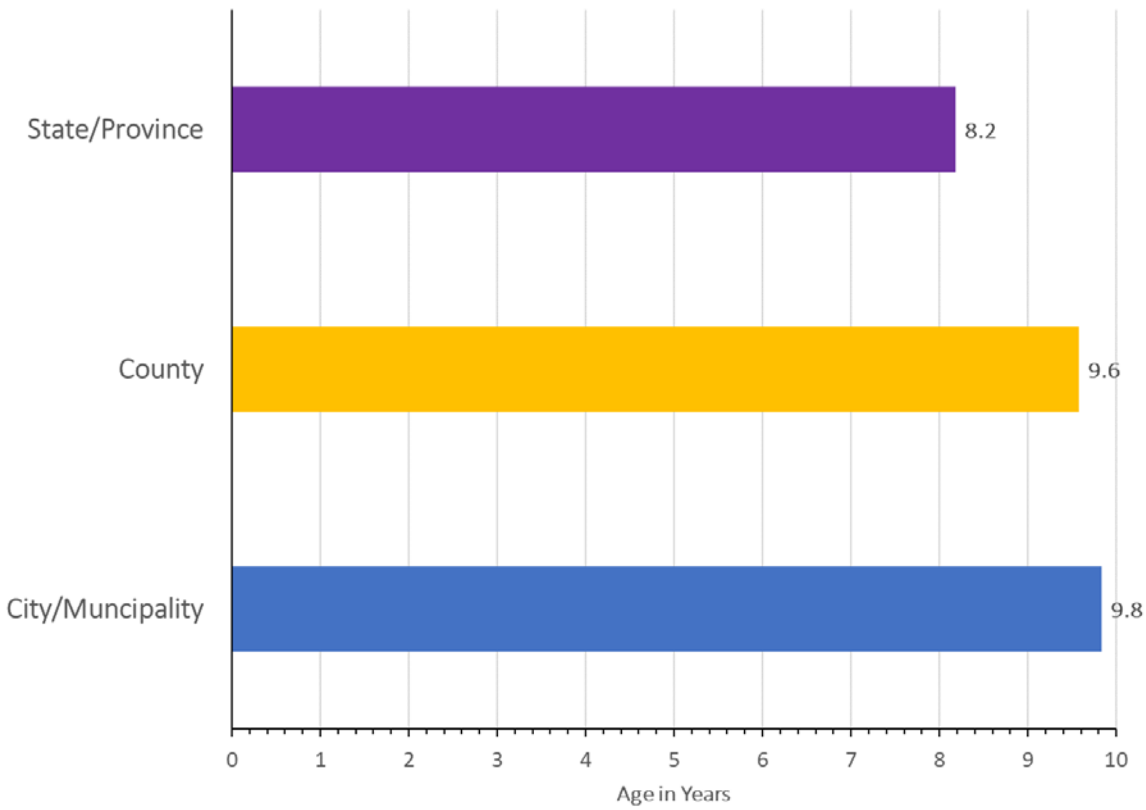


Figure 31. Chart. Age of Traffic Signal Controllers by Agency Type

More detail review of the *Self Assessment* responses revealed the following:

- Five times as many local agencies have traffic signal controllers over 10 years-old compared to only a few individual states and counties with controllers over that age.
- Somewhat surprisingly, 22 percent of the agencies responding that the age of their traffic signal controllers was unknown in comparison to their reporting of their CMM Systems and Technology dimension as Level 2, Level 3, or Level 4.
- Overall, 31 percent of reporting agencies stated that they did not know the age of their controllers.
- More than 57 percent of agencies of signal systems of more than 50 signals have traffic signal controllers less than 10 years-old.
- Only 38 percent of the agencies operating fewer than 50 signals have traffic signal controllers under 10 years-old.
- There was no specific correlation by staff size of the organization and the age of traffic signal controllers.
- Investment of capital and operating funding amounts are being driven by larger State agencies that have established traffic signal programs or agencies that have a specific large investment in new system deployment. There no correlation between advancing age of controllers and supporting

funding for either increased maintenance or significant capital outlays. This does suggest that underfunded agencies are making do with what they have and focusing on day-to-day maintenance activities with their own staff.

Figure 32 shows the percent of reporting agencies that have a traffic signal central system and Figure 33 show those that use the system to store historic signal timing documentation. Interestingly, 10 to 20 percent of these agencies do not employ this capability in their systems.

The *Self Assessment* asked whether responding agencies had a traffic management center; 73 percent stated that they did. Broken out my agency type more counties and states had traffic management centers than city agencies as shown in Figure 34, likely representing the breadth of systems and need for inter-agency and inter-jurisdictional operational approaches. The *Self Assessment* showed that larger agencies have a much higher likelihood of using traffic management center with 77 percent of the agencies with 150 to 1,000 traffic signal and virtually all agencies with more than 1,000 traffic signals (96 percent).

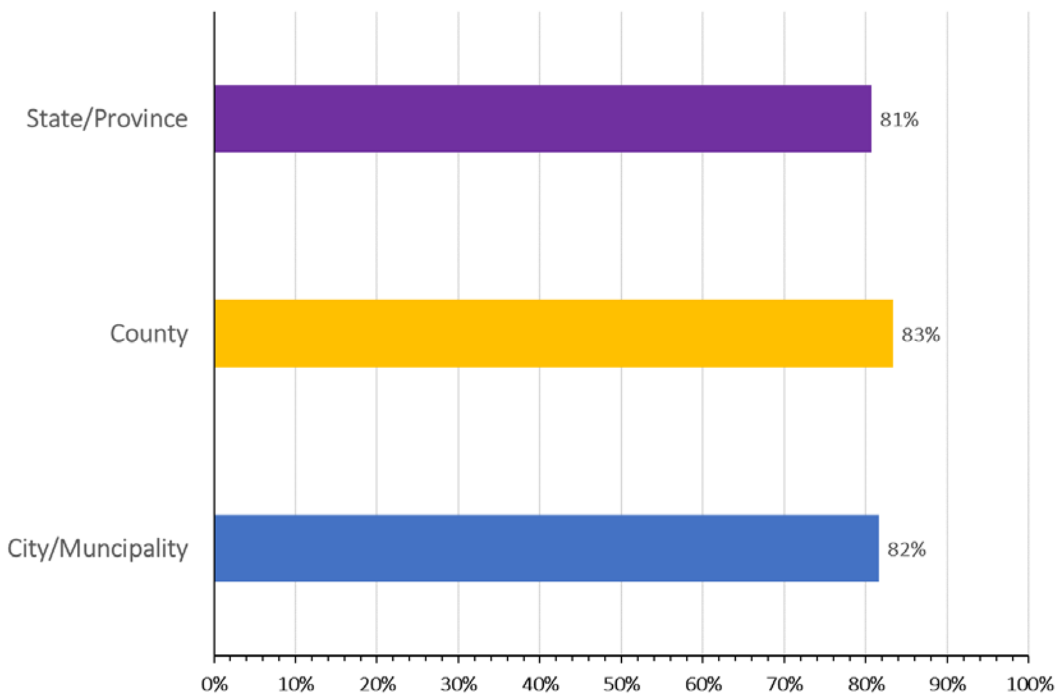


Figure 32. Chart. Agencies with Central System

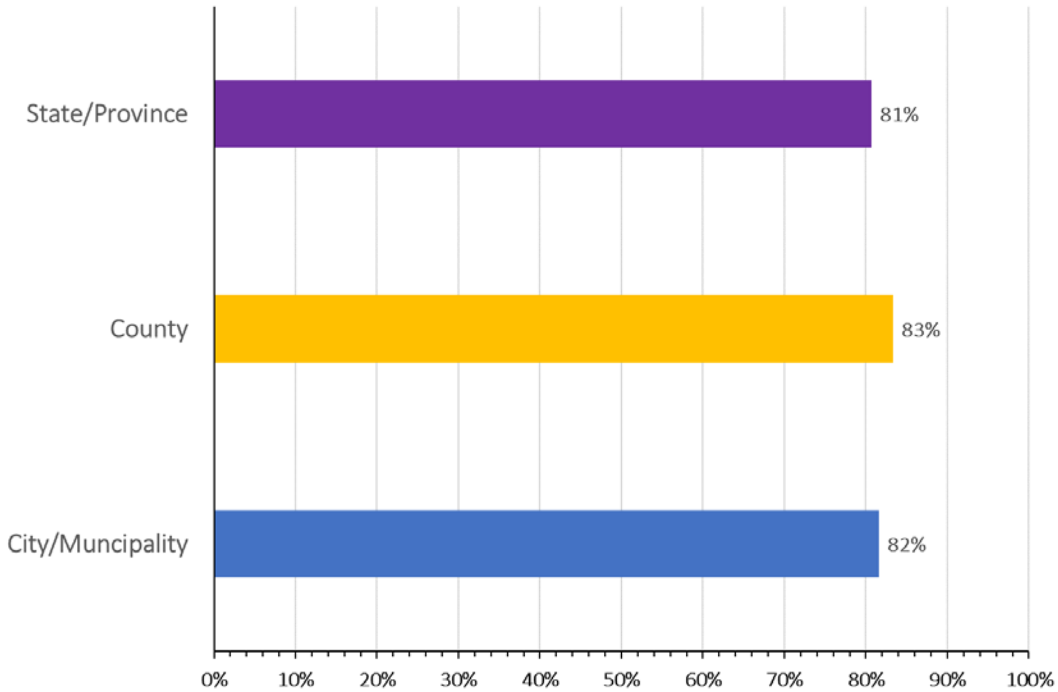


Figure 33. Chart. Agencies with Signal Timing Documentation

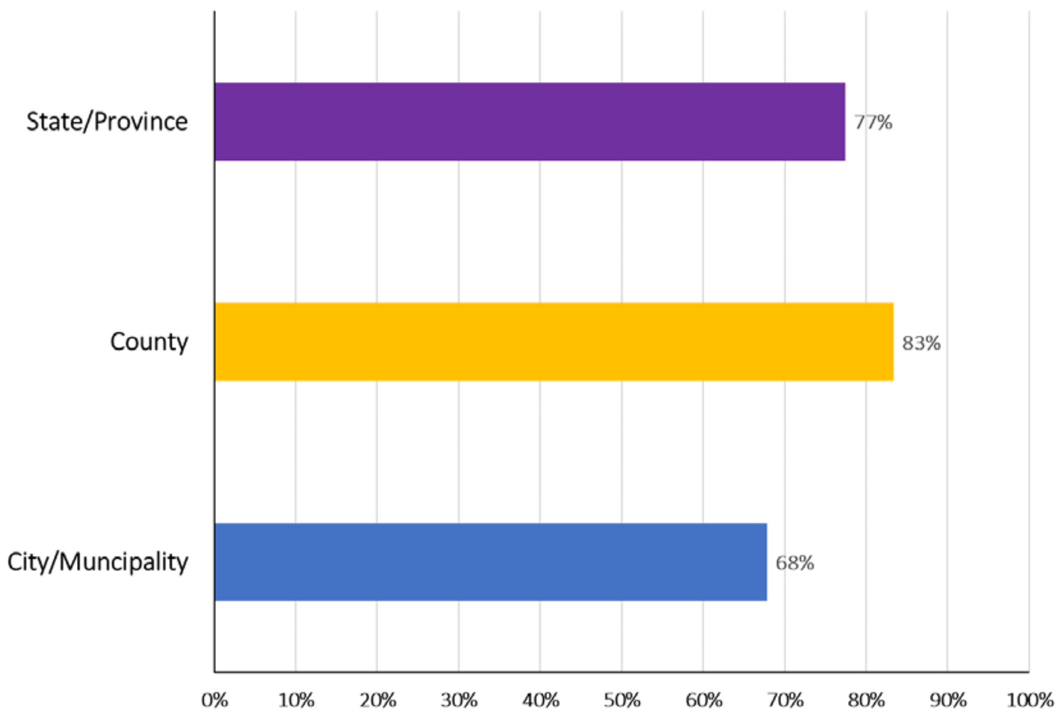


Figure 34. Chart. Agencies with Traffic Management Center

The chart in Figure 35 on the use of cybersecurity measures was developed from 180 affirmative responses from the combination of the *ITS Deployment Survey* and *Self Assessment*. Unfortunately, the result show that more than 50 percent of the agencies in each type of jurisdiction do not have a cybersecurity policy.

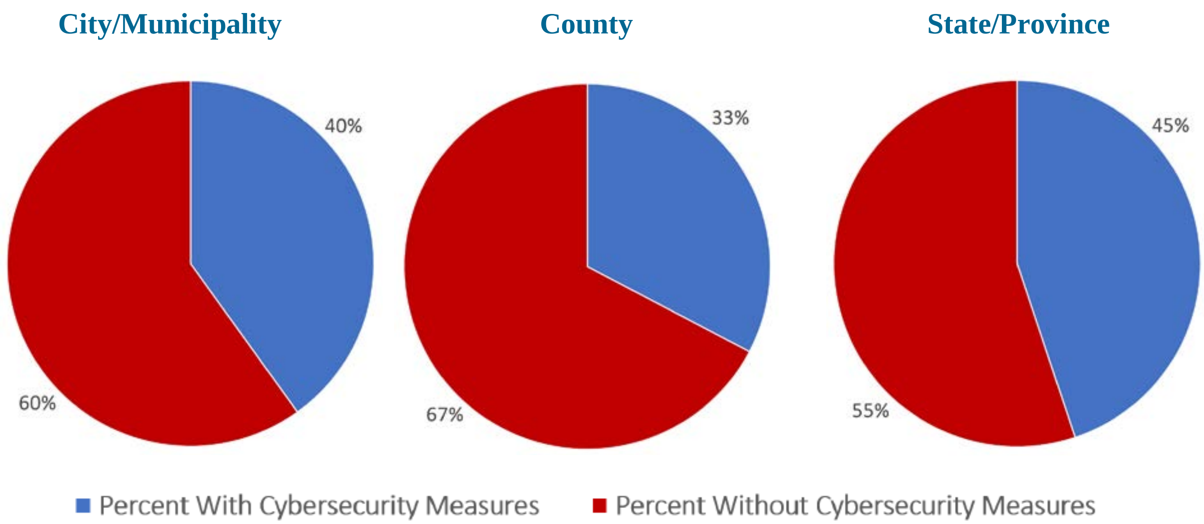


Figure 35. Chart. Percent of Agencies with Cybersecurity Measures by Agency Type

Looking forward to the deployment of next generation transportation technology, the *ITS Deployment Survey* asked agencies whether they have plans to deploy connected vehicle applications. The results for 274 responses are shown in Figure 36. Examining the agencies in more detail than the 34 percent that

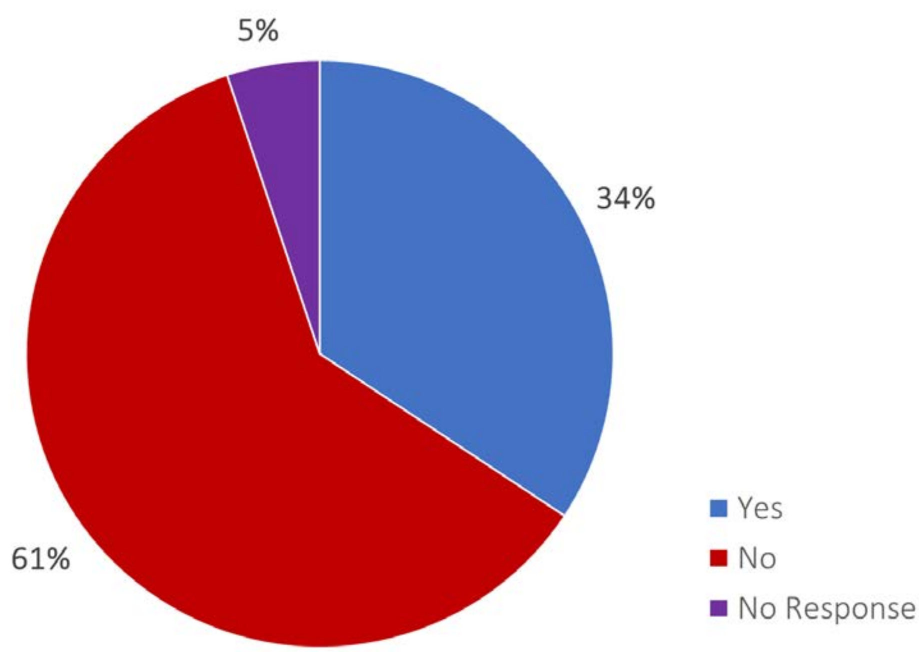


Figure 36. Chart. Percent of Agencies with Plans to Deploy Connected Vehicle Applications

responded affirmatively reveals that very few of the smallest agencies have plans to move forward. However as signal system size increases, 33 percent of agencies managing between 50 and 450 signals and more than 55 percent of agencies with more than 450 signals have plans to move forward in deploying at least on connected vehicle application.

