

A MODEL GUIDE FOR CONDITION ASSESSMENT SYSTEMS

FINAL REPORT

Prepared for:
National Cooperative Highway Research Program
Transportation Research Board
National Academies

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NCHRP Project 20-07, Task 206

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TABLE OF CONTENTS

LIST OF FIGURES	iii
LIST OF TABLES	iv
ACKNOWLEDGMENTS	vii
ABSTRACT	vii
EXECUTIVE SUMMARY	1
CHAPTER 1. BACKGROUND	5
Introduction.....	5
Project Objective	6
Background Summary	6
CHAPTER 2. RESEARCH APPROACH	28
CHAPTER 3. FINDINGS AND APPLICATIONS	37
Condition Assessment Attributes.....	37
Condition Assessment Surveys	43
Links to Strategic and Budget Decisions	46
Implementation	49
CHAPTER 4. FINDINGS AND RECOMMENDATIONS	88
Characteristics of Effective Condition Assessment Systems	88
Developments in CAS	89
Condition Assessment Guide	89
Benefits to Enhanced CAS	89
Research Needs.....	90
REFERENCES	93

LIST OF FIGURES

Figure No.

1	Elements of performance-based planning.....	23
2	Relationship between category, feature, and characteristic.....	23
3	MAP Field Data Collection Form.....	24
4	Sample LOS information for use with a focus group.....	25
5	Flow of information in a performance-based maintenance organization.....	26
6	Service level effectiveness.....	27
7	Drainage assets – Culvert condition attributes.....	53
8	Drainage assets – Curb and gutter condition attributes.....	53
9	Drainage assets – Sidewalk condition attributes.....	54
10	Drainage assets – Ditch/slope condition attributes.....	54
11	Drainage assets – Drop inlet condition attributes.....	55
12	Drainage assets – Underdrain and edgedrain condition attributes.....	55
13	Roadside assets – Fence condition attributes.....	56
14	Roadside assets – Grass mowing condition attributes.....	56
15	Roadside assets – Brush condition attributes.....	57
16	Roadside assets – Litter condition attributes.....	57
17	Roadside assets – Landscaping condition attributes.....	58
18	Roadside assets – Sound barrier condition attributes.....	58
19	Pavement assets – Paved shoulder condition attributes.....	59
20	Pavement assets – Unpaved shoulder condition attributes.....	59
21	Pavement assets – Paved surfaces condition attributes.....	60
22	Bridge condition attributes.....	60
23	Traffic items assets – Signals condition attributes.....	61
24	Traffic items assets – Signs condition attributes.....	61
25	Traffic items assets – Pavement marking condition attributes.....	62
26	Traffic items assets – Pavement marker condition attributes.....	62
27	Traffic items assets – Guardrail condition attributes.....	63
28	Traffic items assets – Guardrail end treatment condition attributes.....	63
29	Traffic items assets – Overhead sign structure condition attributes.....	64
30	Traffic items assets – Impact attenuator condition attributes.....	64
31	Traffic items assets – Highway lighting condition attributes.....	65
32	Special facilities assets – Rest areas condition attributes.....	65
33	Special facilities assets – Tunnel condition attributes.....	66
34	Special facilities assets – Weigh station condition attributes.....	66
35	Special facilities assets – Traffic monitoring system condition attributes.....	67
36	Other assets condition attributes.....	67
37	Methods used to develop condition assessment system (CAS) (Question 1).....	68
38	Use of customer input to develop or modify condition assessment method (Question 2).....	68
39	Distribution of formats used to obtain customer input (Question 3).....	69

Figure No. (continued)

40	Dedicated personnel conducting maintenance condition assessment surveys (Question 4)	69
41	Distribution of frequency of condition assessment surveys (Question 5)	70
42	Equipment used during the conduct of the condition assessment surveys (Question 6) ...	70
43	Use of sampling to collect condition information on any assets (Question 7)	71
44	Distribution of the sample lengths (Question 8).....	71
45	Assets surveyed using the sampling technique (Question 9) Top answers	72
46	Assets surveyed using the sampling technique (Question 9) Remaining answers	72
47	Methods used to ensure the quality of the condition surveys data (Question 10)	73
48	Distribution of the percentage of samples checked (Question 10).....	73
49	Distribution of the man-months spent collecting maintenance condition information (Question 11)	74
50	Links between condition attributes and the agencies' strategic performance measures (Question 12).....	74
51	Strategic performance measures monitored by the agencies (Question 13).....	75
52	Availability of Maintenance Activity Guidelines that identify work activities for performing maintenance (Question 14)	75
53	Availability of Maintenance Activity Guidelines that identify resource requirements for performing maintenance (Question 15)	76
54	Availability of Maintenance Activity Guidelines that identify work methods for performing maintenance (Question 16)	76
55	Availability of Maintenance Activity Guidelines that provide scheduling information for performing maintenance (Question 17)	77
56	Use of the results of condition assessment surveys to establish levels of service (Question 18)	77
57	Distribution of scales used to establish levels of service (Question 19).....	78
58	Performance targets established by the agencies (Question 20).....	78
59	Links between performance targets and the resources needed to provide an established level of service (Question 21).....	79
60	Use of the performance information to develop budget needs (Question 22)	79
61	Weighting the asset categories to prioritize the assets (Question 23)	80
62	Distribution of the assets included by the agencies in five assets having the highest weight (Question 23)	80
63	Use of the results of the condition assessment to program and schedule work activities (Question 24)	81
64	Availability of a computerized maintenance management in the agencies (Question 25)	81
65	Use of the results of the condition assessment to estimate budget needs and/or provide the information needed to evaluate different strategies (Question 26).....	82
66	Use of the results of the condition assessment to schedule work activities (Question 27)	82
67	Links between maintenance work priorities and budget allocations and customer expectations (Question 28)	83

Figure No. (continued)

68	Prioritizing strategic objectives (Question 29)	83
69	Distribution of the agencies responses to whether their condition assessment system has helped to achieve more consistent conditions on a statewide basis (Question 30)	84
70	Groups who are provided the results of the condition assessment surveys (Question 31)	84
71	Availability of an educational component to familiarize the agency’s employees with the condition assessment program (Question 32)	85
72	Education methods used by the agencies to familiarize their employees with the condition assessment program (Question 32)	85
73	Distribution of the agencies’ responses to whether their condition assessment system helped to identify maintenance priorities on a statewide basis (Question 33)	86
74	Advice to an agency just starting the development of its condition assessment techniques (Question 34)	86
75	Factors that contribute to the success of the condition assessment system (Question 35)	87
76	Distribution of the agencies’ responses to the question whether their condition assessment system is a part of an overall Asset Management Program (Question 36)	87

LIST OF TABLES

Table No.

1	Commonly used attributes in condition assessment systems.....	3
2	Sample condition measures from Florida (Stivers et al., 1999).....	18
3	Sample maintenance performance measures (WSDOT, 2004)	19
4	Sample report from MAP (WSDOT, 2004).....	20
5	MAP priority matrix (WSDOT, 2004).....	21
6	Statistical approaches to support MQA activities (from Schmitt et al., 2006a)	22
7	Questionnaire on condition assessment attributes for highway maintenance.....	29
8	Commonly used attributes in condition assessment systems.....	91

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ABSTRACT

This report documents and presents the results of a study of maintenance condition assessment procedures being used in state highway agencies to assess the condition of transportation assets. The information is based on a survey that was distributed during the summer of 2006 to representatives of each State highway agency and information obtained during a literature search. The 36 survey responses provide a representative snapshot of the current state of practice in this area. The findings indicate that maintenance condition assessment procedures are evolving so the results can be used for budgeting and resource scheduling activities. Guidelines in the use of effective condition assessment procedures were also developed under this study. The Guidelines are available as a separate document.

EXECUTIVE SUMMARY

Maintenance departments are continually challenged to use resources more efficiently due to increased competition for transportation funding and reduced work forces. At the same time, the need for effective maintenance practices is increasing as transportation agencies shift their priorities from new construction to preserving the investment that has been made in highway facilities. Maintenance is critical for system preservation and for ensuring the safety of the traveling public as they use the highway network to deliver goods and services or to traverse from their homes to places of employment, commerce centers, recreational facilities, or other locations.

An effective condition assessment system (CAS) is a tool that can be used by transportation agencies to quickly identify maintenance needs, to measure progress towards achieving performance goals, to help monitor the effectiveness of maintenance operations, to estimate resource requirements, and to schedule resources. Coupled with budgeting analysis tools, a CAS also provides the basis for prioritizing maintenance needs, providing feedback on the consequences of various long-term strategies, revising the agency's performance targets, and improving the overall delivery of the maintenance services provided within fixed budgetary constraints.

However, to provide the information needed to conduct these types of analyses, many existing CAS require enhancements. This report introduces the key characteristics of an enhanced CAS and illustrates the differences from the more traditional CAS used in the early days of Maintenance Quality Assurance (MQA) programs. The most effective CAS are outcome-based, using performance attributes that measure characteristics that are important to the traveling public and that can be related to maintenance activities. The CAS should be designed so the information can be used to track operational measures that support the agency's strategic goals, to estimate budget needs to meet performance targets, and to deploy maintenance resources. The increased importance of customer expectations in establishing performance targets and work priorities is emphasized throughout the literature.

To meet these requirements, many agencies have modified, or are in the process of updating, their Pass/Fail rating systems to record the amount of deterioration present in each sample inspected rather than merely indicate whether a sample met a predefined threshold level. A special consideration should be given to the organization of CAS, specifically, to the sampling of an agency's network to evaluate the overall condition of the network with maximum reliability. The report presents statistical tests that can be used to support MQA and CAS activities.

As part of the research, a survey of State practice was conducted. Thirty-six of the fifty States responded to the survey. The results illustrate there are several commonalities to the types of CAS being used in transportation agencies today, but there is a great deal of variability in the attributes that are being measured and the way the condition assessment surveys are conducted. A summary of the most commonly measured attributes in practice today is provided in table 1. The survey results also indicate that condition assessments are typically conducted annually although several states collect the information more frequently to capture seasonal variations in data. Regional or district personnel typically conduct the surveys and record information on paper. Because of the resources required to conduct the condition assessments, many agencies

have adopted sampling techniques using randomly selected stratified samples. Annual training and quality control checks are used to ensure the quality of the data.

A large number of agencies are in the process of transitioning from the traditional Pass/Fail rating systems to the enhanced CAS described in this report. The four areas undergoing the most development are those listed below:

- (1) the use of CAS information to establish performance targets that are linked to resource requirements.
- (2) the use of automated systems to estimate budgets and/or evaluate the impacts of different investment strategies.
- (3) the use of CAS results to schedule maintenance activities.
- (4) the establishment of stronger links between work priorities and customer expectations.

To assist agencies with the development of an enhanced CAS capable of supporting performance-based budgeting activities, a stand-alone *Guide to Maintenance Condition Assessment Systems* was developed under this research project. The Guide describes the characteristics of an enhanced CAS and provides examples of the types of attributes most commonly used. The Guide also illustrates the use of the results of a maintenance condition assessment survey for budgeting and programming activities and for other maintenance planning functions. A Glossary of Terms and list of useful references are also included.

The use of an enhanced CAS provides significant benefits to maintenance practitioners. In addition to obtaining more consistent conditions on a statewide basis, CAS have been used to establish and communicate statewide maintenance priorities more effectively. The enhanced CAS presented in this report also provides the information needed to conduct performance-based budgeting that links resource requirements to each of the possible levels of service. As a result, maintenance departments are better able to estimate the financial implications of moving from one level of service to another in response to changing budgets and/or customer expectations.

Table 1. Commonly used attributes in condition assessment systems.

Asset Type	Attributes
Drainage	
Culverts	<ul style="list-style-type: none"> • Clogged or interrupted flow • Structural deterioration
Curb and Gutter	<ul style="list-style-type: none"> • Structural damage or deterioration • Settlement • Interrupted flow
Ditches	<ul style="list-style-type: none"> • Inadequate drainage due to settling or debris • Eroded flowline
Drop Inlets	<ul style="list-style-type: none"> • Blockage • Broken/missing grate • Structural deterioration
Underdrains	<ul style="list-style-type: none"> • End protection damage • Pipe blocked or crushed
Roadside	
Fence	<ul style="list-style-type: none"> • Length of fence (or fabric) damaged • Length of broke posts
Grass	<ul style="list-style-type: none"> • Grass height
Brush	<ul style="list-style-type: none"> • Obstructions • Encroachment on travelway
Litter	<ul style="list-style-type: none"> • Volume within a certain length • Appearance
Pavements	
Paved Shoulders	<ul style="list-style-type: none"> • Drop-off • Structural distress
Unpaved Shoulders	<ul style="list-style-type: none"> • Drop-off • Build up
Paved Surfaces	<ul style="list-style-type: none"> • Structural distress • Cracking • Faulting • Functional distress • Roughness
Traffic Items	
Signs	<ul style="list-style-type: none"> • Post or panels damaged • Pole or post plumb (or orientation) • Visibility at a standard distance (or legibility)
Pavement Markings	<ul style="list-style-type: none"> • Day visibility • Missing or damaged marking • Night retroreflectivity
Pavement Markers	<ul style="list-style-type: none"> • Number of missing, damaged, or non reflecting • Obstruction

Asset Type	Attributes
Guardrail	<ul style="list-style-type: none"> • Post or rail damage • Orientation • Functionality
Guardrail End Treatments	<ul style="list-style-type: none"> • Post or rail damage • Length functioning as originally intended • Structural integrity
Impact Attenuators	<ul style="list-style-type: none"> • Damage • Functionality • Percent operational
Special Facilities	
Rest Areas	<ul style="list-style-type: none"> • Graffiti • Facilities working properly • Appearance • Mowing • Landscaping • Odor • Cleanliness

CHAPTER 1. BACKGROUND

Introduction

An effective condition assessment system (CAS) is a tool that can be used by transportation agencies to quickly identify maintenance needs, to measure progress towards achieving performance goals, to help monitor the effectiveness of maintenance operations, to estimate resource requirements, and to schedule resources. Coupled with budgeting analysis tools, a CAS also provides the basis for prioritizing maintenance needs, providing feedback on the consequences of various long-term strategies, revising the agency's performance targets, and improving the overall delivery of the maintenance services provided within fixed budgetary constraints.

In many transportation agencies, the use of a formal CAS corresponded to the agency's implementation of a maintenance quality assurance (MQA) program. Guidance in the development and implementation of MQA programs emerged out of NCHRP Project 14-12, Highway Maintenance Quality Assurance, which resulted in an implementation manual and workshops conducted around the country. NCHRP Report 422, *Maintenance QA Program Implementation Manual*, was published after the workshops were conducted. It provides transportation agencies with step-by-step instructions for developing, implementing, and using a MQA program.

Since the time when NCHRP Report 422 was published, there has been a tremendous increase in the use of MQA programs. In fact, most State highway agencies are reportedly collecting maintenance condition information to monitor maintenance activities and schedule resources. However, an increasing number of agencies are interested in using the same information to link performance targets with customer expectations and to estimate budget requirements to improve maintenance planning.

The evolving use of maintenance condition information has forced changes in the way maintenance performance is reported. In the past, maintenance measures were linked to maintenance outputs, such as the quantity of materials used or the number of hours required to complete a maintenance task. While that information is still useful for resource scheduling purposes, it is difficult to link the information to customer expectations or agency performance metrics. To address the need for more customer-oriented service delivery and to develop stronger links between performance measures and budget requirements, today's maintenance managers are moving towards outcome-based performance measures. Instead of monitoring the quantity of resources used, outcome measures report conditions in terms that are more meaningful descriptors of the level of service being provided to the traveling public. For instance, an outcome-based measure might specify the minimum grass height for mowing to occur or the number of hours before roads should be clear of snow after a winter storm.

The performance measures are used to identify and evaluate alternate maintenance strategies and investment options that can be directly linked to the deployment of maintenance forces in accordance with statewide priorities. Commonly referred to as performance-based budgeting or performance-based planning processes, there are several essential elements that must be included (Pickrell and Neumann, 2001):

- Broad goals.
- Objectives.
- Performance measures.
- Analytical methods and data needs.
- Decision support.
- Monitoring and feedback.
- Communicating and reporting results.

The interrelationships among these various activities are illustrated in figure 1. The activities enclosed by the shaded area represent the transportation planning elements that must be added or enhanced to support performance-based budgeting activities. The development or enhancement of new condition assessment techniques is represented in the figure as the data required to support the use of performance measures to monitor maintenance operations.

This study was conducted to document the transitions that are occurring in this area and to develop guidelines that will enable transportation agencies to develop enhanced condition assessment processes that support the use of condition data to improve maintenance planning and budgeting activities. The products developed during this study describe the tools necessary to deliver a more effective program and to better meet the maintenance expectations of the traveling public.

Project Objective

The objective of this research is to develop a Guide for the establishment of a maintenance CAS. The Guide is to be based on a national survey of SHA to gather detailed information on asset condition criteria, techniques, and methods for assessing maintenance needs and conditions. Additionally, the Guide will introduce the use of maintenance condition information for estimating maintenance resource needs to provide targeted levels of service. The Guide was developed as a stand-alone document.

The results of the survey of State practice are published in this final report, which documents the research conducted during the study. The research investigated the state of practice in asset condition assessments and rating (including statistical sampling techniques), the use of asset condition ratings for establishing budget needs for varying levels of service, and the lessons learned in the design, development, and use of maintenance CAS.

Background Summary

The transportation community is undergoing tremendous change in the way it conducts business as agencies become more customer-oriented and business-minded. These changes are evident in the Maintenance and Operations Divisions of SHA as maintenance management practices evolve from an internal focus on maintenance quality to a broader, external focus on customer expectations. At the same time, there is an increased emphasis being placed on maintenance as transportation agencies shift their focus from expansion and new construction to maintenance and system preservation.

As part of this transition, many transportation agencies are updating or enhancing their maintenance management systems (MMS) to better link customer expectations to performance-

based program objectives. A key component to these enhanced MMS is the development of CAS that provide the information needed on a timely basis within any resource constraints that may exist. In addition to the Guide developed during this resource effort, a number of other resources are available to assist agencies with enhancing their existing practices. For instance, the Federal Highway Administration (FHWA) sponsors National Highway Institute (NHI) training course number 131107, *Principles and Practices for Enhanced Maintenance Management Systems*. The American Association of State Highway and Transportation Officials (AASHTO) recently published the *Guidelines for Maintenance Management Systems* (AASHTO, 2005) and the *Asset Management Data Collection Guide* (AASHTO, 2006), and also published the manual on maintenance practices, *Maintenance Manual: The Maintenance and Management of Roadways and Bridges* (AASHTO, 1999). This topic has also been the focus of several sessions at recent Transportation Research Board (TRB) Annual Meetings, with many presentations focusing on the development and use of performance measures for improved maintenance practices. In addition, a Peer Exchange, sponsored by the Midwest Regional University Transportation Center at the University of Madison, was conducted in Madison, WI in October 2004. The *Proceedings* from the Peer Exchange are also available in both electronic and paper formats (Monroe et al., 2005).

A comprehensive literature search was conducted during this study to review the information available to support the development of a maintenance CAS, as well as state-of-practice implemented by the SHA in the U.S. The following areas were researched during this literature review:

- Terminology.
- Evolution of CAS.
- Use of performance measures.
- Maintenance quality assurance (MQA) programs.
- Use and development of condition measures.
- Procedural issues with CAS.

The following sections summarize the information obtained during the literature search on these topics.

Terminology

Clearly defining the terms used in CAS is important because many terms are used interchangeably although the terms may mean very different things in different agencies. While full glossaries of terms are defined by AASHTO (2005) and the National Cooperative Highway Research Program (NCHRP) (Stivers et al., 1999), the following definitions were provided to the participants in the survey of State practice:

- **Condition Assessment.** Condition assessment is a physical inspection and rating of roadway assets to determine the condition of individual assets, roadway sections, or overall road networks.
- **Maintenance Levels of Service (LOS).** Maintenance LOS describes the condition of individual assets as well as the overall condition of the roadway. LOS measures are generally specified in customer service terms related to safety, preservation, convenience,

aesthetics, comfort, and mobility. Some States also measure LOS in terms of environmental impacts or legislative mandates.

- **Maintenance Quality Assurance (MQA).** Maintenance quality assurance is a process of physically inspecting and rating the condition of the roadway assets and maintenance services. The same measures used to rate the condition of the roadway assets are also used to set performance targets. The data from the maintenance quality assurance program are used to assess outcomes, report conditions, and establish LOS.
- **Outcomes.** Outcomes are similar to levels of service and specify the overall results achieved from the maintenance program.
- **Performance Measure.** A performance measure is a unit of measurement used to define asset condition or desired levels of performance. Sample measures include grass height, number of potholes per lane mile, and the percent of signs below standard. In this example, it is also referred to as an attribute or characteristic.
- **Performance Target.** A performance target is a goal or objective for the condition of assets or the road system. A performance target is usually a numerical rating, such as “the percentage of pavement/shoulder drop-off less than ‘x’ inches.” Performance targets may vary by LOS, or may be expressed as a required percentage of assets meeting a particular set of conditions.
- **Performance-Based Budget.** A performance-based budget is based on the annual work program. For the budget to be performance-based, the annual work program must be linked to specified performance targets, LOS, or expected outcomes.

The hierarchical relationship between maintenance categories, features, and characteristics (or attributes) is also important to understand. A maintenance category is defined as a group of related features, such as drainage, roadside, pavement, traffic, and so on. Each category is made up of individual assets, which are also known as features. As part of a CAS, features are monitored in terms of certain characteristics, or attributes. The relationship between these terms is illustrated in figure 2. AASHTO (2006) describes the following general asset groups:

- Pavements – paved and unpaved lanes and shoulders.
- Roadside – features located along the roadside and within the limit of the roadway right-of-way, including vegetation and aesthetics, trees, shrubs, brush, historic markers, and right-of-way fencing.
- Drainage Structures – features that help to remove water from highways, such as cross pipes and box culverts, entrance pipes, curb and gutter, ditches, and edgedrains.
- Traffic – features specific to maintaining safety along the travel way, including attenuators, guardrail, pavement striping, pavement markings, signs, delineators, and highway lighting.
- Structures and Bridges – features related to bridge structures, overhead sign structures, structural culverts, sound barriers, and retaining walls.
- Special Facilities – features including movable bridges, rest areas, tunnels, weigh stations, and traffic monitoring systems.

While there is reportedly a great deal of consistency in the maintenance categories that are used, there is much more variability in terms of the features and characteristics that are included in each category (Adams and Smith, 2006).

Evolution of Condition Assessment Systems

As the importance of maintenance quality increased in the mid- to late-1990s, guidelines for improving the quality of maintenance practices were developed and promoted as MQA programs. They were originally defined as the “actions needed to provide adequate confidence that highway facilities meet specified requirements” (Stivers et al., 1999). As part of a MQA program, CAS were increasingly used as a way to document and report the condition of highway assets. Although primarily developed as internal management tools for resource planning and allocation purposes, the results of the surveys became progressively more important in presenting maintenance funding needs to state legislatures and responding to their demands for greater accountability in public agencies. In some instances, State legislatures mandated the regular reporting of highway asset conditions and funding needs.

The basic components for developing and implementing a MQA program are outlined in NCHRP Report 422 (Stivers et al., 1999). The development phase includes identifying key maintenance activities (and their associated features and characteristics) and determining customer expectations to assist in developing a level of service rating system and maintenance priorities. The implementation of the MQA program begins with training in the rating process and a baseline survey to establish the current LOS being provided. As condition assessments are conducted regularly, the current LOS can be updated and maintenance programs developed. The successful implementation assumes that an agency has the following in place (Stivers et al., 1999):

- A method of documenting work accomplishments.
- Maintenance activity standards that identify labor, equipment, and material costs associated with each work activity.
- An inventory of the highway maintenance features to be maintained.
- Processes to ensure the quality of the data.

Within the MQA framework, transportation assets and activities are grouped into categories, such as drainage, roadside, pavement, traffic items, and guardrail. Within each category, specific assets (features) and attributes are included. For example, the traffic item category might include signals, signs, pavement markings, overhead sign structures, and highway lighting. As part of the CAS, specific characteristics are evaluated for each asset (or feature) so that the physical condition is monitored. Examples of the types of characteristics that might be monitored for sign condition include retroreflectivity, sign height, legibility, post alignment, and visibility at a given distance.

One of the key components of the MQA initiative is the development of a reliable, and statistically valid, method of assessing the condition of the highway assets. Initially, most maintenance agencies developed a CAS that recorded whether or not a feature met a condition standard that had been established by the agency as a desirable LOS. For instance, the examples provided in table 2 were used in Florida in 1994 (Stivers et al., 1999). The thresholds used to rate conditions indicate when maintenance activities are required. And, reports on the percentage of maintenance features that meet the threshold conditions provide useful feedback on how well the agency is responding to agency and/or customer expectations in meeting the desired standard. Different levels of service can be defined using this approach, by establishing the percent of features that pass (or fail) the threshold at each level. For instance, 95 percent of

the features passing might be required when evaluating potholes on an Interstate highway, while only 50 percent passing might be required for potholes on a two-lane secondary highway. This approach of assessing conditions is often referred to as a Pass/Fail assessment method since the outcome is a report of the number of features that pass or fail particular criteria within the limits of the rated sample. An overall rating is also determined for each feature based on whether or not at least 80 percent of the samples met the desired standard. Features with scores significantly below or above the 80 percent target would require either more or less work, respectively, in the next rating period to achieve the desired level.

It is also important to develop maintenance activity priorities before any condition evaluations begin. Florida DOT set “safety of the traveling public” as its highest maintenance priority, “preserving the basic infrastructure” as its second maintenance priority, and “maintaining the operating characteristics of the highway” as its third maintenance priority (Stivers et al., 1999). Other routine maintenance activities fell into the fourth maintenance category, aesthetics. This latter category, which was established as the lowest maintenance priority in Florida, included activities such as mowing, litter removal, roadway sweeping, and other non-essential activities. Depending on the amount of maintenance conducted in any one area, virtually any maintenance activity could change priority periodically. For example, if litter became so thick that it became hazardous to drive at posted highway speeds, it would change from being a low priority to a high priority activity due to safety considerations. By establishing maintenance priorities, an agency has a clearly defined approach for responding to budgetary fluctuations. In Florida DOT, this process has served as the basis for every legislative budget submittal since 1990.

In recent years, some agencies have modified their condition assessment systems to provide more detailed information about the condition of transportation assets. Under these enhanced CAS, raters define condition measures in a manner similar to the Pass/Fail approach, but report the amount of each deficiency present. The quantities are then used to calculate a level of service in terms of a letter grade (such as A to F) or a numerical rating (such as 1 to 5). Reporting the amount of each deficiency present provides the added benefit of being able to estimate maintenance resource needs for any level of service. Under the Pass/Fail approach, if the agency wanted to change the threshold condition used to define sections that pass or fail, it would have no way of determining the funding levels required to correspond to the change. This is due, in part, to the fact that the Pass/Fail approach does not necessarily provide an indication of whether a section passed by a large margin or a small margin. Without that type of information, it is difficult to estimate the impact of changes in funding or work requirements.

There are both similarities and differences between the enhanced CAS and the Pass/Fail approach described earlier. In both methods, all performance measures must be outcome-based, so they provide an indication of the service level that is achieved (rather than the amount of work performed). Additionally, an indication of performance is measured for each approach. The Pass/Fail approach establishes the desired level of service and reports whether a sample meets the established level (or not). The enhanced CAS measures the amount of deficiency present, so the LOS may vary from year to year depending on available funding. In other words, rather than reporting whether a feature meets a given threshold, the number of deficiencies or the percent of the area (or length) that is deficient, is recorded under the enhanced CAS. Under either method, the measurement recorded for each sample can be assigned a LOS and the information can be aggregated statistically to report the overall performance of a district, region, or the entire State.

However, under the enhanced CAS the agency can also estimate the costs required to move the condition of any feature from the current LOS to a different LOS. Additionally, the agency can estimate the additional labor, material, and equipment required to provide the new LOS since resource activity levels are linked to each LOS. To illustrate the tools used under an enhanced CAS, an example of an inspection form from WSDOT's Maintenance Accountability Process (MAP) is provided as figure 3 and an example of its maintenance performance levels are provided in table 3. A sample report is provided as table 4.

Use of Performance Measures

A number of recent activities have been completed to promote the broader use of performance measures to support agency activities beyond their use for tracking and reporting asset condition. For example, practices in eight SHA's (Florida, Kentucky, Louisiana, Maryland, Minnesota, New Mexico, Pennsylvania, and Washington) were used in NCHRP Project 20-24 (Task 20) to illustrate the development and use of strategic performance measures. This project's final report outlined the steps an agency might take to enhance the link between performance measures and its strategic direction and business processes (Cameron, 2003).

Performance measures should reflect the strategic direction of an organization and the public's perceptions of progress towards a goal or good practice. There are typically three levels at which performance measures are used (Pickrell and Neumann, 2000). At the highest level, strategic performance measures are established to reflect the organizational initiatives and goals. There are a limited number of strategic performance measures that are established, and the upper levels of an organization maintain a focus on these measures. An example of a strategic performance measure might be to provide a safe and smooth transportation network.

Strategic performance measures are supported through tactical measures that define the specific goals for the organization. For instance, an agency might include a performance measure for the number of miles of the road network that meet specific targets for smoothness. Then operational measures, such as the International Roughness Index (IRI), are used to report the status towards this goal. The CAS supports the development and monitoring of operational measures that Maintenance Departments can use to support an agency's strategic performance measures.

This topic was discussed in a presentation by the California DOT (Caltrans) at the Maintenance Quality Peer Exchange (Monroe et al., 2005). As part of a statewide initiative to make government agencies more accountable to its citizens, California instituted a Performance Improvement Initiative. As part of that initiative, performance measures were developed to match operational decisions with the administration's vision for the State's transportation system. Strategic initiatives, such as reduced fatalities and system preservation, were translated into maintenance performance measures (such as pavement smoothness and distressed lane miles) that included levels of service for pavements, roadside features, electrical features, and structures. Public relations activities were also carried out to communicate to the public the shift in priorities from service activities to those that supported the State's safety and preservation performance measures.

Maintenance Quality Assurance Programs

In the Maintenance and Operations areas, the development of quantitative quality indicators has been used since the 1960s, when MQA programs were first introduced. NCHRP Report 422 (Stivers et al., 1999) provides guidance to agencies in the development and implementation of these programs. When the MQA programs were initially implemented, many of the indicators used were output-based. As transportation agencies have become more customer-focused, there has been an increased need for the development of quantitative measures that are outcome-based and customer-focused so they can be linked to the strategic performance measures used at the upper levels of an organization and support the budgeting and program development activities incorporated in the new maintenance management systems.

The exchange of experiences in the MQA area was fostered by the University of Wisconsin when it sponsored a national peer exchange on highway maintenance quality assurance on October 11-13, 2004. More than 75 professionals from 3 countries attended the peer exchange, which resulted in the development of a national agenda for MQA program development. The *Proceedings* (Monroe et al., 2005) from the peer exchange document the state of the practice and the challenges, needs, and next steps that are necessary to advance the effective use of MQA practices. The participants' recommendations for future initiatives focused on the following areas (Monroe et al., 2005):

- The use of condition data and funding information to predict outcomes.
- Development of a budget allocation model using MQA data.
- Development of meaningful performance measures for winter operations.
- The integration of pavement management and maintenance management efforts with MQA activities.
- Development of a guide to MQA statistics.
- Development of guides to communicate the importance of maintenance to system preservation.
- Development of common measures across State boundaries.
- The development of stronger links between customer expectations and agency goals, measures, and outcomes.

The development of common performance measures across State boundaries was explored in more detail following the MQA peer exchange, and the results were presented at the 2006 Annual Meeting of the TRB. Adams and Smith (2006) presented the commonly used measures they identified through a review of field guides, rating manuals, reports, and field checklists of participants in the peer exchange. The authors reported that the greatest similarity exists between maintenance categories, but that there is little agreement among those participating in the peer exchange on the specific features or characteristics that are measured (Adams and Smith, 2006).

Use and Development of Condition Measures

In addition to reporting existing conditions, agencies can establish targeted performance levels for each asset or activity that represents its desired LOS. Performance targets are often established based on input from a number of sources, including both external and internal stakeholders. In recent years, there has been an increased use of customer input into the development of performance targets for maintenance. For example, NCHRP Report 511

(Hyman, 2004) provides guidelines to assist agencies with collecting customer input for maintenance activities. Appendix B of NCHRP Report 511 includes a catalog of performance measures organized by maintenance element (such as pavements, shoulders, signs, roadside vegetation, and so on). Other examples of surveys to obtain customer expectations are provided in the literature (Stivers et al., 1999).

Budgetary factors should also play a part in setting performance targets since there is a cost associated with moving the condition of any element from one level of service to another. By quantifying the cost of maintaining each LOS, an agency can begin to use the results of its MQA surveys to determine maintenance funding needs and to establish priorities for the maintenance of different types of assets and activities. Typically, higher classes of roads and elements impacting safety considerations are targeted at higher levels of service than other elements.

To be useful in developing budget needs and conducting trade-off analyses, a rating system must be developed for the performance measures. As discussed earlier, most States initially used a simple Pass/Fail rating. Some agencies feel these systems are limited in their ability to support performance-based budgeting activities, yet states like Florida have used this process for many years with great success. To address the perceived limitations of the Pass/Fail approaches, maintenance agencies are shifting to CAS that record the amount of deterioration, or the number of deficiencies present, in each sample inspected. This information is used to report the LOS being provided for each maintenance feature, often in terms of 5 different service levels. These types of performance measures provide the information needed to estimate the amount of work required to bring the asset up to a particular performance level. For example, a performance measure related to sign retroreflectivity (such as candelas per foot-candle per square foot) might be used to indicate the performance level for each sign that is inspected and may be aggregated to provide the overall level of service on a district, region, or statewide basis.

Performance targets are set for each performance measure to represent the level of service goal established by the agency. Individual performance targets are established for each asset to compare the condition of the network and to estimate budget needs where existing conditions do not meet targeted conditions.

To help agencies establish performance targets, examples of assets at each level of service are provided to upper management, elected officials, and to the public. An example of the type of documentation used by the Arizona Department of Transportation (ADOT) to collect information on the public's perception of its highway maintenance program is provided as figure 4. ADOT provided this information to focus groups in the Phoenix, Tucson, and Flagstaff areas to learn about perceived current levels of service and desired levels of service (Dye Management Group, Inc., 2005). Although this example uses a rating scale of 1 to 5 (with 1 being the highest rating), many other States use a rating similar to the five letter grades used in schools (with an A representing the highest rating and an F representing the lowest rating).

As agencies move towards the use of the enhanced CAS, the information can be used for much more than reporting asset conditions. A number of agencies are using this information to estimate budget needs, establish maintenance priorities, deploy resources, and adjust resources to meet funding constraints. The relationship among these various activities is shown in figure 5, which outlines the flow of information in a performance-based maintenance organization.

Clearly illustrated in this figure is the relationship between the LOS objectives and the budgeting process. By defining the resources required to provide each possible LOS, the budget needs associated with any targeted LOS can be estimated. An iterative process is used to match the targeted LOS to the budget levels available. Once that is done, work priorities can be defined and resources can be deployed appropriately. The CAS process represents the last step in the evaluation process to compare actual performance to the targeted LOS.

As one would expect, the higher the targeted LOS, the higher the level of investment required in terms of maintenance resources. However, higher performance targets also typically correspond to more preventive rather than corrective maintenance activities, which can be more cost-effective in the long run. Higher performance targets can also be more effective because the cost of maintaining a facility in that condition is generally less expensive than applying the more costly corrective maintenance activities. Higher performance targets are also associated with higher degrees of reliability and less risk to the agency. These relationships are illustrated in figure 6.

The results of a CAS can also be used to establish maintenance priorities in support of the agency's strategic performance initiatives. WSDOT uses an approach that prioritizes maintenance activities in accordance with their contribution to program goals for safety, reliability, protecting the investment, and so on. The more an activity contributes to one or more of these program goals, the higher its ranking in the priority scheme. The contributions of maintenance activities in Washington DOT, and the resulting priority rankings, are shown in table 5. Other factors used to establish the priority of maintenance given to a State highway facility include the highway category (a function of traffic and functional classification), its importance to commerce, trucks, school bus routes, or commuters, and its proximity to population centers (WSDOT, 2004).

The results of the condition assessment can also be used to improve the accountability of a transportation agency. WSDOT uses its MAP information to measure both its effectiveness (doing the right things) and its efficiency (doing the right things well) (WSDOT, 2004). Effectiveness is evaluated in terms of meeting the program service level targets and the cost-effectiveness of maintenance operations. To evaluate efficiency, the cost of WSDOT's maintenance activities are compared to national averages and reported to the legislature.

Procedural Issues Associated with CAS

The condition of the network must be assessed on a regular basis so maintenance planning is based on sound information. A number of agencies collect condition information once or twice a year. Surveys conducted more often than annually allow agencies to take into consideration seasonal variations that may be important.

Because the maintenance condition surveys can be very resource intensive, some agencies use a statistically-valid sampling process to represent the condition of the highway assets. Traditionally, agencies use a sampling approach to target a certain percentage of the population to determine the number of samples to be inspected. Other considerations, such as the amount of variability in the data, also should be taken into account. According to the literature, approximately 3 to 35 percent of the population is inspected (Zimmerman and Wolters, 2005). This percentage varies depending on the network size, the goal of the survey, the amount of variability in the data, the desired confidence level, and other factors.

One disadvantage to the use of sampling is that some influential parts of the network may be subjectively excluded from the survey, resulting in skewed information. As an alternative, Stivers et al. (1999) suggests selecting samples of the roadway segment population randomly as a method for periodically selecting roadway segments to evaluate the LOS. Simple random sampling of the total roadway network assures each individual segment in the network the same chance of being chosen for field inspection. Once the segment's length is decided upon, the total number of the segments in the population (i.e., agency's network) can be calculated. For instance, a sample size of 0.1-mile on a highway network of 1,500 miles results in a total of 15,000 samples (1,500 miles/0.1 mile per sample). After numbering the segments, a random number generator can be used to choose the segments for inspection. The number of segments to evaluate, or sample size, is computed using the following formula (Stivers et al., 1999):

$$n = \frac{z^2 s^2}{d^2} \quad (1)$$

where:

n = required sample size.

s = standard deviation of the LOS rating

d = precision (e.g. for precision of ± 5 on a 1 to 100 scale, use 5.0)

z = z-statistic (for 95 percent confidence interval, $z=1.96$)

The above procedure can yield a greater degree of representation if the total roadway segment population is divided into homogeneous groups, or strata (e.g., according to geography [districts, maintenance unit] or facility type [functional class]). At a minimum, 25 segments per stratum (category) should be sampled regardless of the results of equation 1 (Stivers et al., 1999). This approach is used when agencies want to ensure that representative samples are found in each district maintenance unit, county, or roadway type (i.e., Interstate, Primary, Secondary, Tollroad, and so on). When samples are selected entirely on a random basis, there is no way to ensure that all districts will be represented in the survey.

The importance of confidence levels in determining the number of samples to inspect was emphasized in a research study for the Indiana Department of Transportation. The study found that by changing the confidence level from 95 percent to 80 percent, the number of samples to inspect dropped from 305 to 132 out of a total population of 16,240 0.1-mile samples (McCullouch and Sinha, 2003).

Schmitt et al. (2006a and 2006b) presented a summary of basic statistical terms that are used in MQA programs and a synthesis of practices in this area. Additionally, the authors demonstrated the use of traditional statistical methods within an MQA program on an example for the North Carolina Department of Transportation. Examples are provided for using statistics to establish sample size and confidence limits, to stratify data, to compare results from different raters and different years, and to rank sections based on individual measures or overall LOS. A

summary of the recommended statistical approach to be used to address different applications is provided in table 6.

An important consideration in designing a CAS is to establish data collection procedures that can be maintained over time within the resources available. Data may be collected using either manual, or mobile data collection procedures, which may be defined in the following way (AASHTO, 2006):

- Manual methods employ two or more data collectors and a vehicle that is equipped with a device for measuring distances. Condition data may be recorded on paper or in a hand-held data collection device. A portion of the surveys may involve walking to various assets to assess their condition.
- Mobile data collection utilizes vehicles specially equipped with digital cameras, lasers, global position satellite receivers, and computer hardware to capture, store, and process data. Many agencies using this technology consolidate the data collection activities with other functions (such as pavement management) and place images on their servers so they are available across a network.

The advantages and disadvantages of each data collection approach are described in the literature (AASHTO, 2006). Manual methods provide access to assets not easily viewed from the travel lanes but that require a significant commitment of maintenance personnel. Mobile data collection provides a visual record of assets and may allow a number of assets to be rated away from traffic. However, only those assets that can be viewed from the roadway can be rated in this manner and the process may require a large initial investment in equipment.

Agencies making substantial changes to their CAS must also decide whether they will pilot the new CAS before implementing the new procedures on a statewide basis. The Wisconsin DOT (WisDOT) piloted their new CAS for 6 months before the statewide implementation to help facilitate buy-in with the program. Their success is based on several success factors documented by Lebowhl (2003):

- Dedicate a staff position to the program.
- Assemble teams of champions from across the State.
- Pilot the program over a short period of time.
- Have flexible decision making and extensive feedback.
- Communicate extensively.
- Demonstrate strong management support.

WisDOT has been utilizing its Compass program since 2003.

Finally, the *Guidelines for Maintenance Management Systems* offer the following recommendations for developing condition assessment programs (AASHTO, 2005):

- Use the same performance measures for the CAS as are used to set performance targets.
- Ensure that the process is repeatable so condition ratings can be tracked from year to year.
- Develop consistency between condition ratings in each district and/or region so that statewide roll-ups of the data are meaningful.

The results of the literature search, together with the survey of State practice provided in the next chapter, form the basis for the development of the *Guide to Maintenance Condition Assessment Systems* published separately.

Table 2. Sample condition measures from Florida (Stivers et al., 1999).

Maintenance Feature	1994 Condition Standard
Pothole	No defect >0.5 ft ² in area and 1.5 in. deep. Pervious base must not be exposed in any hole.
Cracking (flexible pavements)	99% of roadway is free of unsealed Class III cracking.
Signs	Warning and regulatory signs: 95% are functioning as intended. Information signs: 85% are functioning as intended.
Pavement Striping	70% of each line functioning as intended.
Litter/Debris	The volume of litter does not exceed 6 ft ³ /acre excluding all roadway pavement.
Bush and Tree Control	There is no encroachment of trees, tree limbs, or vegetation lower than 14.5 ft in or over travelway or clear zone, or lower than 10 ft over sidewalks.
Roadside Ditch	The ditch bottom is ≥ ___ ft below the non-paved outside edge of pavement and/or functions as intended. (Rural limited access and rural arterial: 3 Urban limited access and urban arterial: 2.5)

Table 3. Sample maintenance performance measures (WSDOT, 2004).

Group 2 - Drainage Maintenance and Slope Repair

Component				Service Level				
Drainage Maintenance				A	B	C	D	F
Num.	Activities	Condition Indicators	Outcome Measures	Threshold	Threshold	Threshold	Threshold	Threshold
2A1	Maintain Ditches	Ditches with sediment buildup, unable to carry design flow.	Percent of ditches greater than 50% filled with sediment/debris.	0 - 1%	1.1% - 5%	5.1% - 10%	10.1% - 15%	>15%
2A2	Maintain Culverts	Cross culvert pipes plugged with dirt and/or debris, unable to carry design flow.	Percent of pipes/culverts greater than 50% filled, or otherwise deficient.	0 - 2%	2.1% - 5%	5.1% - 10%	10.1% - 20%	>20%
2A3	Maintain Catch Basins & Inlets	Catch basins and Inlets that are blocked or have sediment build-up.	Percent of Inlets blocked 50% or more with debris, or CB with sediment build-up reaching or exceeding flow line of outlet pipe.	0 - 3%	3.1% - 7%	7.1% - 15%	15.1% - 30%	>30%
2A4	Maintain Dention/Retention Basins	Silt basins unable to hold design capacity .	Percent of silt basins greater than 25% filled with sediment.	0 - 1%	1.1% - 5%	5.1% - 10%	10.1% - 15%	>15%
2A5	Slope Repair	Unrepaired erosion or slides encroaching on, or undermining the shoulder or traveled lane.	Percent of centerline miles with slides or erosion encroaching on, or undermining the shoulder or traveled way.	0 - 2%	2.1% - 4%	4.1% - 7%	7.1% - 10%	>10%

Table 4. Sample report from MAP (WSDOT, 2004).

Maintenance Accountability Process

Program M Service Level

Current Service Levels and 2001-03 CLB Commitments

Num.	Activity	1.0		1.9		2.0		2.9		3.0		3.9		4.0		4.9		5.0		5.9	
		+	A	-	+	B	-	+	C	-	+	D	-	+	D	-	+	F	-	+	F
Group 1 - Roadway Maintenance & Operations																					
1A1	Pavement Patching & Repair					✓	●														
1A2	Crack Sealing									✓	●					●					
1A3	Shoulder Maintenance									✓	●		●								
1A4	Sweeping and Cleaning					✓	●														
1B1	Safety Patrol **						✓	●			●										
Group 2 - Drainage Maintenance & Slope Repair																					
2A1	Maintain Ditches									✓	●										
2A2	Maintain Culverts												✓				●				
2A3	Maintain Catch Basins & Inlets														✓	●					
2A4	Maintain Detention/Retention Basins *									✓	●										
2A5	Slope Repair																●		✓		
Group 3 - Roadside & Landscape Maintenance																					
3A1	Litter Pickup															●	✓				
3A2	Noxious Weed Control						✓	●													
3A3	Nuisance Vegetation Control									✓	●										
3A4	Control Of Vegetation Obstructions																	●			✓
3A5	Landscape Maintenance **											✓	●								
Group 4 - Bridge & Urban Tunnel Maintenance & Operations																					
4A1	Bridge Deck Repair **											✓	●								
4A2	Structural Bridge Repair **																✓	●			
4A3	Bridge Cleaning **										✓	●									
4B1	Movable & Floating Bridges Op.**						✓	●													
4B2	Keller Ferry Operations **						✓	●													
4B3	Urban Tunnel Systems Operations **			✓						●											
Group 5 - Snow & Ice Control Operations																					
5B1	Snow & Ice Control Operations *									✓	●										
Group 6 - Traffic Control Maintenance & Operations																					
6A1	Pavement Striping Maintenance								●	✓											
6A2	Raised/Depressed Pavt. Marker Maint.															●				✓	
6A3	Pavement Marking Maintenance														✓			●			
6A4	Regulatory/Warning Sign Maint														✓		●				
6A5	Guide Sign Maintenance										✓	●									
6A6	Guidepost Maintenance												●		✓						
6A7	Guardrail Maintenance				✓	●															
6B1	Traffic Signal Systems **															✓					
6B2	Highway Lighting Systems						✓	●													
6B3	Intelligent Traffic Systems **								●			✓									
6B4	Permits / Franchises **							✓	●												
Group 7 - Rest Area Operations																					
7B1	Rest Area Operations *						✓	●													

Legend	
●	Current Law Budget Service Level Commitment
✓	Service Level Currently Delivered By WSDOT

Table 5. MAP priority matrix (WSDOT, 2004).

MAP Priorities		Provide Safety	Operate Systems Reliably	Protect Our Investments	Support The Economy	Address Legal Mandates	Meet Environmental Responsibilities	Contribute To Comfort & Aesthetics	Priority Ranking	Service Level Priority Value
		Higher <<< Program Goal Rating >>> Lower								
Num.	MAP Activity									
9B2	<i>Disaster Operations</i>	●	●	●	●	⊕	⊕		1	39
1A1	Pavement Patching & Repair	●	⊕	●	●	⊕	○	○	2	38
5B1	<i>Snow & Ice Control Operation</i>	●	●	○	●	⊕		⊕	3	37
6B1	<i>Traffic Signal System Operation</i>	●	●	○	○	●		○	4	36
4B1	<i>Movable & Floating Bridge Operation</i>	⊕	●		●	●			5	35
4B3	<i>Urban Tunnel Systems Operation</i>	⊕	●	⊕	⊕	⊕	●	○	6	34
4B2	<i>Keller Ferry Operation</i>	⊕	●	○	●	○			7	33
6A7	Guardrail Maintenance	●	⊕	⊕	○	○	○	○	8	32
3A2	Noxious Weed Control			⊕	●	●	●	⊕	9	31
4A2	Structural Bridge Repair	⊕	⊕	●	○	⊕	⊕	○	10	30
6B3	<i>SC & DI System Operation</i>	●	⊕	○	○	○	○	○	11	29
3A4	Control of Vegetation Obstructions	⊕	⊕	⊕	⊕	⊕	⊕	⊕	12	28
6B4	<i>Permits/Franchises</i>	○	⊕	⊕	⊕	●	○	○	13	27
2A2	Maintain Culverts	○	⊕	●	○	○	⊕	○	14	26
6A4	Regulatory Sign Maintenance	⊕	⊕	○	○	●		⊕	15	25
2A5	Slope Repairs	⊕	⊕	⊕	○	⊕	⊕	○	16	24
1A2	Crack Sealing	○	⊕	●	○		○		17	23
4A1	Bridge Deck Repair	○	○	●	⊕	○		○	18	22
1B1	<i>Safety Patrol</i>	⊕	⊕	⊕		⊕	○	○	19	21
7B1	<i>Rest Area Operation</i>	○	⊕	⊕	⊕	○	⊕	⊕	20	20
6B2	<i>Highway Lighting Systems Operation</i>	⊕	○	○	○	○		●	21	19
6A1	Pavement Striping Maintenance	⊕	○			⊕		●	22	18
2A3	Maintain Catch Basins & Inlets	○	○	⊕	○	⊕	⊕	○	23	17
6A2	Raised/Depressed Pavement Markers	⊕	○			⊕		●	24	16
1A4	Sweeping and Cleaning	○	○	○	○	○	●	⊕	25	15
3A3	Nuisance Vegetation Control	○		⊕	⊕	○	⊕	⊕	26	14
2A1	Maintain Ditches	○	○	⊕	○	○	⊕	⊕	27	13
1A3	Shoulder Maintenance	○	○	⊕	○	○	⊕	⊕	28	12
2A4	Maintain Detention/Retention Basins		○	○	○	⊕	●	○	29	11
3A1	Litter Pickup				○	○	●	●	30	10
6A5	Advisory Sign Maintenance	○	○	○	⊕	○		⊕	31	9
3A5	Landscape Maintenance			○	⊕	○	○	●	32	8
6A6	Guidepost Maintenance	○	○	○	○	○		⊕	33	7
4A3	Bridge Cleaning			⊕	○		⊕	⊕	34	6
6A3	Pavement Marking Maintenance	○	○			○		⊕	35	5
1A5	Misc. Roadway Maintenance			○	○	○	○	○	36	4
2A6	Misc. Drainage Maintenance			○	○	○	○	○	37	3
4A4	Misc. Bridge Maintenance			○	○	○	○	○	38	2
3A6	Misc. Roadside Maintenance			○	○	○	○	○	39	1
Non-prioritized Support Operations										
8B1	<i>Customer Response & Field Supervision</i>									
8B2	<i>Employee Technical & safety Training</i>									
8B3	<i>Support Operations</i>									
9B1	<i>3rd Party Damage Repair</i>									

LEGEND:

Contribution To Program Goals

- - Critical Impact
- ⊕ - Significant Impact
- - Contributing Impact
- No Impact

Operational Activities In Bold-Italics

Table 6. Statistical approaches to support MQA activities (from Schmitt et al., 2006a).

Maintenance Activity to be Conducted	Recommended Statistical Approach
Determining the number of samples to yield valid information	Statistical distributions and statistical parameters can assist in determining sample size. LOS confidence interval estimation equations can provide an interrelationship of sample size, variability, confidence level, precision, and data distribution parameters.
Developing confidence in an estimate	Confidence intervals can be constructed around the average using the chosen level of confidence (i.e., 95 percent), underlying variability, and sample size.
Stratifying data in terms of geographical or highway features	Analysis of variance can detect whether there is a difference between features of data (region, crews, etc), while incorporating the variability into the determination. Some States may have significant differences between regions that can be detected using analysis of variance.
Comparing results of MQA data collectors	T-tests can detect the mean difference between data sets generated by two different MQA data collectors. Then, with the assistance of power curves, the “true” mean difference between them can be measured and controlled. A whole host of standard statistical tests are available with which to compare data sets obtained by different MQA technicians or teams.
Determining differences in ratings between years	F-tests and t-tests can provide a statistical comparison of means. Paired-sample t-tests are used when data are collected from the same roadway segment from year to year, while a two-sample t-test is used when the roadway segments are independent of each other.
Looking for outliers in the data	Outliers, or data points that are abnormal from a distribution, can detect trouble signs. Several standard tests for outliers exist, and the chi-square or other goodness-of-fit tests can be used to check normality.
Reporting data	Beginning with simple fundamental statistical measures is always the best start (plot the data, calculate the average and standard deviation, etc.). The sampling design largely drives if/how a statistically valid analysis can proceed, so effort must be placed on sampling design at the beginning.

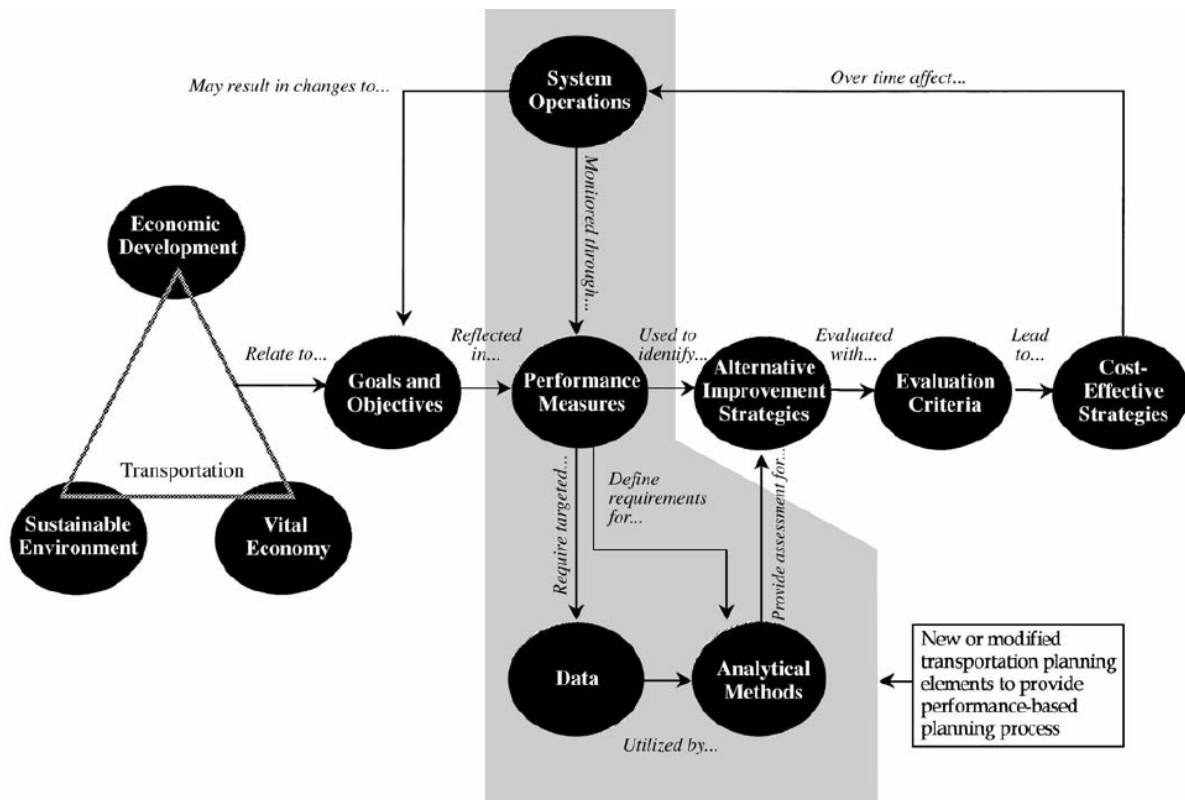


Figure 1. Elements of performance-based planning (Pickrell and Neumann, 2001).

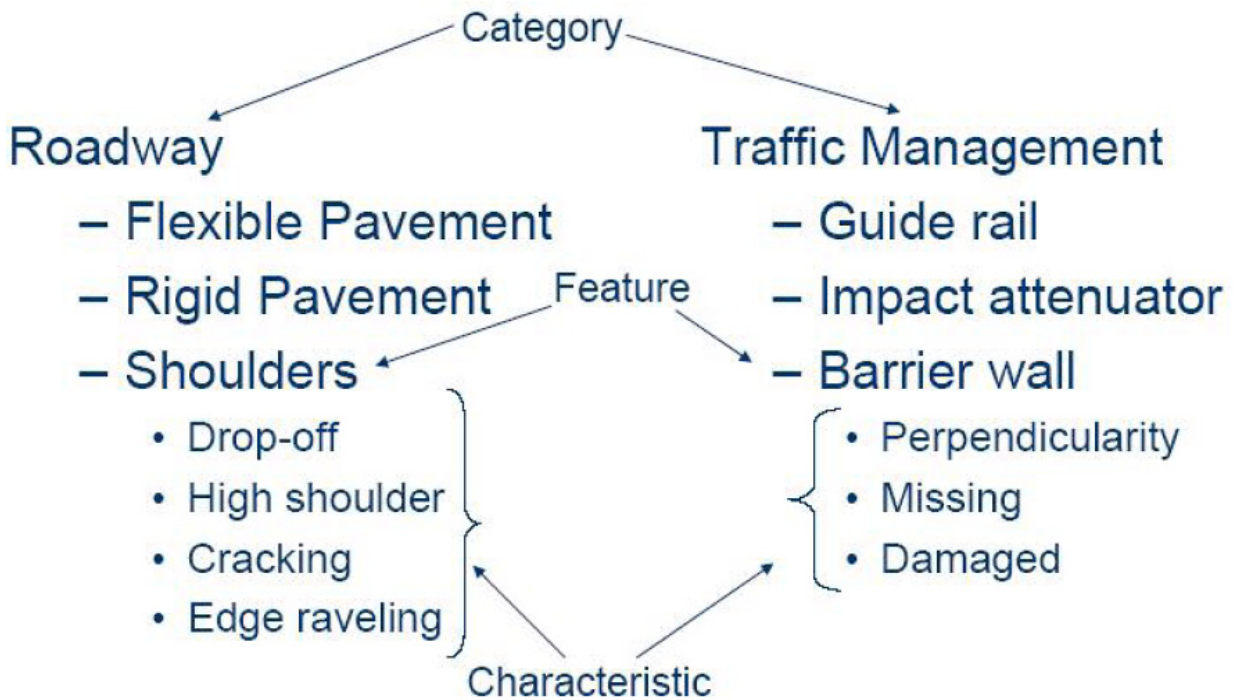


Figure 2. Relationship between category, feature, and characteristic (Adams and Smith, 2006).

MAP Field Data Collection Form

Site Number:	<input type="text"/>	SR:	<input type="text"/>	SRMP:	<input type="text"/>	Region:	<input type="text"/>	Area:	<input type="text"/>	<input type="checkbox"/> Moved	
Taken By:	<input type="text"/>					Date:	<input type="text"/>		<input type="checkbox"/> QAQC		

PAVED SHOULDER

Total Width of Paved Shoulders:	<input type="text"/>
Shoulder Potholes Sq. Ft. of Shoulder Potholes:	<input type="text"/>
Shoulder Alligator Cracking Sq. Ft. of Alligator Cracking:	<input type="text"/>
Shoulder Cracking Lin. Ft. of Longitudinal Cracking:	<input type="text"/>
Lin. Ft. of Transverse Cracking:	<input type="text"/>
Shoulder Edge Raveling Lin. Ft. of Edge Raveling:	<input type="text"/>
Shoulder Edge Drop-Off Lin. Ft. of Edge Drop-Off \geq 2":	<input type="text"/>
Shoulder Sweeping/Cleaning Lin. Ft. of Shldr. Debris Build-Up:	<input type="text"/>
Width of Shldr. Debris Build-Up:	<input type="text"/>
Shoulder Humps, Sags And Settlements Sq. Ft. of Deficiencies:	<input type="text"/>

Comments

1x 528	6x 3168
2x 1056	7x 3696
3x 1584	8x 4224
4x 2112	9x 4752
5x 2640	

DRAINAGE

Ditches	
Linear Feet of Ditches:	<input type="text"/>
Linear Feet of Ditch \geq 50% Full:	<input type="text"/>
Culverts	
Number of Culverts:	<input type="text"/>
Number of Culverts Deficient:	<input type="text"/>
Catch Basins - Inlets	
Number of Basins / Inlets:	<input type="text"/>
Num. of Deficient Basins / Inlets:	<input type="text"/>
Slope Failures	
Slope Failure Present 1 = Yes 0 = No	<input type="text"/>

ROADSIDE

Total Width of Roadside:	<input type="text"/>
Noxious Weeds Sq. Ft. of Noxious Weeds:	<input type="text"/>
Nuisance Vegetation Sq. Ft. of Nuisance Vegetation:	<input type="text"/>
Vegetation Obstructions Vegetation Obstruction Present 1 = Yes 0 = No	<input type="text"/>
Litter Number of Pieces of Litter:	<input type="text"/>

TRAFFIC

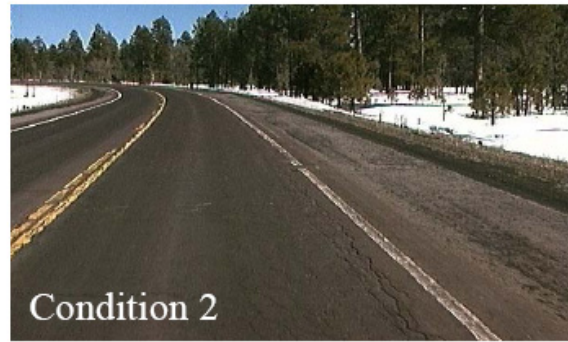
Raised / Recessed Pavement Markers	
Num. of Raised Pvmt. Markers:	<input type="text"/>
Num. of Markers Worn/Missing:	<input type="text"/>
Pavement Markings	
Number of Pavement Markings:	<input type="text"/>
Number of Markings Worn:	<input type="text"/>
Guideposts	
Number of Guideposts:	<input type="text"/>
Num. of GPs Broken/Damaged:	<input type="text"/>
Guardrail	
Lin. Ft. of Guardrail:	<input type="text"/>
Lin. Ft. of Guardrail Damaged:	<input type="text"/>

MAP Field Data Form - EF Revised 8/2006

Figure 3. MAP Field Data Collection Form (WSDOT, 2006).



Condition 1: This pavement is in very good to perfect condition. A road which is so smooth that at the speed you are traveling you would hardly know the road was there. You doubt that if someone made the surface smoother that the ride would be detectably nicer.



Condition 2: This pavement is in good condition with good ride quality.



Condition 3: This pavement is in fair condition with fair ride quality.



Condition 4: This pavement is in poor condition with poor ride quality.



Condition 5: This pavement is impassable. A road which is so bad that you doubt that you or the car will make it to the end at the speed you are traveling – like traveling along railroad tracks along the ties.

Figure 4. Sample LOS information for use with a focus group (Dye Management Group, Inc., 2005).

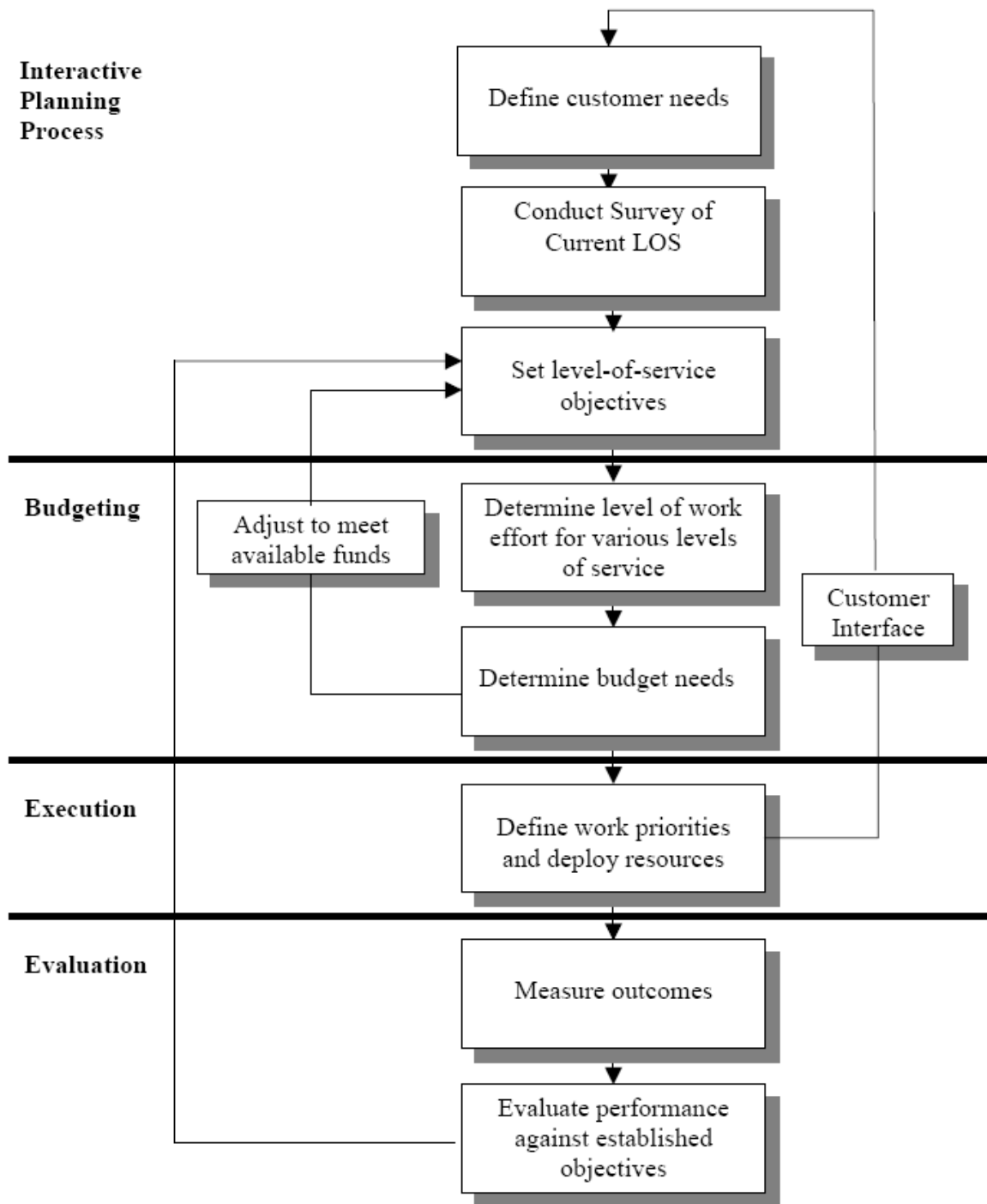


Figure 5. Flow of information in a performance-based maintenance organization (Dye Management Group, 2005).

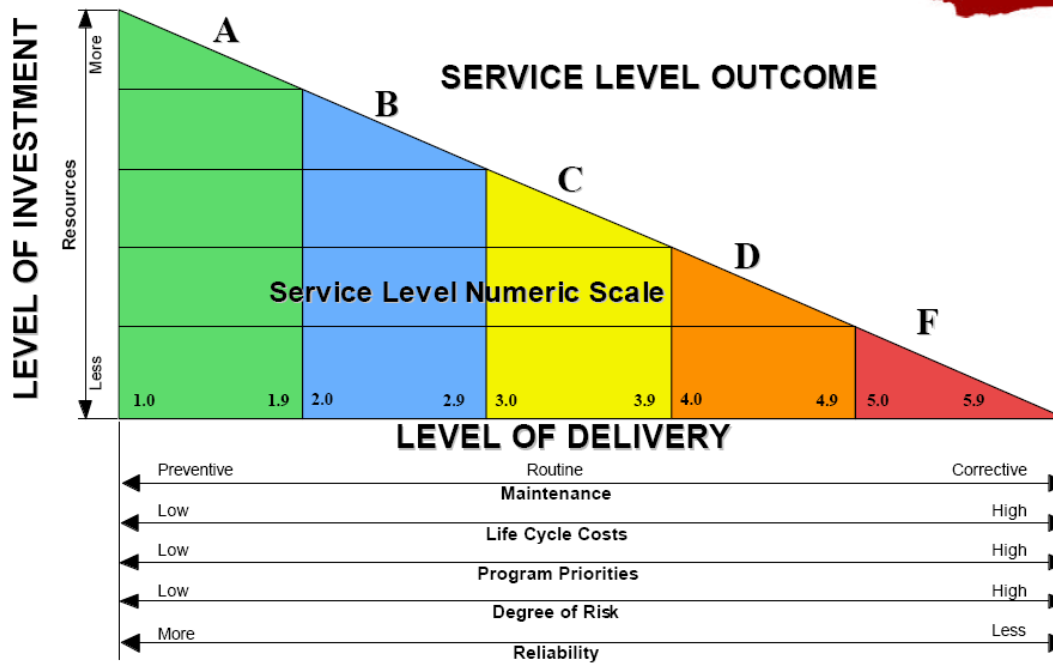


Figure 6. Service level effectiveness (WSDOT, 2004).

CHAPTER 2. RESEARCH APPROACH

Two approaches to collecting information were used to conduct the synthesis of the State highway agencies' (SHA) practices in the use of condition assessment systems (CAS) to support maintenance management activities. One approach involved conducting a literature search to determine the CAS-related issues as they have been addressed previously. Because of dramatic changes that have been taking place in this area over the past several years, the literature search focuses on materials published within the last 10 years. The relevant documents were obtained from many sources, including engineering libraries, internet and conference websites, CD-ROMs, and other sources.