For those agencies responding affirmatively, an additional question requesting information on the type of applications planned for deployment was asked. As shown in Figure 37, the five most commonly pursued applications are the following:

- Intelligent Traffic Signals Systems (68 percent)
- Advanced Traveler Information Systems (53 percent)
- Incident and Emergency Management (48 percent)
- Pedestrian / Bicycle Applications (43 percent)
- Road Weather (35 percent)

These five applications represent areas of practice where there has been significant research, deployment, and lead agency implementation that is now moving to the second and third round of deployment at agencies of varying sizes.

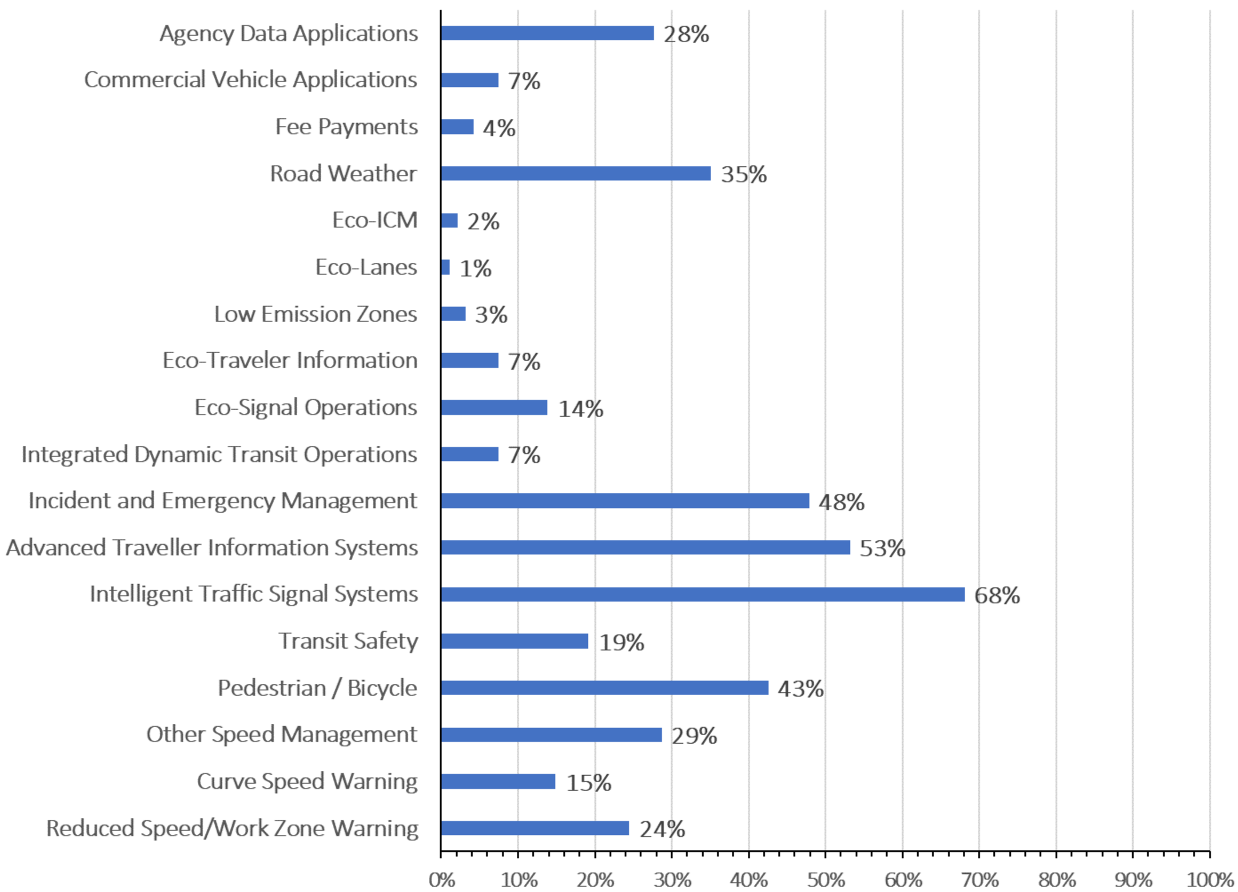


Figure 37. Chart. Type of Connected Vehicle Applications Planned

Maintenance

Maintenance describes those activities used to identify, respond, prevent, and document recurring work to preserve the traffic signal system on an ongoing basis. A very basic level of maintenance is an absolute requirement as non-functional traffic signals are highly visible and are unsafe to the traveling public. The maintenance program should inform planning, design, and operations decisions to align these program areas with maintenance resources and capabilities. High quality and reliable operations cannot be sustained without field infrastructure reliability. Figure 38, Figure 39, and Figure 40 present *Self Assessment* responses for the identification of maintenance issues, performance of preventive maintenance, and use maintenance records.

There are several different ways to identify traffic signal maintenance issues. This can be the result of automated monitoring of the traffic signal for faults in the controller and associated equipment reported though central system software or other notification system. Preventive maintenance is a regularly scheduled assessment of the equipment and operating conditions in the context of conformance to technology operational requirements and service life. Field observations and public service requests are two forms of response maintenance to reports of system or equipment malfunctions that may occur on an ad hoc, non-recurring basis.

The results show in Figure 38 that more than 85 percent of State agencies use preventive maintenance and field observations while 55 to 65 percent of city and county agencies do so. More State agencies use automated monitoring (64 percent) than county (46 percent) or city agencies (43 percent) which is reflective of the size and complexity of the responding agencies traffic signal systems. More than 50 percent of agencies use public service requests for response maintenance. Additionally, responses showed agencies with five or fewer staff and less than 50 signals have few agencies that use automated monitoring and rely on other methods.

The objective of preventive maintenance is avoid equipment failure before it occurs. The goal is to preserve equipment reliability by addressing old or worn components prior to failure. This approach emphasizes a state of good repair such that all equipment is operating and maintained within design parameters. Beyond the expected outcomes of extending equipment life cycle, addressing issues prior to malfunction, reducing severity of failures and better allocation of resources, an important aspect is risk management. An agency can be exposed to tort liability claims for negligence should it fail to proactively maintain its traffic signal system. Thus, preventive maintenance is widely used traffic signal system management practice suggesting that has a high value and benefits those organizations that employ the practice. In addition, the practice strongly supports the mitigation of agency risk and legal exposure.

Only a small portion of agency reported that the do not perform preventive maintenance as shown in Figure 39, less than 17 percent, although an additional 13 to 20 percent indicated they rarely do so. More than 74 percent of agencies at the state, county and city level indicated that they routinely perform preventive maintenance. Additionally, agencies do perform project-based preventive maintenance, in most cases this was associated with agencies that were also using a routine approach that extended to traffic signal projects.

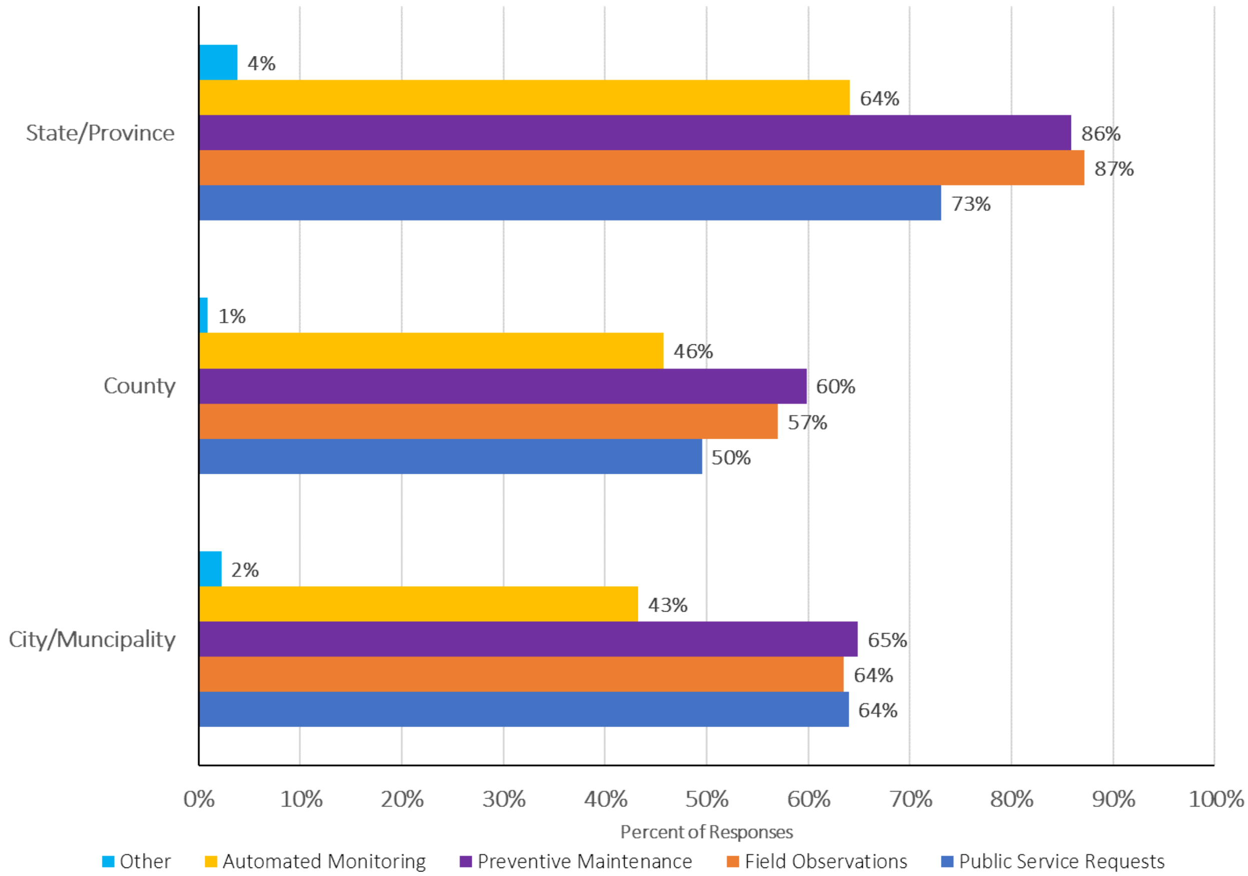


Figure 38. Chart. Identification of Maintenance Issues[7]

Figure 40 examines the type of maintenance records agencies use. Proper documentation accounting for the authorization, timeliness and work performed at a signalized intersection is an important aspect of risk management and protection from tort liability.

Over 75 percent of agencies of all sizes report some sort for asset management system. A majority of agencies use a work order system to respond to and document maintenance requests. Also, a majority of agencies continue to retain paper records in the controller cabinet at signalized intersections.

Additionally, in the *Self Assessment* agencies with larger staff sizes, more than 11 people, use paper records at the intersection, work orders and asset management at a significantly high percentage than less staffed agencies.

[7] Includes information from both the *Self Assessment* and *ITS Deployment Survey*.

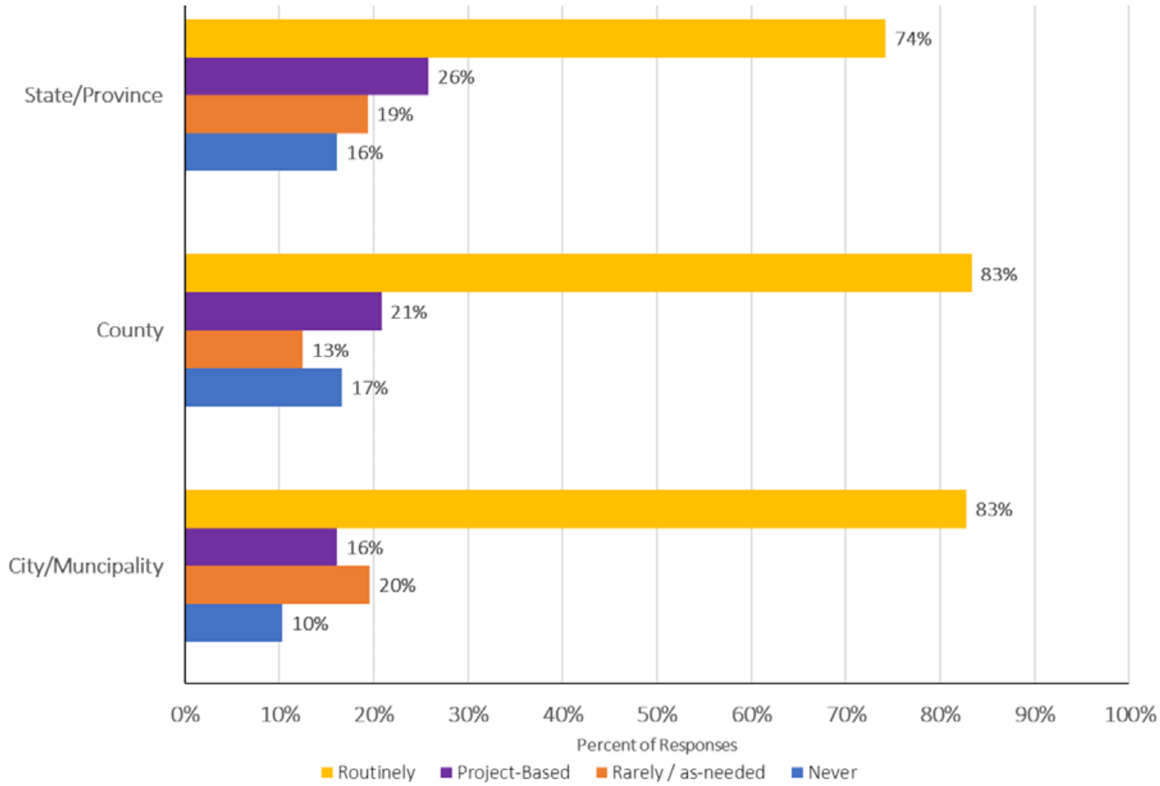


Figure 39. Chart. Performance of Preventative Maintenance Activities

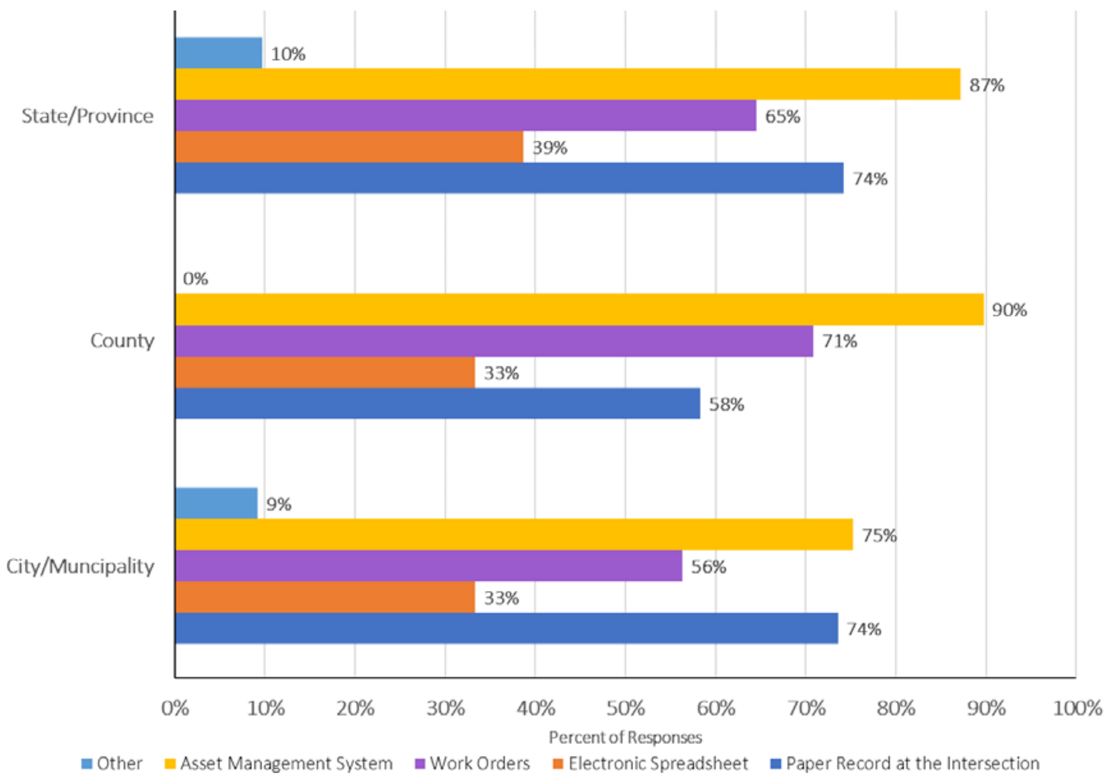


Figure 40. Chart. Records for Maintenance Activities[8]

[8] The Asset Management System responses include data from the *ITS Deployment Survey*.

Operations

Operations are activities related to the development, installation, and management of timing plans for traffic signals and the supporting applications for non-motorized users and special types of intersection control. This encompasses traffic signal phase sequence, coordination, detector operation, displays, timing parameters, and other related operational characteristics of traffic signal controllers. The effectiveness of traffic signal operations is considered through the methods used to identify operational issues in a similar manner to maintenance activities as well as the use of various traffic signal timing software tools. Review and updates to the intersection-specific timing, operational, and coordination aspects of signalized intersections based on stated objectives is extremely important, especially where changes in traffic volumes and/or adjacent land uses occur.