In addition to the literature search, a detailed survey of State practice in the use of maintenance CAS was conducted to assist in developing a Guide to help agencies enhance their existing capabilities or to develop a new CAS to better support the maintenance and operation of transportation assets. Additionally, the survey provides information on States' use of CAS results in their budgeting and strategic decision-making processes. Finally, the survey participants were asked to evaluate the implementation of their CAS and share the lessons they learned during the development and implementation of it. The survey was conducted with a questionnaire that included 37 questions. The questionnaire (see table 7) was distributed to all SHA electronically, and 36 responses were received. The results of the survey were summarized and used to develop guidelines that reflect best practice.

Table 7. Questionnaire on condition assessment attributes for highway maintenance.

Condition Assessment Attributes For Highway Maintenance		
1. For each asset listed below, identify the performance measure being used by your agency to monitor highway maintenance conditions or needs. If you are not monitoring the condition of a particular asset, please mark "n/a."		
ASSET CATEGORY	ASSET TYPE	CONDITION ATTRIBUTES USED TO ESTABLISH PERFORMANCE MEASURES
Drainage	Culvert	<input type="checkbox"/> Clogged or Flowline interrupted (above a certain percentage) <input type="checkbox"/> Structural deterioration <input type="checkbox"/> N/A Other:
	Curb & Gutter	<input type="checkbox"/> Settlement (Displacement/heaving) <input type="checkbox"/> Undermining <input type="checkbox"/> Flowline interrupted <input type="checkbox"/> Structural damage/spalling <input type="checkbox"/> Curb/gutter cracking <input type="checkbox"/> Curb/gutter low curb reveal <input type="checkbox"/> N/A Other:
	Sidewalk	<input type="checkbox"/> Cracking <input type="checkbox"/> Structural deterioration <input type="checkbox"/> Displacement/heaving <input type="checkbox"/> Settlement <input type="checkbox"/> N/A Other:
	Ditch/Slope	<input type="checkbox"/> Settlement <input type="checkbox"/> Misalignment <input type="checkbox"/> Structural deterioration <input type="checkbox"/> Inadequate drainage (due to silting, debris, or scour) <input type="checkbox"/> Eroded flowline <input type="checkbox"/> N/A Other:
	Drop Inlet	<input type="checkbox"/> Insufficient capacity <input type="checkbox"/> Blockage <input type="checkbox"/> Structural deficiency <input type="checkbox"/> Grate broken/missing <input type="checkbox"/> N/A Other:
	Underdrain & Edgedrain	<input type="checkbox"/> End protection damage <input type="checkbox"/> Pipe crushed <input type="checkbox"/> Pipe blocked <input type="checkbox"/> N/A Other:

Table 7. Questionnaire for survey of State practice (cont.).

ASSET CATEGORY	ASSET TYPE	CONDITION ATTRIBUTES USED TO ESTABLISH PERFORMANCE MEASURES
Roadside	Fence	<input type="checkbox"/> Length of broken posts <input type="checkbox"/> Length of fabric or fence damaged <input type="checkbox"/> Rusted fence connections <input type="checkbox"/> Vegetation on fence present Other:
	Grass Mowing	<input type="checkbox"/> Grass height <input type="checkbox"/> N/A Other:
	Brush	<input type="checkbox"/> Obstructions to signs, sight distance, etc. <input type="checkbox"/> Encroachment on travelway <input type="checkbox"/> N/A Other:
	Litter	<input type="checkbox"/> Volume within a certain length <input type="checkbox"/> N/A Other:
	Landscaping	<input type="checkbox"/> Appearance <input type="checkbox"/> N/A Other:
	Sound Barrier	<input type="checkbox"/> Functionality <input type="checkbox"/> Structural integrity <input type="checkbox"/> N/A Other:
Pavement	Paved Shoulders	<input type="checkbox"/> Drop-off <input type="checkbox"/> Structural distress <input type="checkbox"/> Functional distress <input type="checkbox"/> Rumble strip not functioning <input type="checkbox"/> Travel way & shoulder separation <input type="checkbox"/> N/A Other:
	Unpaved Shoulders	<input type="checkbox"/> Drop-off <input type="checkbox"/> Build up <input type="checkbox"/> N/A Other:
	Paved Surfaces	<input type="checkbox"/> Structural distress <input type="checkbox"/> Functional distress <input type="checkbox"/> Cracking <input type="checkbox"/> Faulting <input type="checkbox"/> Roughness <input type="checkbox"/> N/A Other:

Table 7. Questionnaire for survey of State practice (cont.).

ASSET CATEGORY	ASSET TYPE	CONDITION ATTRIBUTES USED TO ESTABLISH PERFORMANCE MEASURES
Bridge	Bridge	<input type="checkbox"/> Condition ratings <input type="checkbox"/> Structural adequacy <input type="checkbox"/> Functional adequacy <input type="checkbox"/> Drainage (Scour and Erosion) <input type="checkbox"/> N/A Other:
Traffic Items	Signals	<input type="checkbox"/> Post damage <input type="checkbox"/> Pole/post plumb <input type="checkbox"/> Visibility <input type="checkbox"/> Bulbs burned out <input type="checkbox"/> Signal orientation <input type="checkbox"/> N/A Other:
	Signs (Both ground and overhead)	<input type="checkbox"/> Panels damaged <input type="checkbox"/> Pole/post plumb <input type="checkbox"/> Retroreflectivity at standard distance <input type="checkbox"/> Visibility at standard distance <input type="checkbox"/> Standard height <input type="checkbox"/> Post damage <input type="checkbox"/> Legibility <input type="checkbox"/> Sign orientation <input type="checkbox"/> Obstructions <input type="checkbox"/> N/A Other:
	Pavement Marking	<input type="checkbox"/> Day visibility <input type="checkbox"/> Night retroreflectivity <input type="checkbox"/> Missing/damaged <input type="checkbox"/> N/A Other:
	Pavement Marker	<input type="checkbox"/> Number missing, damaged, non-reflective, or obstructed <input type="checkbox"/> N/A Other:
	Guardrail	<input type="checkbox"/> Height <input type="checkbox"/> Damage <input type="checkbox"/> Rusted <input type="checkbox"/> Post damage <input type="checkbox"/> Functionality <input type="checkbox"/> Condition <input type="checkbox"/> N/A Other:
	Guardrail End Treatment	<input type="checkbox"/> End treatment damage <input type="checkbox"/> End treatment alignment <input type="checkbox"/> Post damage <input type="checkbox"/> Functions as originally intended <input type="checkbox"/> N/A Other:

Table 7. Questionnaire for survey of State practice (cont.).

ASSET CATEGORY	ASSET TYPE	CONDITION ATTRIBUTES USED TO ESTABLISH PERFORMANCE MEASURES
Traffic Items (continued)	Overhead Sign Structure	<input type="checkbox"/> Structural integrity <input type="checkbox"/> Lights working (if applicable) <input type="checkbox"/> N/A Other:
	Impact Attenuator	<input type="checkbox"/> Misaligned <input type="checkbox"/> Structurally damaged <input type="checkbox"/> Functionality <input type="checkbox"/> N/A Other:
	Highway Lighting	<input type="checkbox"/> Percent operational <input type="checkbox"/> Structural integrity <input type="checkbox"/> N/A Other:
Special Facilities	Rest Areas	<input type="checkbox"/> Graffiti <input type="checkbox"/> Facilities working properly <input type="checkbox"/> Appearance <input type="checkbox"/> Mowing <input type="checkbox"/> Landscaping <input type="checkbox"/> Odor <input type="checkbox"/> Cleanliness <input type="checkbox"/> N/A Other:
	Tunnels	<input type="checkbox"/> Lighting <input type="checkbox"/> Debris <input type="checkbox"/> Drainage <input type="checkbox"/> N/A Other:
	Weigh Stations	<input type="checkbox"/> Functionality <input type="checkbox"/> Appearance <input type="checkbox"/> N/A Other:
	Traffic Monitoring Systems	<input type="checkbox"/> Functionality <input type="checkbox"/> N/A Other:
Other	Other	<input type="checkbox"/> N/A Other:
1. How was your condition assessment system developed?		<input type="checkbox"/> Using inhouse staff <input type="checkbox"/> Based on a consultant's recommendation <input type="checkbox"/> Combination of consultant & inhouse efforts <input type="checkbox"/> Through another method – Please describe:
2. Have you used customer input to develop or modify your condition assessment method in any way?		<input type="checkbox"/> Yes <input type="checkbox"/> No

Table 7. Questionnaire for survey of State practice (cont.).

ASSET CATEGORY	ASSET TYPE	CONDITION ATTRIBUTES USED TO ESTABLISH PERFORMANCE MEASURES
3.	If you have used customer input, what format was used to obtain this information?	<input type="checkbox"/> Customer surveys <input type="checkbox"/> Focus groups <input type="checkbox"/> Phone surveys <input type="checkbox"/> Some other method – Please describe:
Condition Assessment Surveys		
4.	Who conducts your maintenance condition assessment surveys?	<input type="checkbox"/> Central office maintenance personnel <input type="checkbox"/> District/region personnel <input type="checkbox"/> Consultants or Contractors <input type="checkbox"/> Other:
5.	How frequently are the surveys conducted?	<input type="checkbox"/> Annually <input type="checkbox"/> Every other year <input type="checkbox"/> Some assets are collected annually and others are collected every other year <input type="checkbox"/> Other:
6.	Please mark each type of equipment used during the conduct of the condition assessment surveys.	<input type="checkbox"/> Pen/pencil/paper <input type="checkbox"/> Hand-held computers <input type="checkbox"/> Hand-held computers with GPS <input type="checkbox"/> Vans with panoramic cameras (videolog) <input type="checkbox"/> Vans with panoramic & downward facing cameras <input type="checkbox"/> Vans with lasers <input type="checkbox"/> Voice recording devices <input type="checkbox"/> Other:
7.	Does your agency use sampling to collect condition information on any assets?	<input type="checkbox"/> Yes <input type="checkbox"/> No
8.	If you answered yes to the previous question, please select the length of your sample size.	<input type="checkbox"/> 0.10-mile <input type="checkbox"/> 0.50-mile <input type="checkbox"/> Other:
9.	If you answered YES to question 8, please identify which assets are surveyed using the sampling technique. (Select all that apply). <input type="checkbox"/> Culverts <input type="checkbox"/> Curb & gutter <input type="checkbox"/> Sidewalk <input type="checkbox"/> Ditch <input type="checkbox"/> Drop Inlet <input type="checkbox"/> Underdrain & Edgedrain <input type="checkbox"/> Fence <input type="checkbox"/> Grass mowing <input type="checkbox"/> Brush <input type="checkbox"/> Litter <input type="checkbox"/> Landscaping <input type="checkbox"/> Sound barrier <input type="checkbox"/> Shoulders <input type="checkbox"/> Paved surfaces <input type="checkbox"/> Bridge	<input type="checkbox"/> All assets are rated within the sample area <input type="checkbox"/> Only the assets marked below are rated in the sample area: <input type="checkbox"/> Signal <input type="checkbox"/> Sign <input type="checkbox"/> Pavement marking <input type="checkbox"/> Pavement marker <input type="checkbox"/> Guardrail <input type="checkbox"/> Guardrail end treatment <input type="checkbox"/> Overhead sign structure <input type="checkbox"/> Impact attenuator <input type="checkbox"/> Traffic barriers <input type="checkbox"/> Highway lighting <input type="checkbox"/> Rest areas <input type="checkbox"/> Tunnels <input type="checkbox"/> Weigh stations <input type="checkbox"/> Traffic monitoring systems

Table 7. Questionnaire for survey of State practice (cont.).

ASSET CATEGORY	ASSET TYPE	CONDITION ATTRIBUTES USED TO ESTABLISH PERFORMANCE MEASURES
10. How do you ensure the quality of the data you receive from the surveys? Select all that apply.		<input type="checkbox"/> We do not check the quality of data from surveys <input type="checkbox"/> Conduct training classes for the raters before each survey <input type="checkbox"/> Conduct independent checks of data from representative samples. Approximately _____% of samples are checked <input type="checkbox"/> Raters do not inspect assets they are responsible for maintaining <input type="checkbox"/> A team of raters is used <input type="checkbox"/> Ratings are compared to previous surveys <input type="checkbox"/> Other
11. Approximately how many equivalent man-months are spent collecting this maintenance condition information in your agency (excluding surveys conducted for the Federal Bridge Inspection Program or pavement management)?		<input type="checkbox"/> Less than 1 man-month <input type="checkbox"/> 1 to 2 man-months <input type="checkbox"/> 2 to 3 man-months <input type="checkbox"/> 3 to 4 man-months <input type="checkbox"/> 4 to 5 man-months <input type="checkbox"/> 5 to 6 man-months <input type="checkbox"/> More than 6 man-months
Links to Strategic and Budget Decisions		
12. Are your condition attributes linked to your agency's strategic performance measures?		<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Somewhat
13. What strategic performance measures does your agency monitor?		<input type="checkbox"/> Asset condition <input type="checkbox"/> Mobility and accessibility <input type="checkbox"/> Operations and maintenance <input type="checkbox"/> Safety <input type="checkbox"/> Other:
14. Do you have Maintenance Activity Guidelines in place that identify work activities for performing maintenance work?		<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not yet, but they are under development
15. Do you have Maintenance Activity Guidelines in place that identify resource requirements for performing maintenance work?		<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not yet, but they are under development
16. Do you have Maintenance Activity Guidelines in place that identify work methods for performing maintenance work?		<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not yet, but they are under development
17. Do you have Maintenance Activity Guidelines in place that provide scheduling information for performing maintenance work?		<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not yet, but they are under development
18. How are the results of your condition assessment surveys used to establish levels of service?		<input type="checkbox"/> On a statewide basis <input type="checkbox"/> On a district basis <input type="checkbox"/> On a maintenance unit basis <input type="checkbox"/> On a county basis <input type="checkbox"/> On another basis – Please identify: <input type="checkbox"/> We do not establish levels of service

Table 7. Questionnaire for survey of State practice (cont.).

<p>19. If you have established levels of service, please indicate the scale that is used.</p>	<input type="checkbox"/> Pass/Fail <input type="checkbox"/> A, B, C, D, F <input type="checkbox"/> 1, 2, 3, 4, 5 <input type="checkbox"/> A combination of the approaches listed, depending on the type of asset <input type="checkbox"/> Other:
<p>20. Have you established performance targets?</p>	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not yet, but they are under development
<p>21. Have you established links between performance targets and the resources needed to provide that level of service?</p>	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not yet, but the links are under development
<p>22. Is your performance information used to develop your budget needs?</p>	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not yet, but this is under development
<p>23. If the performance measures are used to develop budget needs, do you apply weights to any category of assets to place more priority on some assets over others?</p>	<input type="checkbox"/> Yes – If so, list the 5 assets having the highest weight: <input type="checkbox"/> No <input type="checkbox"/> Not yet, but this is under development
<p>24. Are the results of the condition assessment used to program and schedule work activities?</p>	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not yet, but this is under development
<p>25. Do you have a computerized maintenance management system in place?</p>	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not yet, but this is under development
<p>26. If you have a computerized maintenance management system in place, does it use the results of the condition assessment to estimate budget needs and/or provide the information needed to evaluate different strategies?</p>	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not yet, but this is under development
<p>27. If you have a computerized maintenance management system in place, does it use the results of the condition assessment to schedule work activities?</p>	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not yet, but this is under development
<p>28. Are your maintenance work priorities and budget allocations linked to customer expectations?</p>	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not yet, but this is under development
<p>29. In what order would your agency prioritize these four strategic objectives? Number your responses 1 to 4, with 1 being the highest priority.</p>	Safety Preserve asset investment Maintain operations Aesthetics

Table 7. Questionnaire for survey of State practice (cont.).

Implementation	
30. Has your condition assessment system helped your agency to achieve more consistent conditions on a statewide basis?	<input type="checkbox"/> Yes <input type="checkbox"/> No
31. Identify all those who are provided the results of the condition assessment surveys.	<input type="checkbox"/> Employees <input type="checkbox"/> Legislature <input type="checkbox"/> Governor <input type="checkbox"/> Public <input type="checkbox"/> Stakeholders <input type="checkbox"/> Management Other:
32. Did you have an education component to familiarize your employees with the program?	<input type="checkbox"/> Yes - Please describe: <input type="checkbox"/> No
33. Has your condition assessment system helped your agency to identify maintenance priorities on a statewide basis?	<input type="checkbox"/> Yes <input type="checkbox"/> No
34. What are the top 3 pieces of advice you would share with an agency just starting the development of its condition assessment techniques?	1. 2. 3.
35. What 3 factors most contributed to the success of your system?	1. 2. 3.
36. Is your condition assessment system part of an overall Asset Management Program?	<input type="checkbox"/> Yes <input type="checkbox"/> No – it is not part of our existing, or planned, Asset Management Program <input type="checkbox"/> No – we do not have an overall Asset Management Program

Are you interested in providing more detailed information to showcase your practices?

- Yes
 No

CHAPTER 3. FINDINGS AND APPLICATIONS

A key source of information during this research was the conduct of a survey of State practice in the use of maintenance condition assessment systems (CAS) to support the maintenance and operation of transportation assets. This chapter documents the responses to the survey, which include responses from 36 State highway agencies (SHA). The survey results were used in developing a Guide for establishing, or enhancing, CAS that provide the information needed to link customer expectations to maintenance budgeting and scheduling activities. The survey participants commented on a variety of topics, including the types of measures currently being used, any changes that are expected, and lessons learned during the process.

Note that throughout this chapter, the number of responses to a question may not match the total number of responding agencies (36). In some cases, questions were left blank if the topic did not relate to the agency's practices.

Condition Assessment Attributes

In the first section of the questionnaire, the SHAs were asked to identify the performance measures used to monitor highway maintenance conditions or needs. In the survey instrument, and in this report, the condition attributes are grouped into the following asset categories and types:

- Drainage (culvert, curb and gutter, sidewalk, ditch/slope, drop inlet, underdrain and edg drain).
- Roadside (fence, grass mowing, brush, litter, landscaping, sound barrier).
- Pavement (paved shoulders, unpaved shoulders, paved surfaces).
- Bridge.
- Traffic items (signals, signs, pavement marking, pavement marker, guardrail, guardrail end treatment, overhead sign structure, impact attenuator, highway lighting).
- Special facilities (rest areas, tunnels, weigh stations, traffic monitoring systems).
- Other.

The following sections summarize the survey responses related to the condition assessment attributes for each of the asset categories.

Drainage

Culvert. According to the survey, 28 of 34 responding agencies indicate a certain percentage of clogged culverts or culverts with an interrupted flowline as a trigger for their maintenance activities. Nineteen agencies report structural deterioration of the culvert as a condition attribute. Six SHAs do not monitor culvert condition. Out of 28 agencies that monitor culvert condition, nine named other performance measures including condition of inlet and outlet ditches, end damage, roadway settlement, and other measures. Figure 7 shows the distribution of the SHAs' responses.

Curb & Gutter. The responses received from 36 SHAs show that 14 agencies do not monitor the conditions of curbs and gutters. The majority of the other 22 agencies indicate that

structural damage (15 SHAs), settlement (13 SHAs), and interruption of flowline (12 SHAs) are critical condition attributes for drainage maintenance. The remaining responses are distributed as follows (see figure 8):

- Undermining (7 SHAs).
- Curb/gutter cracking (6 SHAs).
- Curb/gutter low curb reveal (4 SHAs).
- Other (4 SHAs).

Sidewalk. The survey reveals that the majority of SHAs (23 of 35 respondents) do not include sidewalks in their Highway Maintenance CAS. The remaining 12 agencies reported the following sidewalk condition attributes:

- Structural deterioration (11 SHAs).
- Cracking (9 SHAs).
- Displacement/heaving (9 SHAs).
- Settlement (8 SHAs).
- Other (5 SHAs).

Figure 9 illustrates distribution of the agencies' responses.

Ditch/Slope. According to the survey of 35 respondents, ditch/slope conditions are monitored by 29 SHAs. In 26 of the 29 SHAs monitoring this type of asset, inadequate drainage due to silting, debris, or scour triggers the ditch/slope maintenance activities. An eroded flowline is reported as a critical condition attribute by 18 SHAs. Figure 10, where the distribution of the responses is shown, indicates additional condition attributes for ditches and slopes, such as structural deterioration (9 responses), settlement (6 responses), misalignment (4 responses), and other (3 responses).

Drop Inlet. Being asked to indicate condition attributes for this asset type, 25 of 35 respondents mention blockade of a drop inlet, 16 agencies report broken/missing grate, and 15 agencies indicate structural deficiency of a drop inlet. Five agencies add insufficient capacity as a condition attribute used to establish measure of the drop inlet performance, and two agencies give other responses. The survey indicates that 7 SHAs do not monitor the condition of drop inlets. The distribution of the responses is shown in figure 11.

Underdrain & Edgedrain. The responses received from the 35 agencies show that 19 of them do not include this type of asset in their CAS. The other 16 respondents marked the following condition attributes of underdrain/edgedrain as important (see figure 12):

- End protection damage (13 SHAs).
- Pipe blocked (13 SHAs).
- Pipe crushed (11 SHAs).
- Other (3 SHAs).

Roadside

Fence. The survey shows that the majority of respondents (23 of 34 agencies) monitor fence condition on a regular basis. The distribution of the responses shown in figure 13 indicate the damaged length of fabric or fence as the most commonly used condition attribute (16 SHAs). It is followed by length of broken posts (11 SHAs), the presence of vegetation on a fence (7 SHAs), and the rusted fence connections (3 SHAs). Six agencies give responses that differ from the aforementioned ones.

Grass Mowing. According to the survey, 25 of 34 respondents consider the grass height as a trigger for their maintenance activities. The other eight responses included mowing width, undesirable vegetation, sight distance obstruction, and so on. Seven agencies reported that they do not monitor grass mowing at all. Figure 14 presents the distribution of the responses about this asset.

Brush. Thirty-four SHAs responded to the question related to this asset type. Twenty-three respondents reported obstruction to signs and sight distance as a condition attribute used to establish a measure of the roadside performance. Seventeen responses indicated encroachment on a travelway as a critical condition, and five responses were classified as “other.” The survey reveals that eight SHAs do not monitor brush (see figure 15).

Litter. According to responses obtained from 34 agencies, the litter condition attributes are distributed as follows (see figure 16):

- Volume within a certain length (22 SHAs).
- N/A (no monitoring) (9 SHAs).
- Other (6 SHAs).

Landscaping. According to the distribution of responses presented in figure 17 (34 SHAs answered the question), 19 agencies do not include landscaping in their highway maintenance CAS. Thirteen responses indicate the appearance of landscape as a condition attribute, while six responses are grouped in the “other” category.

Sound Barrier. The analysis of the SHAs’ answers related to a sound barrier suggests that the majority of the respondents (26 of 34 agencies) do not monitor a sound barrier condition. The remaining eight agencies provided the following condition attributes for this asset type (see figure 18):

- Functionality (4 responses).
- Structural integrity (5 responses).
- Other (3 responses).

Pavement

Paved Shoulders. The survey shows that 28 of 35 agencies monitor the paved shoulder condition. The distribution of the responses (see figure 19) indicate the drop-off (24 SHAs) and a structural distress (20 SHAs) as the most important attributes for the evaluation of the paved shoulders condition. They are followed by the travelway/shoulder separation (12 SHAs) and a

functional distress (9 SHAs). One SHA mentions functioning of a rumble strip as one of the condition attributes for the paved shoulders. Three responses are entered in the “other” category.

Unpaved Shoulders. According to the survey, only 6 of 35 respondents do not track the performance of unpaved shoulders. The condition attributes reported by the remaining 29 respondents are distributed as follows (see figure 20):

- Drop-off (28 responses).
- Build up (22 responses).
- Other (6 responses).

Paved Surfaces. Out of 35 respondents, 22 include monitoring of the paved surfaces conditions in their highway condition assessment activities. The distribution of their responses about the condition attributes of the performance measures is shown in figure 21. According to this distribution, the condition attributes can be placed in the following order of frequency:

- Structural distress (19 responses).
- Cracking (19 responses).
- Faulting (14 responses).
- Functional distress (12 responses).
- Roughness (11 responses).
- Other (2 responses).

Bridge

The survey shows that 23 of 35 agencies do not include bridges in their highway CAS. The remaining 12 agencies report the following condition attributes:

- Condition ratings (11 SHAs).
- Structural adequacy (8 SHAs).
- Functional adequacy (6 SHAs).
- Drainage (scour and erosion) (8 SHAs).
- Other (1 SHAs).

Figure 22 shows the distribution of the responses related to bridge condition attributes.

Traffic Items

Signals. According to the survey, the majority of respondents (22 of 35 SHAs) do not include signals in their highway maintenance CAS. The distribution of the responses from those agencies who do monitor the condition of signals (see figure 23) indicate that burned out bulbs are the most frequently reported signals condition attribute (10 SHAs). It is followed by the visibility (6 SHAs), the post damage (5 SHAs), the signal orientation (5 SHAs), and a pole/post plumb condition (4 SHAs). Six agencies provided other responses.

Signs (ground and overhead). This type of asset appears to be a part of condition assessment system in 31 of 35 SHAs surveyed. According to the results of the survey, the condition attributes related to the signs are distributed as follows (see figure 24):

- Panels damaged (22 SHAs).
- Pole/post plumb (16 SHAs).
- Retro-reflectivity at standard distance (13 SHAs).
- Visibility at standard distance (19 SHAs).
- Standard height (12 SHAs).
- Post damage (20 SHAs).
- Legibility (19 SHAs).
- Sign orientation (14 SHAs).
- Obstructions (12 SHAs).
- Other (9 SHAs).

Pavement Marking. The responses received from 35 agencies show that the most agencies (31 of 35 respondents) regard the pavement marking as an important asset and monitor its condition. Day visibility and missing/damaged marking are mentioned as condition attributes in the majority of responses (24 for both attributes). Fifteen SHAs report they monitor night retro-reflectivity, and eight agencies provided other responses. Figure 25 provides distribution of the answers.

Pavement Marker. The survey reveals that 23 of 35 respondents monitor the condition of pavement markers. Twenty responses identify the number of missing, damaged, non-reflective, or obstructed pavement markers as a condition attribute, while four responses are classified as “other” (see figure 26).

Guardrail. Out of 35 respondents to this question, only five do not monitor guardrail condition. The responses received from the remaining 30 agencies report the following attributes are used to establish performance measures (the responses are placed in order of frequency):

- Damage (28 responses).
- Post Damage (22 responses).
- Condition (20 responses).
- Functionality (18 responses).
- Height (18 responses).
- Rusted (11 responses).
- Other (6 responses).

Figure 27 illustrates the distribution of the responses.

Guardrail End Treatment. According to the responses received from 34 SHAs, 11 of them do not monitor guardrail end condition. The remaining 23 agencies reported assessing the condition of the guardrail end treatment based on the following condition attributes:

- End Treatment Damage (22 SHAs).
- End Treatment Alignment (8 SHAs).
- Post Damage (14 SHAs).
- Functions as Originally Intended (11 SHAs).
- Other (5 SHAs).

The distribution of the responses between the agencies is shown in figure 28.

Overhead Sign Structure. Twenty-six of 35 respondents report no monitoring of the condition of an overhead sign structure. Eight respondents identify the structural integrity as a condition attribute for this type of asset, six agencies mention lights working as an additional condition attribute, and two agencies provide other answers. Figure 29 illustrates the distribution of the responses.

Impact Attenuator. According to the distribution of the responses presented in figure 30, the majority of SHAs (22 of 35 respondents) include this asset in their Highway Maintenance CAS. Twenty of 22 agencies reported structural damage as a trigger to the impact attenuator maintenance. The other condition attributes reported by the respondents are functionality (17 SHAs) and misalignment (10 SHAs). Three agencies provided other responses.

Highway Lighting. The survey shows that 20 of 34 respondents do not monitor the condition of their highway lighting system. The remaining 15 agencies use percent operational (13 SHAs) and structural integrity (9 SHAs) to establish performance measures for this asset type. Figure 31 illustrates the distribution of the agencies' responses.

Special Facilities

Rest Areas. The SHAs' responses to the question about the rest areas indicate that 22 of 34 respondents consider the rest areas as a part of their asset management system. Those agencies that monitor the rest areas' condition mentioned the following condition attributes:

- Graffiti (16 SHAs).
- Facilities working properly (18 SHAs).
- Appearance (19 SHAs).
- Mowing (18 SHAs).
- Landscaping (16 SHAs).
- Odor (14 SHAs).
- Cleanliness (19 SHAs).
- Other (4 SHAs).

The distribution of the responses is shown in figure 32.

Tunnels. The survey reveals that, in most of the agencies (26 of 34 SHAs), tunnels are not included in the Highway Maintenance Condition Assessment System (HMCAS) (see figure 33). The agencies that do monitor the condition of tunnels as part of their HMCAS evaluate tunnel lightning (5 responses), debris (4 responses), drainage (2 responses), and other condition attributes (2 responses) to assess the performance of tunnels.

Weigh Stations. According to the survey, the great majority of the respondents (31 of 34 SHAs) do not monitor this type of asset (see figure 34). Nevertheless, one SHA assesses performance of its weigh stations by the appearance; another SHA considers both appearance and functionality; and a third SHA additionally checks scale accuracy to establish performance measure for this type of asset.

Traffic Monitoring Systems. Thirty-two agencies responded to this question. Only six of them monitor the functionality of their traffic monitoring systems as a part of a HMCAS (see figure 35).

Other Assets

Under this category, the agencies were asked to provide information about the assets that were not included in the questionnaire. The responses are distributed as follows (see figure 36):

- Noxious weeds (2 SHA).
- Delineators (2 SHA).
- Special markings (1 SHA).
- Winter maintenance activities (1 SHA).
- Encroachments (1 SHA).
- Mailboxes (1 SHA).
- Public rating (1 SHA).
- Sweeping (1 SHA).
- Other (14 SHA).

In addition to the condition attributes survey, the participants were asked to characterize their CAS by answering a series of questions. The agencies' responses to these questions are summarized in the next section.

Condition Assessment Surveys

Question 1. How was your condition assessment system developed?

Thirty-four SHAs answered this question. According to their responses, 15 agencies used in-house staff to develop their condition assessment system, one agency used a consultant's recommendation, and 11 agencies used combination of both. Nine agencies reported other methods. Figure 37 shows the distribution of the SHAs' responses for Question 1.

Question 2. Have you used customer input to develop or modify your condition assessment method in any way?

Half of the 32 agencies that responded to this question answered "Yes," while the other half of the respondents reported "No" to using customer input in any way (see figure 38).

Question 3. If you have used customer input, what format was used to obtain this information?

According to the survey, the format for obtaining the customer input varied among 16 agencies and included the following (see figure 39):

- Customer surveys (13 responses).
- Focus groups (3 responses).
- Phone surveys (3 responses).
- Other (5 responses).

Question 4. Who conducts your maintenance condition assessment surveys?

Thirty-three SHAs answered this question. According to the responses, in the majority of agencies, the condition assessment surveys are conducted by the district/region personnel (24 SHAs). In nine agencies, the central office maintenance personnel are involved in the surveys. Six respondents use consultants' or contractors' services. Eight agencies provided other responses. Figure 40 shows the distribution of the agencies' responses.

Question 5. How frequently are the surveys conducted?

According to the distribution of the SHAs' responses shown in figure 41, 13 of 33 respondents conduct the condition assessment surveys every year. Two agencies report biennial surveys, while, in seven agencies, some assets are collected annually and others are collected every other year. Fourteen respondents mentioned a different survey frequency or commented on their answers.

Question 6. Please mark each type of equipment used during the conduct of the condition assessment surveys.

The survey reveals that most of the respondents (27 of 33 agencies) use pen/pencil and paper to record the condition of their highway assets. The other equipment used is reported as follows (see figure 42):

- Hand-held computers (9 SHAs).
- Hand-held computers with GPS (4 SHAs).
- Vans with panoramic cameras (videolog) (6 SHAs).
- Vans with panoramic & downward facing cameras (6 SHAs).
- Vans with lasers (3 SHAs).
- Voice recording devices (4 SHAs).
- Other (9 SHAs).

Question 7. Does your agency use sampling to collect condition information on any assets?

As shown in figure 43, there were 21 "Yes" answers and 12 "No" answers to this question.

Question 8. If you answered yes to the previous question, please select the length of your sample size.

According to the survey (see distribution of the responses in figure 44), 12 of 21 agencies that use sampling collect condition information from 0.1-mile (160-m) sections. The rest of the respondents report the other sample lengths as follows (see figure 44):

- 0.2 mile (1 agency).
- 0.3 mile (1 agency).
- 0.5 mile (2 agencies).
- 1 mile (4 agencies).
- Other (3 agencies).

Question 9. If you answered YES to question 8, please identify which assets are surveyed using the sampling technique.

Twenty-one agencies responded to this question. Six of them reported surveying all assets listed in the first part of the questionnaire (see chapter 2). The distribution of the other responses is shown in figure 45 (top answers) and figure 46 (the other answers). The most frequently reported assets (14 responses each) are shoulders, guardrails, litter and ditches, while the least frequently mentioned assets (2 responses) are rest areas. Ten agencies reported paved surfaces, curb-and-gutter, and fence are surveyed using the sampling technique.

Question 10. How do you ensure the quality of the data you receive from the surveys?

The survey shows that, out of 33 respondents, only six do not check the quality of data from the surveys (see figure 47). The remaining 27 agencies provided the following information:

- Fourteen agencies conduct training classes for the raters before each survey.
- Sixteen agencies conduct an independent check of the data from representative samples, while seven of them check 10 percent of samples, and five agencies check 5 percent of samples. One SHA verifies 100 percent of the data, while two other SHA reportedly check between 1 and 1.5 percent of the samples. Figure 48 illustrate this information.
- Six agencies report that their raters do not inspect assets they are responsible for maintaining.
- Thirteen agencies use a team of raters to ensure the quality of the survey data.
- In ten agencies, ratings are compared to previous surveys.
- Six agencies provided other responses.

Question 11. Approximately how many equivalent man-months are spent collecting this maintenance condition information in your agency (excluding surveys conducted for the Federal Bridge Inspection Program or pavement management)?

Thirty agencies responded to this question. According to the survey, the time spent collecting the maintenance condition information varies among the respondents from less than 1 man-month to more than 6 man-months. The responses are distributed as follows (see figure 49):

- Less than 1 man-month (1 SHA).
- 1 to 2 man-months (9 SHAs).
- 2 to 3 man-months (3 SHAs).
- 3 to 4 man-months (1 SHA).
- 4 to 5 man-months (2 SHAs).
- 5 to 6 man-months (0 SHAs).
- More than 6 man-months (13 SHAs).

Links to Strategic and Budget Decisions

One of the objectives of this research is to explore the SHAs' practices in developing the quantitative measures linked to the strategic performance measures used at the upper levels within an organization, which is expected to support the budgeting and program development activities incorporated in the new maintenance management systems. This section summarizes the agencies' responses to the questions related to their maintenance activity guidelines and their incorporation of the condition assessment system into their budget and strategy decisions.

Question 12. Are your condition attributes linked to your agency's strategic performance measures?

Out of 32 respondents, 16 answered "Yes" to this question; 12 characterized their attributes as somewhat linked; and four reported no links between their condition attributes and the strategy performance measures. Figure 50 illustrates the distribution of the agencies' responses.

Question 13. What strategic performance measures does your agency monitor?