As the model for movement on streets has changed from a vehicle-centric perspective to an all-users perspective, the addition of user specific functionality has expanding the portfolio of applications at signalized intersections to address different user groups, such as bicycles, pedestrian, transit, and emergency vehicles as well as advanced approaches to signal timing to address specific needs. The overarching goal of these activities is to create safety and efficient operation of traffic signals for all users.

The results show in Figure 41 that in excess of 95 percent of all agencies use public service requests and field observations to identify operational issues at signalized intersections. Additionally, 75 percent of responding agencies use preventive maintenance to identify operational issues. Only 41 percent of agencies use automated monitoring, a similar value to agencies' use of this approach for identifying maintenance issues. It is notable that the percentage of agencies using public service requests to receive issues related to operations is significantly higher than for maintenance activities.

As shown in Figure 41, preventative maintenance inspections, complaints and field observations are the primary approach employed by agencies responding to the survey to identify operational issues. The results suggest that the majority of operational issues are identified reactively and could exist days, weeks, or moths before they are identified and corrected. Safety improvements, and reductions in unnecessary delays and congestion could be realized with automation that seeks to proactively identify operational issues. Operational issues include things like, inadequate green time for a phase, phase sequence issues or timing that is not appropriate for traffic conditions.

Agencies have a wide variety of tools available to support the timing of traffic signals. Figure 42 presents information from the *Self Assessment* on a number of approaches. Although 80 percent of agencies use signal timing optimization software, 59 percent use simulation software and a smaller number (28 percent) use automated traffic signal performance measures, most (93 percent) continue to use field observations as an important tool for development of traffic signal timing.

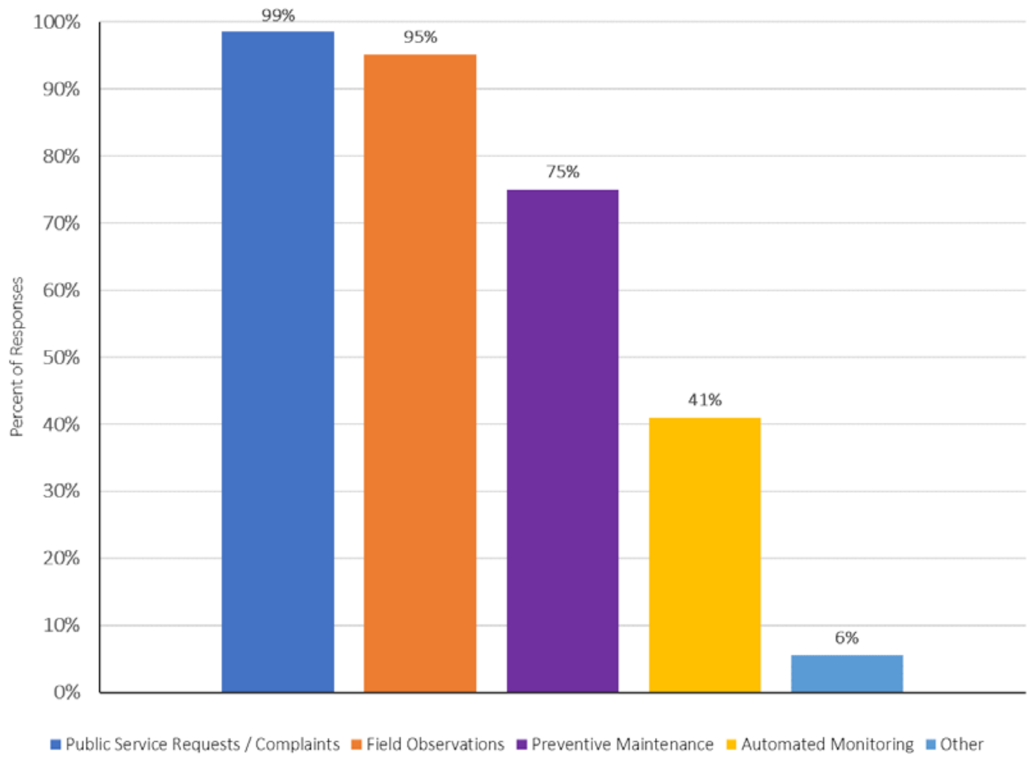


Figure 41. Chart. Identification of Operations Issues

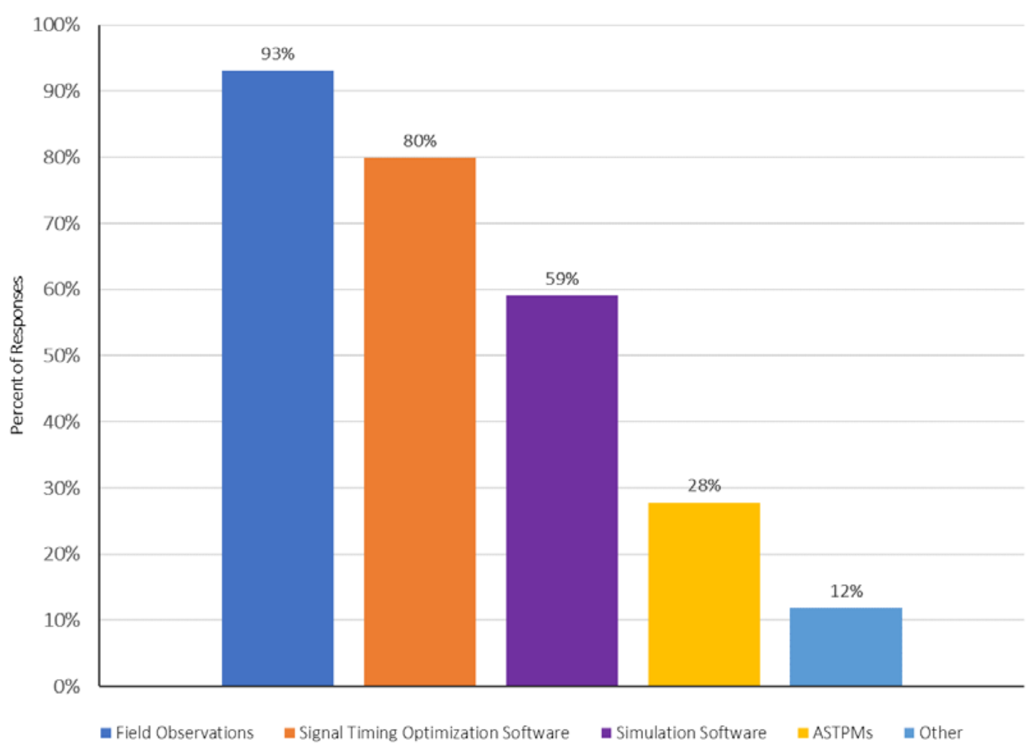


Figure 42. Chart. Use of Signal Timing Tools

Bicycle detection and bicycle signals are relatively new traffic signal applications. The *Self Assessment* responses show in Figure 43 that more than 32 percent of agencies have traffic signal detection that can detect bicycles. Between 13 and 16 percent of agencies depending on the type of jurisdiction report having bicycle signals in their system. The low value for this statistic is more likely related to the number of dedicated bicycle lanes on signalized intersection approaches than for other reasons.

Figure 44 presents results related to pedestrian applications. The Americans with Disabilities Act (ADA) requires intersections to be accessible. This includes both physical infrastructure such as ramps as well as pedestrian signals (if provided) that are accessible. The results show that more than 71 percent of the response have ADA accessible traffic signals.

Additionally, pedestrian indications are used by 70 percent of city agencies, though less so at County and State agencies. This would be primarily be due to the more rural nature of some of these jurisdictions. More than 81 percent of all agencies and 90 percent of responding cities indicated they use actuated pedestrian signals.

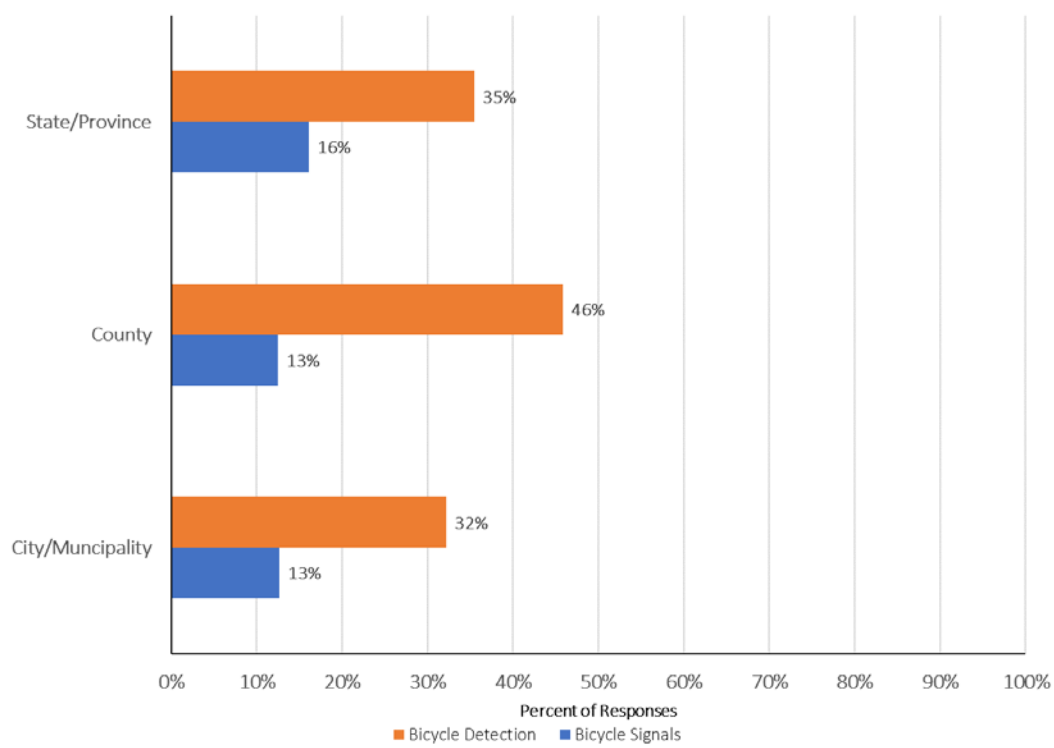


Figure 43. Chart. Bicycle Applications Used at Traffic Signals

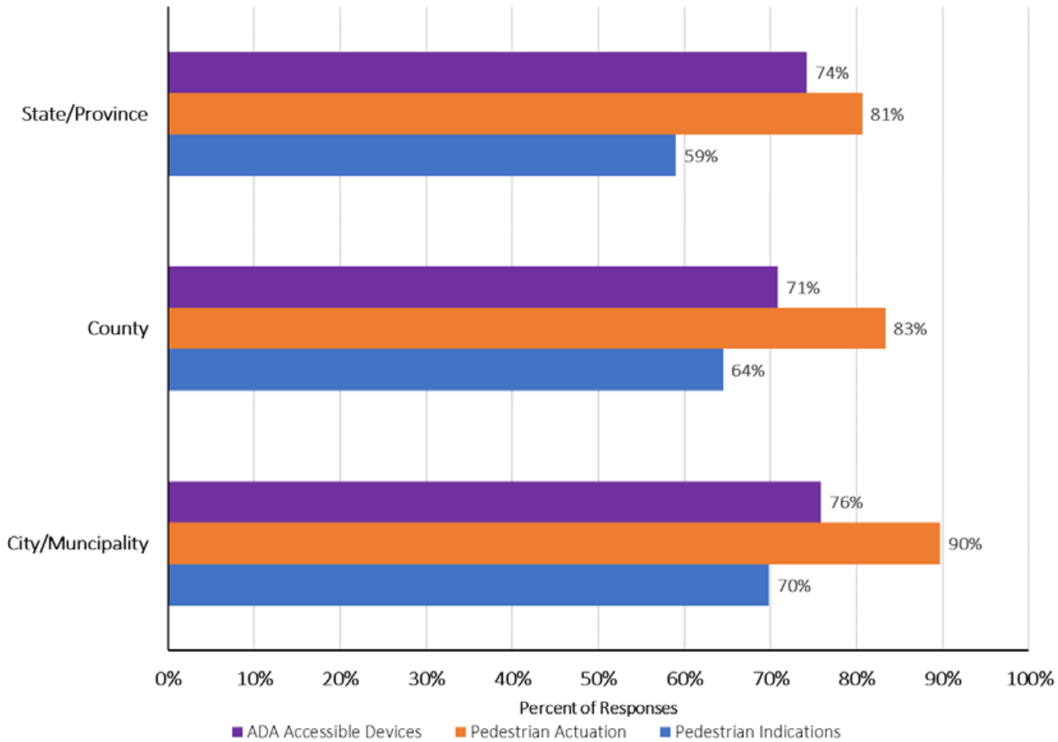


Figure 44. Chart. Pedestrian Applications Used at Traffic Signals[9]

Specific control, indications, plans, preemption, or special functions used by agencies at traffic signals are shown in Figure 45. The results show that preemption at signalized intersection is used by 82 percent of the agencies for emergency vehicles, 25 percent for transit vehicles, and 57 percent for rail crossings. The lower percentages for transit and rail crossings is primarily an indication of the lack of service in the jurisdiction. Flashing yellow arrows are used by 60 percent of the agencies and 44 percent use signal timing plans specifically created for special events. Less used by responding agencies traffic responsive control (18 percent), adaptive control (18 percent), ramp metering (6 percent), or red clearance extension (12 percent). Generally, percentage of use is related to the jurisdictional control or the duration of technology availability. Flashing yellow arrows appear to be an exception as the appear to have gained good acceptance by agencies.

Management

Management encompasses the methods and practices that an organization uses to carry out the strategies to achieve various goals and objectives. The use of traffic signal management plans to document policy and guidance have been shown to align, design, operations, management and maintenance activities to provide a high standard of service within their constrained fiscal environment. Traffic signal management plans provide a high -level method to document and connect the goals, objectives, strategies and performance measures that agencies uses to achieve the most important

[9] The Pedestrian Indication responses include data from the *ITS Deployment Survey*.

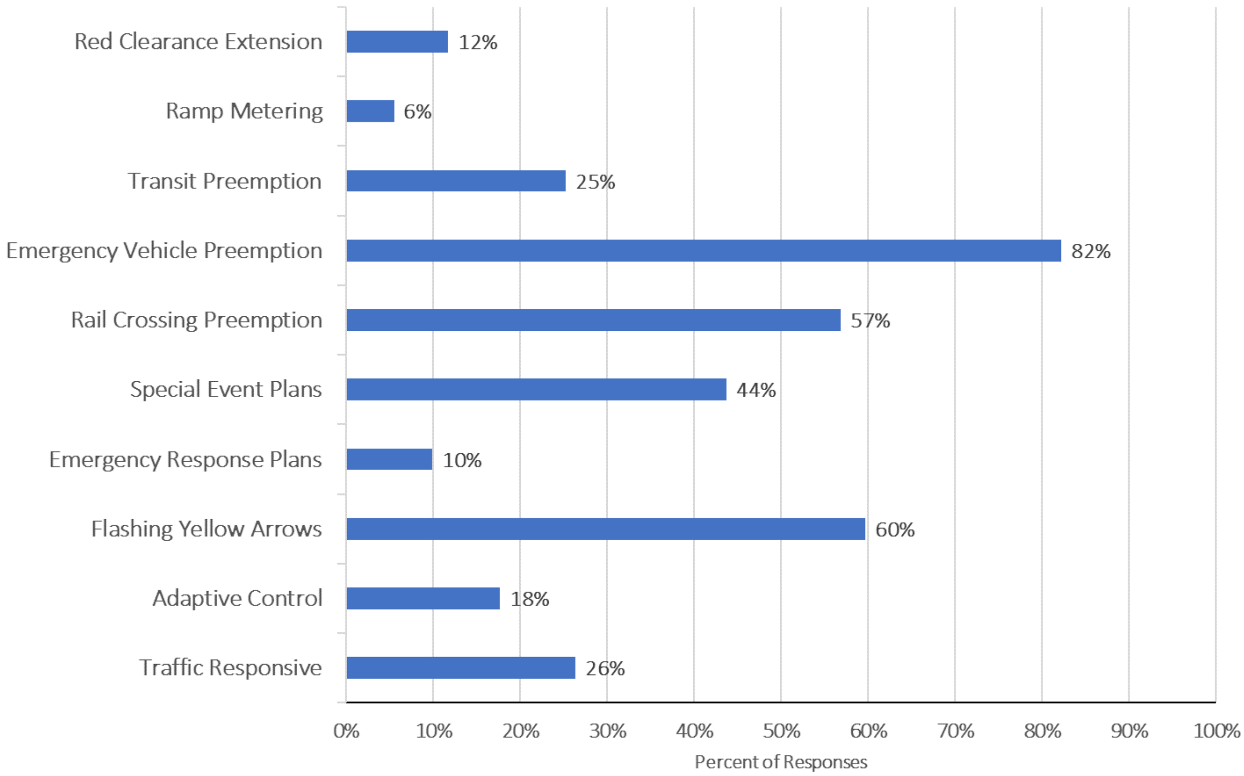


Figure 45. Chart. Specific Control, Indications, Plans, Preemption, or Special Functions Used at Traffic Signals[10]

outcomes given a limited set of resources. These documents strategically connect agency activities related to traffic signal design, operations, maintenance, and management with the goals and objectives.