The responses of the 31 agencies that answered this question indicate that operations and maintenance is the most often used strategic measure of performance (23 SHAs). It is followed by safety (22 SHAs) and asset condition (21 SHAs). Fifteen respondents included mobility and accessibility in the list of strategic measures. At least one SHA monitors environment in addition to the aforementioned measures. The distribution of the SHAs' responses is shown in figure 51.

Question 14. Do you have Maintenance Activity Guidelines in place that identify work activities for performing maintenance?

Thirty-three SHAs responded to this question. According to the distribution of responses (see figure 52), the great majority of the respondents (29 SHAs) have maintenance activity guidelines, while two agencies are developing them. Only 2 of 33 participants in the survey do not use maintenance activity guidelines to identify their maintenance activities.

Question 15. Do you have Maintenance Activity Guidelines in place that identify resource requirements for performing maintenance?

The survey shows that 26 of 33 respondents use maintenance activity guidelines to identify resource requirements for performing maintenance. In three agencies, those guidelines are under development, while four agencies do not have them in place (see figure 53).

Question 16. Do you have Maintenance Activity Guidelines in place that identify work methods for performing maintenance?

Thirty-one SHAs responded to this question. The answers are distributed as follows (see figure 54):

- Yes: 24 respondents.
- No: 5 respondents.
- Under development: 2 respondents.

Question 17. Do you have Maintenance Activity Guidelines in place that provide scheduling information for performing maintenance?

According to the survey, a half of respondents (16 of 32 SHAs) use maintenance activity guidelines for scheduling maintenance, 13 agencies do not have those guidelines in place, while in three agencies, the scheduling guidelines for maintenance are under development (see figure 55).

Question 18. How are the results of your condition assessment surveys used to establish levels of service?

An analysis of the 31 agencies' responses to this question reveals that 21 SHAs use the results of their condition surveys on a statewide basis, and 14 SHAs do it on a district basis. Three agencies report using the results of condition surveys on a county basis, and seven agencies use them on a maintenance unit basis. Five respondents do not establish levels of service. Figure 56 shows the distribution of the agencies' responses.

Question 19. If you have established levels of service, please indicate the scale that is used.

Thirty respondents reported the following scales used to establish levels of service (see figure 57):

- Pass/Fail (5 SHAs).
- A, B, C, D, F (10 SHAs).
- 1, 2, 3, 4, 5 (6 SHAs).
- A combination of the approaches above (3 SHAs).
- Other (6 SHAs).

Question 20. Have you established performance targets?

The survey shows that 17 of 33 participants in the survey have established performance targets, while 10 agencies are still developing them. Six agencies reported that they do not have performance targets in place. Figure 58 provides the distribution of the agencies' responses.

Question 21. Have you established links between performance targets and the resources needed to provide that level of service?

According to the SHAs responses, approximately a third of the agencies (10 of 33 respondents) link their performance targets to the resources needed to provide a desired level of service, while in 10 agencies, those links are under development (see figure 59). Thirteen SHAs answered “No” to this question.

Question 22. Is your performance information used to develop your budget needs?

This question yielded approximately the same distribution of responses as in Question 21 (see figure 60). According to the survey, it appears that 12 of 34 respondents link their performance information to their budgeting process. The same number of agencies are developing these links. Ten agencies do not use performance information to develop their budget needs.

Question 23. If the performance measures are used to develop budget needs, do you apply weights to any category of assets to place more priority on some assets over others? If yes, list the 5 assets having the highest weight.

Among the 22 agencies that use the performance measures to develop budget needs, the responses to the first part of the question are distributed as follows (see figure 61):

- Yes (8 SHAs).
- No (4 SHAs).
- Under development (10 SHAs).

Those agencies that use weighting to prioritize their highway assets included the following assets in their top-five list:

- Guardrail (3 SHAs).
- Shoulders (3 SHAs).
- Signs (3 SHAs).
- Marking (3 SHAs).
- Pavements (2 SHAs).
- Signals (2 SHAs).
- Snow & Ice (2 SHAs).
- Striping (2 SHAs).
- Potholes (2 SHAs).
- Other (6 SHAs).

Figure 62 shows the distribution of the top-five assets among the respondents.

Question 24. Are the results of the condition assessment used to program and schedule work activities?

Eighteen of 32 respondents to this question program their maintenance activities using the results of the condition assessment; nine agencies are still in the process of development; and 5 agencies do not link their maintenance schedule to the condition assessment system (see figure 63 for the distribution of the responses).

Question 25. Do you have a computerized maintenance management system in place?

Thirty-four agencies responded to this question, and their answers are distributed as follows (see figure 64):

- Yes (22 SHAs).
- No (5 SHAs).
- Under development (7 SHAs).

Question 26. If you have a computerized maintenance management system in place, does it use the results of the condition assessment to estimate budget needs and/or provide the information needed to evaluate different strategies?

An analysis of the 26 responses to this question suggests that currently a very small number of agencies (4 respondents) use the results of the condition assessment in their computerized maintenance management system (MMS) to make strategy- and budget-related decisions. Twelve agencies answered “No” to this question, while 10 SHAs are currently developing the tools to incorporate the condition assessment system in their MMS. Figure 65 shows the distribution of the agencies’ responses.

Question 27. If you have a computerized maintenance management system in place, does it use the results of the condition assessment to schedule work activities?

The 27 SHAs’ responses to this question are distributed as follows (see figure 66):

- Yes (5 SHAs).
- No (13 SHAs).
- Under development (9 SHAs).

Question 28. Are your maintenance work priorities and budget allocations linked to customer expectations?

The survey shows that only 25 percent of the respondents (8 of 32 SHAs) are currently linking their work priorities and budget allocations to customer expectations. Another 25 percent of the agencies (8 of 32) are in the process of developing such a link, while a half of the respondents (16 SHAs) do not consider customer expectations in their prioritization and budget allocation policies. Figure 67 provides the distribution of the SHAs’ responses.

Question 29. In what order would your agency prioritize these four strategic objectives? Number your responses 1 to 4, with 1 being the highest priority.

Thirty-four agencies responded to this question. The distribution of responses is shown in figure 68. Figure 68 indicates that the great majority of the agencies (28 of 34) place safety as the top priority. The following two objectives—preservation of asset investment and maintenance operations—are placed by most agencies as the second or third priority. All respondents but one consider aesthetic as the least important strategic objective.

Implementation

In the last section of the questionnaire, the respondents were asked to evaluate the success of the implementation of their CAS. This section summarizes the analysis of the agencies' responses related to the CAS implementation.

Question 30. Has your condition assessment system helped your agency to achieve more consistent conditions on a statewide basis?

According to the survey, in 23 of 30 SHAs, conditions that are more consistent were achieved using CAS. Seven agencies provided a negative answer (see figure 69) to this question.

Question 31. Identify all those who are provided the results of the condition assessment surveys.

Thirty agencies answered this question. The distribution of their responses (shown in figure 70) indicates that the results of the condition assessment surveys are provided to the following groups:

- Employees (25 SHAs).
- Legislature (16 SHAs).
- Governor (11 SHAs).
- Public (5 SHAs).
- Stakeholders (9 SHAs).
- Management (27 SHAs).

The analysis of the responses above suggests that in most cases the results of the condition surveys do not go beyond the agency level. Slightly more than one half of the respondents inform the legislature about the assets' condition, and a small number of agencies provide the public with the results of the condition assessment surveys.

Question 32. Did you have an education component to familiarize your employees with the program? If yes, please describe.

The survey results indicate that 15 of 29 agencies responding to this question provided different forms of education to their employees to familiarize them with the condition assessment program (see figure 71). The following forms of education are reported (see figure 72):

- Training (11 SHAs).
- Meeting (2 SHAs).
- Presentations (3 SHAs).
- Other (3 SHAs).

In one agency, District Employees were invited to assist with the evaluations by going on week-long trips to other Districts. This provided a hands-on approach to training that was very effective. At least two agencies mentioned on-line training or use of the intranet to convey information.

Question 33. Has your condition assessment system helped your agency to identify maintenance priorities on a statewide basis?

Twenty-nine agencies responded to this question, while 25 of them find the CAS helpful in identifying maintenance priorities on a statewide basis (see figure 73).

Question 34. What are the top 3 pieces of advice you would share with an agency just starting the development of its condition assessment techniques?

SHA provided a variety of suggestions to agencies beginning the development of their condition assessment techniques. Figure 74 shows the distribution of the answers that were provided. The top six pieces of advice provided by the respondents are as follows:

1. Obtain buy-in from field professionals (9 responses).
2. Learn from other States (7 responses).
3. Develop performance measures (7 responses).
4. Get high-level support (6 responses).
5. Keep it simple (5 responses).
6. Provide adequate training (5 responses).

Other suggestions include the following:

- Standardize as much as possible by using clear definitions for rating criteria, for example.
- Consider more than a handful of examples before tailoring a rating criteria to your needs.
- Budget adequate resources and provide raters with everything they need to complete the work.
- Keep it manageable and practical.
- Start with your most valuable asset first.

Question 35. What 3 factors most contributed to the success of your system?

There were a total of 69 responses from 23 respondents to this question. The top five factors identified as most important to success of the condition assessment system (see figure 75) are provided below:

1. Upper management support (9 responses).
2. Keep it simple (6 responses).
3. Adequate staffing (6 responses).
4. Training (6 responses).
5. Experienced field personnel (6 responses).

Other factors that contributed to success include the following:

- Field/Central Office participation in the development of the rating system.
- Extracting information that was available from other systems.
- Establishing a commitment across the board.
- Allowing sufficient time to develop and implement the program.

- Building instant credibility by using experience maintenance supervisors to conduct evaluations.
- Identifying a project champion to see the project through.

Question 36. Is your condition assessment system part of an overall Asset Management Program?

Out of 31 respondents, nine report that their CAS is part of an overall Asset Management Program, while seven agencies do not consider CAS as part of the program. Fifteen agencies do not have an overall Asset Management Program. Figure 76 provides the distribution of the SHAs' responses to this question.

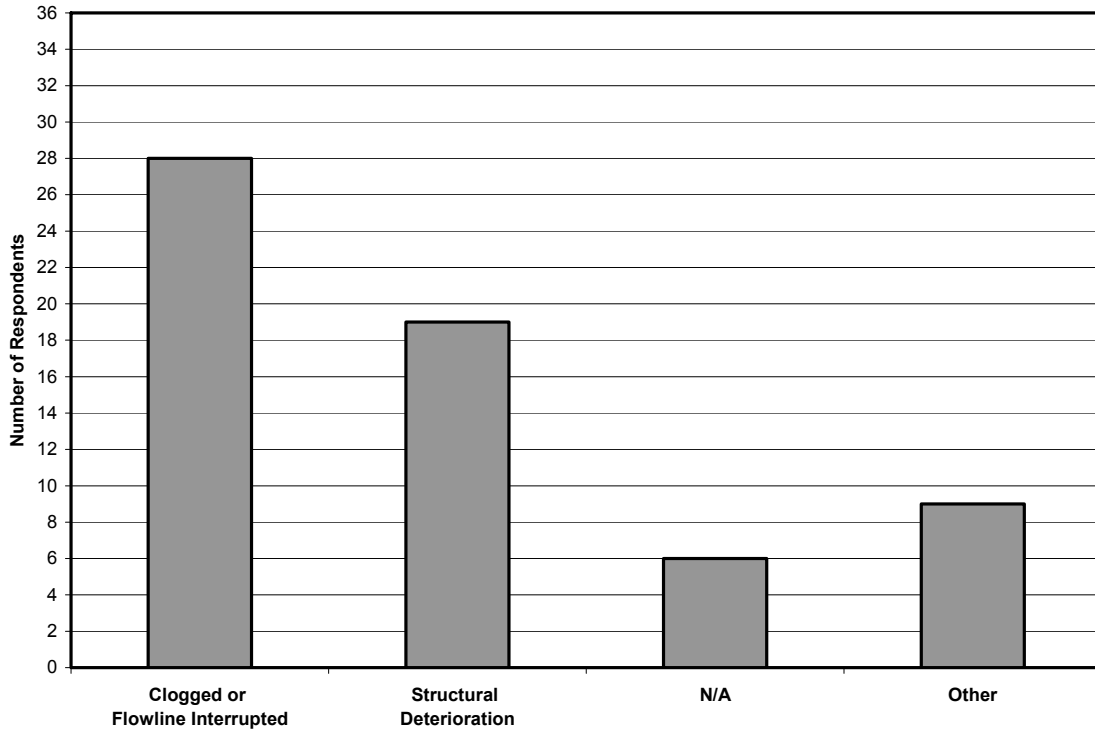


Figure 7. Drainage assets – Culvert condition attributes.

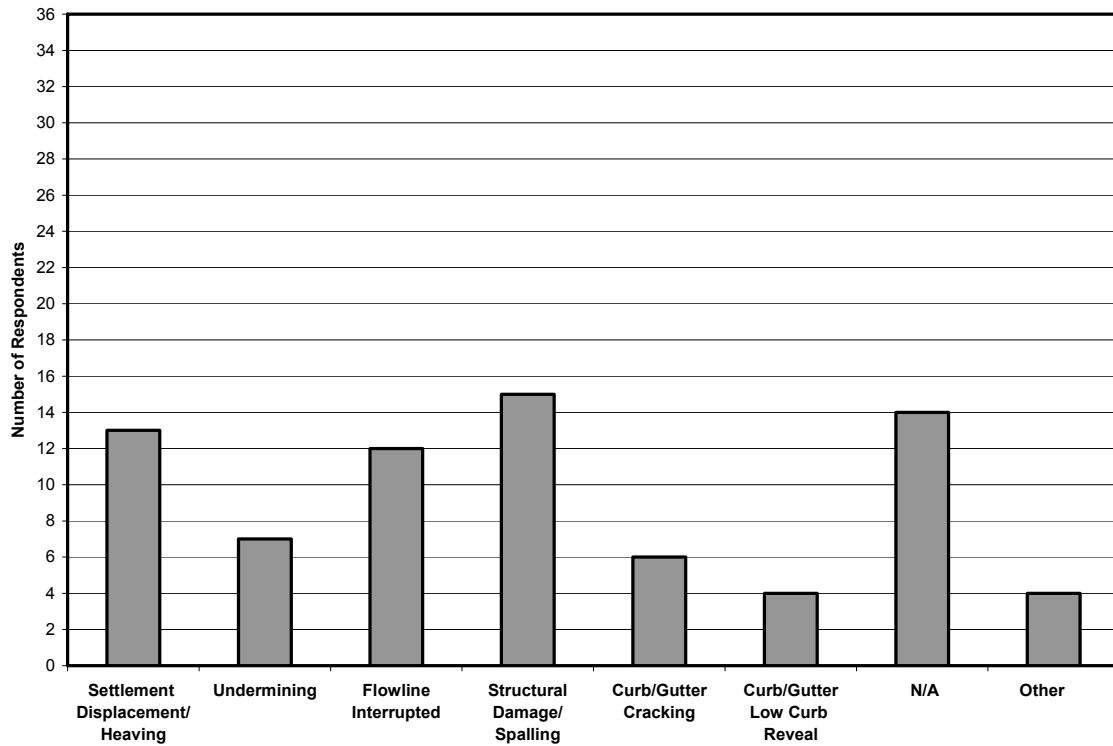


Figure 8. Drainage assets – Curb and gutter condition attributes.

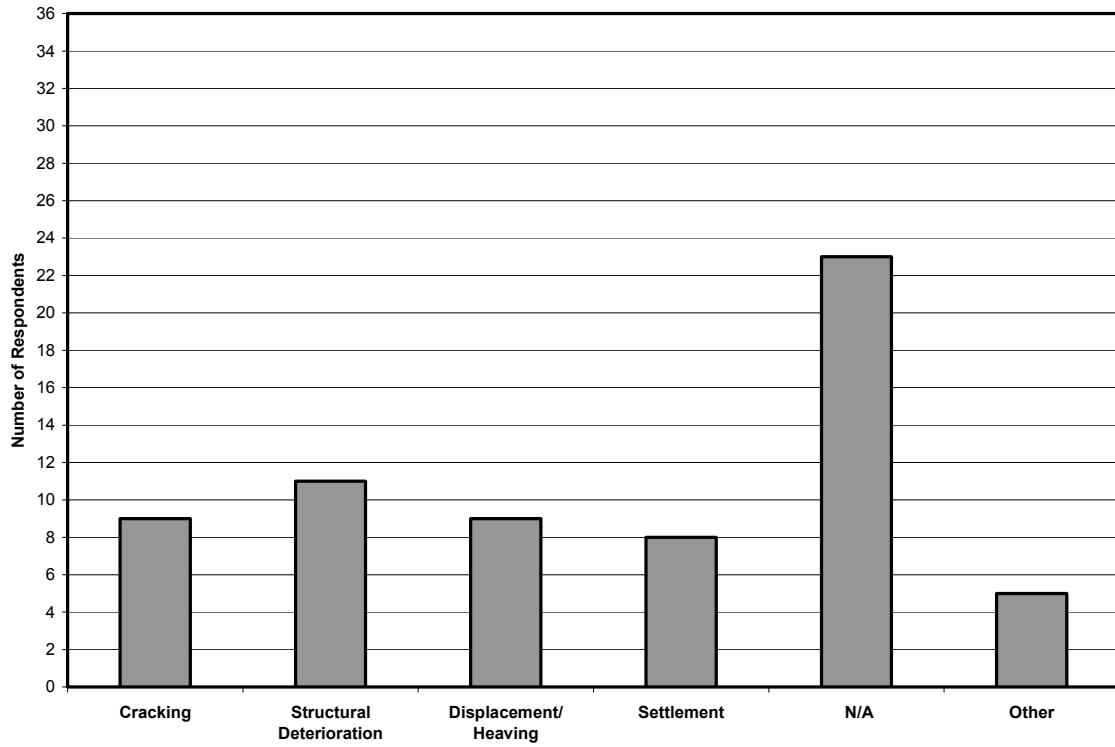


Figure 9. Drainage assets – Sidewalk condition attributes.

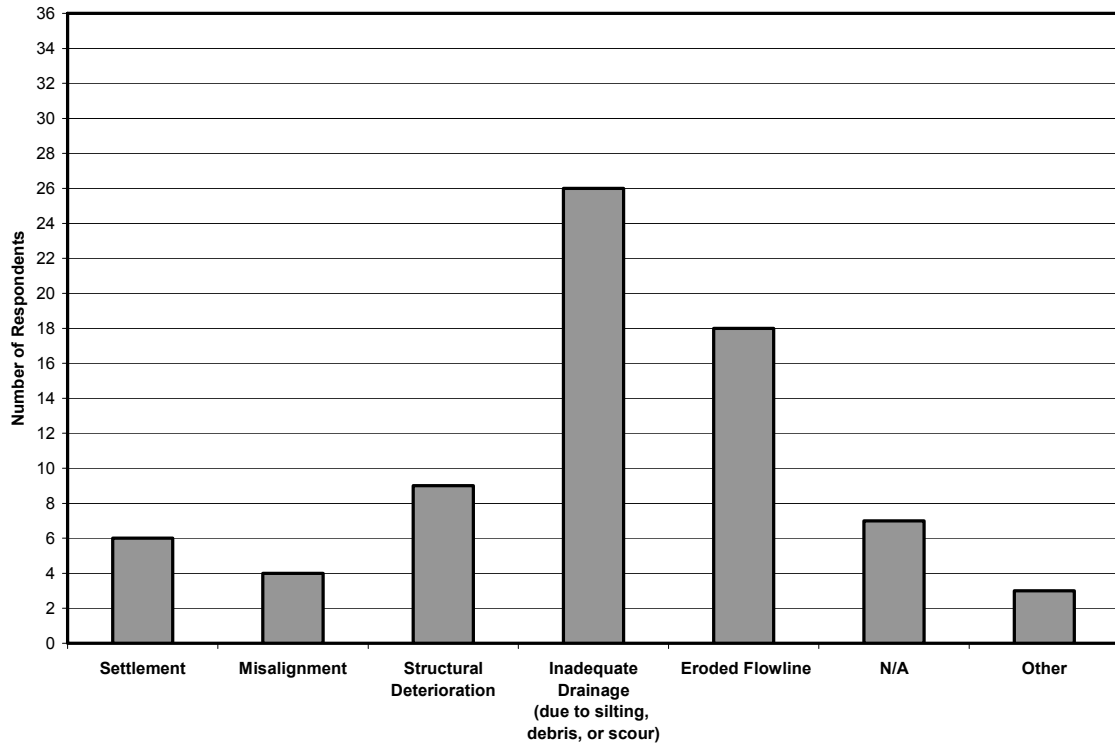


Figure 10. Drainage assets – Ditch/slope condition attributes.

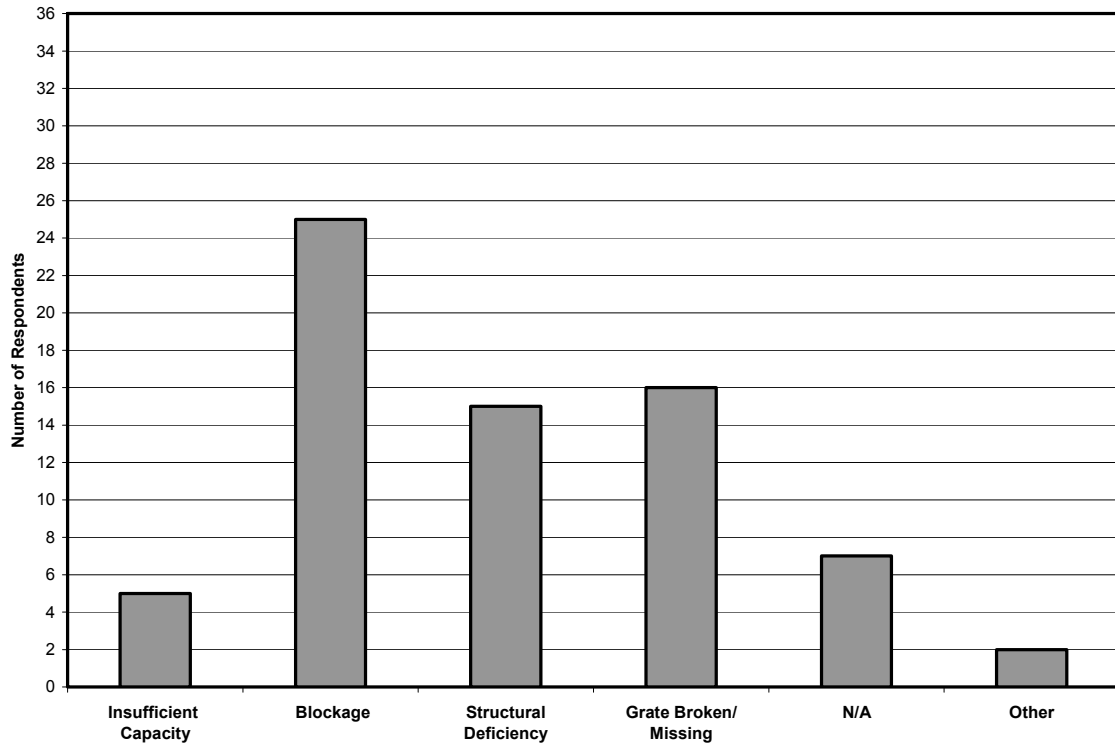


Figure 11. Drainage assets – Drop inlet condition attributes.

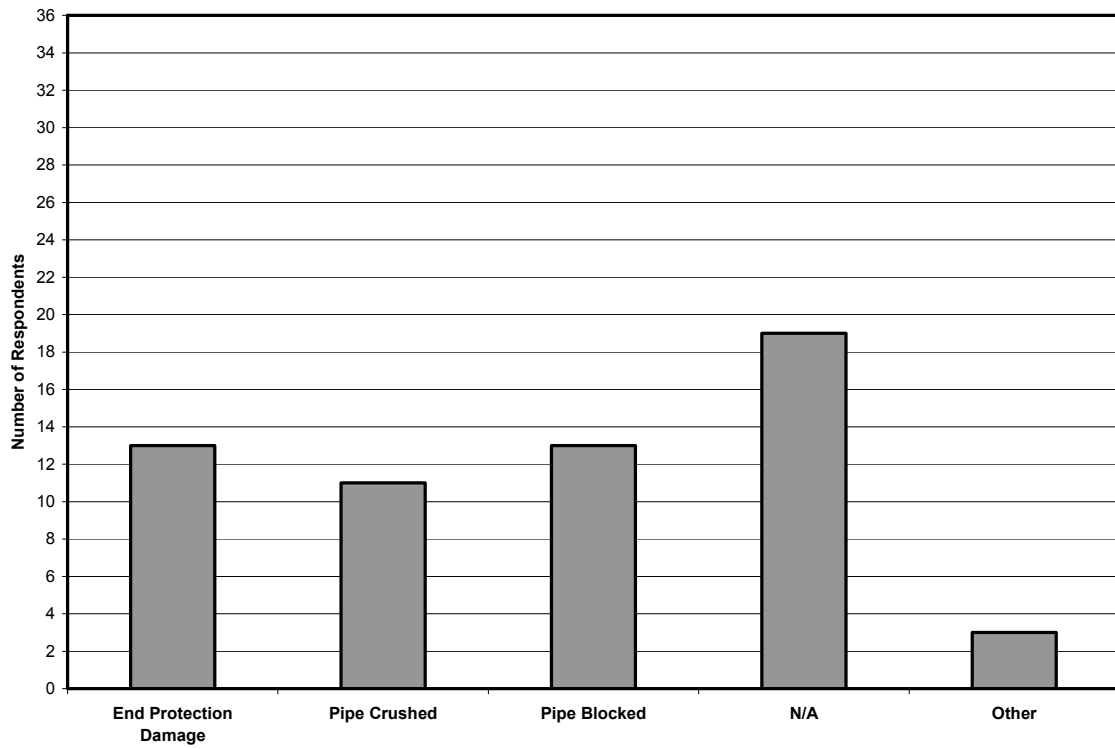


Figure 12. Drainage assets – Underdrain and edgedrain condition attributes.

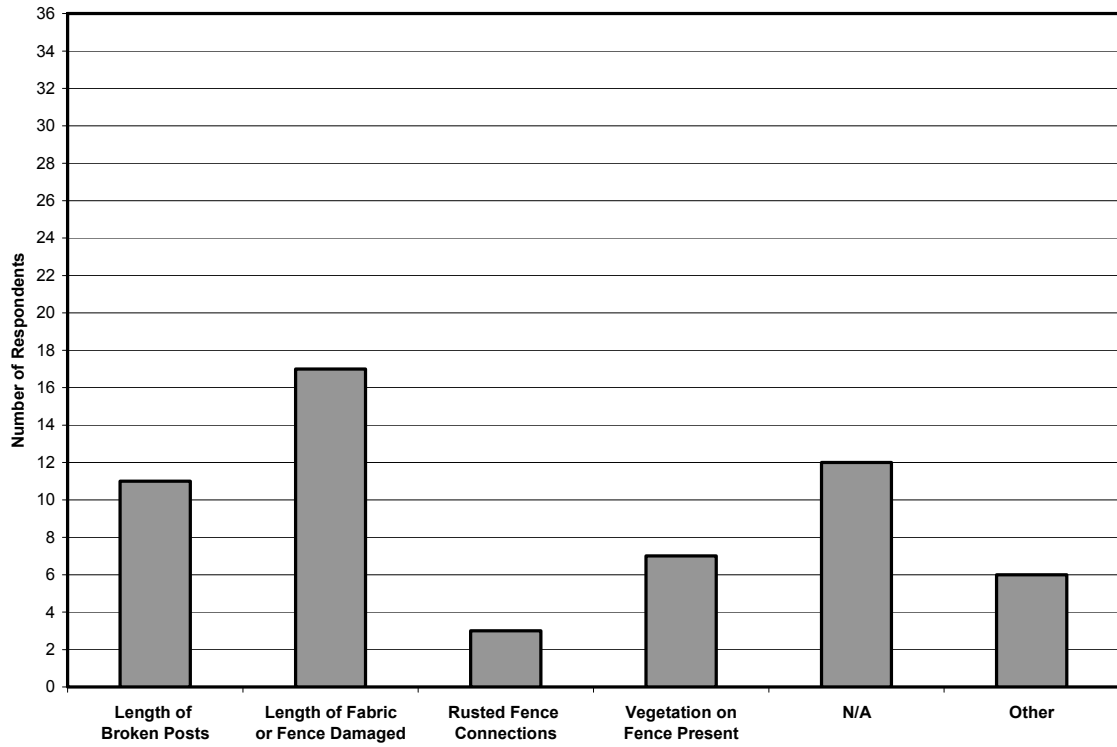


Figure 13. Roadside assets – Fence condition attributes.

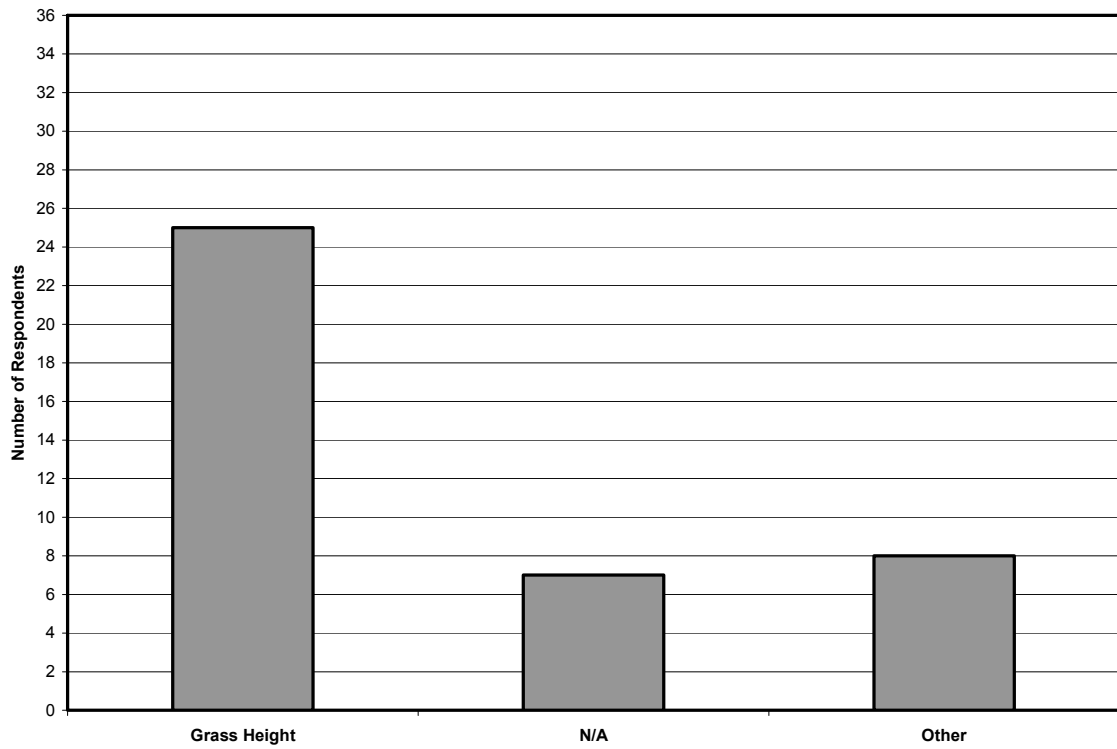


Figure 14. Roadside assets – Grass mowing condition attributes.

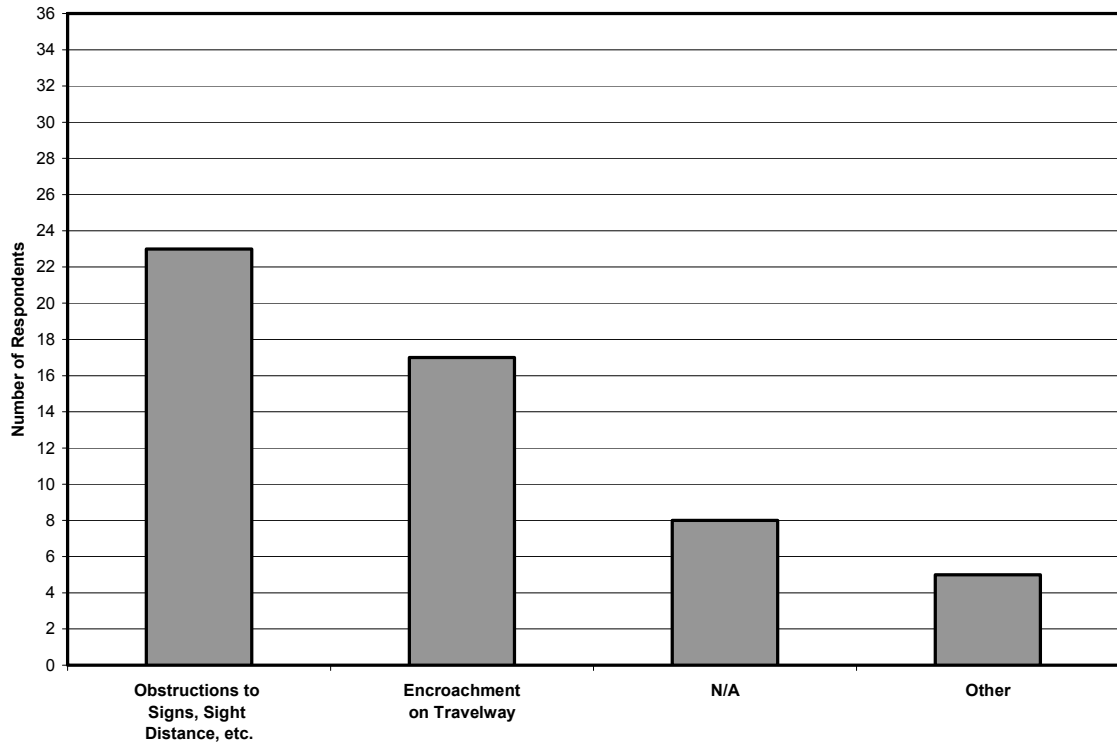


Figure 15. Roadside assets – Brush condition attributes.