Agencies were asked in the *Self Assessment* whether they had a document or documents that guide their traffic signal program. Figure 46a shows that 51 percent of the agencies reported have these document(s). Figure 46b breaks down this information further, by examining whether a topic area is included and whether associated goals and objectives are included as well. Of those agencies with a guidance document, 71 percent included design, 47 percent included operations and 38 percent included operations. Much lower percentages of agencies included statements related to goals and objectives for these content elements. Interestingly in the performance measurement section that follows, the significant majority of agencies reported using measures in operations and maintenance.

[10] The Adaptive Control, Transit Preemption, Emergency Vehicle Preemption, Rail Crossing Preemption, responses include data from the *ITS Deployment Survey*.

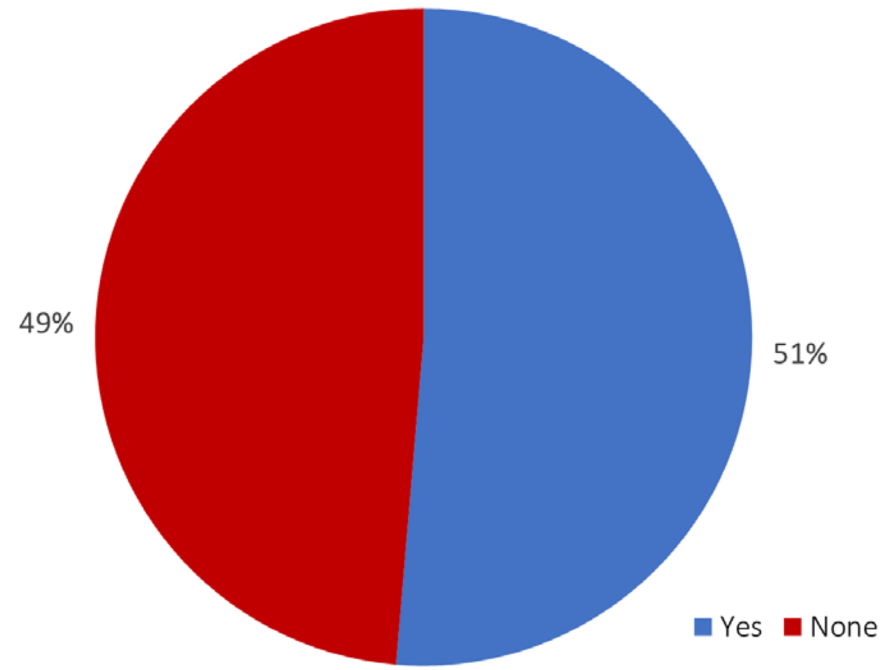


Figure 46a. Chart. Policy and Guidance Documentation Use by Agencies

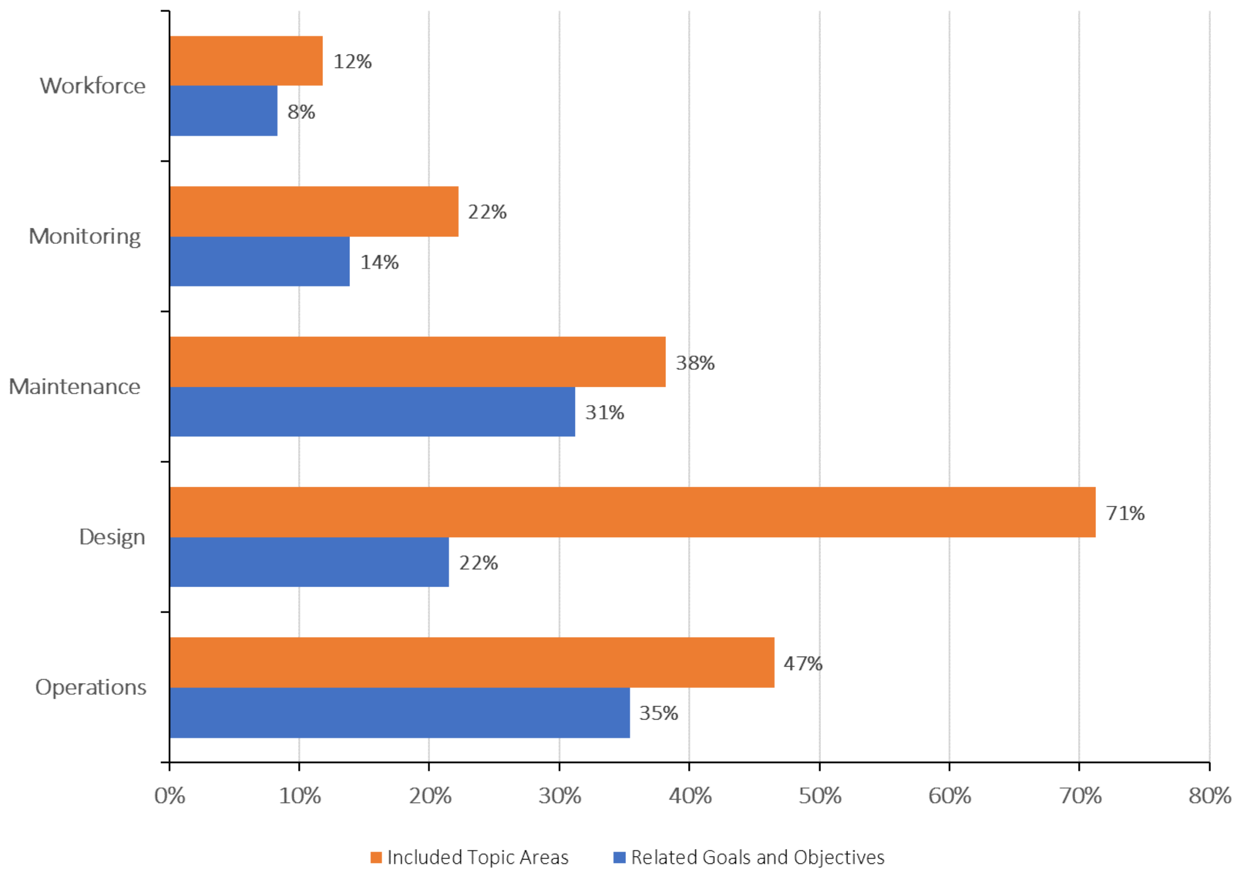


Figure 46b. Chart. Content Elements of Policy and Guidance Documentation

Systems engineering is an approach to project delivery that encourages up-front planning and definition of a system prior to the identification, selection and implementation of a technology solution.[11] It fits within the overall systems management approach of traffic signal management plans. The process includes four major elements, each with feedback loops. A systems engineering process begins by documenting stakeholder needs and expectations, and the way the system is intended to operate in a Concept of Operations. The next element of system requirements defines what the system is to do. This is followed by elements that develop a plan to verify that the requirements are met, concluding with validation of those requirement with the verification plan. When applied to traffic signal systems the implementation of this process leads to improved system quality.

The chart in Figure 47 on the use of system engineering was developed from 144 responses from the combination of the *Self Assessment*. The results show that 28 percent of city agencies, 13 percent of county agencies, 17 percent of state agencies use a systems engineering approach in the delivery of their traffic signal program.

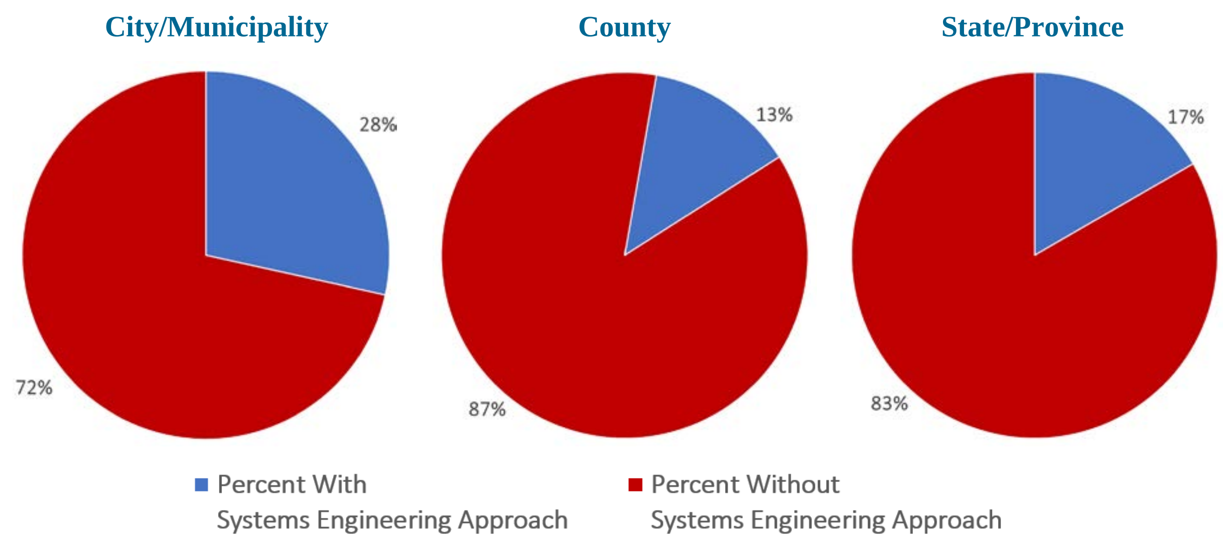


Figure 47. Chart. Use of Systems Engineering Approach by Agency Type

Performance Measurement

Performance measurement assesses the effectiveness of the range of strategies and tactics across all areas of a traffic signal program. Effective performance management requires the use of both outcome and output measures that are directly linked to organizational objectives. The results shown in Figure 48 indicate that 98 percent of agencies have performance measures they use for maintenance activities. For operations 83 percent of agencies report using performance measures in the agency traffic signal program.

[11]In addition to being a noteworthy practice for the delivery of quality project, Federal requirements described in 23 CFR 940 mandate that systems engineering analysis be performed for all ITS systems deployed using Federal funds.

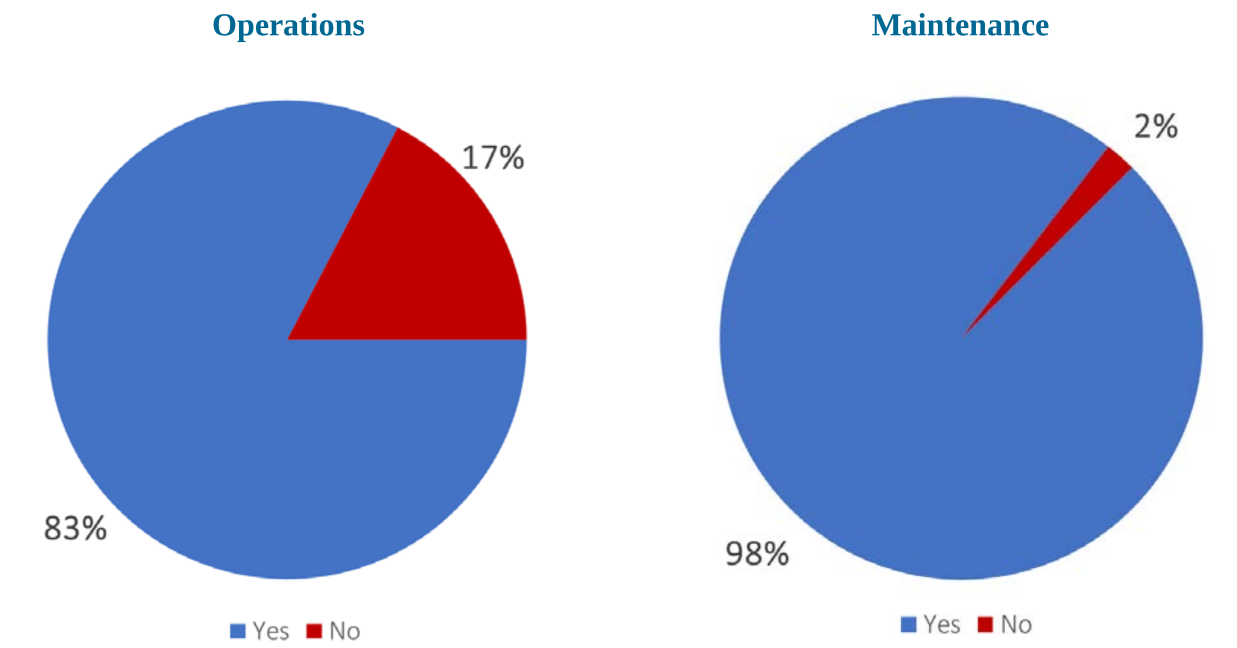


Figure 48. Chart. Agency Use of Performance Measures[12]

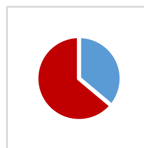
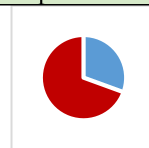
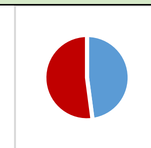
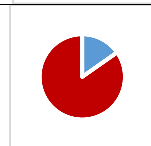
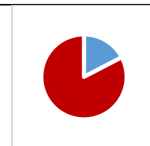
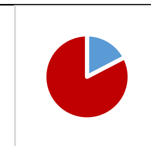
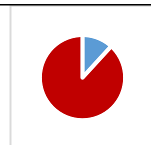
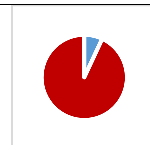
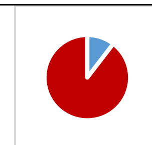
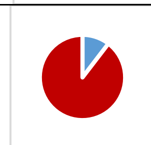
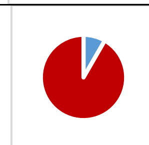
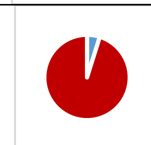
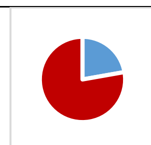
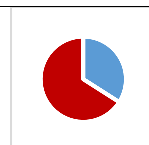
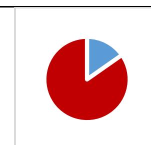
Organization and Staffing

This element of benchmarking examines the workforce capability of core competencies to carry out the elements of the traffic signal program, including recruitment, training, and staff development. Questions in this section were broken out by design, operations and maintenance activities allowing some broad conclusions to be drawn.

Entering knowledge for staff joining an agency traffic signal program results are show in Table 6. This is typically information that is contained in the position description for particular jobs. Nearly 50 percent of maintenance staff have basic general knowledge in technical and engineering topics with 36 percent in design and 31 percent in operations. Most responses indicate less than 17 percent of agencies require knowledge of technical and engineering topics at the specific, specific advanced, or subject matter expert levels. Innovative technology implementation is valued by 34 percent of the responding agencies in operations.

[12] The responses include data from the *ITS Deployment Survey*.

Table 6. Entering Knowledge for Staff Joining Traffic Signal Program

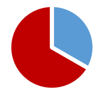
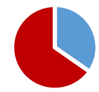
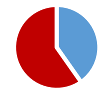
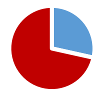
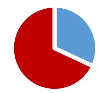
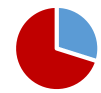
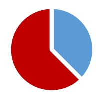
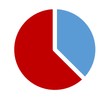
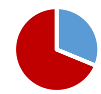
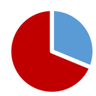
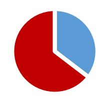
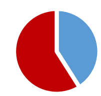
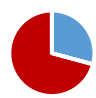
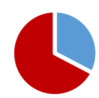
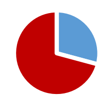
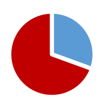
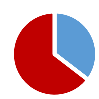
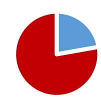
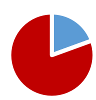
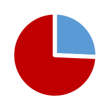
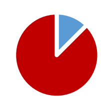
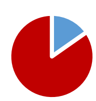
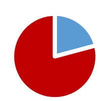
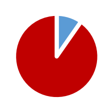
	Design	Operations	Maintenance
Basic knowledge "generally" in engineering and technical topics			
Specific knowledge of traffic signals technical and engineering topics			
Specific advanced knowledge of traffic signals technical and engineering topics			
Specific expert knowledge of traffic signals technical and engineering topics			
Capability to implement innovative traffic signal technologies that have not been deployed before			

■ Yes ■ No

Professional development and training is necessary for an organizations staff to stay up to date with current technology and engineering practices as well as meeting the requirements of engineering licensure and other technical and engineering certifications. Table 7 shows that agencies support a wide range of these activities, but the results show that no more than 40 percent of the agencies support any specific type of professional develop across the three program areas. The support declines based on relative cost, value, or staff time. Support for professional development for operations staff is generally high for all types of professional development.

The position descriptions for various engineering and technician positions typically includes licensure and certification requirements. Table 8 shows that design (67 percent) and operations (53 percent) staff are reported to have professional engineering license in their position descriptions. Nearly half of the agencies reported IMSA Level I and IMSA Level II traffic signal technician certifications for maintenance staff.

Table 7. Agency Support for Professional Development

	Design	Operations	Maintenance
In-house Training			
Self-Study			
Webinars			
Instructor-led Training			
Local Meetings			
Regional Meetings			
Technical Committees			
National / International Meetings			

■ Yes ■ No

Table 8. Agency Position Description Certification Requirements

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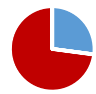
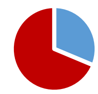
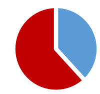
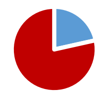
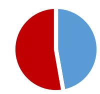
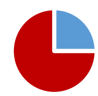
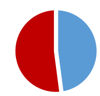
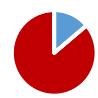
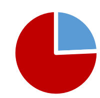
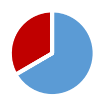
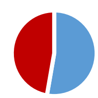
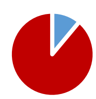
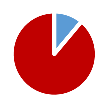
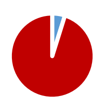
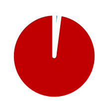
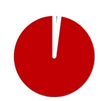
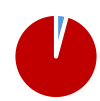
None			
IMSA Level I			
IMSA Level II			
IMSA Level III			
Professional Engineer			
Professional Transportation Operations Engineer			
Project Management Professional			
Other			

■ Yes ■ No

Collaboration

Collaboration is driven by the desire to improve both the breadth coordinated performance internally to an organization and with external partners for both transactional day-to-day events as well as for programmatic and relational activities. Collaboration occurring a between different levels of organizations adds to its credibility and buy-in from participants. This is a key element of a goals and objectives driven program that the context and associated goals and objectives from other partners are evaluated as part of program delivery.

The results presented in Figure 49 show that 92 percent of agencies traffic signal program staff collaborate together, 59 percent of which is on a routine basis and 42 percent on a project basis. The results presented in Figure 50 show that 86 percent of agencies traffic signal program staff collaborate with other internal stakeholders such as planning, construction, public safety, or information technology, etc., 51 percent of which is on a project basis and 38 percent on a routinely.

The results presented in Figure 51 show that 74 percent of agencies traffic signal program staff collaborate with external stakeholders such as the public, media, private entities, etc., 49 percent of which is on a project basis and 24 percent on a routinely or rarely/as needed.

The results presented in Figure 52 show that 57 percent of agencies traffic signal program staff collaborate regional activities with other agencies, 39 percent of which is on a project basis and 35 percent routinely. The results showed that 28 percent of agencies reported that they never coordinate regionally.

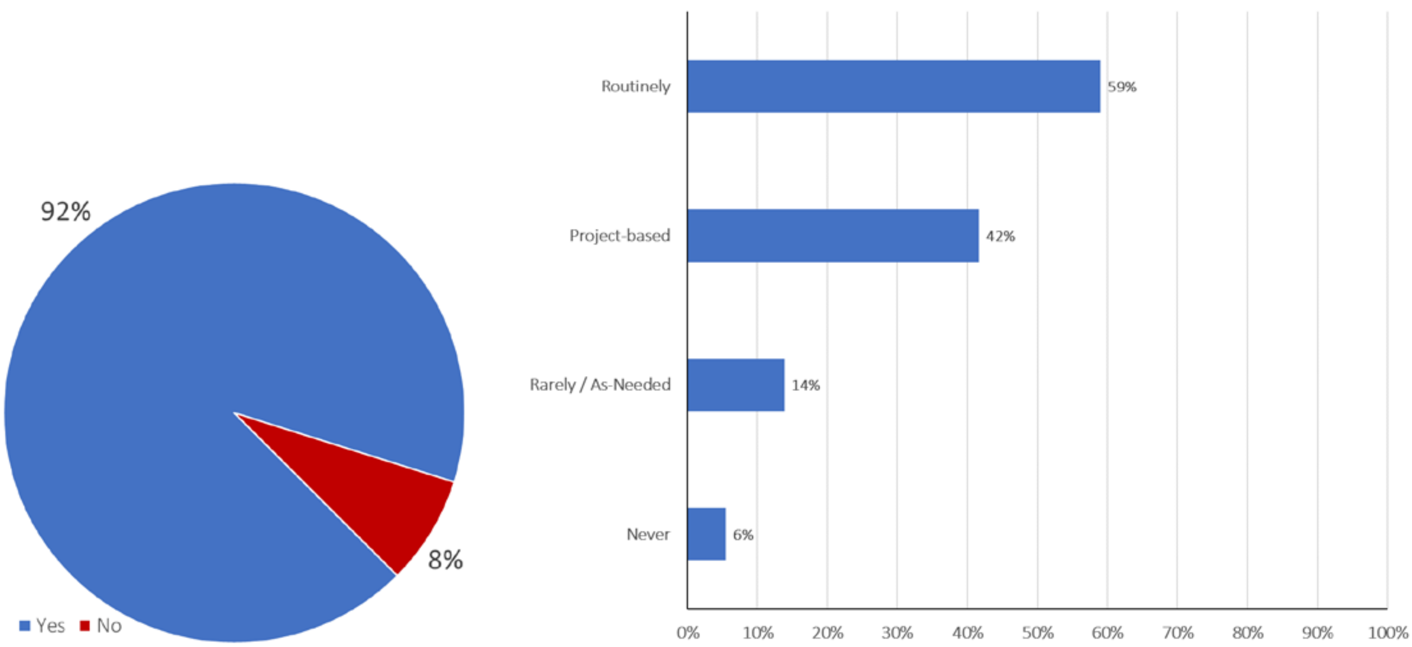


Figure 49. Chart. Traffic Signal Program Staff Collaboration

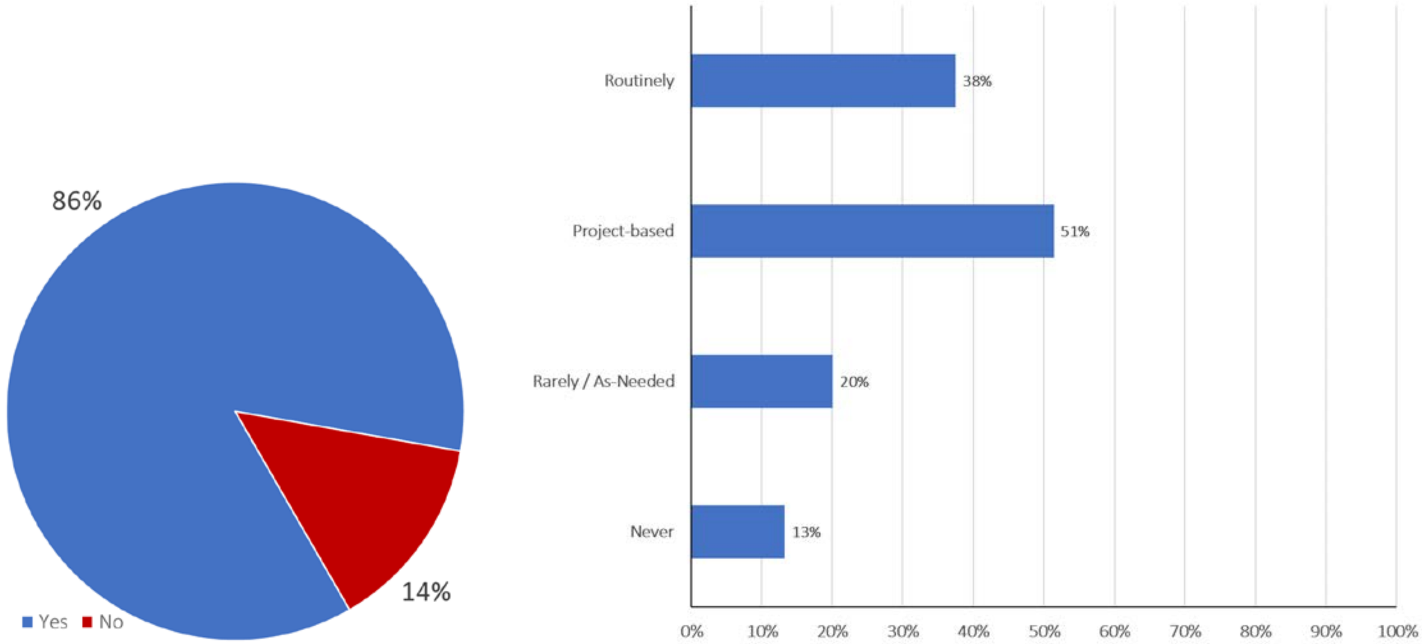


Figure 50. Chart. Internal Stakeholder Collaboration

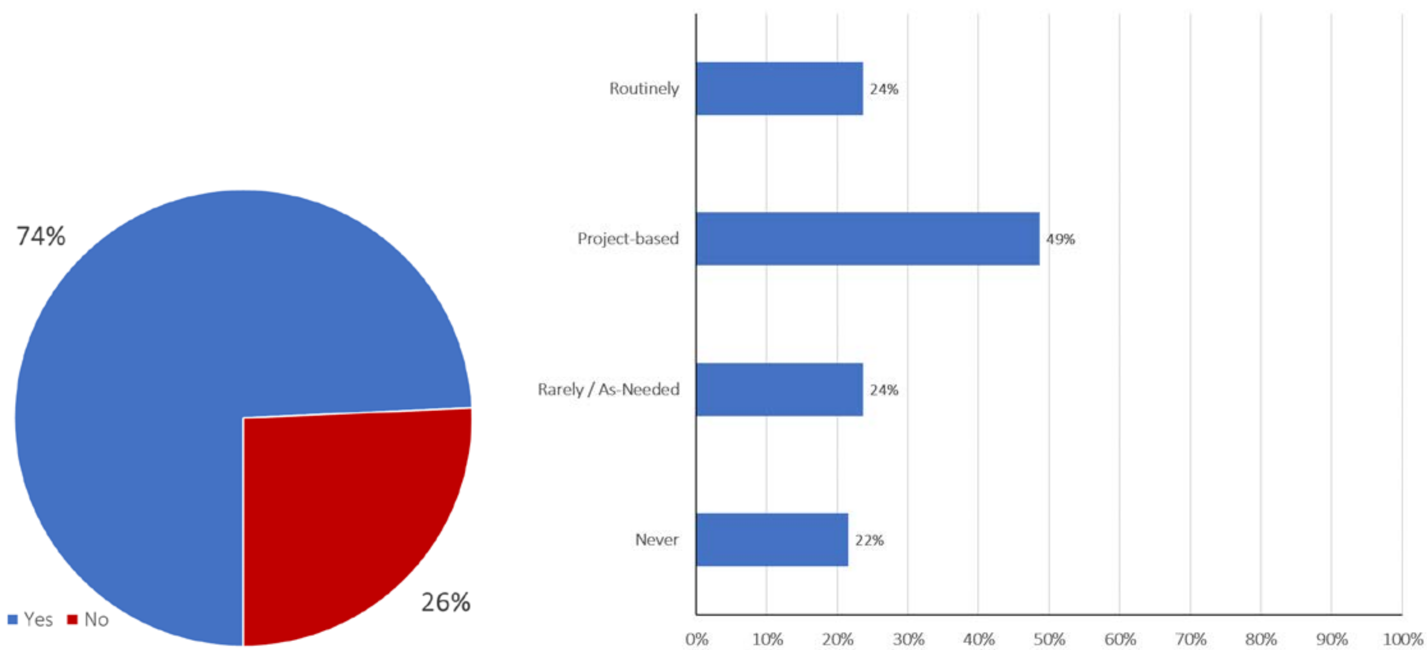


Figure 51. Chart. External Organization Collaboration

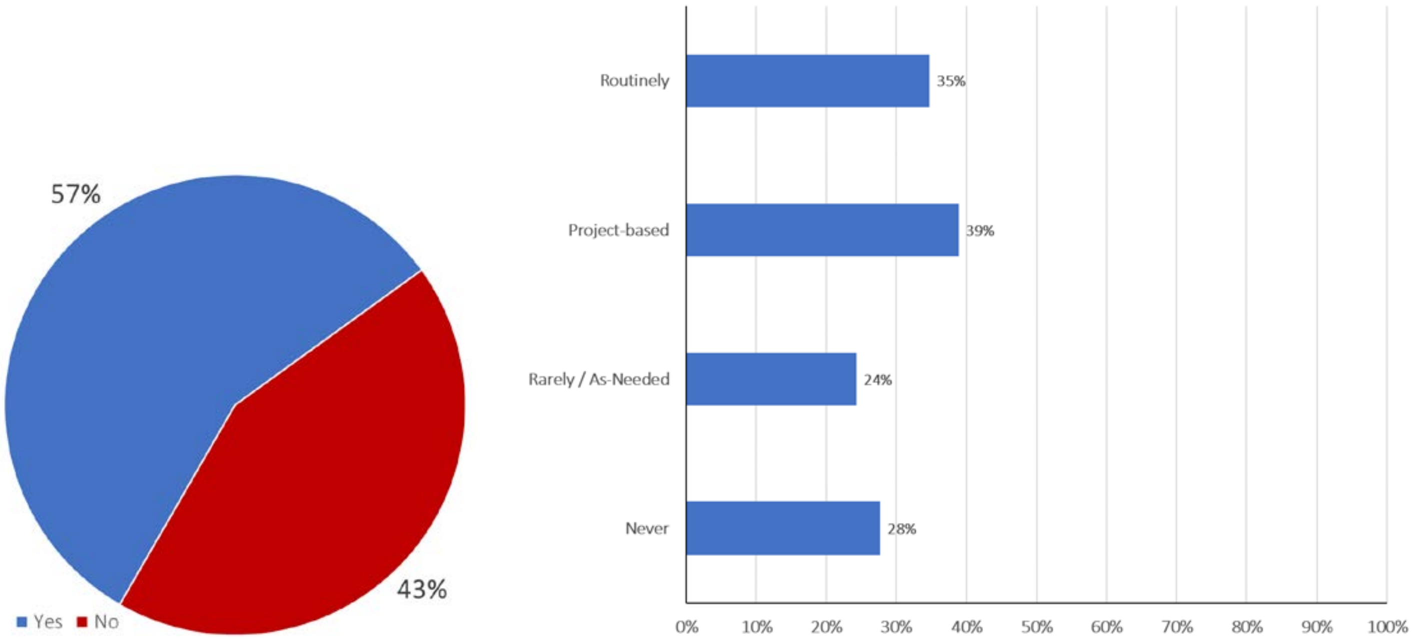


Figure 52. Chart. Regional Activities Collaboration

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4 Case Studies and Resources

Finding the Approach That Works for Your Organization

Agencies that manage traffic signal systems are diverse in term of level of government, geographic coverage, number of traffic signals, staffing, and fiscal resources. Each organization functions within a set of the jurisdictionally defined constraints, typically with the flexibility to define their program goals and objectives in context that decision-makers can understand.

Agencies that express and document their operations philosophy, goals, objectives, and performance measures in the form of a Traffic Signal Management Plan consistently demonstrate a greater capacity to implement and operate systems, sustain resources and a maintain a proficient work force. Significant benefits accrue to jurisdictions that identify that the approach the works best for their organization and follow through with developing and, more importantly, implementing their self-defined program goals and objectives with the overall framework of their community's direction. There are supporting resources for agencies to self-perform this type of effort or to engage a facilitator to assist the agency guiding the process.

This section provides sample agency case studies for reference as well as a summary of the resources that are available for transportation professionals. Additional resources are available through the Traffic Signal Benchmarking and State of the Practice website (www.tsbenchmarking.com).

Case Studies

The agency case studies show a snapshot of key attributes including staff size, signal system size, miles of roadway and program budget as well as their snapshot of *Self Assessment* rating across the five dimensions of capability and their subareas. The case studies conclude with a narrative description of the agency's different practices supporting the capability rating along with summary of implementation and benefits of developing their traffic signal program.

Clark County Washington (Vancouver, WA)

Traffic Signal Program Summary

11 Traffic signal program staff

135 Traffic signals managed

2,600 Miles of roadway

$3.5M Traffic signal operations and maintenance

Clark County, Washington manages the traffic signals in the unincorporated areas of the county of 475,000 population.