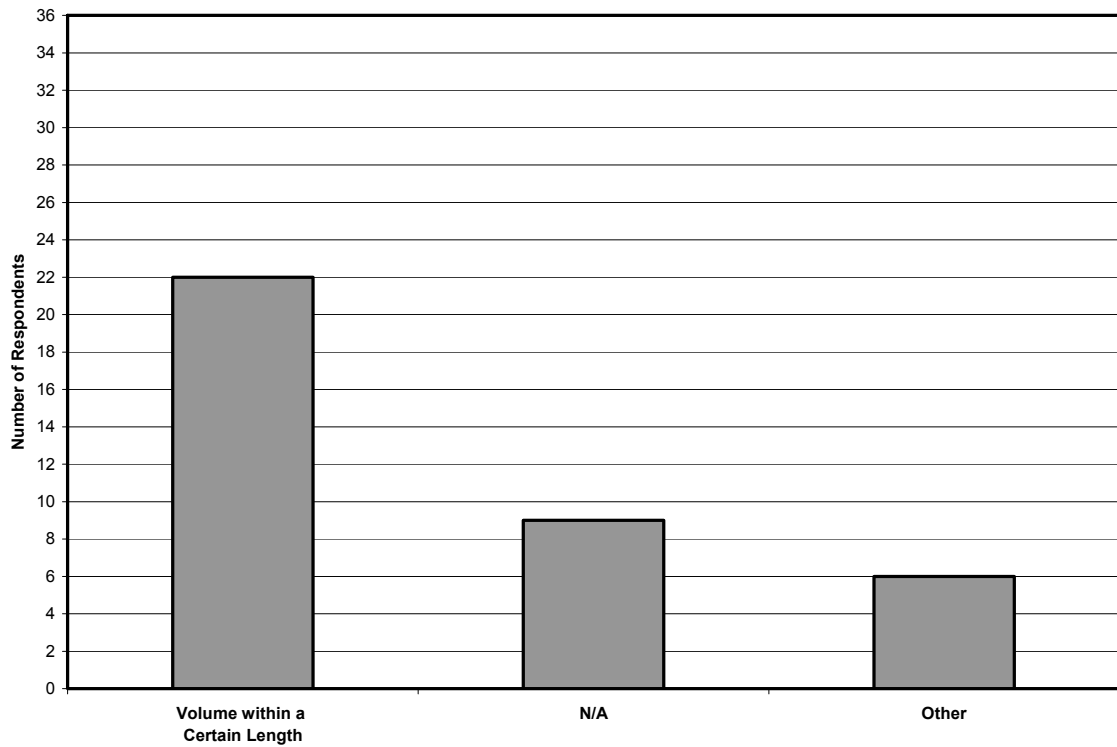


Figure 16. Roadside assets – Litter condition attributes.

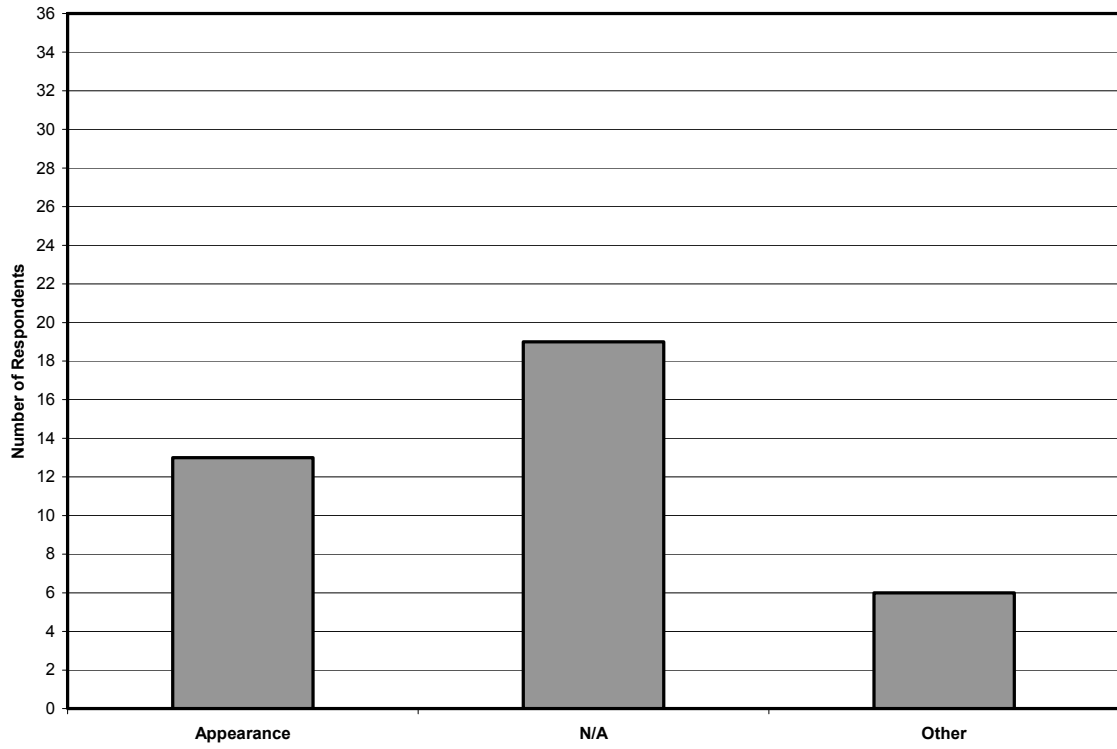


Figure 17. Roadside assets – Landscaping condition attributes.

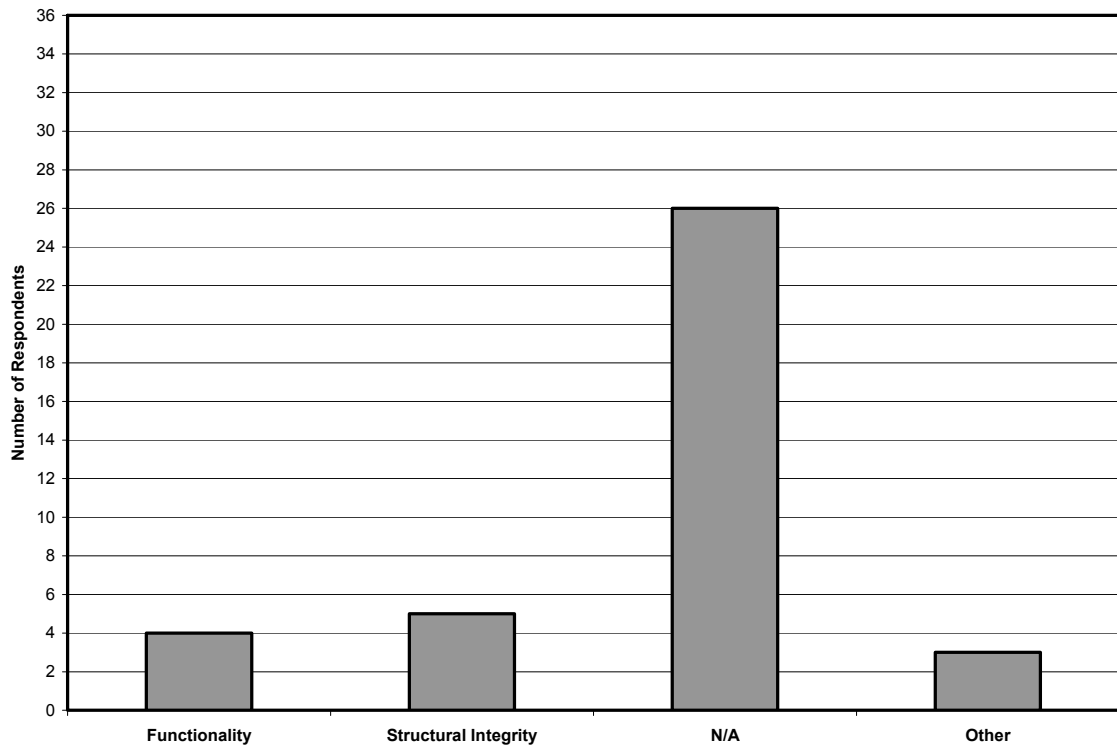


Figure 18. Roadside assets – Sound barrier condition attributes.

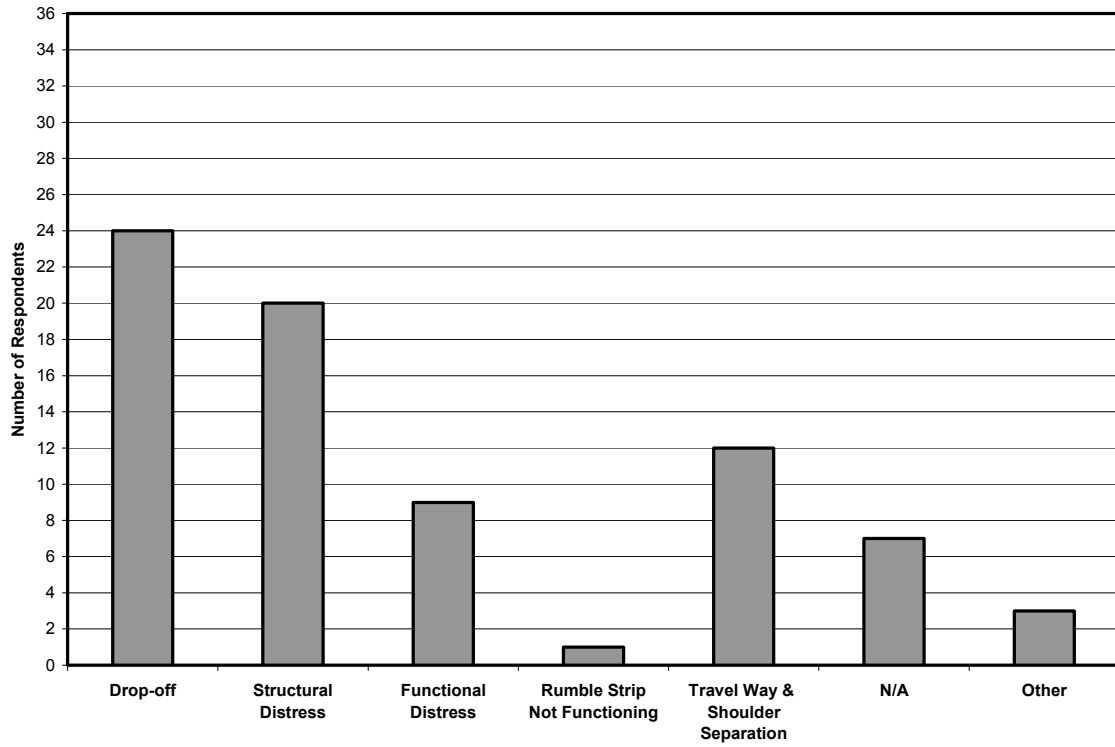


Figure 19. Pavement assets – Paved shoulder condition attributes.

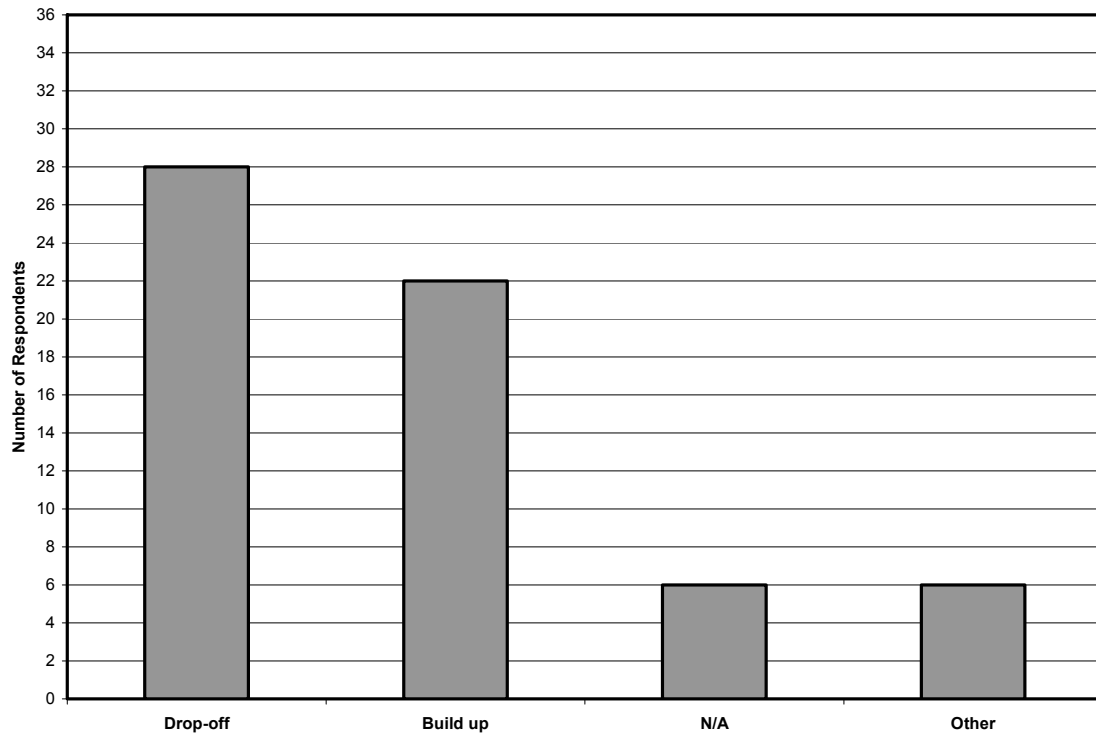


Figure 20. Pavement assets – Unpaved shoulder condition attributes.

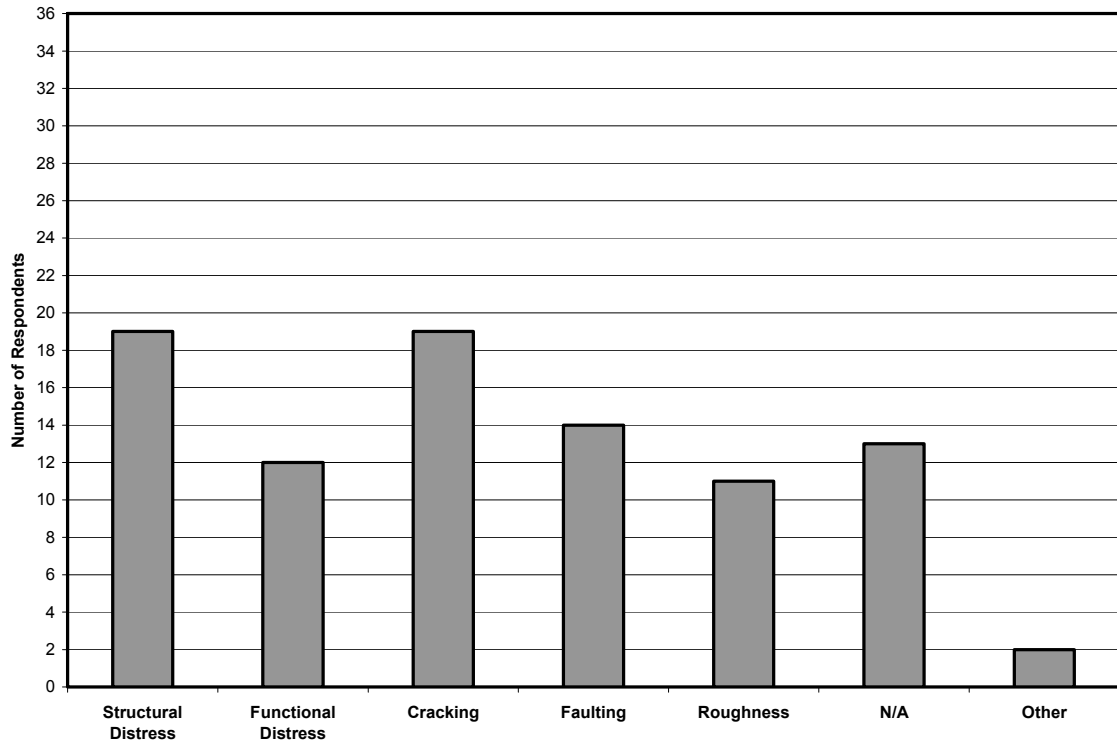


Figure 21. Pavement assets – Paved surfaces condition attributes.

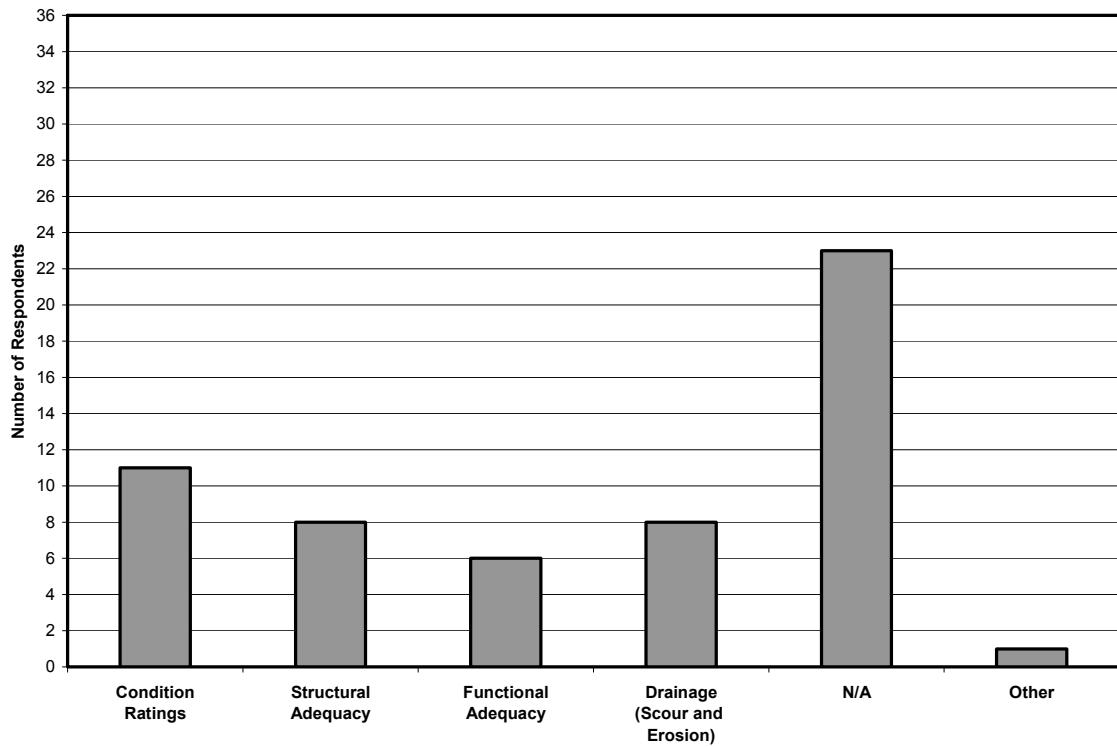


Figure 22. Bridge condition attributes.

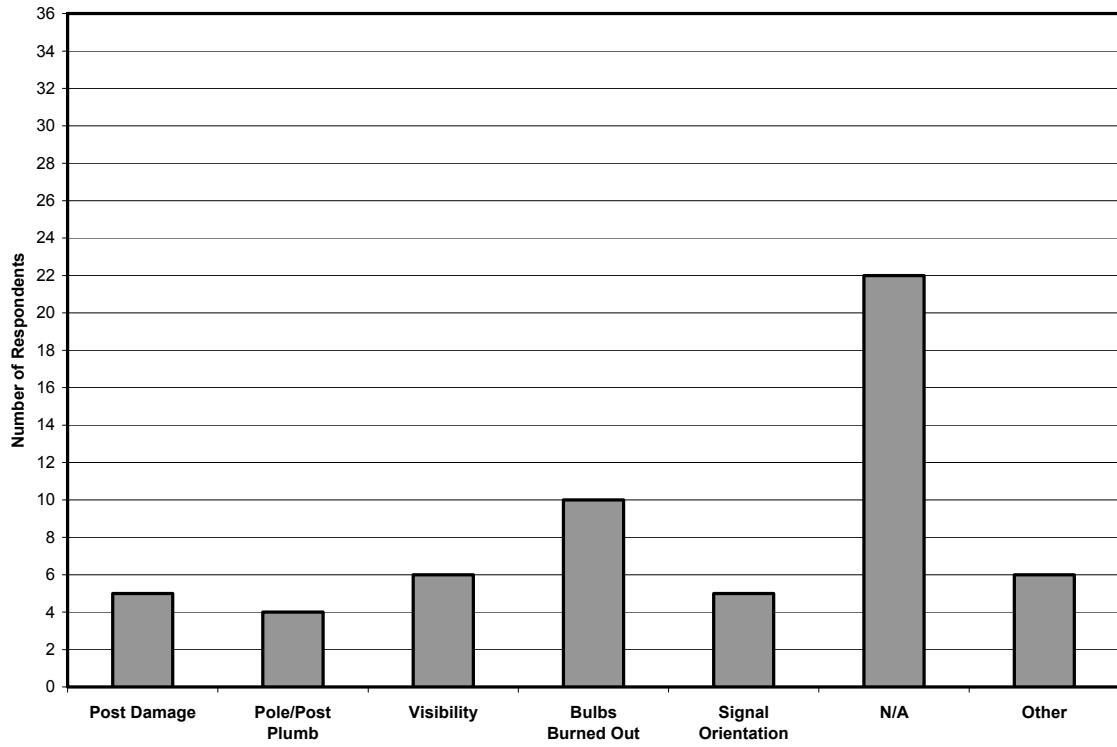


Figure 23. Traffic items assets – Signals condition attributes.

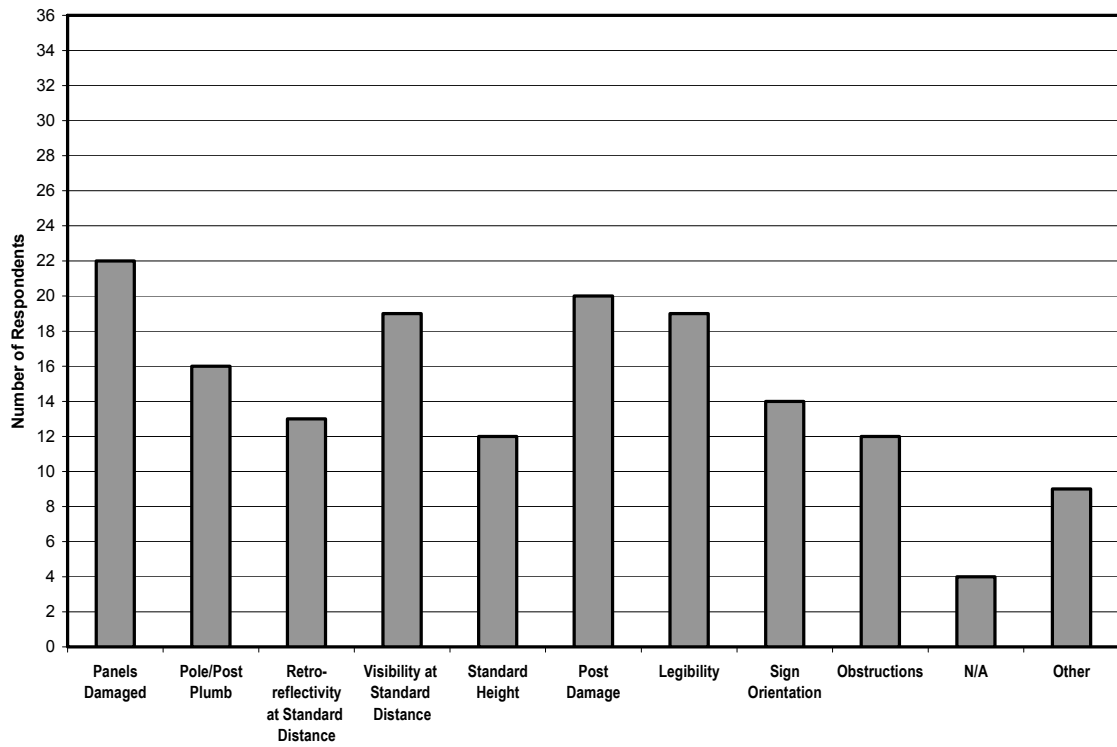


Figure 24. Traffic items assets – Signs condition attributes.

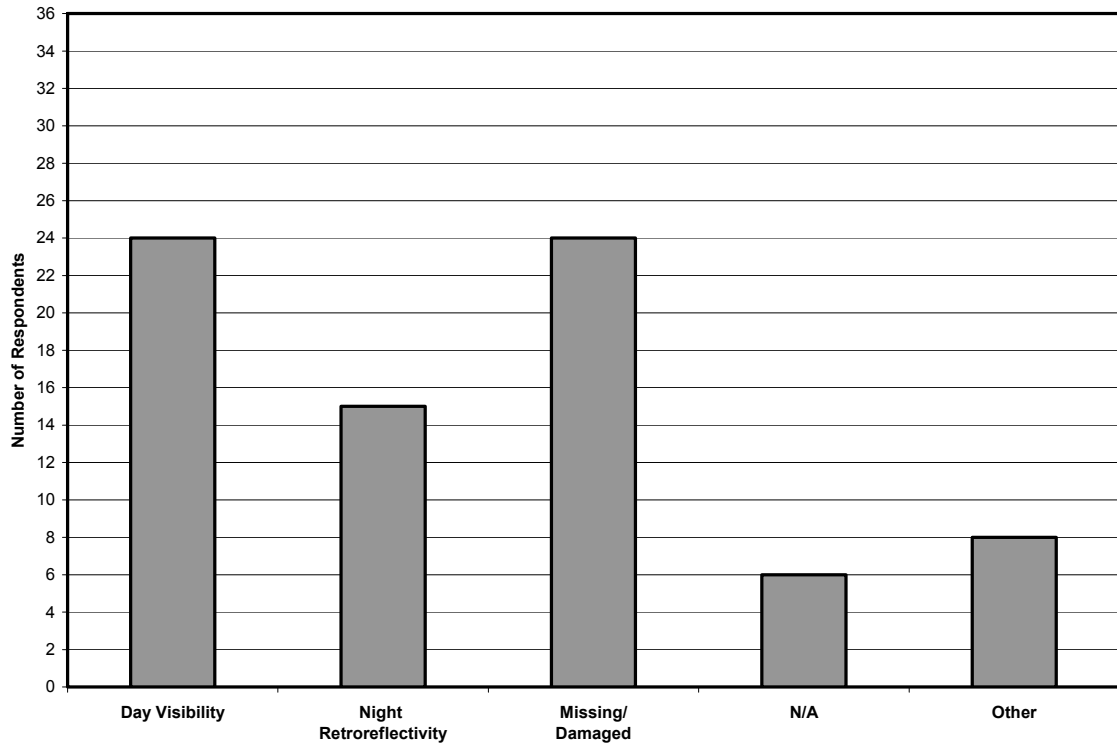


Figure 25. Traffic items assets – Pavement marking condition attributes.

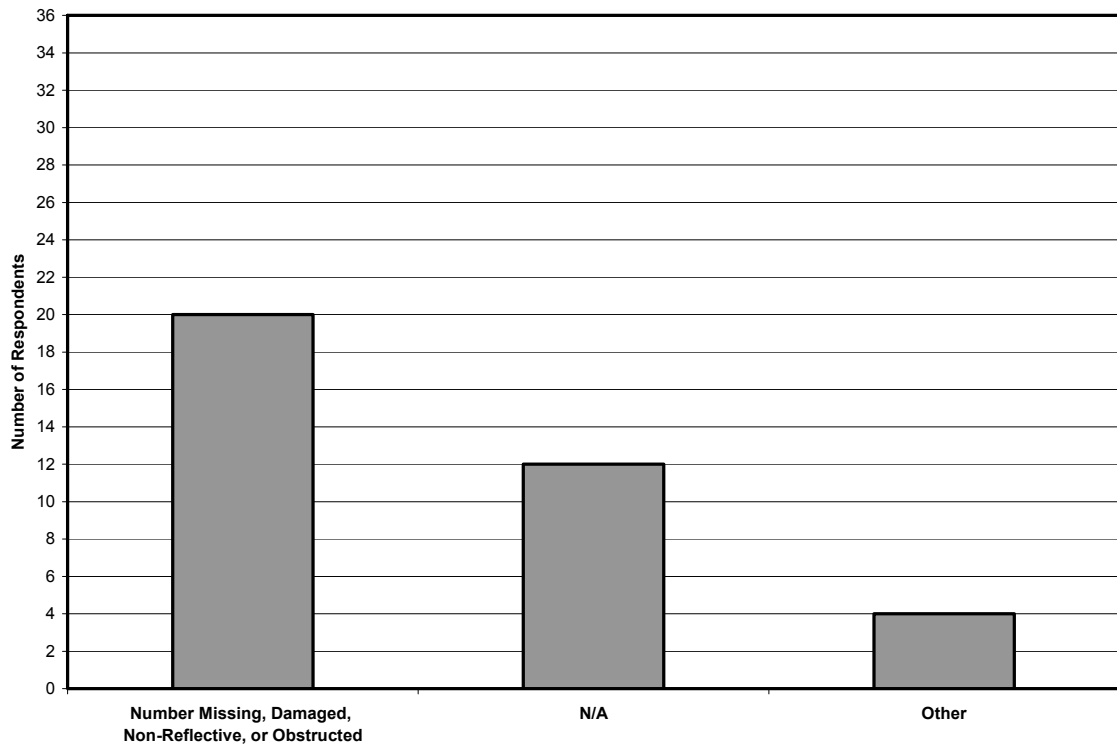


Figure 26. Traffic items assets – Pavement marker condition attributes.

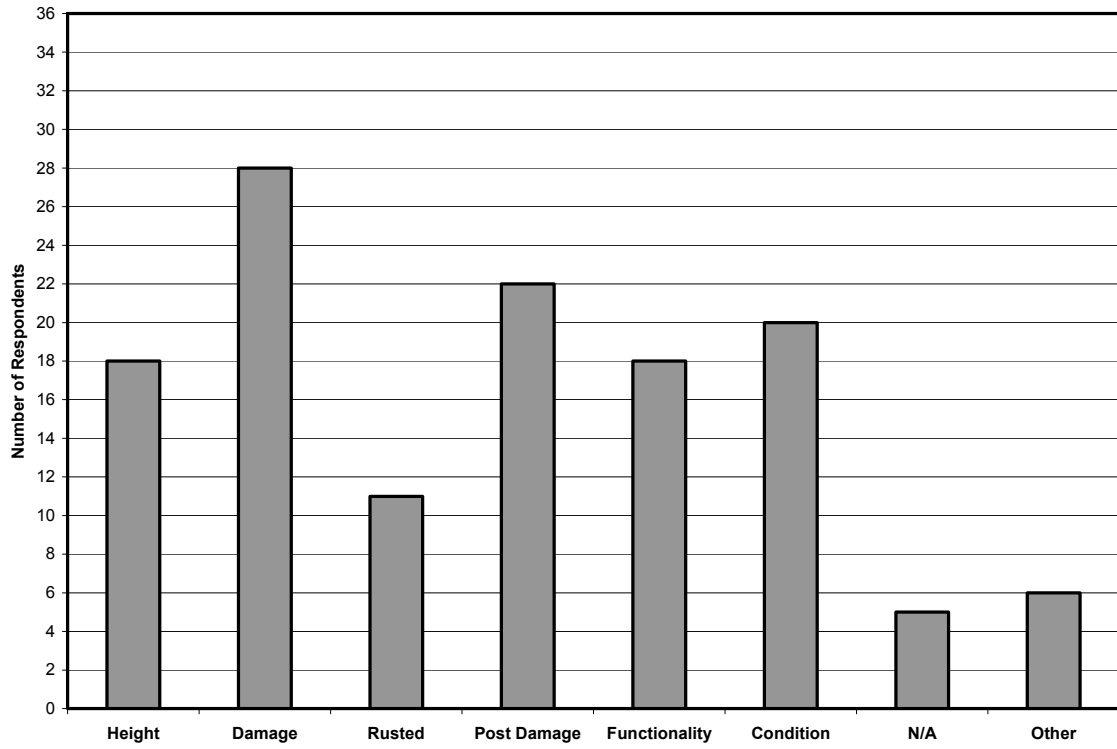


Figure 27. Traffic items assets – Guardrail condition attributes.

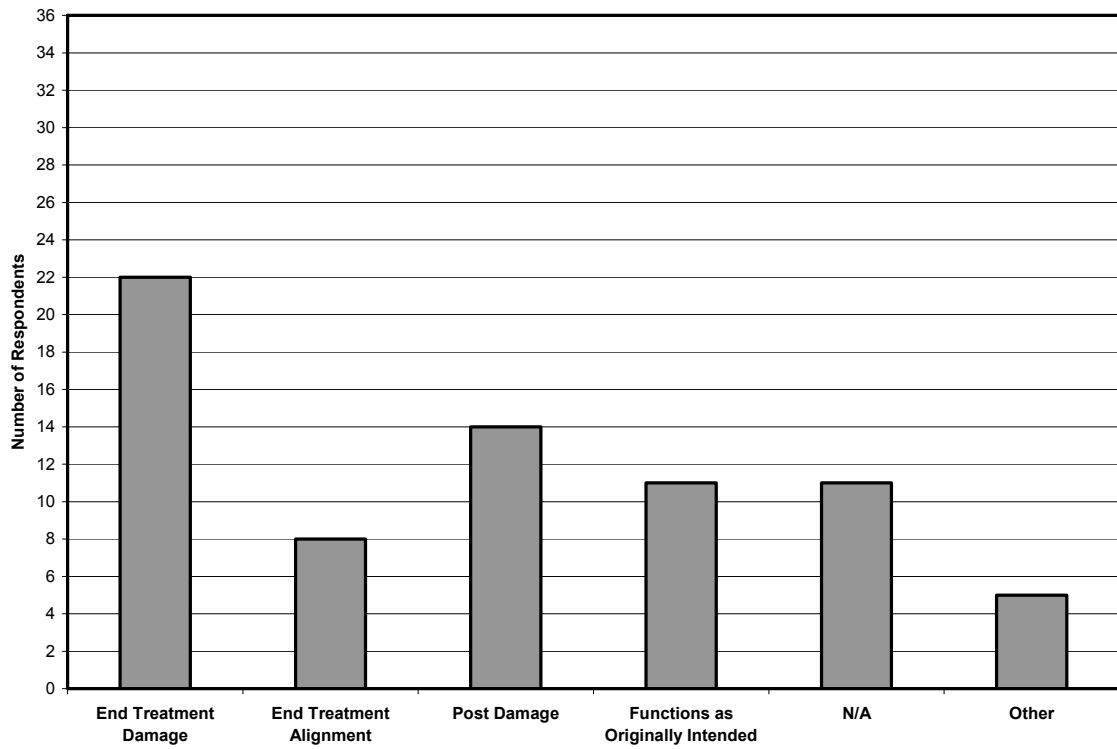


Figure 28. Traffic items assets – Guardrail end treatment condition attributes.

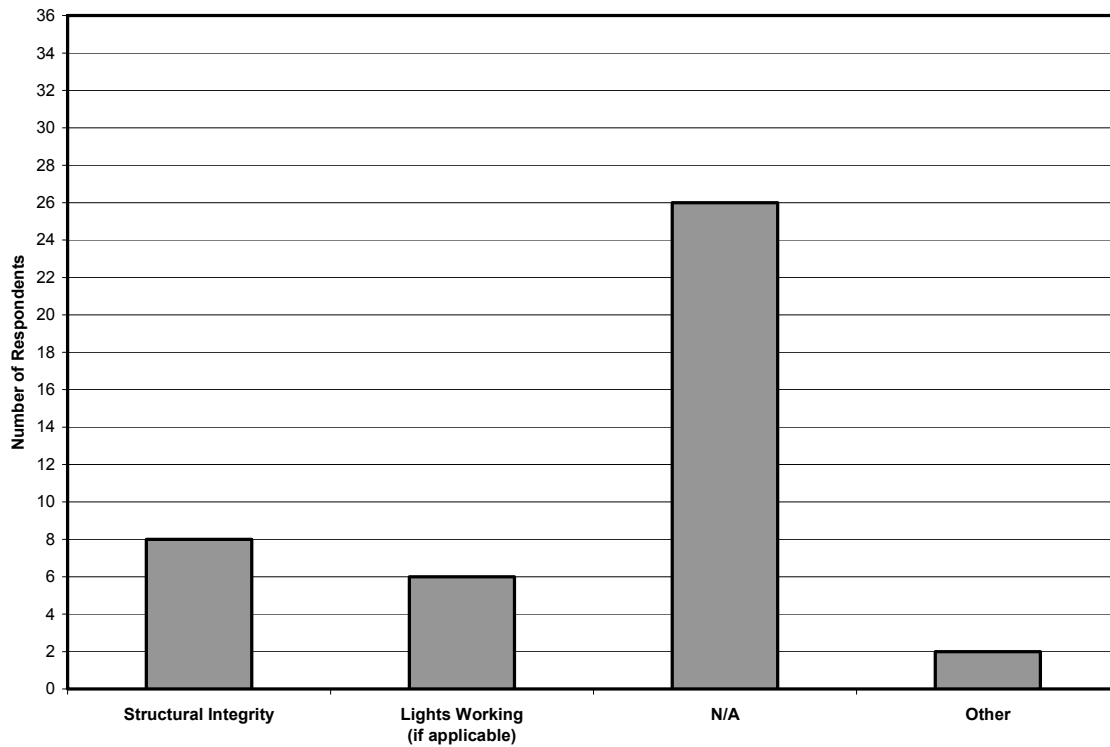


Figure 29. Traffic items assets – Overhead sign structure condition attributes.

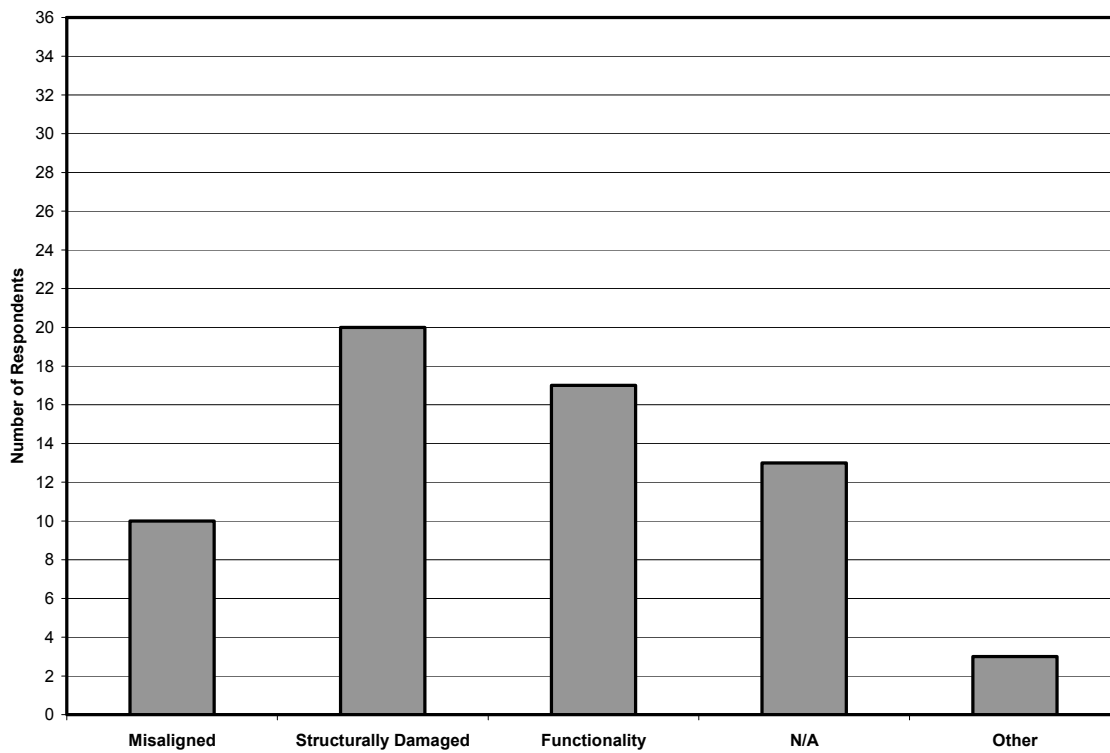


Figure 30. Traffic items assets – Impact attenuator condition attributes.

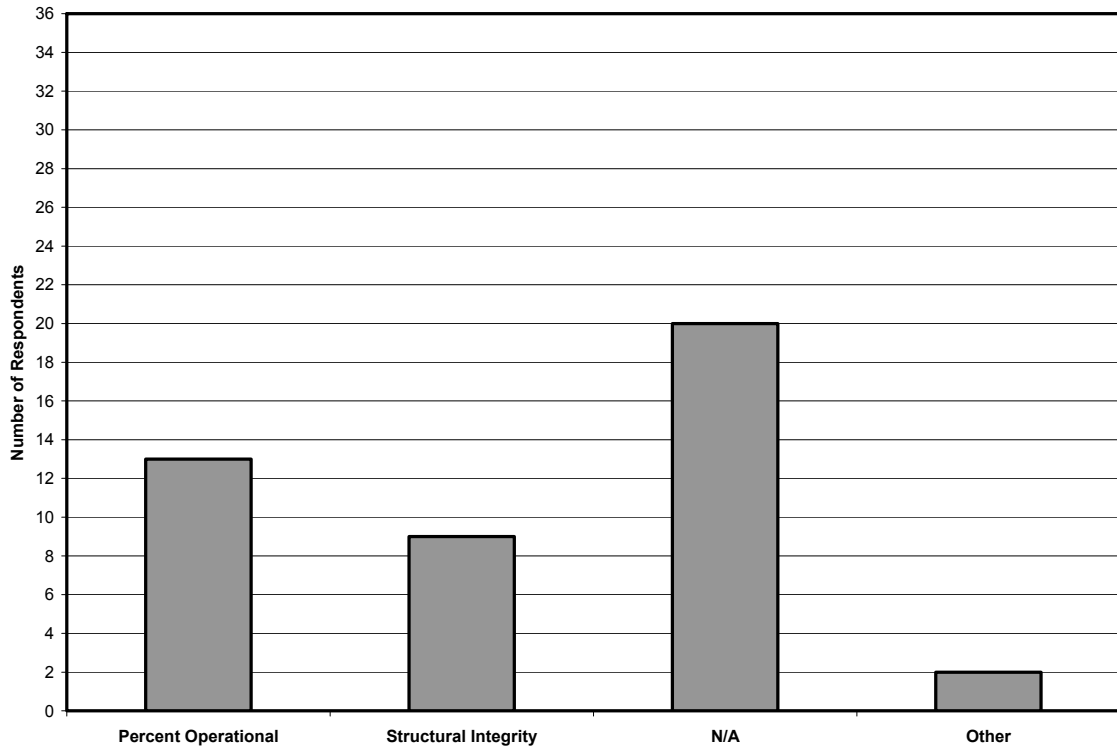


Figure 31. Traffic items assets – Highway lighting condition attributes.

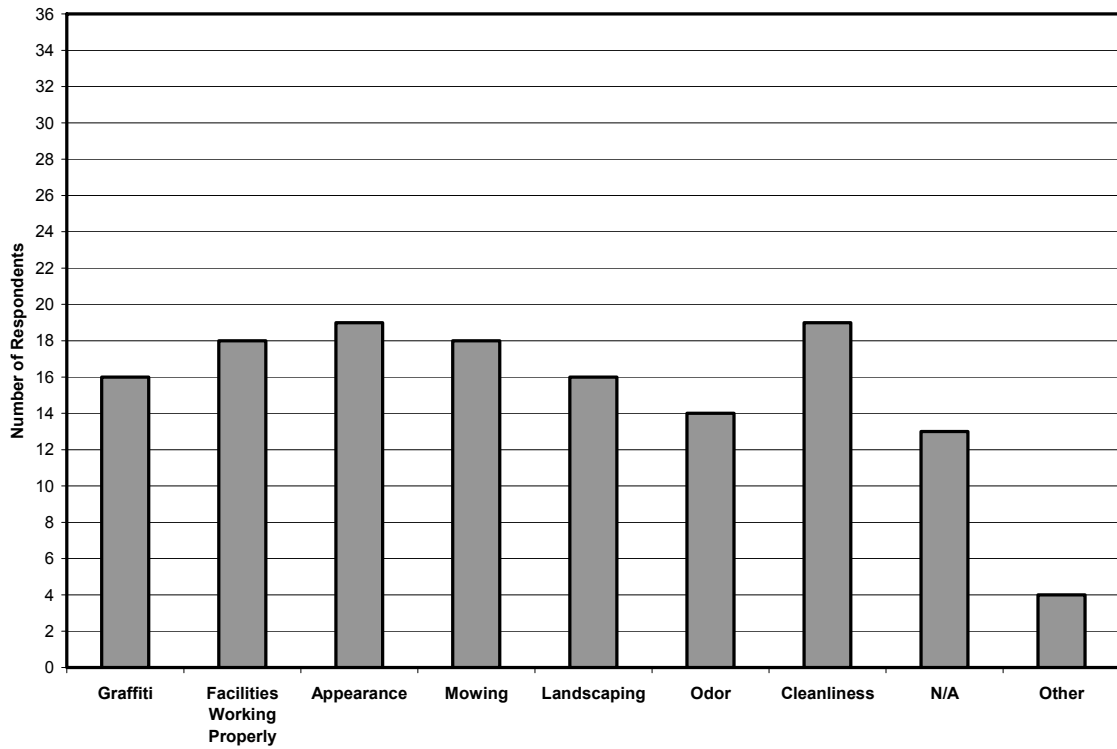


Figure 32. Special facilities assets – Rest areas condition attributes.

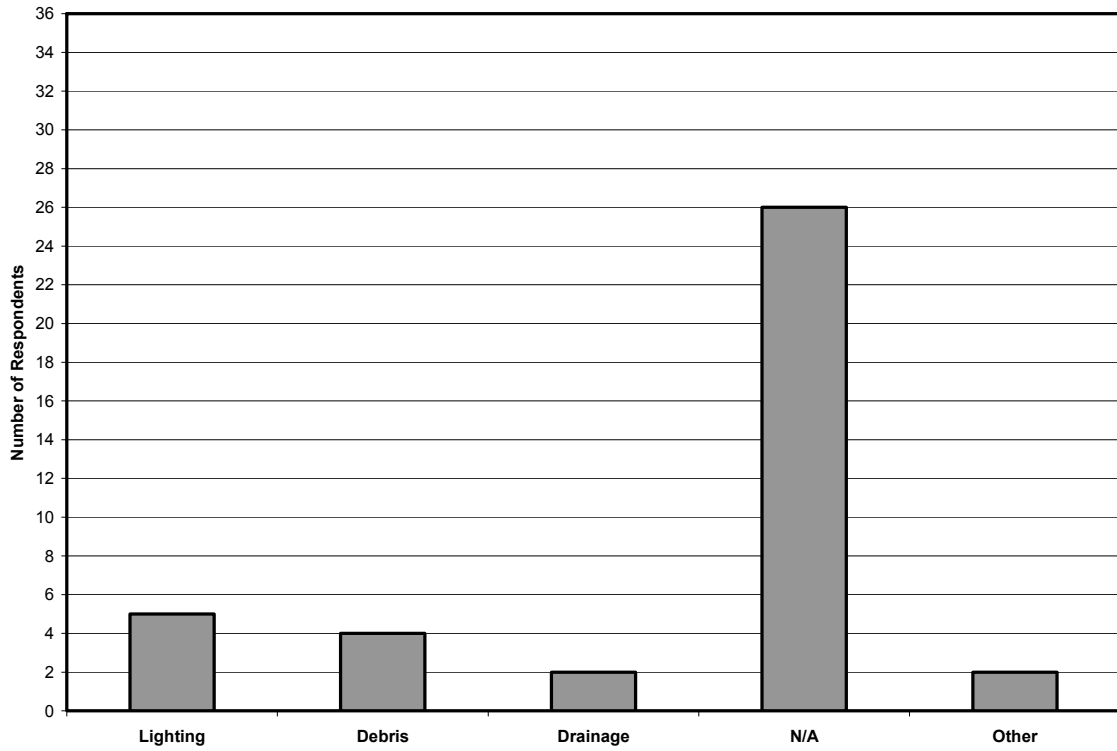


Figure 33. Special facilities assets – Tunnel condition attributes.

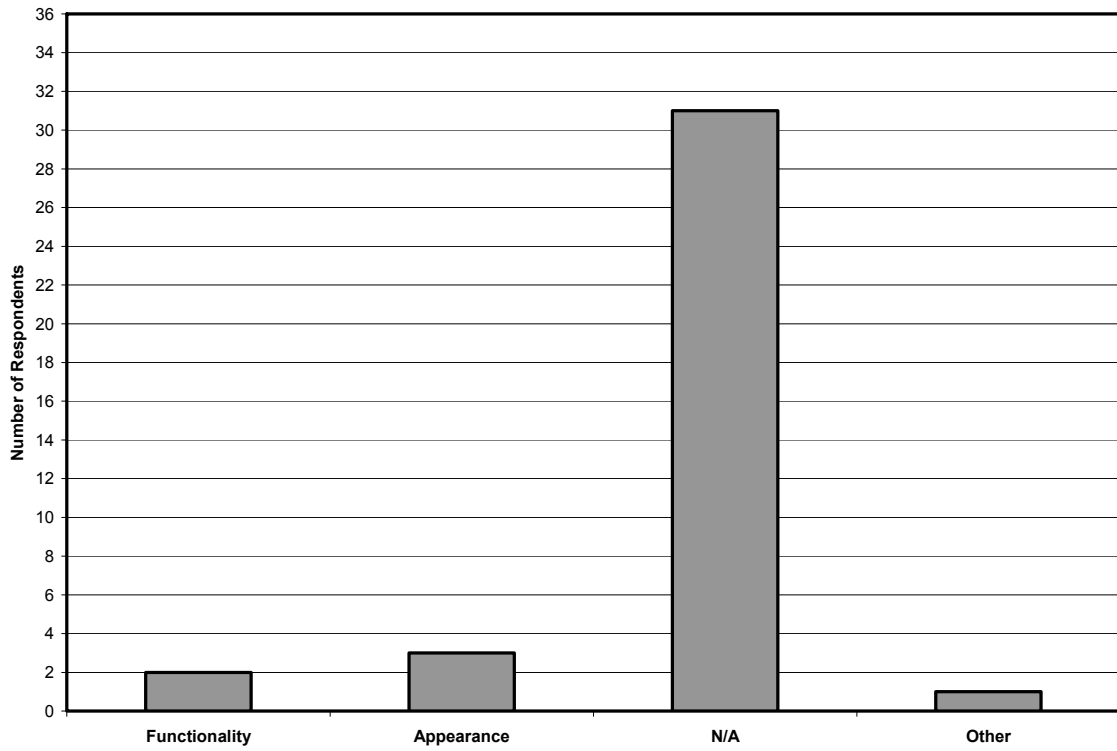


Figure 34. Special facilities assets – Weigh station condition attributes.

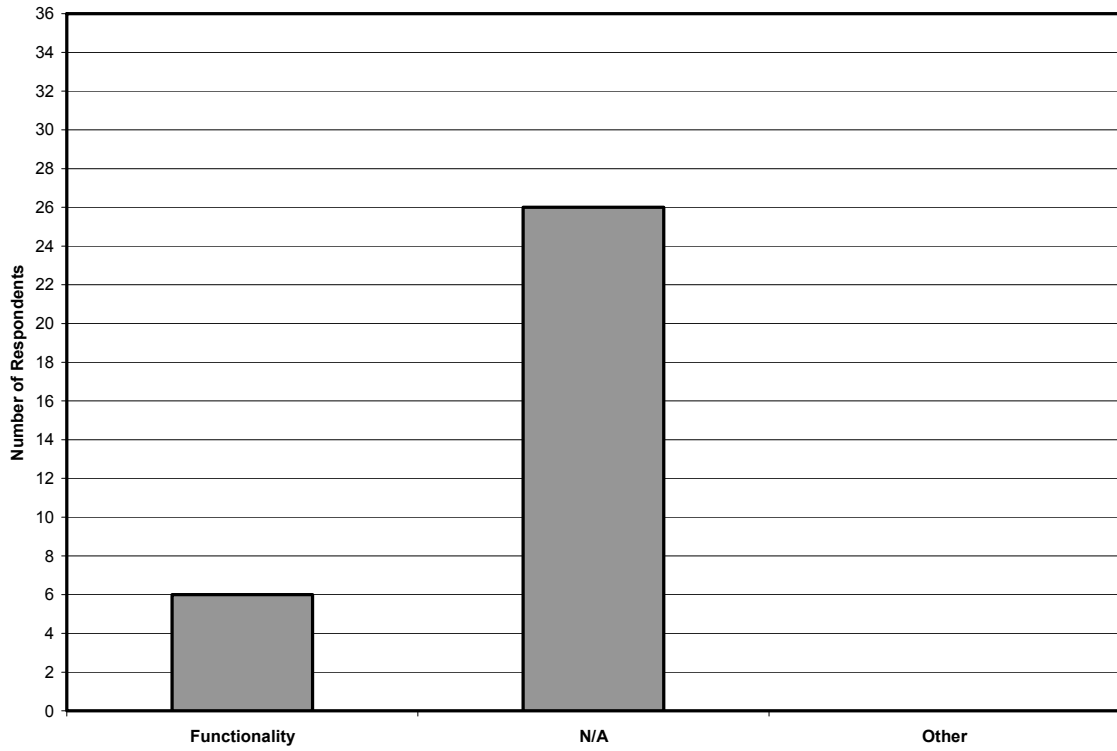


Figure 35. Special facilities assets – Traffic monitoring system condition attributes.

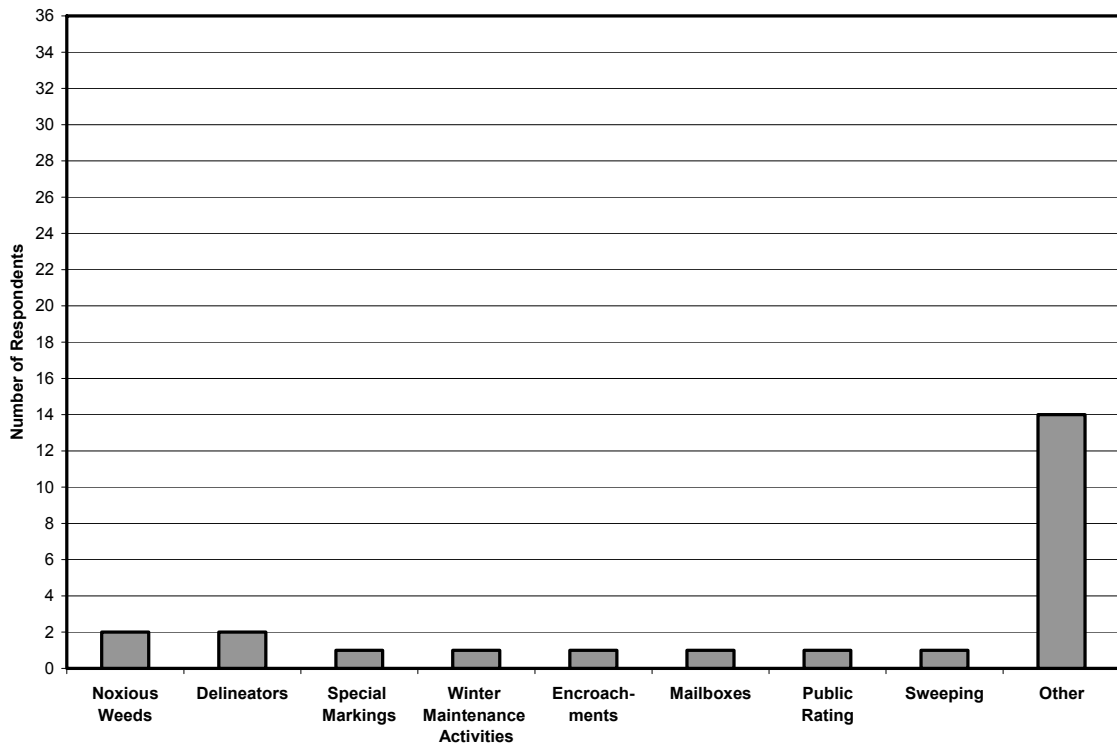


Figure 36. Other assets condition attributes.

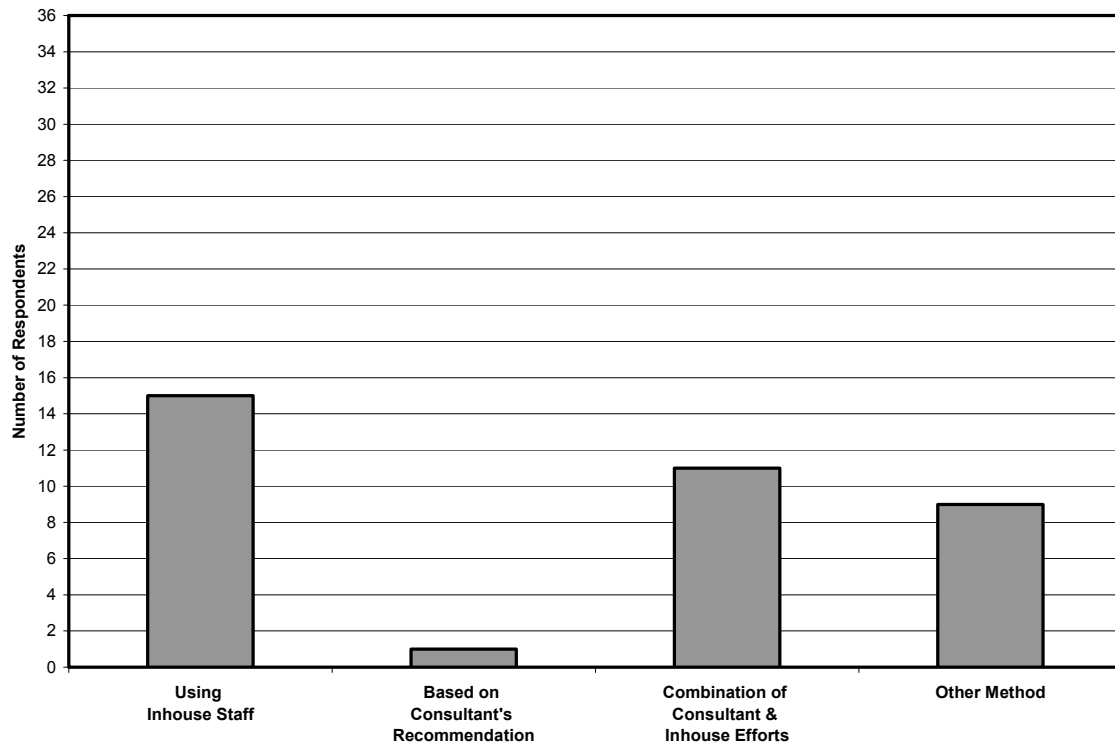


Figure 37. Methods used to develop condition assessment system (CAS) (Question 1).

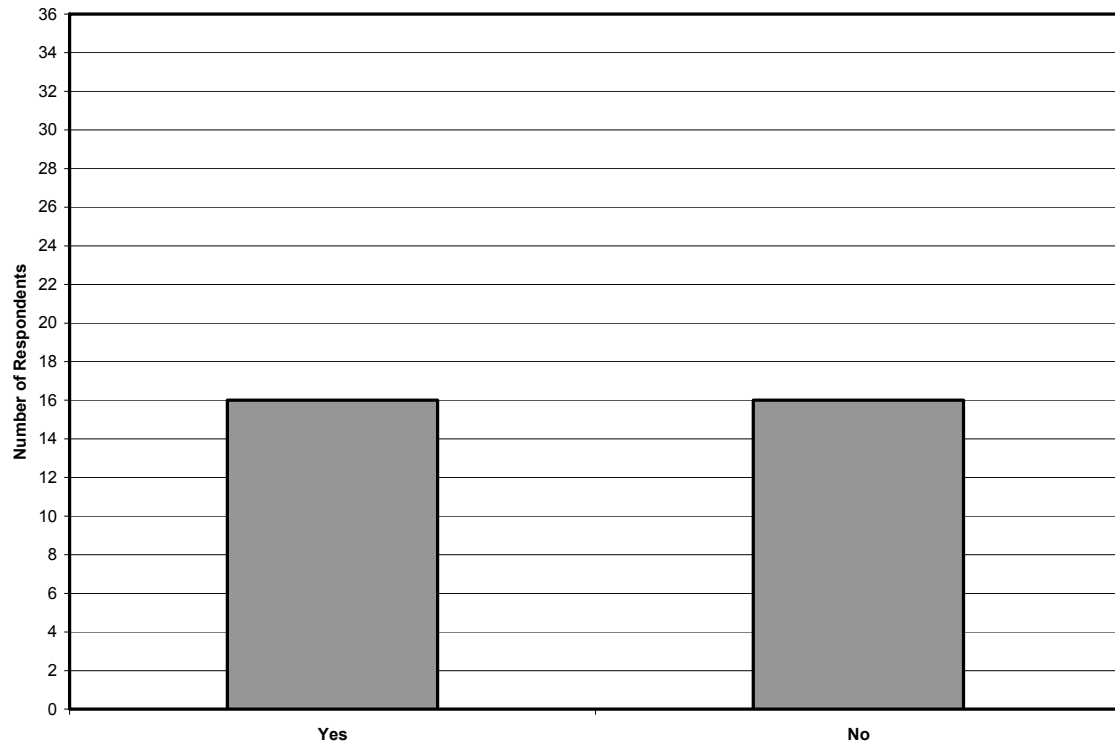


Figure 38. Use of customer input to develop or modify condition assessment method (Question 2).

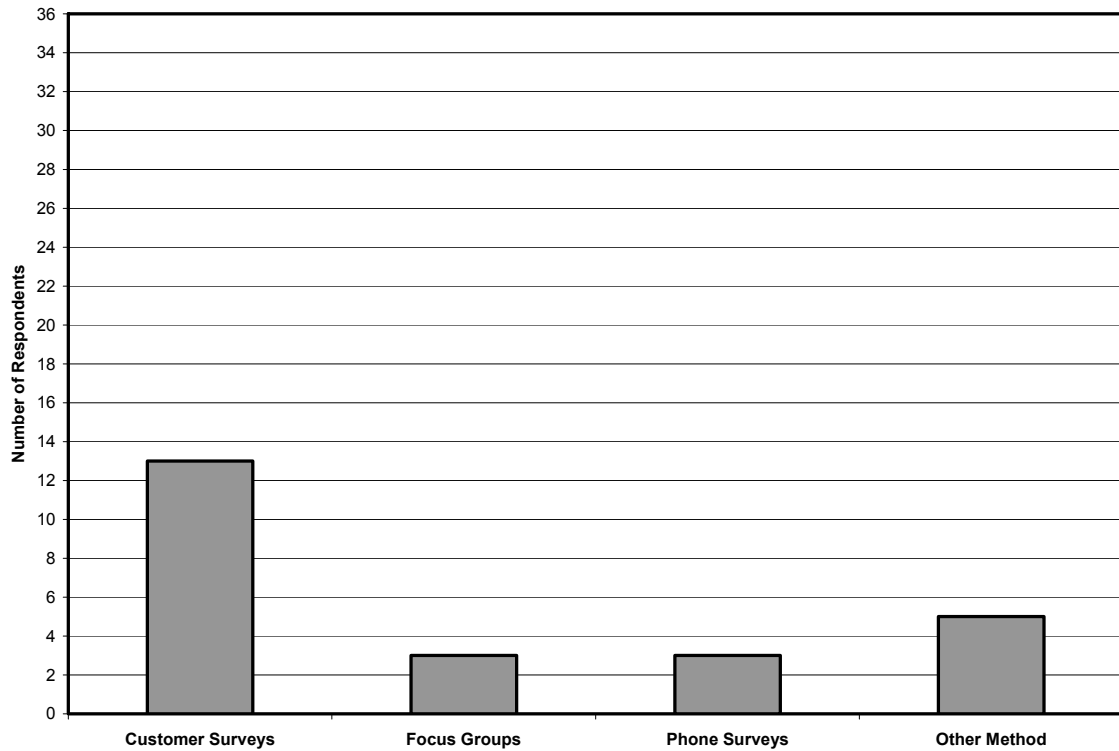


Figure 39. Distribution of formats used to obtain customer input (Question 3).

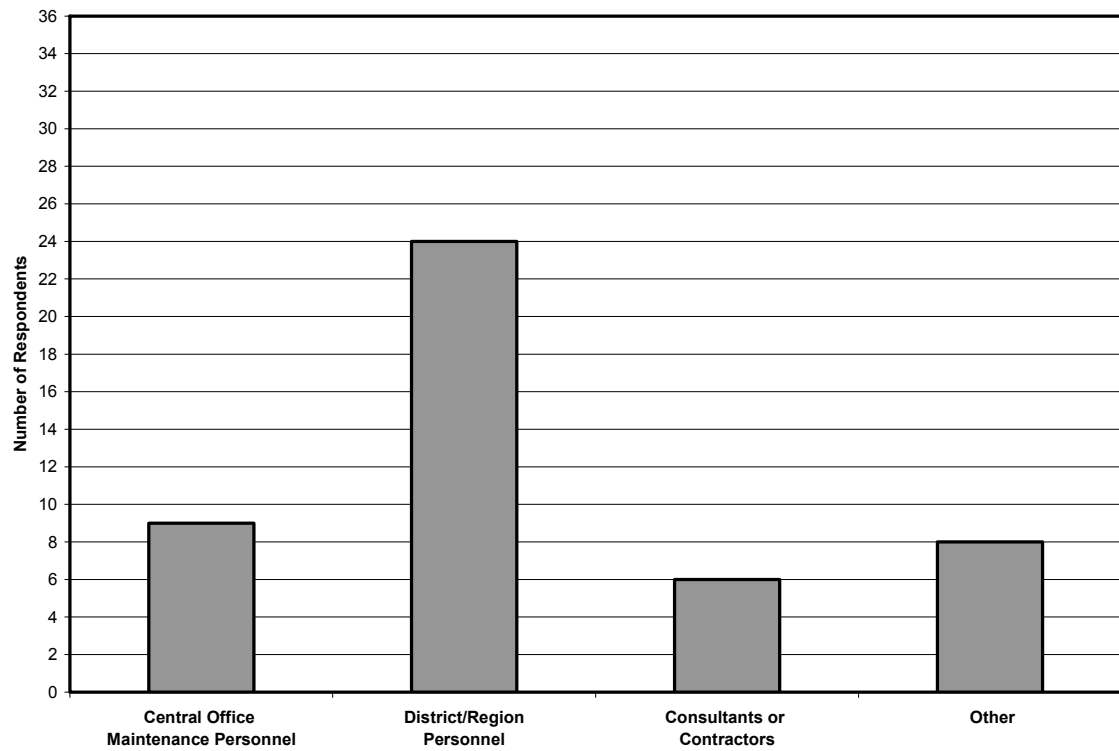


Figure 40. Dedicated personnel conducting maintenance condition assessment surveys (Question 4).

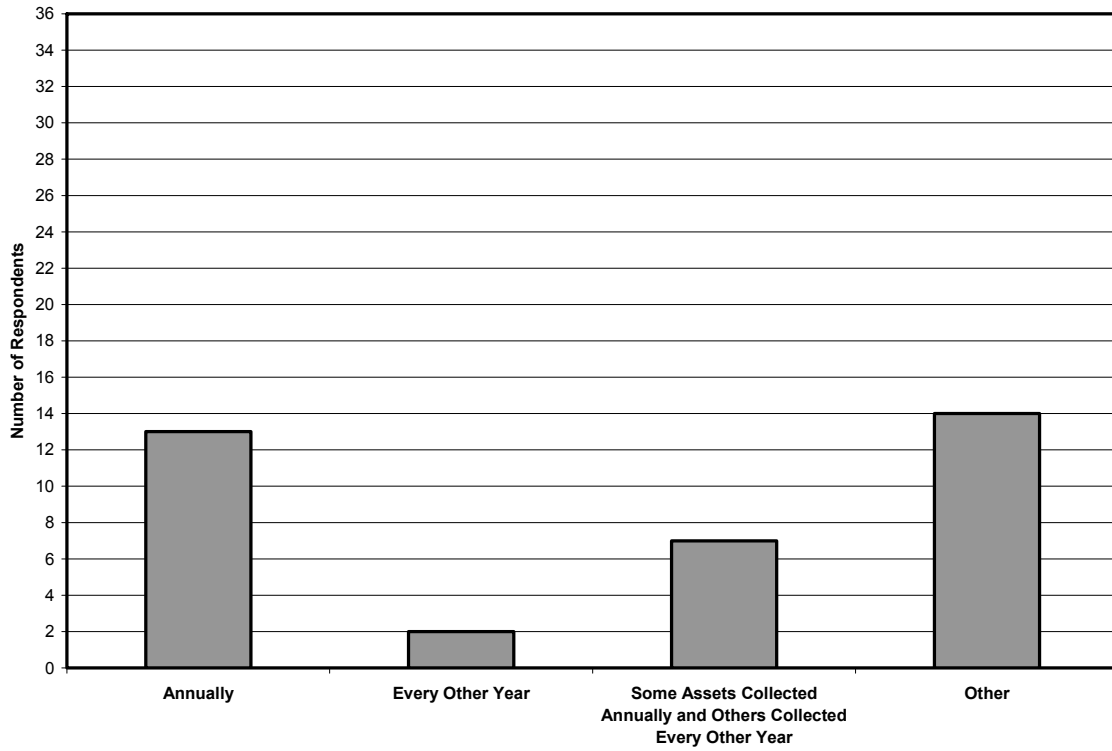


Figure 41. Distribution of frequency of condition assessment surveys (Question 5).

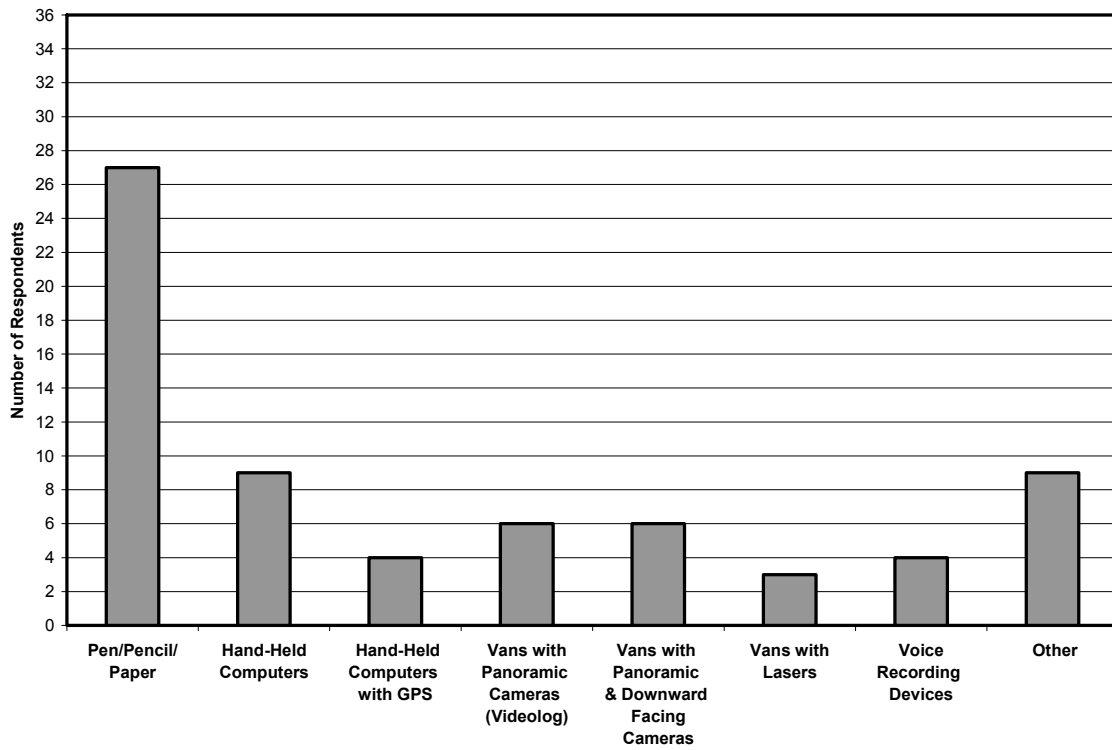


Figure 42. Equipment used during the conduct of the condition assessment surveys (Question 6).