Organizational Self Assessment

	Level 1 Ad Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grade
Systems and Technology			√		B
Infrastructure			√		B
Business Processes					
Design			√		B
Operations			√		B
Maintenance			√		B
Management			√		B
Workforce			√		B
Management and Administration / Leadership					
Culture		√			C
Organization		√			C
Collaboration		√			C
Performance		√			C
Overall			√		B-

Source: *2018 Traffic Signal Benchmarking and Self Assessment.*

Capability and Maturity

Clark County, Washington's overarching Signal Timing, Evaluation, Verification, and Enhancement (STEVE) program collects data to further refine and improve signal timing and coordination on the county's busiest streets. The County has established the following objectives for their traffic signal program to:

- Time traffic signals for safe and efficient travel
- Manage existing roadway system
- Defer expensive capital projects

- Gather data to help make informed decisions
- Provide information to the public

These objectives were established to support the implementation of ASTPMs beginning in 2014 with a pilot project where the Southwest Washington Regional Transportation Council worked with the County, the City of Vancouver, and Washington State Department of Transportation . This is a collaborative outcome of work with Trafficware to develop an ATSPM module in the agency's traffic signal controllers that stores and supports the evaluation of high-resolution data, Bluetooth data, alarms, and event logs, and other signal timing events to develop performance measures that supports Clark County's the traffic signal program's objectives. The advanced system to log performance data for traffic signals and arterial corridors tracks numerous metrics, such as overall travel time and percentage of traffic arriving at the intersection with a green signal. Implementation of ASTPMs have been impetus for advancing the county's capabilities across the different capability dimensions beyond technology and infrastructure implementation.

Implementation and Outcomes

Clark County's implementation traffic signal program management has benefited from proactive partnership and collaboration and is guiding the focused implementation of the agency's work program. Clark County has upgraded all of its 106 traffic signals with upgraded ATSPM capable controllers. As a result, the timing of these signals are adjusted in real time functioning within a central traffic responsive operation based on data automatically collected from Bluetooth devices, additional video, and radar detection. Infrastructure upgrades include new conduit to the poles and cabinet along with new larger junction boxes as well as progressive replacement of older outdated electrical services to meet current code requirements.

In addition to traffic signal upgrades to support the new system, the county has also been implemented:

- LED vehicle and pedestrian signal indications
- Pedestrian push buttons to make intersections accessible
- Countdown pedestrian signals
- Battery back ups
- Flashing yellow arrows

The county's goal is to manage traffic signals as an integrated network using arterial operations strategies with an infrastructure life cycle approach, not simply a collection of individual intersections. With changes recently made to traffic signals, drivers are able to travel on Clark County's arterial roadways more reliably with less delay.

Additional Information

To learn more, visit https://www.clark.wa.gov/public-works/traffic-signals

Georgia Department of Transportation

Traffic Signal Program Summary

80 Arterial Engineers statewide	**6,383** traffic signals on the State Highway System	**17,926** miles of roadway	**$65.6M** annual traffic control program budget

Organizational Self Assessment

	Level 1 Ad Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grade
Systems and Technology				√	A
Infrastructure			√		B
Business Processes					
Design			√		B
Operations			√		B
Maintenance			√		B
Management			√		B
Workforce				√	A
Management and Administration / Leadership					
Culture		√			C
Organization		√			C
Collaboration			√		B
Performance			√		B
Overall				√	A-

Source: *2018 Traffic Signal Benchmarking and Self Assessment.*

Capability and Maturity

Georgia Department of Transportation (GDOT) shares responsibility with local agencies for the operation of 6,400 of the State's 9,500 signals. GDOT developed traffic signal programs to manage the traffic signals throughout the state of Georgia. These programs support different geographical areas of the state but are intended to address local and regional transportation needs in a consistent manner leveraging methods and techniques learned from each program. These programs are the Regional Traffic Operations Program (RTOP) and Regional Traffic Signal Operations (RTSO) program:

- Regional Traffic Signal Operations that focuses on arterial operations across the state, outside of metro Atlanta. GDOT manages a RTSO program focused on providing operational and maintenance support for traffic signals outside of the Metro Atlanta area defined in RTOP. It aims to apply a contextual approach to the active management of arterials through improved signal operations. RTSO is a newer program that continues to evolve with a goal of improving and expanding signal communications. This will allow for proactive operations and maintenance of all traffic signals in Georgia, regardless of their location or ownership. The RTSO program is comprised of three (3) regions. The regions are defined along GDOT District boundaries. Region 1 includes Districts 1 and 6; Region 2 includes Districts 3, 4, and a portion of District 7 (Cobb, Douglas, and Fulton Counties); and Region 3 includes Districts 2, 5 and a portion of District 7 (DeKalb, Rockdale, and Clayton Counties). The RTSO regions in GDOT currently have a separate consultant contract supporting each of the regions. These consultant contracts utilize Traffic Signal Operations Engineers (TSOE) to remotely provide traffic signal monitoring and needed adjustments to the traffic signal systems.

- GDOT manages RTOP in the Metro Atlanta area. With active management of over 1,900 signals, the RTOP utilizes many advanced features in traffic signal software to provide optimum operation of traffic signals. These signals are found on several "regionally significant corridors" throughout the Metro Atlanta area. Many of these signals have CCTV cameras located at each intersection that allows for remote monitoring, which reduces response time and allows for more wide-spread active management. RTOP originally focused on corridors of regional significance, meaning those corridors that carry high volumes of vehicles and which experience recurring congestion. A secondary focus was added to include corridors that were important to mobility throughout the region. As RTOP matured and expanded regionally, the program shifted from a corridor to a zone approach. This change was implemented to more efficiently manage their human resources and allow for better regional coordination.

GDOT partnered with the Utah Department of Transportation to leverage their experience deploying open source ATSPM software to better manage the operations and maintenance of signals. GDOT's ATSPM deployment follows the same basic architecture used in Utah and features a public-facing website (https://traffic.dot.ga.gov/ATSPM/) to make data and analysis readily available. With more than 98 percent of signals that GDOT owns or shares operational responsibilities are capable of high resolution data, with over 6,800 reporting back to GDOT's system. GDOT uses ATSPM as its primary tool to improve operations and manage maintenance

A challenge looking ahead is the depth of work force in succession planning as a number of the projects are led by agency champions with shared support from in-house technical staff and outside consultants.

Implementation and Benefits

GDOT used the deployment of ATSPMs as a focal point to advance the program management of their traffic signal program. GDOT utilized an in-house workforce to install, configure, and monitor the performance data provided by the ATSPM system and is extending those capabilities. To enable the new capabilities, GDOT upgraded CPUs in the existing 2070 controllers and invested in development of documentation to support installation and configuration of the open source software. Upgrading existing technology accelerated deployment and enabled the ATSPM-capable signals to retain the same 2070 architecture that is common to 99 percent of signal controllers in the State. Additional detection equipment was installed at specific intersections to enhance data collection capabilities.

GDOT's traffic signal program features:

- Integration of performance measure tools in signal timing manuals and specifications
- System performance evaluation based on probe and high-resolution data

- Pro-active and prioritized approach with signal timing at the State level and with local agencies
- Training and engineering support for local agencies across the State
- Public portal for historic operational data

Additional Information

To learn more, visit http://www.dot.ga.gov/DS/SafetyOperation/TrafficSignals and https://traffic.dot.ga.gov/ATSPM

Maricopa County Department of Transportation (Phoenix, AZ)

AZTech Regional Traffic Signal Program Summary

14
Arterial Engineers Agencywide

170
traffic signals on the State Highway System

5,216
miles of roadway on the State Highway System

$N/A
traffic signal maintenance and signal retiming

Organizational Self Assessment

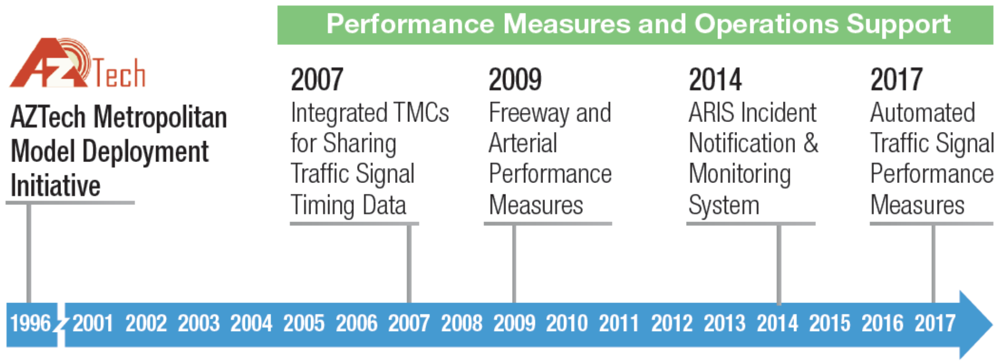
	Level 1 Ad Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grade
Systems and Technology		√			C
Infrastructure (N/A)					N/A
Business Processes					
Design		√			C
Operations		√			C
Maintenance		√			C
Management		√			C
Workforce		√			C
Management and Administration / Leadership					
Culture		√			C
Organization		√			C
Collaboration				√	A
Performance		√			C
Overall		√			C+

Source: *Automated Traffic Signal Performance Measures Case Studies.*

Capability and Maturity

Maricopa County Department of Transportation (MCDOT) jointly with Arizona Department of Transportation (ADOT)plays a leadership role in the 24-member consortium called the AZTech Regional Partnership in Arizona launched in 1996. Members of the partnership represent organizations in the Phoenix metropolitan area and work collaboratively under the shared mission of providing seamless transportation across jurisdictional boundaries.

Maricopa County's traffic signal management program is part of AZTech's long-term technology deployment initiative since the inception of AZTech. In 2016, as a next step in the evolution of AZTech, Maricopa County launched a regional ATSPM pilot program with 70 signalized intersections distributed across member jurisdictions, which today integrates 581 signals equipped with high-resolution controllers. The regional goal is to ultimately integrate 2,300 signals.



Maricopa County's deployments leverage the existing Maricopa Association of Governments (MAG) Regional Communication Network communication infrastructure and AZTech 's Regional Archived Data System (RADS) to minimizing implementation costs, integrate with regional traffic management centers, and maximizing the availability of the technology in the region. To support ATSPM deployment RADS will centrally implement virtual ATSPM servers for participating agencies.

AZTech has demonstrated success in collaboration, informed travelers, advancing traffic signal an ITS technology to support operations, and partner agencies organizing for operations.

Implementation and Benefits

AZTech is an operational partnership of regional transportation interests to improve coordination throughout the Phoenix area. The technical expertise through AZTech has enabled advancement of traffic signal and ITS deployment across the Phoenix region. Jurisdictions that are home to the AZTech systems are responsible for the collaborative traffic signal operations across jurisdictional boundaries. AZTech takes responsibility for the consolidation, analysis, and storage of data for its members systems.

AZTech has been spearheading initiatives to create an operations certification program that captures operations skill sets and capabilities, and this is helping to shape national guidance on operations staff capabilities. AZTech partners are piloting needed operational foundation to advance Integrated Corridor Management (ICM) across multiple agency infrastructure. AZTech identified the following benefits to operations focus areas:

- Well-informed traveling public
- Qualified, well-trained staff and a pipeline of new talent
- Leverage regional infrastructure and partnerships to support proactive system management
- Incident management is responsive and effective on freeways and arterials
- Performance measures tell the story supported by ATSPMs
- Upper management, the public and elected/appointed officials appreciate our value·
- Technology supports operations innovation

Additional Information

To learn more, visit http://www.aztech.org/

Utah Department of Transportation

Traffic Signal Program Summary

28
Traffic Signal Personnel

1,270
traffic signals on the State Highway System

>16,000
miles of roadway on the State Highway System

$5M
traffic signal maintenance and signal retiming

Organizational Self Assessment

	Level 1 Ad Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grade
Systems and Technology			√		B
Infrastructure			√		B
Business Processes					
Design			√		B
Operations		√			C
Maintenance		√			C
Management			√		B
Workforce			√		B
Management and Administration / Leadership					
Culture			√		B
Organization			√		B
Collaboration		√			C
Performance		√			C
Overall			√		B-

Source: *2018 Traffic Signal Benchmarking and Self Assessment.*

Capability and Maturity

The Utah Department of Transportation's (UDOT) guiding document is their Traffic Signal Management Plan[13] which sets their vision and guiding principles, establishes goals and links performance measures to objectives. Each of the Plan's four topic areas (maintenance, design, operations, and management and administration) provide descriptions of strategies, specific performance measures and an action plan to advance the agency's capability in that area. Concluding the Plan is a summary of collaborative agreements with other agency and the expectations for on-going review/update. As a result of the Traffic Signal

[13] Utah Department of Transportation Traffic Signal Management Plan, February 5, 2016, http://www.udot.utah.gov/main/uconowner.gf?n=29256708738824069 accessed May 20, 2019.

Management Plan UDOT has been able to move forward in multiple dimensions to CMM Level 3 and define actions to move advance other dimensions of capability.

Implementation and Benefits

As an example of the implementation of the actions plan, for the operations and maintenance dimensions UDOT employs an ATSPM system that operates independently of their central traffic signal system to monitor performance. UDOT's ATSPM software was developed in-house by UDOT's Department of Technology Services with high return on investment in mind. The resources invested in the program provide high-value benefits including the ability to assess and improve traffic flow, detect system malfunctions, and quantify multiple measures of performance. This reduces congestion and emissions, and improves safety and operation and maintenance efficiency. UDOT's ATSPM implementation is designed to be cost-effective and not reliant on costly proprietary applications or a centralized traffic management system. Resource investments are required to connect new signals and repair existing signal hardware, as well as monitor and manage the system.

ATSPM enables UDOT to proactively manage traffic signal timing and quickly identify maintenance issues that affect traffic flow. Today, UDOT's ATSPM contains a suite of data visualization reports that can be used to evaluate the quality of traffic progression along corridors and identify unused green time for allocation to other intersection movements. System reports of vehicle delay, volumes, and speeds can be used to evaluate the effectiveness of signal timing adjustments. ATSPM tools speed up decision making and help UDOT staff prioritize operation and maintenance efforts. UDOT's ATSPM also features a public-facing website (http://udottraffic.utah.gov/atspm/) that allows users to generate charts

UDOT is collecting ATSPM at 99 percent of its 1,270 traffic signals. Partner agencies have connected 90 percent of their 912 signals and report data through the same centralized operation. Utah's end goal is to have all signals statewide connected and contributing data to their existing ATSPM system. Since implementing its ATSPM program, UDOT has noted a significant drop in public complaints and requests for traffic signal retiming supporting the agency's mobility goals. The ATSPM system quickly identifies problems such as failed detectors and sends a simple email notification.

Additional Information

To learn more, visit https://www.udot.utah.gov/main/f?p=100:pg:0:::1:T,V:4810, and http://udottraffic.utah.gov/atspm

Resources

National Operations Center of Excellence

The National Operations Center of Excellence (NOCoE) serves as an important foundation for institutionalizing management and operations into the transportation industry. The NOCoE is an outgrowth of the National Transportation Operations Coalition and is partnership of AASHTO, ITE, and ITS America with support from FHWA. In addition, The NOCoE offers various technical services in support of the operations community, including the following:

- Ongoing assessment and synthesis of emerging best practice experience
- Training and capacity building programs
- Lead state and best practices peer exchange webinars
- Regional TSMO best practice peer exchanges
- National TSMO summits
- On-call assistance to transportation agencies and other organizations to identify best practice material and other resources to address specific technical and policy issues
- Ongoing support for selected SHRP2 products
- Initial assessment of the state of transportation operations research and development in the United States and a plan for integration into the NOCoE
- TSMO practice area forums where practitioners can exchange technical information and advice, including a private sector forum to engage private sector users on an ongoing basis

The Center has taken on the role as a clearinghouse for the following topics:

- Signal Phase and Timing (SPaT) Challenge
- TSMO workforce development
- Research in Operations database
- Emerging freeway operations concepts
- Operations-related resources for connected and autonomous vehicles

In addition, the Center offers a web portal, www.transportationops.org , which contains case studies, links to variety of operations-related resources, discussion forums, and a calendar of TSMO-related events.

Federal Highway Administration

Office of Operations

The FHWA Office of Operations provides national-level leadership for USDOT in the management and operations of the surface transportation system. Among the office's responsibilities are the areas of congestion management, intelligent transportation systems (ITS) deployment, traffic operations, emergency management, and freight management and operations. Specific resources for traffic signal management and operations are available through the following:

- Arterial Management Program (https://ops.fhwa.dot.gov/arterial_mgmt/index.htm). The objective of the Arterial Management Program is to advance performance based management practices and operations strategies in traffic signal programs that promote the safety, mobility and efficient use of roadway capacity for all users. The program has four focus areas: Traffic Signal Program

Management, Regional Traffic Signal Operations Programs, Traffic Signal Timing and Operations Strategies, and Automated Traffic Signal Performance Measures. For each of the focus areas, available resources include support, training and technical assistance. Regional Traffic Signal Programs have demonstrated the capacity to accelerate and sustain improvements through collaboration and ATSPMs have demonstrated ability to improve street operations for the traveling public with low initial investment.
- Resource Center Operations Team provides the latest information on traffic signal program and operations practices and ITS technology along with key FHWA initiatives and key points of contact. (www.fhwa.dot.gov/resourcecenter/teams/operations/index.cfm)
- Peer-to-Peer Program offers free short-term technical assistance to agencies seeking to improve transportation operations. The effectiveness of the program stems from the knowledge and experience of those who participate as peers provide. The program is responsive to satisfy time constraints identified by the requesting agency and is confidential for the requesting agencies, allowing them to make strategic decisions privately without prematurely engaging the consultant community. This assistance is free upon request to enable agencies with limited resources to participate.