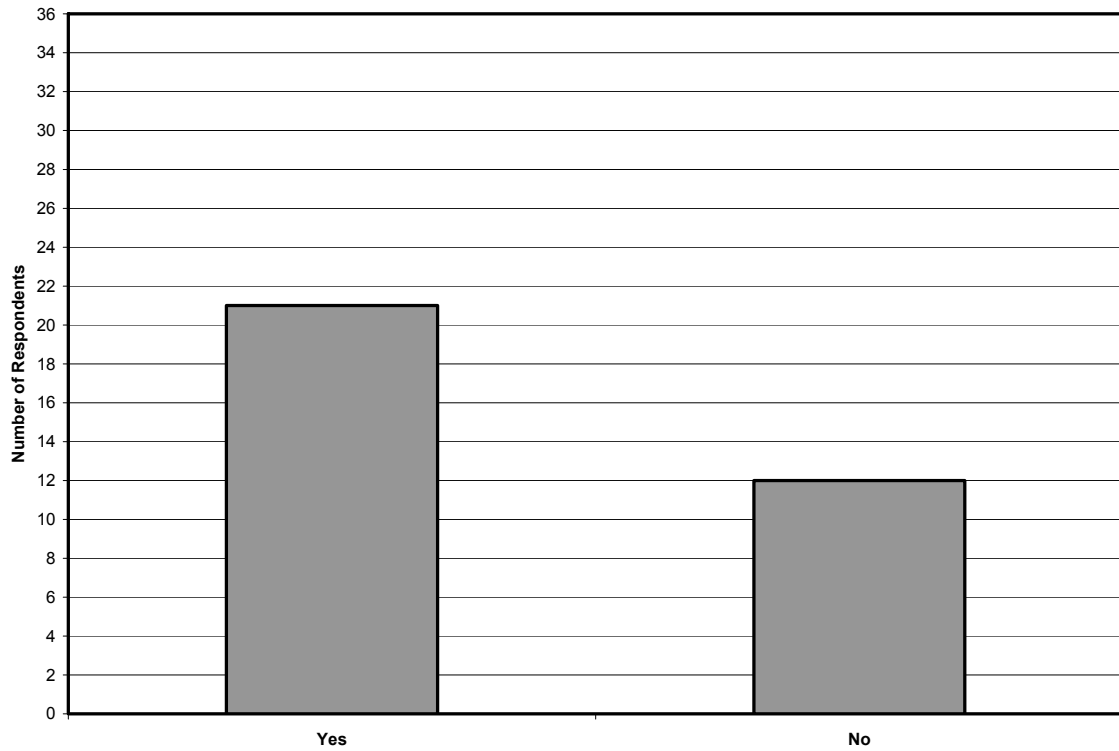


Figure 43. Use of sampling to collect condition information on any assets (Question 7).

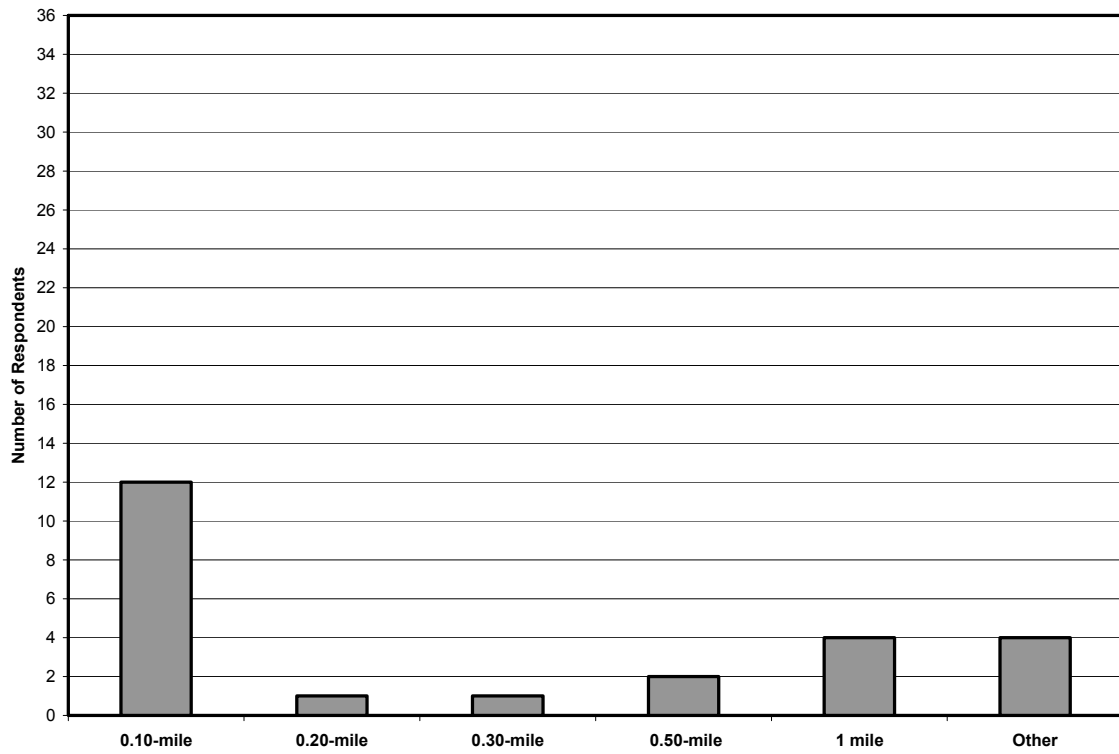


Figure 44. Distribution of the sample lengths (Question 8).

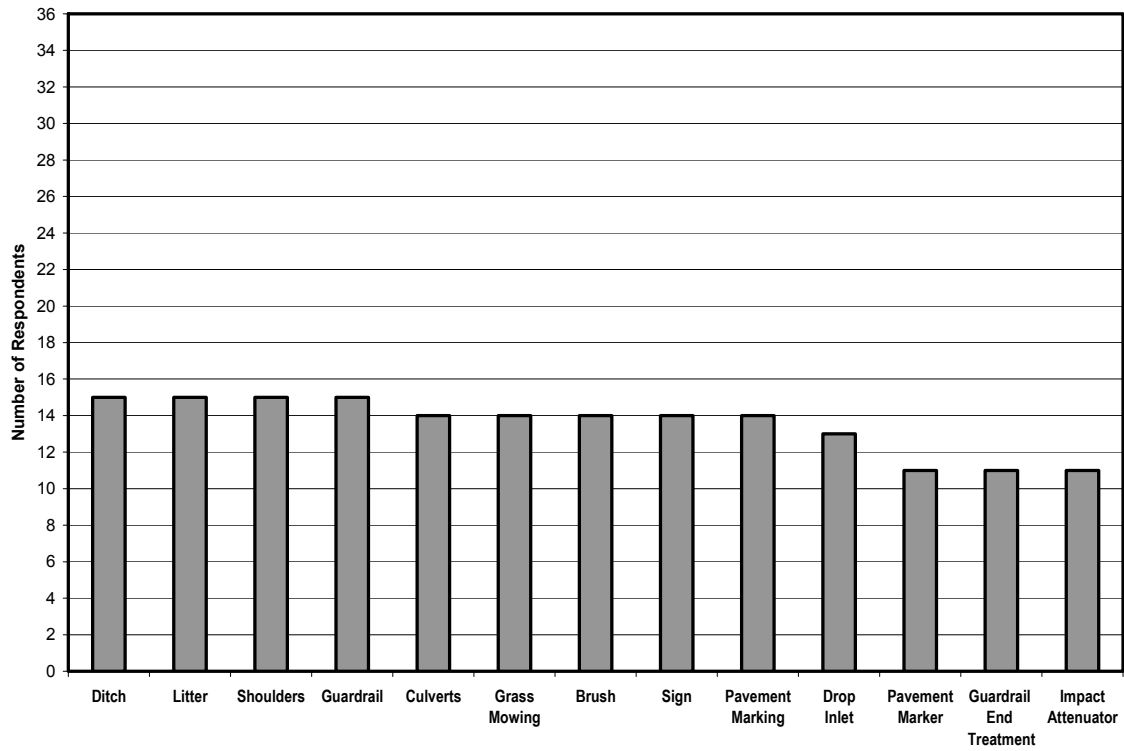


Figure 45. Assets surveyed using the sampling technique (Question 9). Top answers.

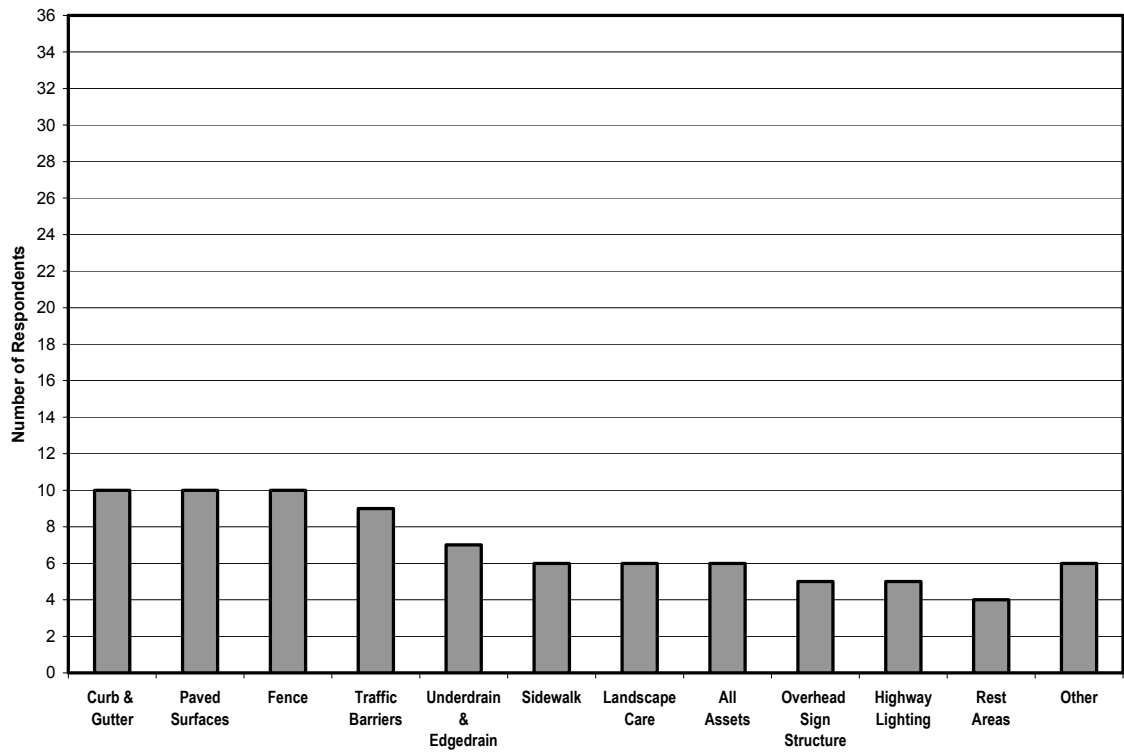


Figure 46. Assets surveyed using the sampling technique (Question 9). Remaining answers.

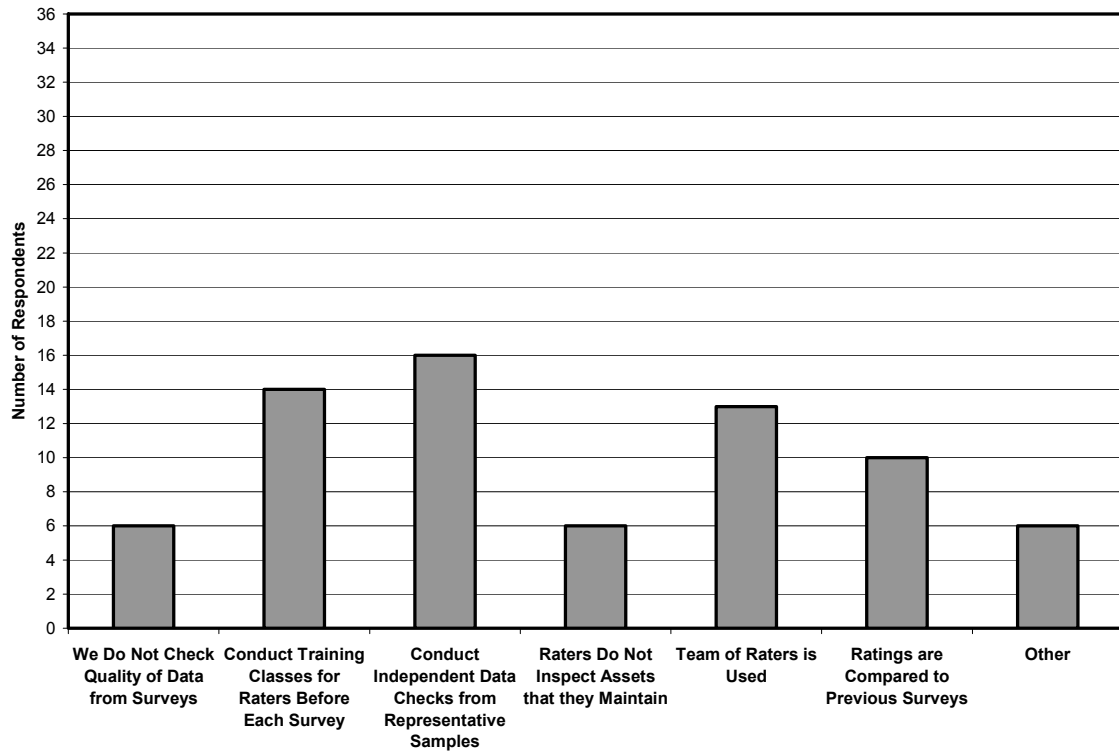


Figure 47. Methods used to ensure the quality of the condition surveys data (Question 10).

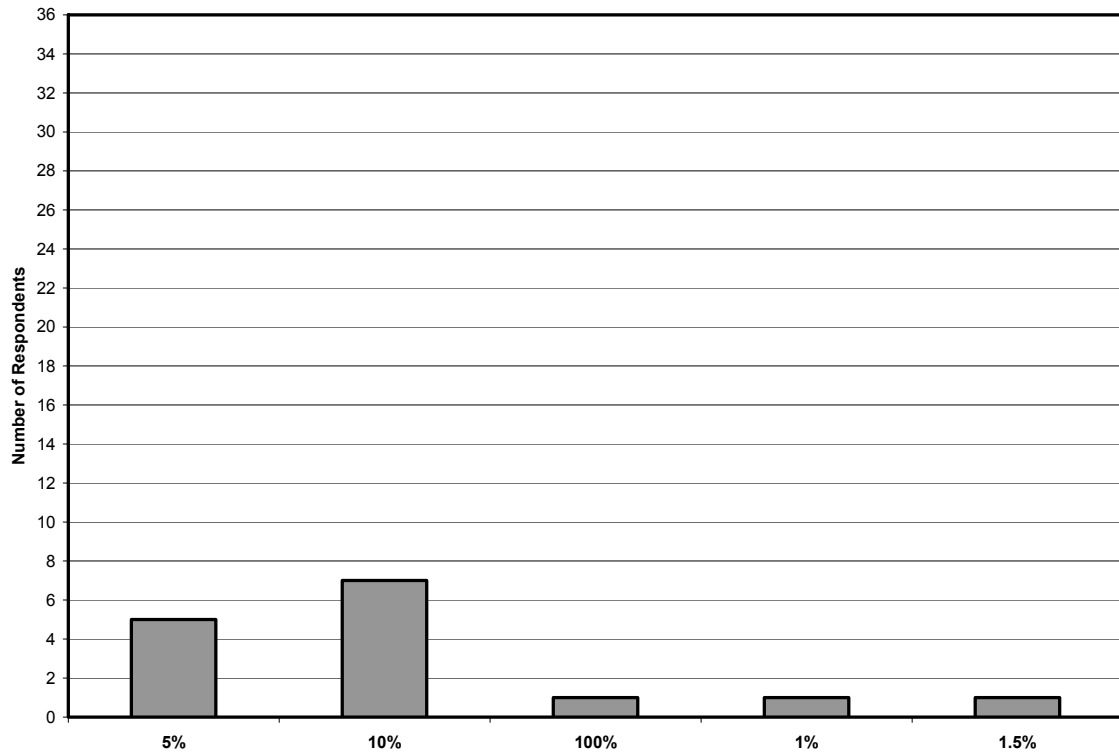


Figure 48. Distribution of the percentage of samples checked (Question 10).

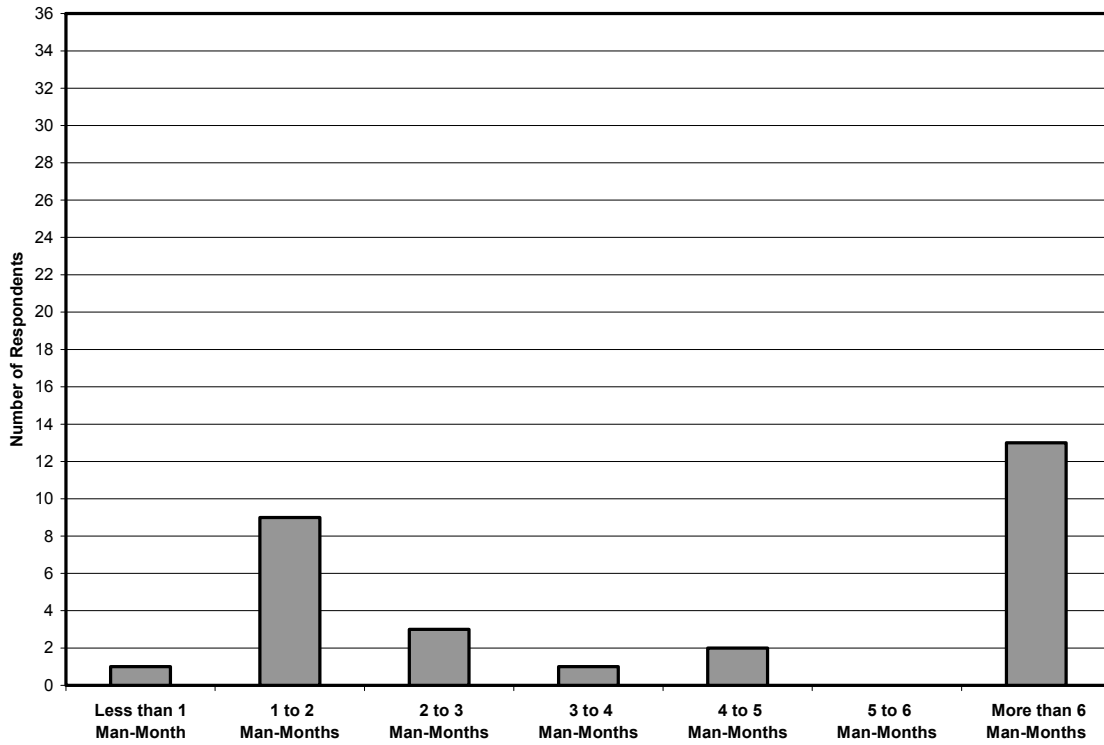


Figure 49. Distribution of the man-months spent collecting maintenance condition information (Question 11).

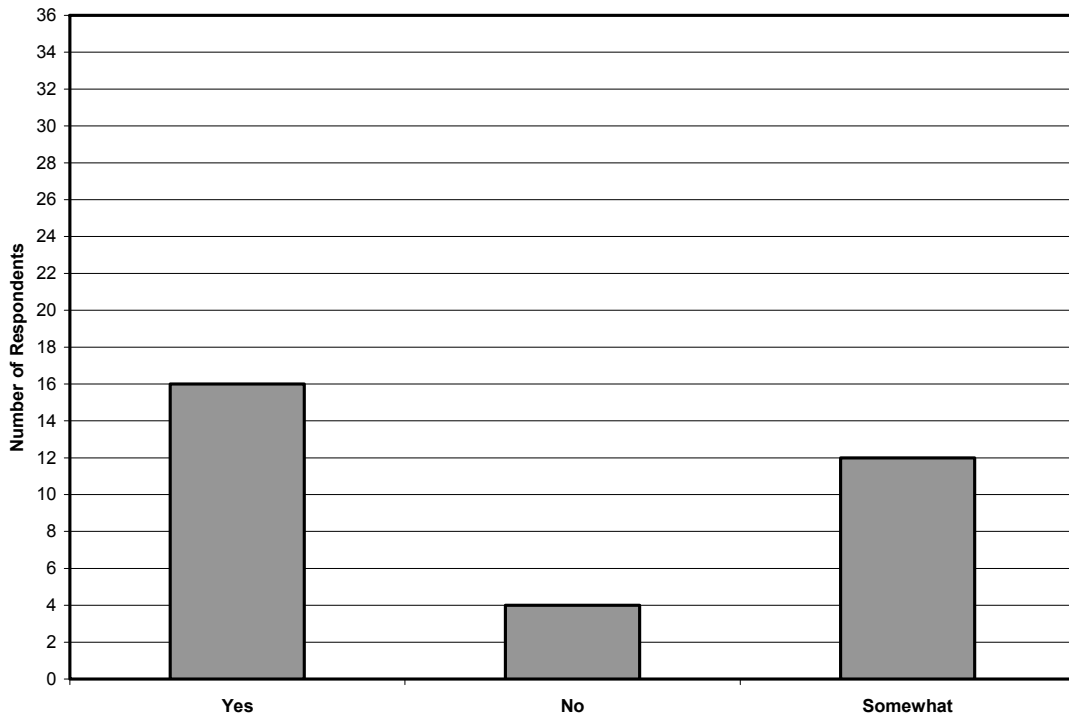


Figure 50. Links between condition attributes and the agencies' strategic performance measures (Question 12).

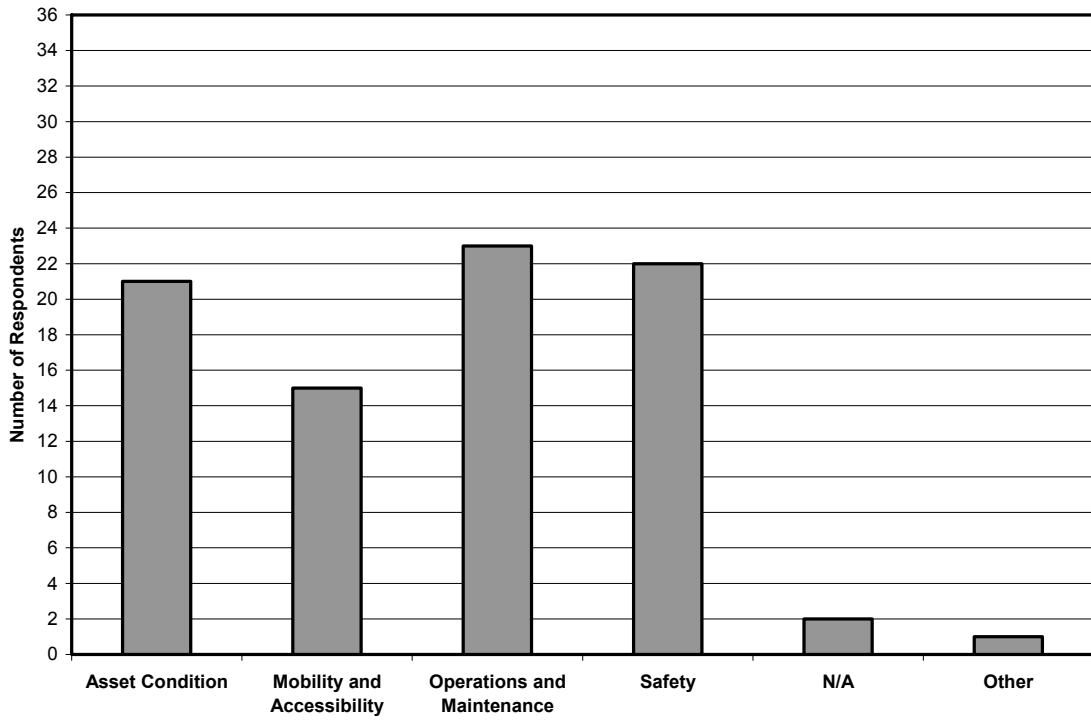


Figure 51. Strategic performance measures monitored by the agencies (Question 13).

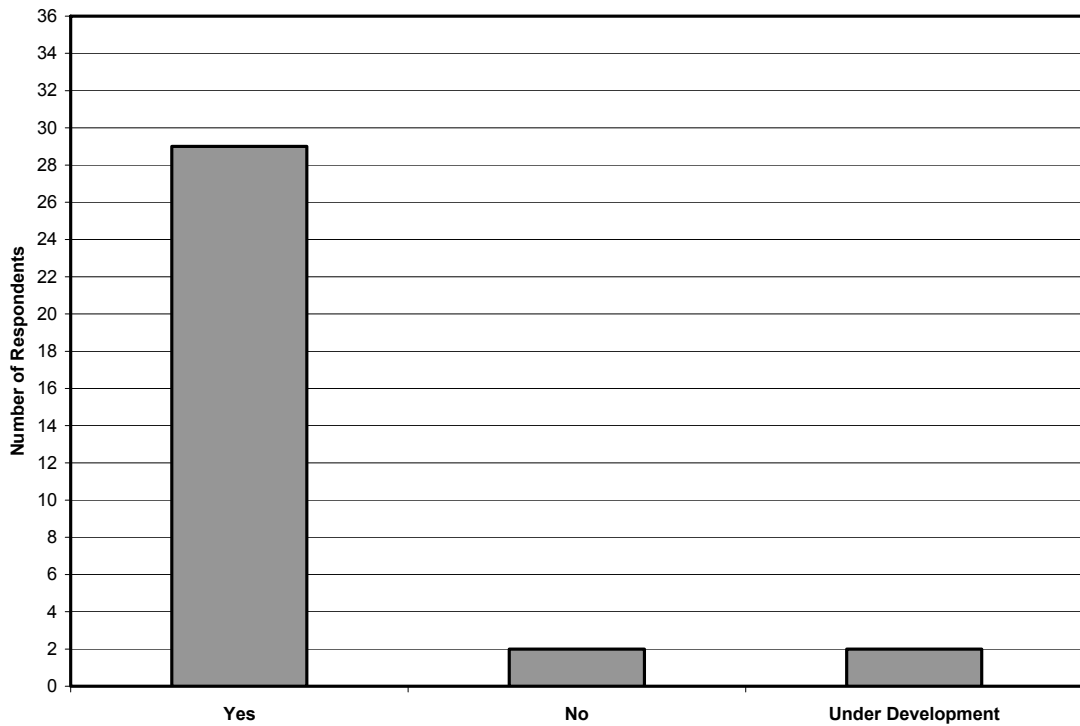


Figure 52. Availability of Maintenance Activity Guidelines that identify work activities for performing maintenance (Question 14).

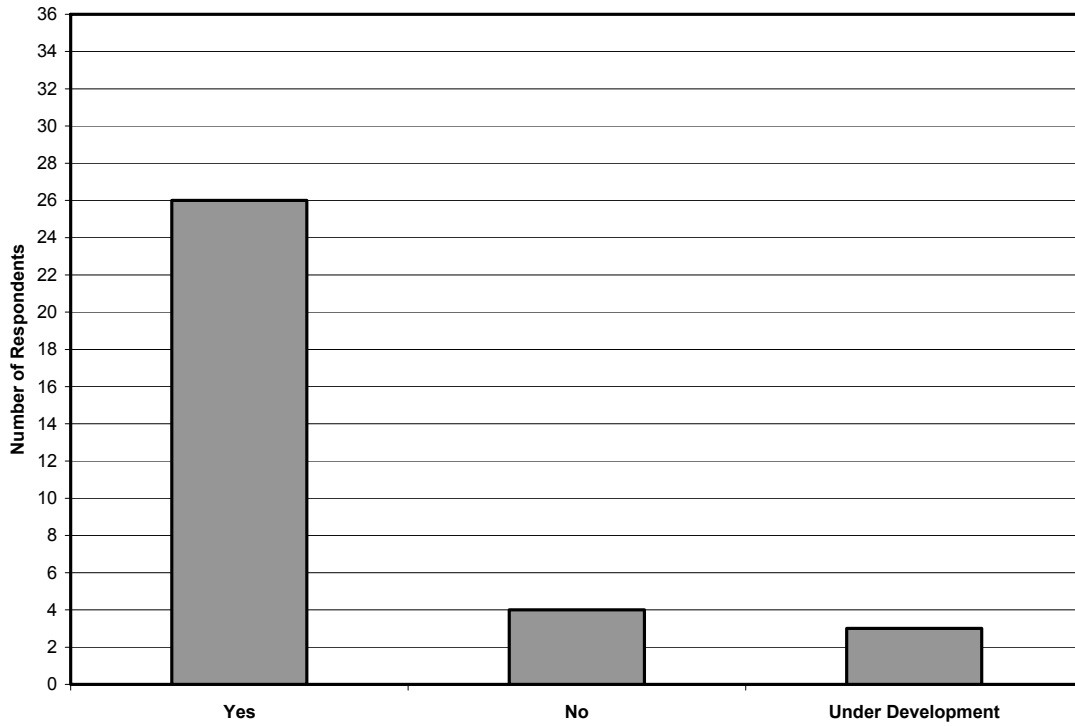


Figure 53. Availability of Maintenance Activity Guidelines that identify resource requirements for performing maintenance (Question 15).

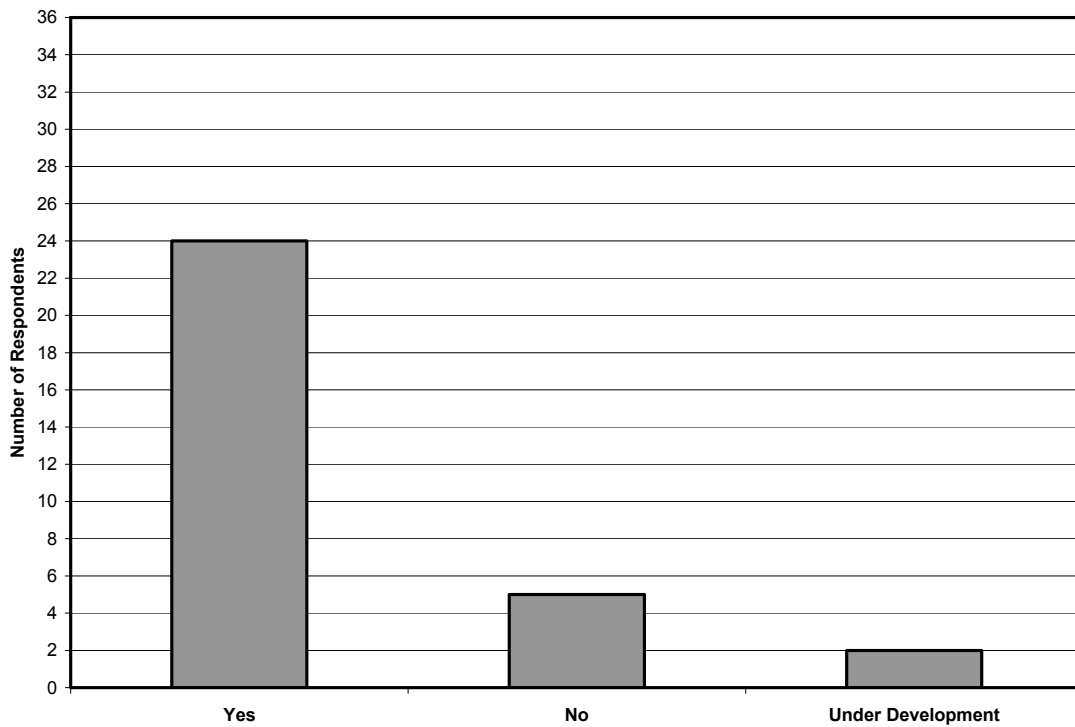


Figure 54. Availability of Maintenance Activity Guidelines that identify work methods for performing maintenance (Question 16).

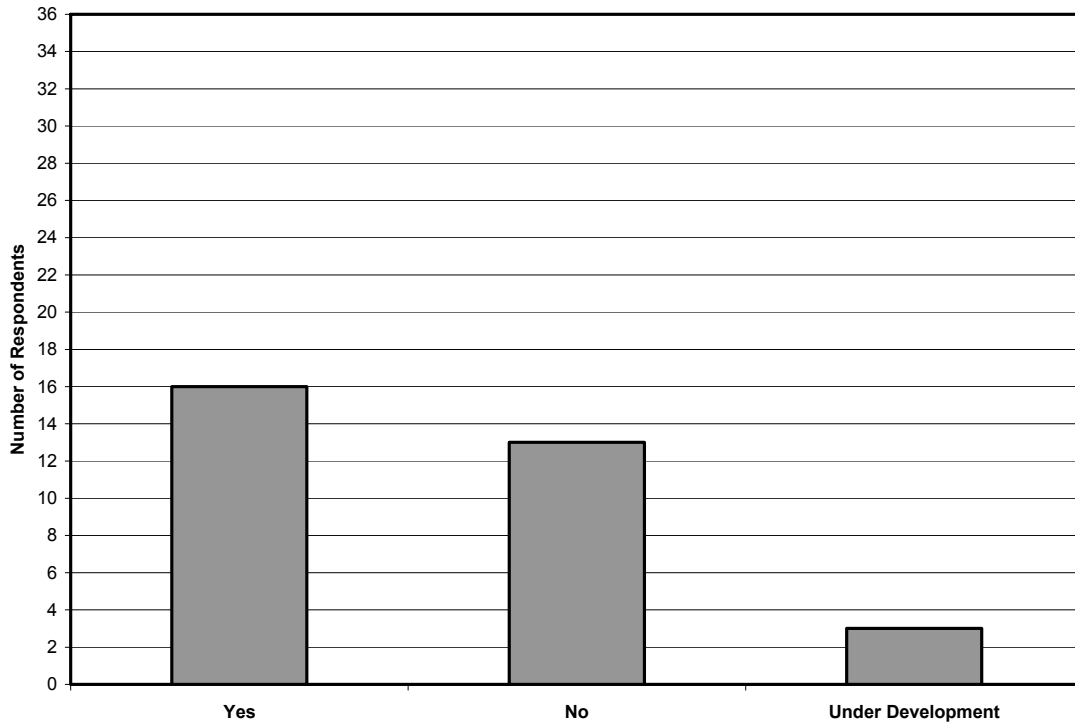


Figure 55. Availability of Maintenance Activity Guidelines that provide scheduling information for performing maintenance (Question 17).