Every Day Counts

The Every Day Counts initiative seeks to identify and rapidly deploy effective but underutilized innovative practices working collaboratively with State departments of transportation, local, and tribal agencies. In the context of traffic signal operations the following are applicable:

- Automated Traffic Signal Performance Measures (ASTPMs) responds to the challenge of transportation agencies who typically rely on complaints or manual data collection to identify the need for signal retiming projects and their resulting outcomes. The technology is high value in relation to cost, as ATSPMs can be applied to a wide range of signalized intersections and use existing infrastructure to the greatest extent possible. A number of implementation options are available, ranging from a low-cost, open-source code framework to a fully integrated traffic signal system.
- ATSPMs consist of a high-resolution data-logging capability added to existing traffic signal infrastructure and data analysis techniques. This provides agency professionals with the information needed to proactively identify and correct deficiencies so they can manage traffic signal maintenance and operations functions in support of an agency's safety, mobility and community goals. In addition, ATSPMs can support the validation of other technologies and operational strategies, such as adaptive signal control and emerging connected vehicle applications such as SPaT integration.
- Visit https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/atspm.cfm to learn more.
- Adaptive Signal Control Technology initiative (ASCT) initiative focuses on utilizing systems engineering to align agency objectives and needs with technology solutions by developing traceable requirements to guide the selection and testing process for traffic signal systems. ASCT is an operations strategy that responds to variability in demand that is difficult to address through traditional methods. The main benefits of ASCT over conventional signal systems include the following:
  - Continuous distribution of time for green lights equitably for all traffic movements
  - Improvement in travel time reliability by progressively moving vehicles through green lights
  - Reduction in congestion by creating smoother flow
  - Prolong the effectiveness of traffic signal timing
  - Visit https://www.fhwa.dot.gov/innovation/everydaycounts/edc-1/asct.cfm to learn more

Office of Safety Intersection Program Intersection Safety Program

The FHWA Intersection Safety Program supports this national, State, and local priority and provides a number of resources focused on improving the safety of intersections (website: https://safety.fhwa.dot.gov/intersection/conventional/signalized/). Intersections represent a disproportionate share of the safety problem.[14] As a result, organizations such as the FHWA, NHTSA, ITE, AASHTO), the American Automobile Association (AAA), and other private and public organizations are devoting resources to help reduce the problem.

National Highway Institute

The National Highway Institute , a division of FHWA (website: www.nhi.fhwa.dot.gov), provides professional development to transportation professionals to improve the performance of the transportation industry. Recent available course offerings related to traffic signal management and operations include the following:

- FHWA-NHI-133121 Traffic Signal Design and Operations. This course focuses on better managing the congestion and delays that exist on our streets and roadways with a complete understanding of effective traffic signal timing and optimization techniques. Well-developed, designed, implemented, maintained, and operated traffic signal control projects are essential to this process. The course provides information on the engineering tools available to support traffic signal design, and to optimize, analyze, and simulate traffic flow. In addition, it covers the application of the *Manual of Uniform Traffic Control Devices* (MUTCD) to intersection signal displays, as well as signal timing, computerized traffic signal systems, control strategies, integrated systems, traffic control simulation, and optimization software.
- FHWA-NHI-133122 Traffic Signal Timing Concepts. This course builds on the Traffic Signal Design and Operations course concepts to build technical expertise in signal timing by focusing on the relationship between network context and operational objectives to inform the design of signal timing parameters. The course goes beyond the traditional signal timing process by overlaying an objective-driven, performance-oriented approach to select the appropriate methods for design and operation of traffic signal timing. The intent is to move the participants agency from an ad-hoc citizen complaint-driven processes with little documentation and infrequent attempts to quantify performance or improvements to a well-managed, objective driven process for the timing and retiming of traffic signals,
- FHWA-NHI-133123 Systems Engineering for Signal Systems Including Adaptive Control. This course focuses on supporting transportation professionals in identifying the needs for improved traffic operations and utilizes systems engineering principles for the implementation of traffic signal operational improvements. The course provides traffic operations managers and personnel a comprehensive view of what is required throughout the process to deploy of a new traffic control system with adaptive signal control as an example implementation. The overall goal of the course is to assist traffic operations staff in identifying traffic control system objectives and needs at the outset of a project to facilitate planning, designing and implementing a new traffic control system.
- Traffic Signal Management Plan Workshop This workshop is intended to help agencies direct their limited resources towards meeting the needs of the agencies most important stakeholders through the development of a Traffic Signal Management Plan. The Traffic Signal Management Plan is a management tool to document and align an agency's traffic signal design, operation and maintenance strategies to achieve basic service objectives. The workshop places emphasis on an

[14] 27.4 percent (10,267) of U.S. traffic fatalities occurred at intersection in 2016 and of that subtotal, 30.6 percent occurred at signalized intersections (3,145).

agency developing a simply stated goal and then developing objectives, strategies and tactics enabling them to clearly articulate their operational objectives and meaningfully measure their performance. Contact your FHWA Division Office or the FHWA Resource Center to get additional information about this workshop.

American Association of State Highway and Transportation Officials

AASHTO is an organization that represents state agency transportation professionals from all 50 states, the District of Columbia, and Puerto Rico (website: www.transportation.org). The organization serves as a liaison between state departments of transportation and the Federal government. As a standards development organization, AASHTO sets technical standards for design, construction of highways and bridges, materials, and many other areas of knowledge. Two key committees have portfolios that include in the area of traffic signal management and operations:

- Subcommittee on System Operations and Management focuses on 1) advancing State DOTs in their organizational structure and focus on operations; 2) enhanced use of performance monitoring and measurement to operate systems on a real time basis; 3) enhanced development, deployment and integration of technology, standards, and best practices; and 4) improved coordination and partnerships with other stakeholders, interests, and associations.
- Subcommittee on Traffic Engineering focuses on 1) effectiveness of traffic control practices and devices in terms of public safety, traffic operations, convenience, and cost; 2) federal regulatory mandates; 3) advancements in methods and equipment, which reduce costs, lower energy consumption, improve motorist guidance, and lessen accident experience; and 4) recommended improvements in standards and guidelines contained in the Manual on Uniform Traffic Control Devices (MUTCD).

American Public Works Association

APWA provides tools and resources along with supporting professional committees to individuals, agencies, or corporations with an interest in public works and infrastructure issues (website: www.apwa.net). Their membership includes public works directors; city engineers; transportation managers; and representatives from engineering and other consulting firms. APWA's Transportation Committee focuses on transportation issues that affect public works departments.

Institute of Transportation Engineers

The Institute of Transportation Engineers (ITE) facilitates the application of technology and scientific principles to research, planning, functional design, implementation, operation, policy development and management for any mode of ground transportation. Through its products and services, ITE promotes professional development of its members, supports and encourages education, stimulates research, develops public awareness programs and serves as a conduit for the exchange of professional information (website: www.ite.org). Specific groups within the organization that work on traffic signal management issues are:

- Transportation System Management and Operations Council promotes dialogue and innovation through the set of strategies represented by TSMO to anticipate and manage congested traffic conditions, and lessen other unpredictable causes of crashes, delay, and disruption.
- Traffic Engineering Council creates and delivers products relating to the design, operation, and maintenance of roadway networks and the relationship of these facilities with the other modes of transportation. The council has a large portfolio of projects to develop recommended practices, informational reports, and other resources of practical use.
- Public Agency Council identifies, develops, and delivers relevant products on management, leadership, organizational, institutional and related issues affecting employment in or interaction with the public sector.

In addition, ITE is standards development organization and has led with AASHTO and National Electronic Manufacturers Association the development of various ITS standards related to the Advanced Traffic Controller (ATC), ATC cabinet, NTCIP communications, etc., along with the associated professional capacity building webinar curriculum.

ITS America

ITS America provides the transportation community with knowledge on best practices and industry advancements for technologies that improve the safety, security and efficiency of the nation's surface transportation system (website: www.itsa.org). ITS America offers:

- Forums as member-driven committees that serve as the focal point for dialogue and networking on the challenges and opportunities surrounding research and deployment of ITS. Each Forum smaller ad hoc or standing committees that concentrate on specific ITS challenges, needs, or opportunities. The Transportation Management Forum addresses the issues of traffic signal management and operations in the context of ITS technology.
- The Knowledge Center houses webinars, industry link, and technical and scientific papers presented at ITS America Annual Meeting and World Congress event hosted in North America since 2000.
- Sessions dedicated to traffic and transportation management at ITS America Annual Meetings including sessions on Utilizing Performance Measures for Traffic Signal Systems and ITS for Intersection Safety.

International Municipal Signal Association

IMSA is an organization with the objectives to improve the efficiency, installation, construction, and maintenance of public safety equipment and systems by increasing the knowledge of its members in the practice areas of traffic controls, fire alarms, radio communications, roadway lighting, work zone traffic control, emergency medical services and other related systems. IMSA is best known in the traffic engineering profession through its certification programs for traffic signal technology and traffic signal inspection which many agencies incorporate into the requirements for engineering and technical position descriptions (website: www.imsasafety.org).

Transportation Research Board

The Transportation Research Board engages transportation practitioners, researchers, public officials, and other professionals in a range of interdisciplinary, multimodal activities to lay the foundation for innovative transportation solutions. Specific groups and programs related to traffic signal management operations are:

- Traffic Signal Systems Committee, AHB25 (https://signalsystems.engineering.iastate.edu/) This committee is concerned with provision of the safe and efficient movement of people and goods on surface streets through the use of traffic management systems. The scope includes system design, implementation, operations, and maintenance; development of traffic operations centers; development of traffic management strategies; integration and operational evaluation of surface street systems with freeway, traveler information, and transit systems; and incorporation of surface street systems into Intelligent Transportation Systems (ITS).
- Regional Transportation System Management and Operations Committee, AHB10 (http://sites.google.com/site/trbrtsmocommittee) This committee is concerned with regional transportation systems management to maximize transportation system performance in metropolitan areas, including coordinated and integrated decision-making approaches to operations and the harmonization of operations with planning, construction, preservation, and maintenance of transportation facilities.
- National Cooperative Highway Research Program conducts research in problem areas that affect highway planning, design, construction, operation, and maintenance nationwide and has developed many useful reports in the traffic signal management subject area including those at the end of this section.

Consortium for ITS Training and Education

The Consortium for ITS Training and Education (CITE) at (www.citeconsortium.org) provides integrated advanced transportation training and education program on ITS subject matter. The program, based on a consortium of universities, is open to anyone pursuing a career in advanced transportation. Instruction offered through CITE may include graduate and undergraduate level courses, as well as skill-based training and technology transfer. CITE coordinates, creates, and maintains advanced transportation courseware based on the needs of government and industry using distance learning tools. These courses are now jointly offered thru ITE as well.

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5 Conclusions

The CMM results reported in this report demonstrate that the reporting organizations are on average operating at an Established level of maturity. An Established level means that basic strategy applications are understood; key processes support requirements identified and key technology and core capacities under development, but there is limited internal accountability and uneven alignment with external partners.

Findings

The Self Assessment demonstrated that agencies overall are employing established processes where there is an understanding of basic strategy applications, support for requirement for those processes are in place, and key technology and core capacities under development. However, in general, there is limited internal accountability and uneven alignment with external partners. Agencies with five or fewer staff or less than 50 signals are characterized by activities and relationships largely ad hoc, informal, and champion-driven, substantially outside the mainstream of other DOT-related activities. Each of the agencies that participated can benefit by using their individual results to identify strengths in their signal systems and opportunities for improvement; some already have.

Management, operations, and maintenance practices that consider agency objectives, capabilities, and resource constraints are now recognized to have great potential to improve the performance of the transportation system. More recently, there has been allocated funding toward traffic signal programs based on meeting performance management, economic vitality, safety, and community livability goals. The subsequent aspiration step is for agencies to move to the next higher level of capability consistent with their program objective to standardize strategy applications which are implemented in priority contexts and managed for performance; they also need to develop documents and integrate technical and business processes into their transportation agency and align partnerships.

To be successful requires a combination of effective leadership, commitment to operations, and outcomes on the street when direction is provided to work within resources constraints. Traffic signal program management plans with well-stated objectives and measures are a byproduct of effective leadership. The application of the strong effort that this approach takes to traffic signal programs reduces risk and makes the achievement of performance-based objectives more likely for the agency, policy makers, and pubic.

The Nation's traffic engineering professionals continue to move forward to improve traffic signal operations for their communities. Given appropriate management, workforce development, and fiscal resources, these professionals are dedicated to make the best use of the existing transportation network to handle the growing traffic demand. That includes ensuring that traffic signals provide the best operation possible to the community and economy. In addition, the environment benefits from reduced fuel consumption and better air quality.

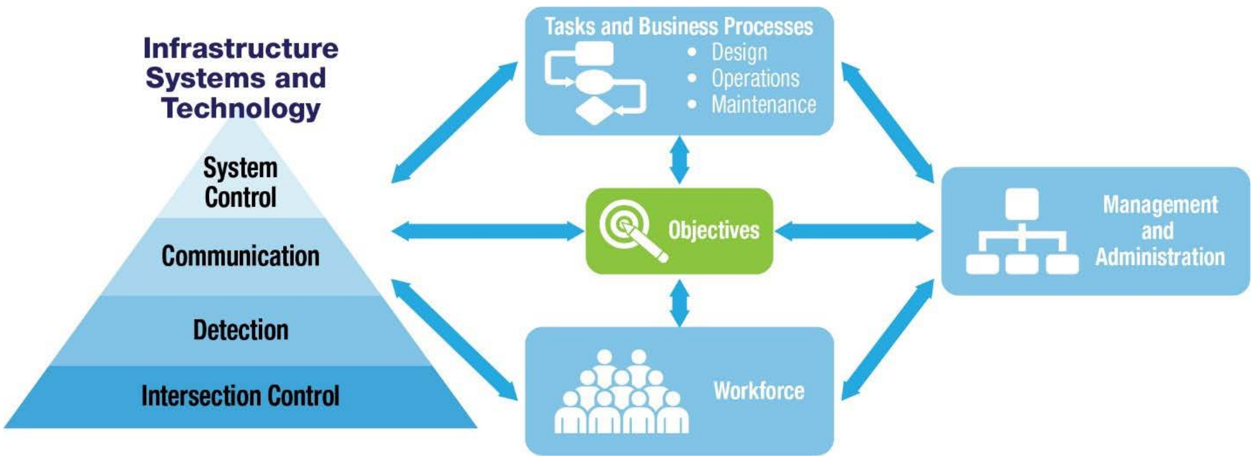
The agencies managing traffic signal systems can and want to do better in the daily management and operations of traffic signals, but this will be accomplished only through the support of local public sector leadership. Proactive traffic signal management based on objectives-based measurable traffic signal program management plans are critical—our Nation's quality of life and the environment depend on it.

Recommendations

To meet the purpose and intent of improving organizational capability to manage transportation on the Nation's roadways, a programmatic approach to traffic signal management and operations ensures that transportation goals such as safety, mobility, reliability, and state-of-good-repair are attained within the organization's capability and resource constraints. The maturity of each area of the program can be assessed to determine the level of risks to sustained attainment of the programs objectives. The recommended approach is to organize as an agency service delivery for traffic signal systems around the Traffic Signal Program Model[15] presented in the Figure 53.

The model simplifies and illustrates the relationships between the four core areas of a traffic signal program:

- Infrastructure, Systems, and Technology, shown as hierarchal triangle on the left
- Workforce, shown as rectangle at the bottom
- Tasks and Business Processes, shown as a rectangle at the top
- Management and Administration, shown as a rectangle on the right



Source: FHWA

Figure 53. Graphic. Traffic Signal Program Model

Traffic signal program objectives, shown at the center of the model, are the output of a process that continually evaluates context to extract attainable objectives from goals. Goals are the high-level, broad expressions of the desired outcomes that are experienced by stakeholders. Context is the dynamic physical, operational, and organizational influence that determines the priority of the goals and leads to a selection of attainable objectives. Objectives are what the program must do to make progress towards one or more goals. Within each area of the program areas are the activities (strategies) and the methods (tactics) that must be applied, to pursue attainment of objectives. The reliability of the program to consistently deliver activities and methods that attain objectives is assessed through evaluation of the program process using the *Traffic Signal Benchmarking and Self Assessment*.

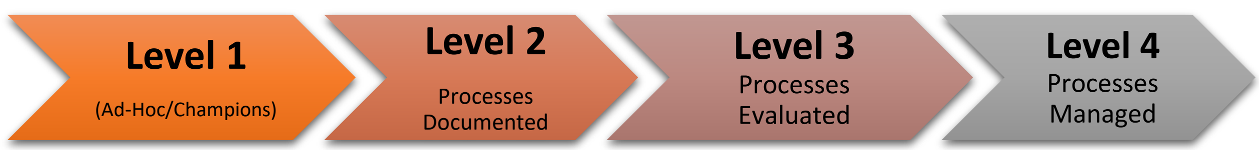
[15] Adopted from: Catherine Smith, Bob Norton, Debbie Ellis, (1992) "Leavitt's Diamond and the Flatter Library: A Case Study in Organizational Change," Library Management, Vol. 13 Issue: 5, pp.18-22,

At the center of the model is a process that evaluates context against the goals of the program to support selection of attainable objectives (shown in detail in Figure 54). The process of evaluating context is ongoing and the program should be able to attain all identified objectives. The infrastructure, systems, and technology are an outcome of the program; the arrows shown between each area of the program and objectives are intended to illustrate the close relationship between all program areas. The application of the *Self Assessment* to program provides an evaluation of how reliably the programs processes will sustain attainment of the objectives. The *Self Assessment* is a tool used in the traffic signal program plan to identify gaps in capability to support the development of an action plan for program improvement. A successful program effectively balances the activities of the four program areas to ensure objectives are persistently attained.

Source: FHWA

Figure 54. Graphic. Traffic Signal Program Model Goals, Context, Objectives, Strategies, and Tactics

By combining the CMM assessment technique with the traffic signal program model by using the S*elf Assessment,* the presence of gaps in capability become an indicator of risk within any of the four program areas to the attainment of program goals and objectives. As described in Chapter 2, four broad levels of maturity and capability have been defined (Figure 55): Level 1 – Ad Hoc, Level 2 – Established, Level 3 – Measured, Level 4 – Managed.



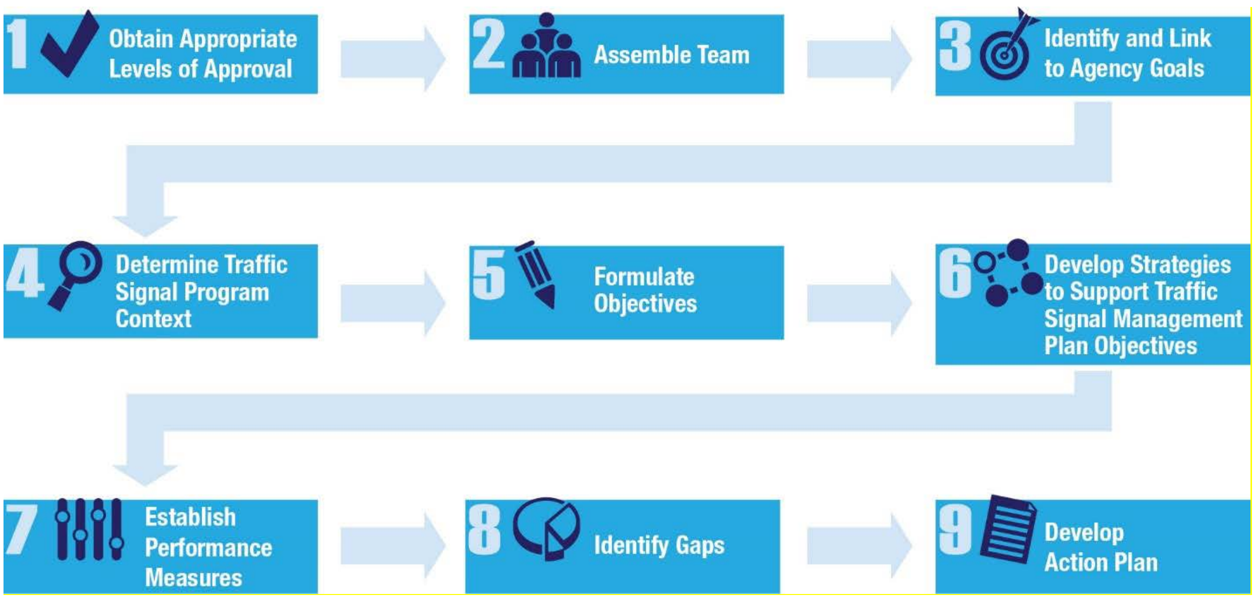
Source: FHWA

Figure 55. Graphic. Traffic Signal Program Levels of Capability Maturity

By understanding the difficulty and benefits of achieving a maturity level, an organization can make a conscious decision about which maturity level best supports its current needs. Although resource investments are frequently required to improve the capability and maturity of any program area, the actions to move from level to level are process-oriented. It is important to consider the interdependence of the program areas; an investment in any program area will almost always require some degree of organizational change through the entire organization, if there is a desire to sustain the value of investments over long periods of time. An example of this is frequently demonstrated with investment in systems and technology; which typically require workforce training and improved design, operations and maintenance business processes, and subsequent reporting by the management and administration program area.

Making Your Case - Actions to Take Now

A well-crafted traffic signal management plan (TSMP) provides a mechanism for all program stakeholders to clearly articulate the relationship between the activities of the traffic signal program and the goals of the transportation agency and larger TSMO context. Relating the activities of the program to agency and TSMO goals with the support of objectives and performance measures is fundamental to gaining the support of stakeholders for the program and critical to successfully competing for resources. A TSMP does the work of demonstrating the connection between traffic signal operations and maintenance activities and organizational and TSMO goals, such as safety, mobility, reliability, resilience, and efficiency. The TSMP development process is show in Figure 56.



Source: FHWA

Figure 56. Graphic. Traffic Signal Management Plan Development Process

- Identify and champion a committee to discuss the need for and approach to developing the TSMP. The committee should evaluate existing agency standards, guidelines, and other documents that support traffic signal planning, management, design, operations, and maintenance activities. The committee should discuss how the document will address the organization of the agency, scale of the network, and inclusion or reference to existing guidelines, policy documents, and other materials. A good practice is to formalize the effort by creating a charter that states the objective of committee, scope of the effort, and schedule prior to entering the development process.[16]

[16] Contact your State Federal Highway Administration (FHWA) Division Office if training or support is desired. The FHWA Resource Center and National Highway Institute may provide support in the form of workshops, web-based training, or instructor-led training to support the development of TSMPs.

- Agencies can jump start traffic signal program planning by routinely completing the *Traffic Signal Benchmarking and Self Assessment* and include meaningful measures that are directly connected to the programs objectives and reported in a manner that is appropriate and consistent with the needs of stakeholders.
- Kick off TSMP development as shown in the nine steps involved in the development process, as shown in Figure 56. The size, complexity, and capability and maturity of the organization will influence the scope and extent of the TSMP. The scale of the network (Statewide, district, regional, citywide, corridor) and presence of existing guidelines, policy documents, checklists, and documentation of design operations and maintenance are the main influencers of the level of effort involved in developing the TSMP.
- An action plan developed as an outcome of completing the *Self Assessment* and subsequent TSMP development process will provide a number of actions an organization might consider implementing to address risks that are related to a particular dimension and level of capability. However, in the *Self Assessment*, traffic signal systems is viewed as a subset of the larger TSMO program. The capability levels and the actions are more focused and defined from a traffic signal manager's perspective. The actions may require other agency functions or other agencies to be the responsible party, which is intended to foster multi-agency collaboration and dialogue about traffic signal systems at the regional level.
- Develop an outreach strategy for policymakers and the public for the traffic signal program management plan.

There are ongoing and innovative programs available through peer networks, research, professional capacity building, and resources available from FHWA as well as professional organizations. There are many opportunities for transportation professionals to move their agencies forward to the next level of organizational capability.

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Appendix A – 2018 Traffic Signal Benchmarking and Self Assessment Organizational Capability Results

Table 9. Number of Responses by Signal System Size, Agency Type, and Staff Size for Systems and Technology Dimension

	Level 1 Ad-Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grand Total
Signal System Size					
Less than 50	21	9	1	3	34
50 to 150	7	16	7	12	42
150 to 450	6	17	7	5	35
450 to 1,000	2	1	3	2	8
More than 1,000	1	7	11	6	25
TOTAL	37	50	29	28	144
Agency Type					
City/Municipality	27	32	12	16	87
County	6	4	9	5	24
State/Province	4	13	8	6	31
Other Jurisdiction	0	1	0	1	2
TOTAL	37	50	29	28	144
Staff Size					
5 or Less	24	12	5	8	49
6 to 10	9	17	7	9	42
11 to 20	3	8	4	3	18
21 to 50	0	8	8	5	21
More than 50	1	5	5	3	14
TOTAL	37	50	29	28	144

Table 10. Number of Responses by Signal System Size, Agency Type, and Staff Size for Infrastructure Dimension

	Level 1 Ad-Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grand Total
Signal System Size					
Less than 50	11	14	4	5	34
50 to 150	6	18	10	8	42
150 to 450	4	16	13	2	35
450 to 1,000	0	3	3	2	8
More than 1,000	0	6	12	7	25
TOTAL	21	57	42	24	144
Agency Type					
City/Muncipality	18	33	21	15	87
County	3	9	7	5	24
State/Province	0	14	13	4	31
Other Jurisdiction	0	1	1	0	2
TOTAL	21	57	42	24	144
Staff Size					
5 or Less	16	19	9	5	49
6 to 10	5	18	11	8	42
11 to 20	0	10	5	3	18
21 to 50	0	5	12	4	21
More than 50	0	5	5	4	14
TOTAL	21	57	42	24	144

Table 11. Number of Responses by Signal System Size, Agency Type, and Staff Size for Business Processes - Design Dimension

	Level 1 Ad-Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grand Total
Signal System Size					
Less than 50	10	19	1	4	34
50 to 150	6	22	4	10	42
150 to 450	3	25	5	2	35
450 to 1,000	0	4	1	3	8
More than 1,000	0	12	7	6	25
TOTAL	19	82	18	25	144
Agency Type					
City/Muncipality	16	48	9	14	87
County	2	13	2	7	24
State/Province	1	19	7	4	31
Other Jurisdiction	0	2	0	0	2
TOTAL	19	82	18	25	144
Staff Size					
5 or Less	15	27	1	6	49
6 to 10	3	22	7	10	42
11 to 20	1	16	1	0	18
21 to 50	0	11	5	5	21
More than 50	0	6	4	4	14
TOTAL	19	82	18	25	144

Table 12. Number of Responses by Signal System Size, Agency Type, and Staff Size for Business Processes - Operations Dimension

	Level 1 Ad-Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grand Total
Signal System Size					
Less than 50	12	16	1	5	34
50 to 150	8	22	8	4	42
150 to 450	3	19	13	0	35
450 to 1,000	0	3	3	2	8
More than 1,000	2	12	8	3	25
TOTAL	25	72	33	14	144
Agency Type					
City/Muncipality	19	44	15	9	87
County	2	10	9	3	24
State/Province	4	16	9	2	31
Other Jurisdiction	0	2	0	0	2
TOTAL	25	72	33	14	144
Staff Size					
5 or Less	18	23	4	4	49
6 to 10	4	22	11	5	42
11 to 20	1	10	6	1	18
21 to 50	0	11	7	3	21
More than 50	2	6	5	1	14
TOTAL	25	72	33	14	144

Table 13. Number of Responses by Signal System Size, Agency Type, and Staff Size for Business Processes - Maintenance Dimension

	Level 1 Ad-Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grand Total
Signal System Size					
Less than 50	8	17	3	6	34
50 to 150	3	23	11	5	42
150 to 450	3	18	10	4	35
450 to 1,000	1	5	2	0	8
More than 1,000	0	13	9	3	25
TOTAL	15	76	35	18	144
Agency Type					
City/Muncipality	11	44	19	13	87
County	2	12	7	3	24
State/Province	2	19	8	2	31
Other Jurisdiction	0	1	1	0	2
TOTAL	15	76	35	18	144
Staff Size					
5 or Less	10	25	8	6	49
6 to 10	3	21	12	6	42
11 to 20	1	12	3	2	18
21 to 50	1	12	5	3	21
More than 50	0	6	7	1	14
TOTAL	15	76	35	18	144

Table 14: Number of Responses by Signal System Size, Agency Type, and Staff Size for Business Processes - Management Dimension

	Level 1 Ad-Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grand Total
Signal System Size					
Less than 50	18	10	1	5	34
50 to 150	17	15	7	3	42
150 to 450	9	16	9	1	35
450 to 1,000	1	4	3	0	8
More than 1,000	7	7	7	4	25
TOTAL	52	52	27	13	144
Agency Type					
City/Muncipality	36	29	13	9	87
County	9	6	7	2	24
State/Province	7	16	6	2	31
Other Jurisdiction	0	1	1	0	2
TOTAL	52	52	27	13	144
Staff Size					
5 or Less	27	15	3	4	49
6 to 10	12	15	11	4	42
11 to 20	2	11	3	2	18
21 to 50	7	7	5	2	21
More than 50	4	4	5	1	14
TOTAL	52	52	27	13	144

Table 15. Number of Responses by Signal System Size, Agency Type, and Staff Size for Workforce Dimension

	Level 1 Ad-Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grand Total
Signal System Size					
Less than 50	12	15	2	5	34
50 to 150	4	17	16	5	42
150 to 450	4	16	13	2	35
450 to 1,000	0	3	4	1	8
More than 1,000	3	8	11	3	25
TOTAL	23	59	46	16	144
Agency Type					
City/Muncipality	15	35	26	11	87
County	5	8	9	2	24
State/Province	3	15	10	3	31
Other Jurisdiction	0	1	1	0	2
TOTAL	23	59	46	16	144
Staff Size					
5 or Less	15	18	11	5	49
6 to 10	2	23	12	5	42
11 to 20	2	7	7	2	18
21 to 50	1	8	12	0	21
More than 50	3	3	4	4	14
TOTAL	23	59	46	16	144

Table 16. Number of Responses by Signal System Size, Agency Type, and Staff Size for Management and Administration / Leadership - Culture Dimension

	Level 1 Ad-Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grand Total
Signal System Size					
Less than 50	13	15	1	5	34
50 to 150	9	19	8	6	42
150 to 450	4	20	9	2	35
450 to 1,000	0	2	4	2	8
More than 1,000	2	14	5	4	25
TOTAL	28	70	27	19	144
Agency Type					
City/Municipality	20	37	18	12	87
County	5	10	5	4	24
State/Province	3	21	4	3	31
Other Jurisdiction	0	2	0	0	2
TOTAL	28	70	27	19	144
Staff Size					
5 or Less	19	20	4	6	49
6 to 10	5	21	11	5	42
11 to 20	1	10	4	3	18
21 to 50	1	12	6	2	21
More than 50	2	7	2	3	14
TOTAL	28	70	27	19	144

Table 17. Number of Responses by Signal System Size, Agency Type and Staff Size for Management and Administration / Leadership - Organization and Staffing Dimension

	Level 1 Ad-Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grand Total
Signal System Size					
Less than 50	15	12	2	5	34
50 to 150	12	20	8	2	42
150 to 450	7	20	6	2	35
450 to 1,000	2	4	1	1	8
More than 1,000	2	14	6	3	25
TOTAL	38	70	23	13	144
Agency Type					
City/Municipality	26	38	13	10	87
County	8	10	4	2	24
State/Province	4	20	6	1	31
Other Jurisdiction	0	2	0	0	2
TOTAL	38	70	23	13	144
Staff Size					
5 or Less	23	16	5	5	49
6 to 10	7	24	8	3	42
11 to 20	3	10	3	2	18
21 to 50	3	12	4	2	21
More than 50	2	8	3	1	14
TOTAL	38	70	23	13	144

Table 18. Number of Responses by Signal System Size, Agency Type and Staff Size for Management and Administration / Leadership - Collaboration Dimension

	Level 1 Ad-Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grand Total
Signal System Size					
Less than 50	12	15	1	6	34
50 to 150	8	18	11	5	42
150 to 450	5	20	6	4	35
450 to 1,000	1	3	3	1	8
More than 1,000	1	16	5	3	25
TOTAL	27	72	26	19	144
Agency Type					
City/Muncipality	19	40	16	12	87
County	5	8	7	4	24
State/Province	3	23	3	2	31
Other Jurisdiction	0	1	0	1	2
TOTAL	27	72	26	19	144
Staff Size					
5 or Less	18	21	5	5	49
6 to 10	5	21	9	7	42
11 to 20	3	8	5	2	18
21 to 50	0	15	2	4	21
More than 50	1	7	5	1	14
TOTAL	27	72	26	19	144

Table 19. Number of Responses by Signal System Size, Agency Type and Staff Size for Management and Administration / Leadership - Performance Dimension

	Level 1 Ad-Hoc	Level 2 Established	Level 3 Measured	Level 4 Managed	Grand Total
Signal System Size					
Less than 50	20	7	1	6	34
50 to 150	21	14	7	0	42
150 to 450	13	10	11	1	35
450 to 1,000	0	5	3	0	8
More than 1,000	6	14	3	2	25
TOTAL	60	50	25	9	144
Agency Type					
City/Muncipality	40	26	14	7	87
County	11	7	6	0	24
State/Province	8	16	5	2	31
Other Jurisdiction	1	1	0	0	2
TOTAL	60	50	25	9	144
Staff Size					
5 or Less	30	9	5	5	49
6 to 10	19	15	8	0	42
11 to 20	4	6	6	2	18
21 to 50	3	14	2	2	21
More than 50	4	6	4	0	14
TOTAL	60	50	25	9	144

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