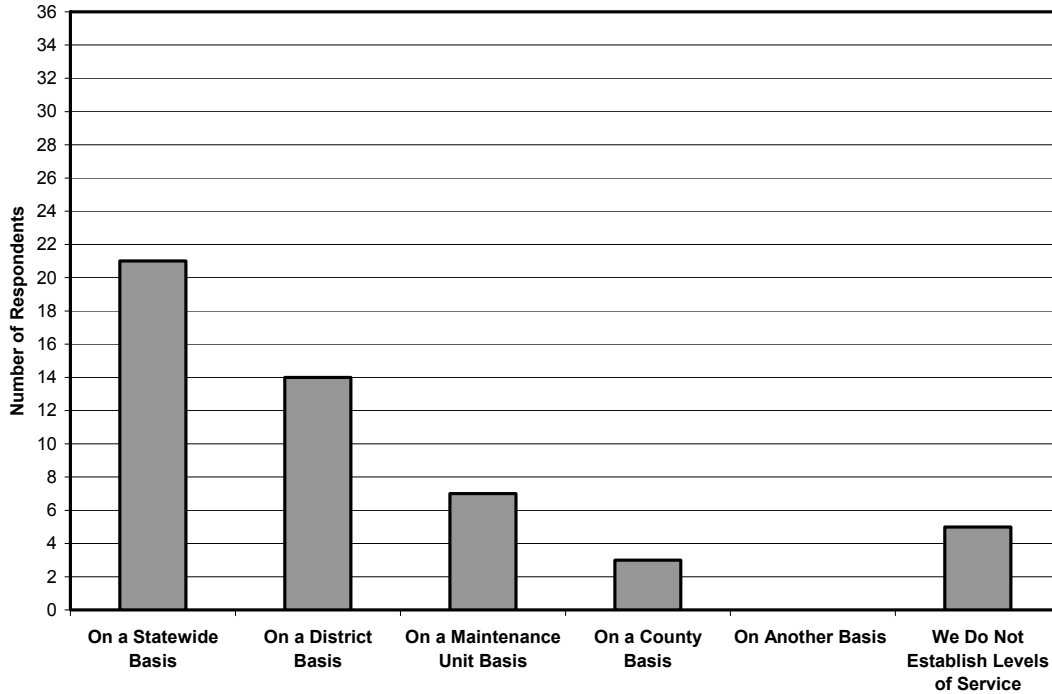


Figure 56. Use of the results of condition assessment surveys to establish levels of service (Question 18).

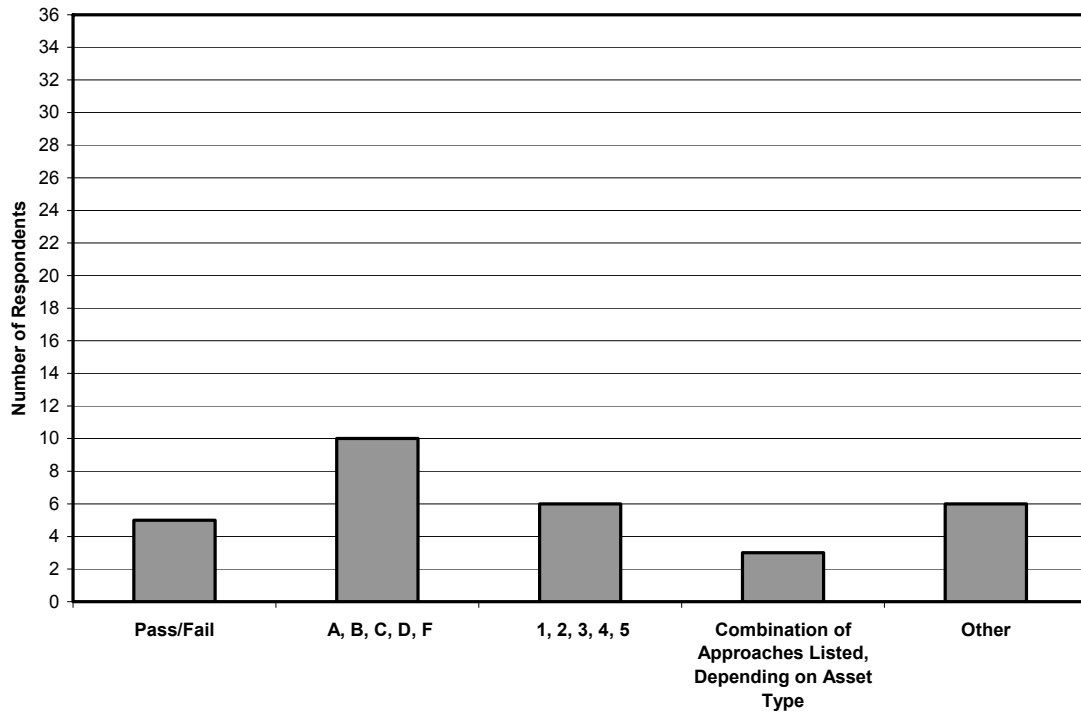


Figure 57. Distribution of scales used to establish levels of service (Question 19).

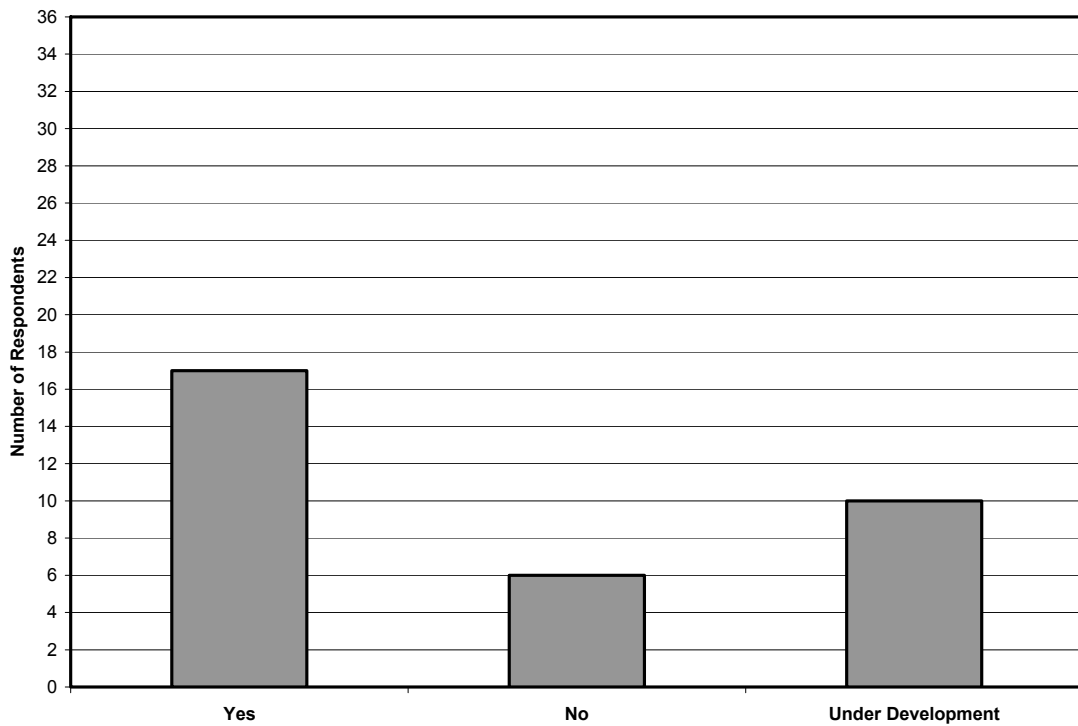


Figure 58. Performance targets established by the agencies (Question 20).

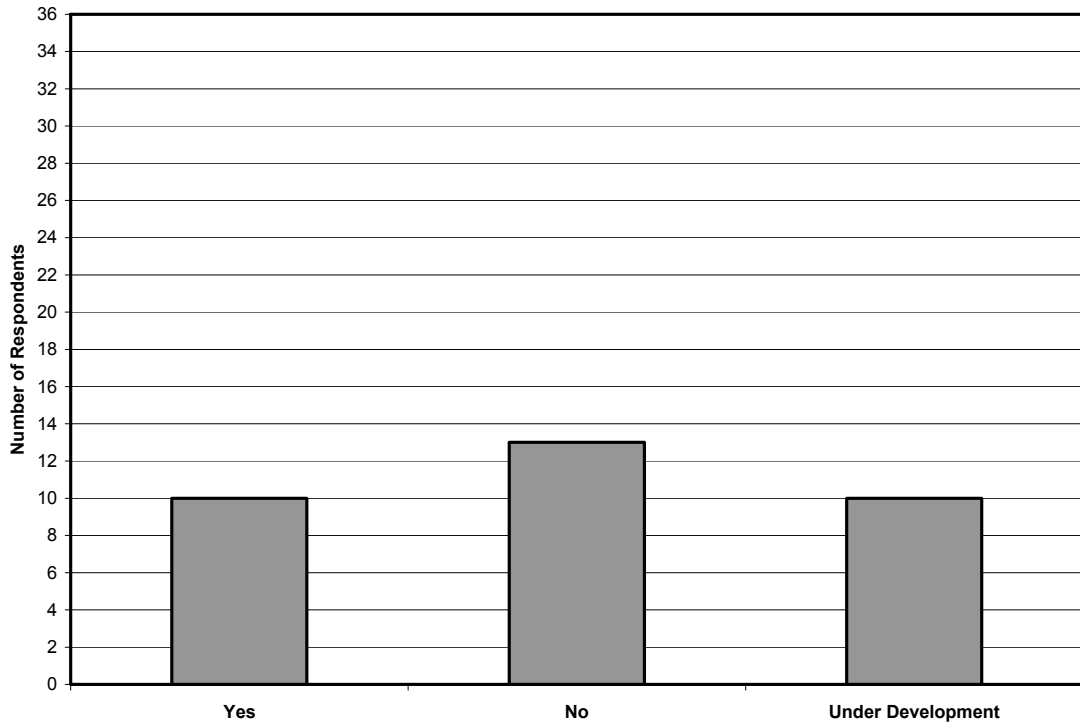


Figure 59. Links between performance targets and the resources needed to provide an established level of service (Question 21).

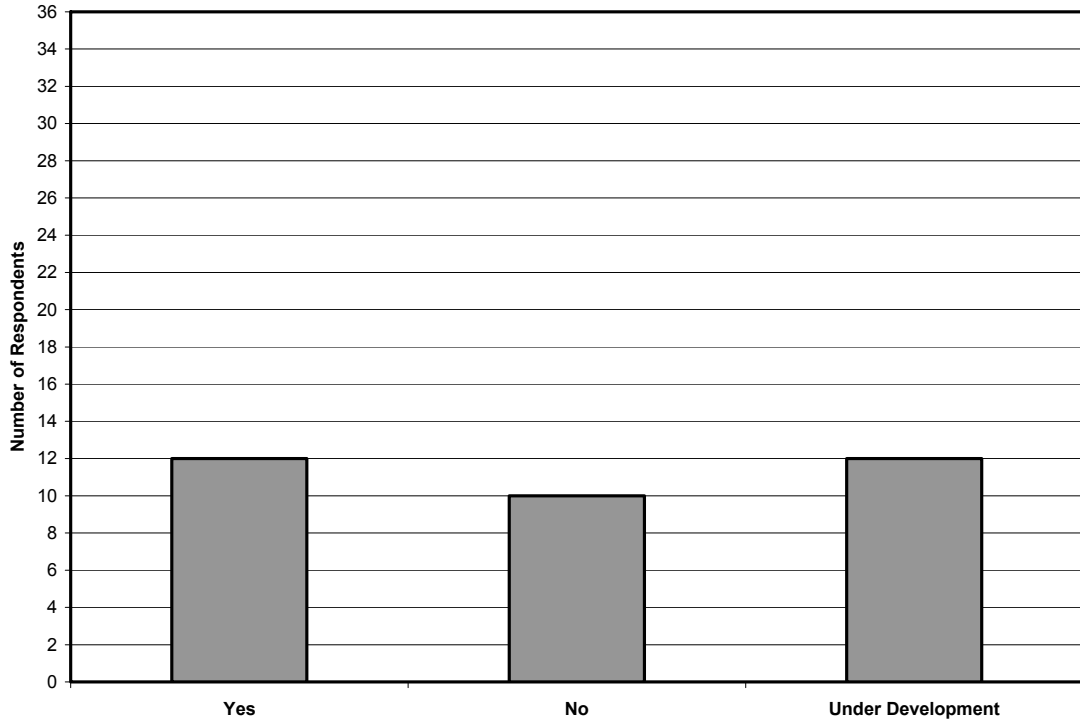


Figure 60. Use of the performance information to develop budget needs (Question 22).

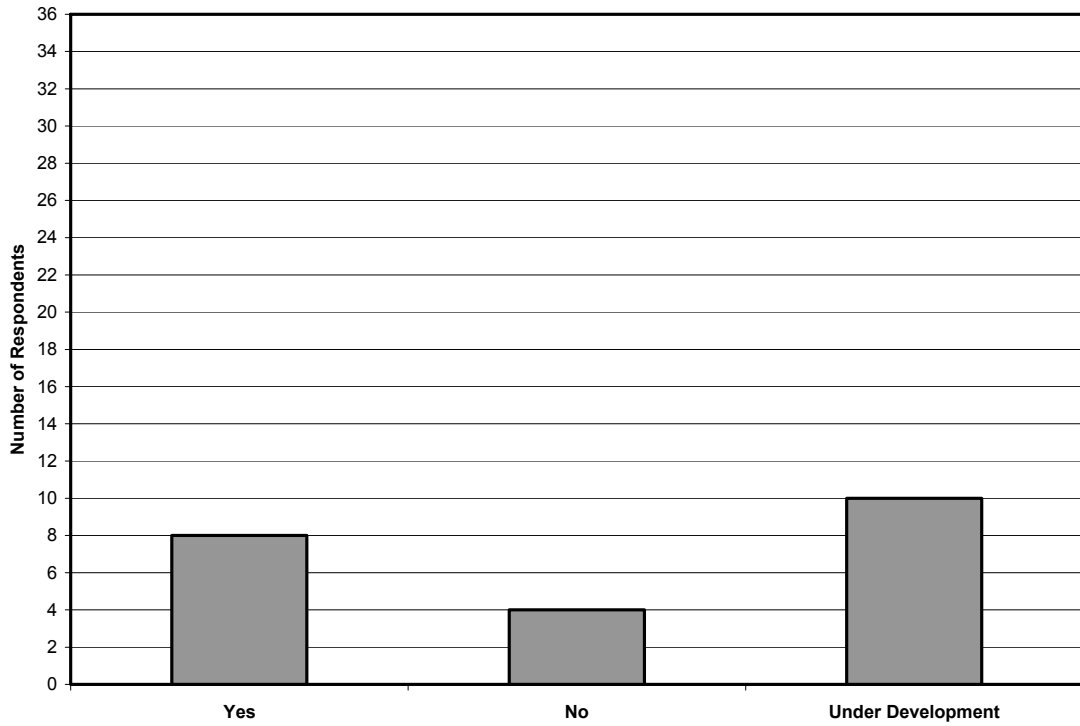


Figure 61. Weighting the asset categories to prioritize the assets (Question 23).

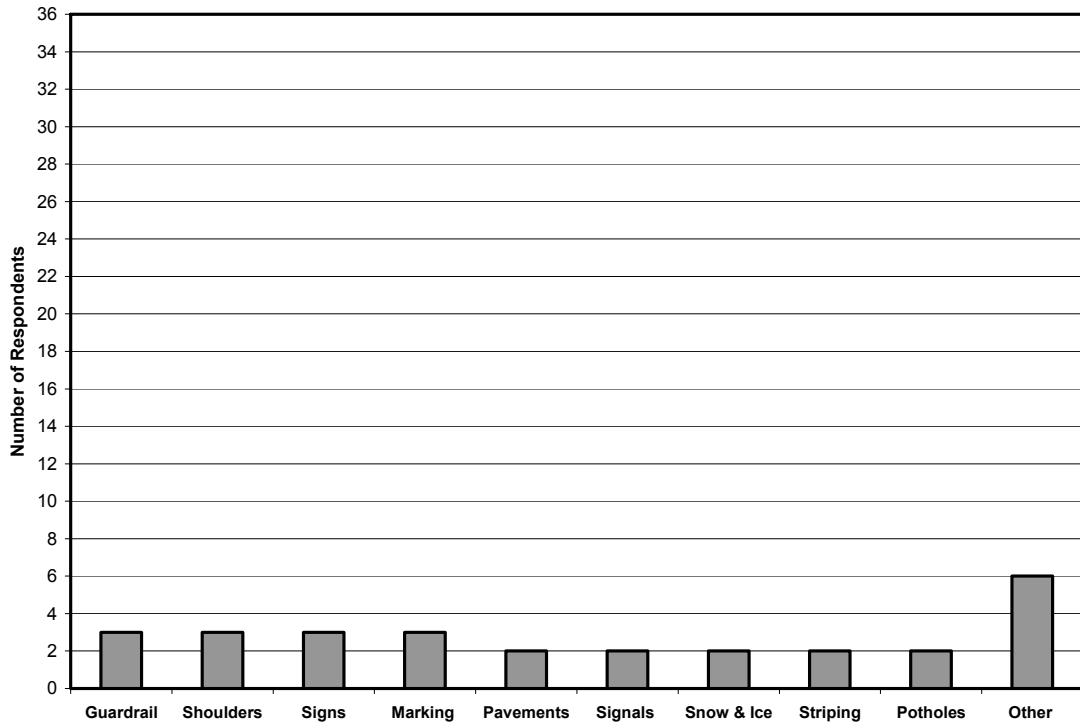


Figure 62. Distribution of the assets included by the agencies in five assets having the highest weight (Question 23).

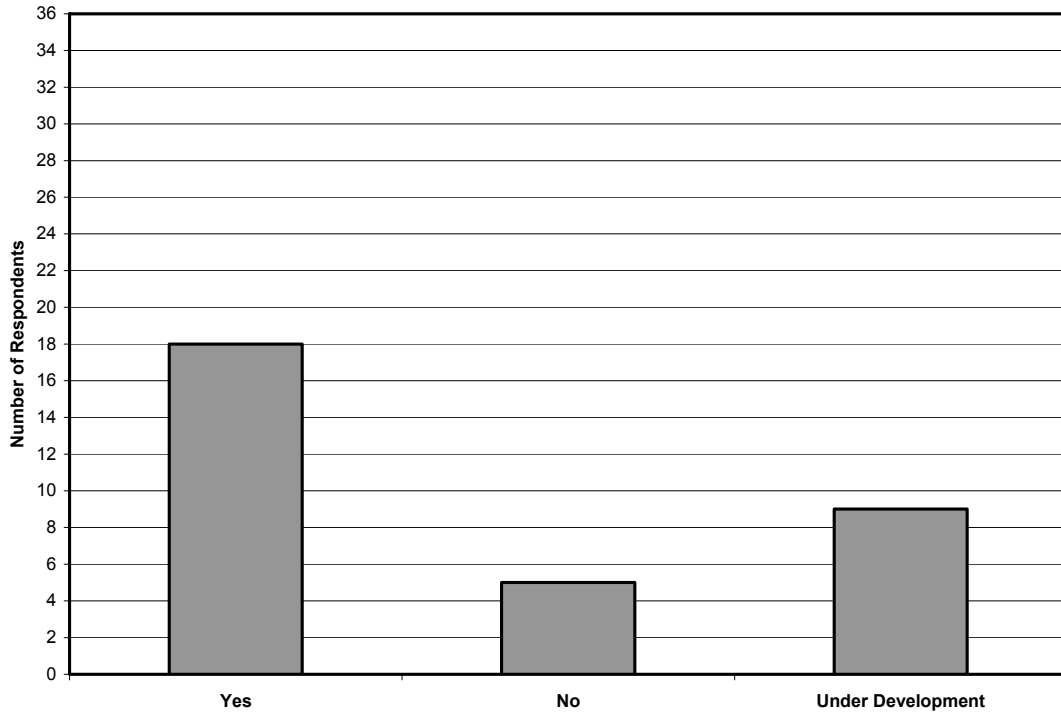


Figure 63. Use of the results of the condition assessment to program and schedule work activities (Question 24).

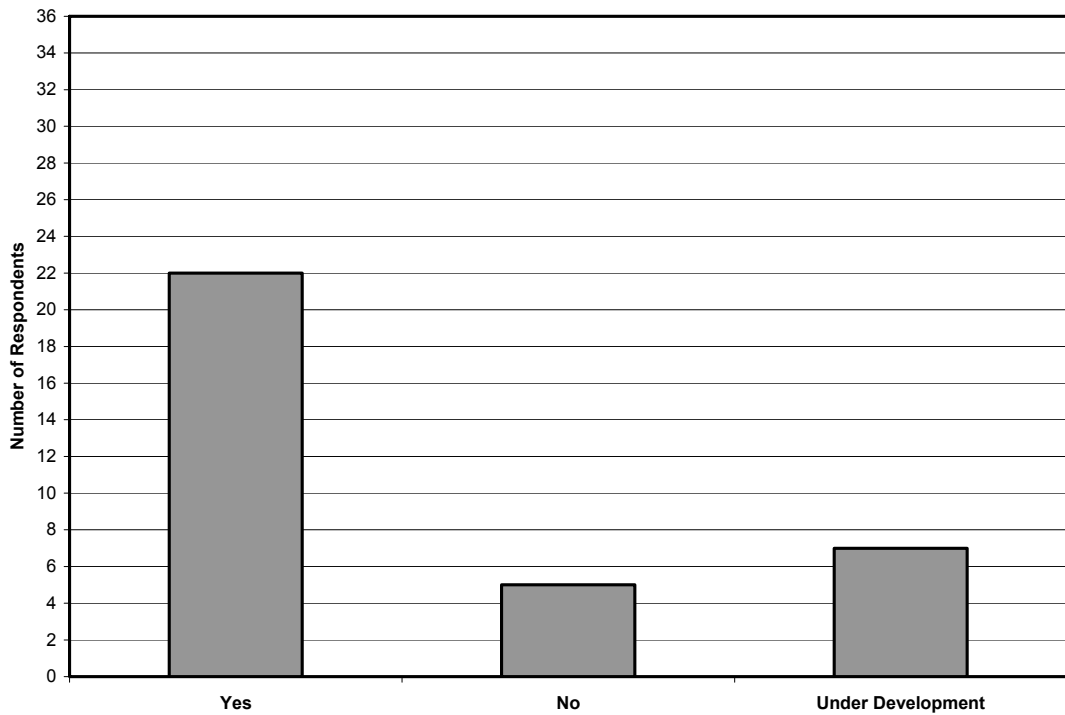


Figure 64. Availability of a computerized maintenance management in the agencies (Question 25).

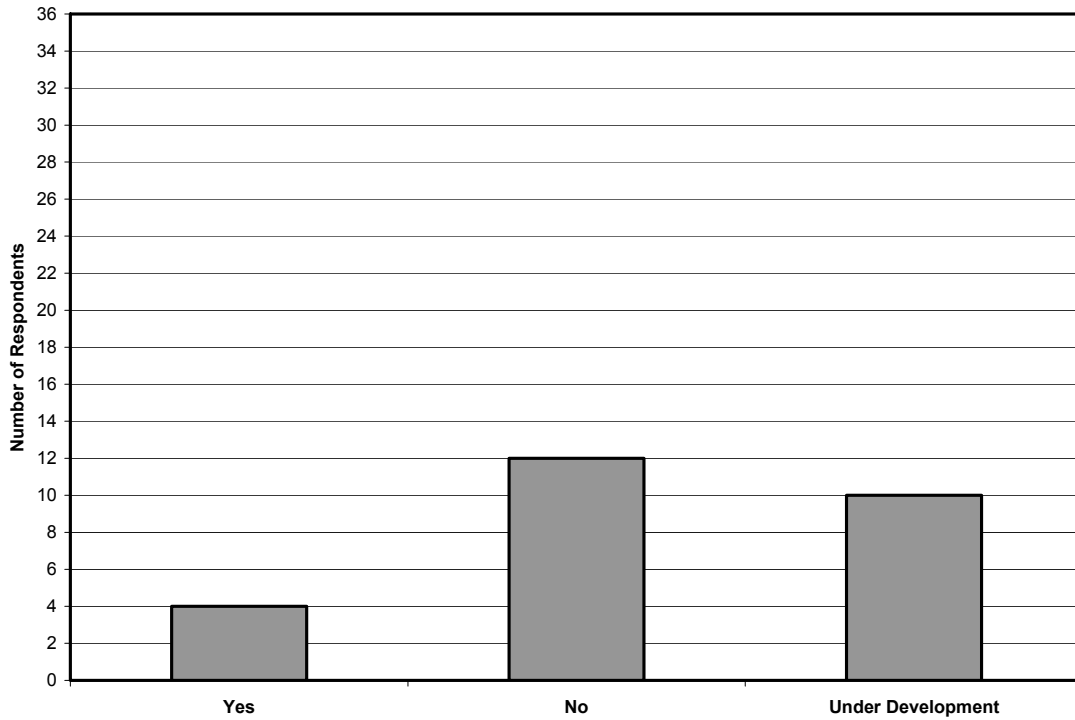


Figure 65. Use of the results of the condition assessment to estimate budget needs and/or provide the information needed to evaluate different strategies (Question 26).

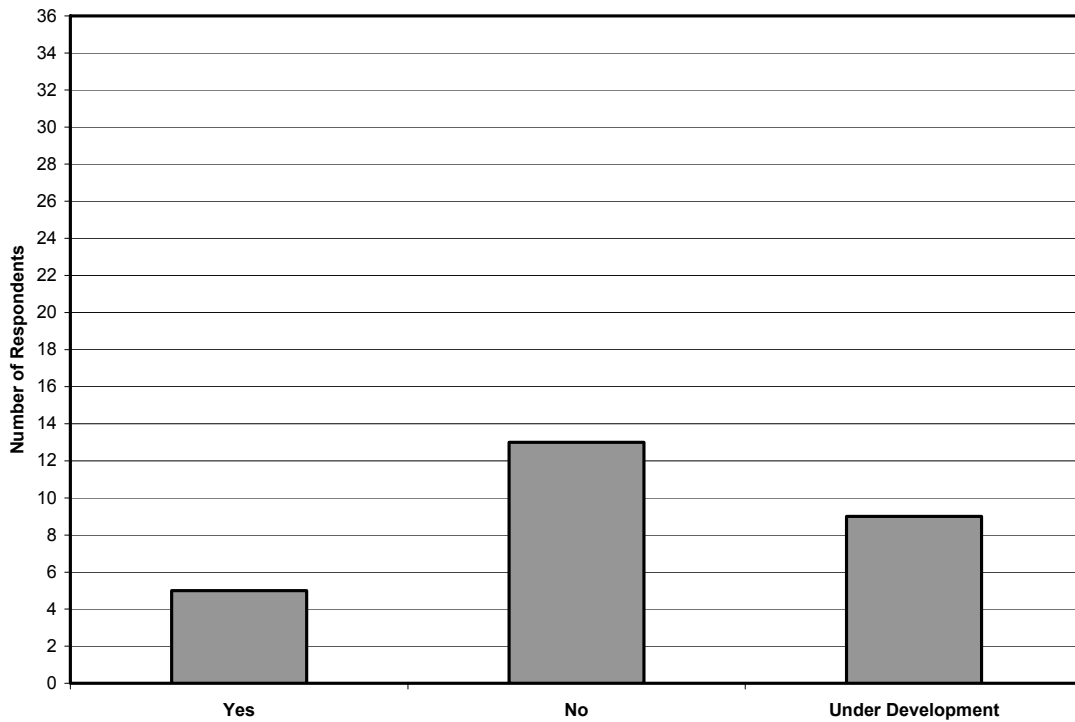


Figure 66. Use of the results of the condition assessment to schedule work activities (Question 27).

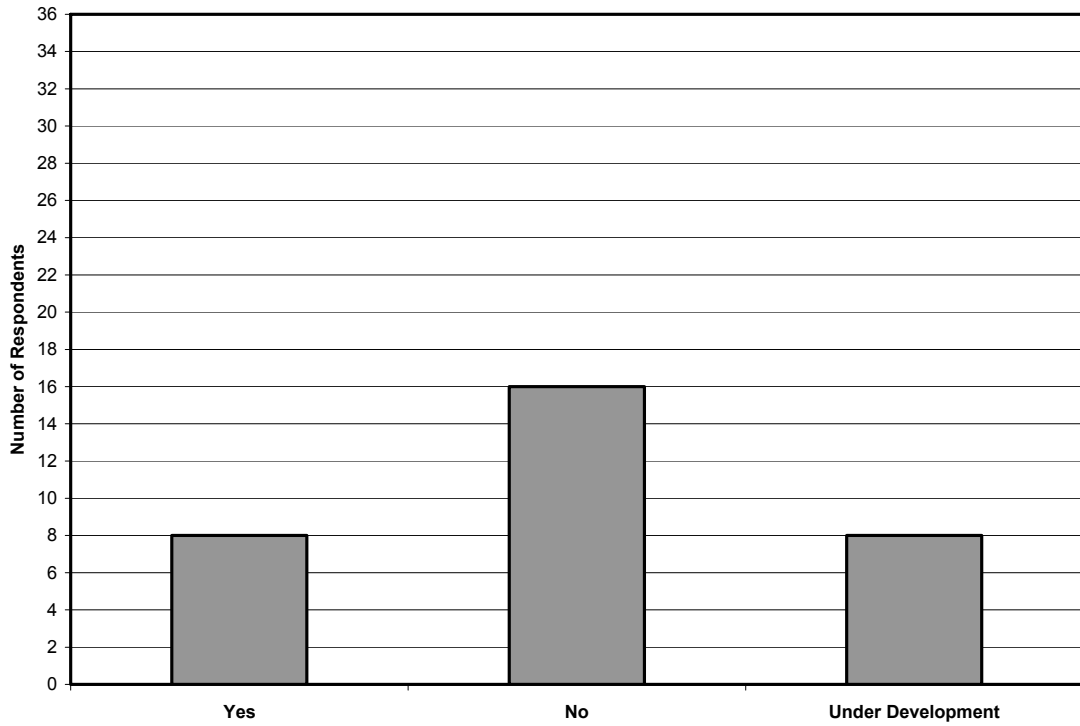


Figure 67. Links between maintenance work priorities and budget allocations and customer expectations (Question 28).

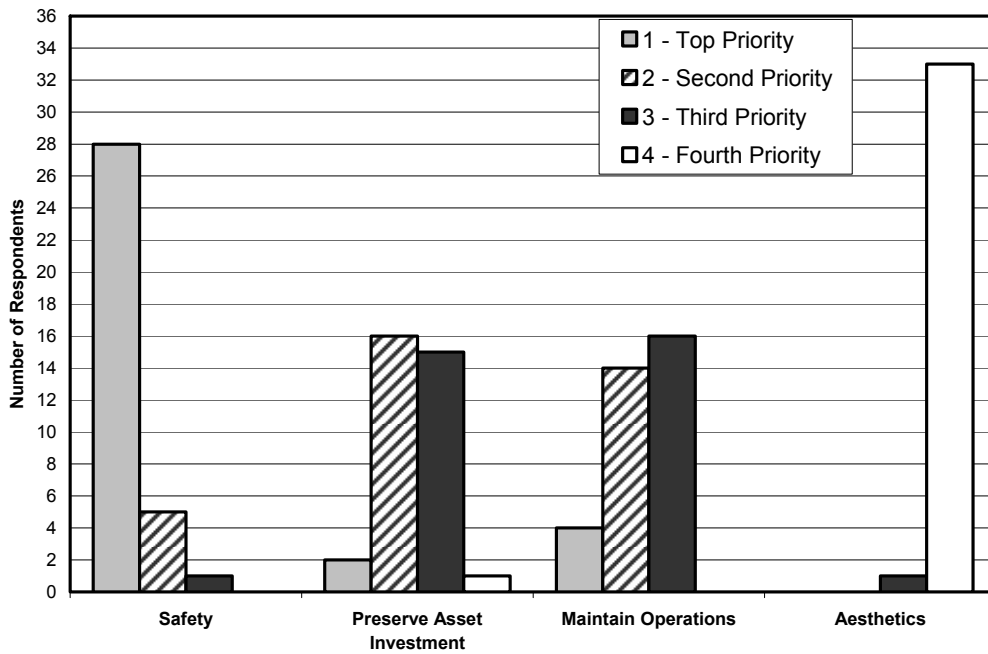


Figure 68. Prioritizing strategic objectives (Question 29).

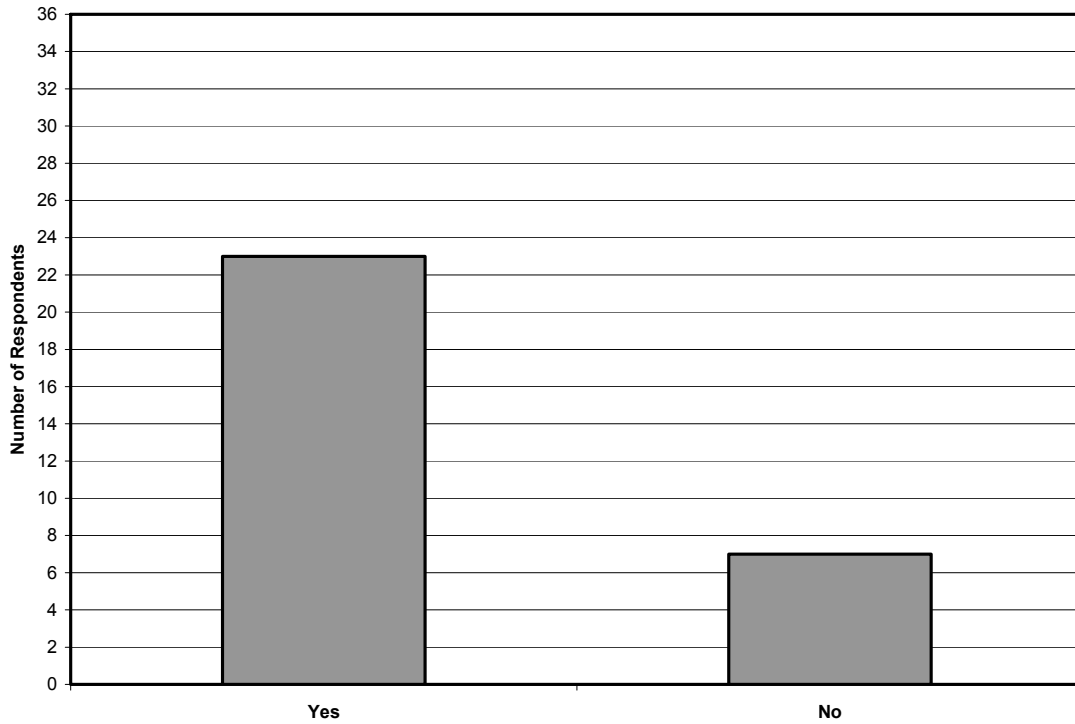


Figure 69. Distribution of the agencies responses to whether their condition assessment system has helped to achieve more consistent conditions on a statewide basis (Question 30).

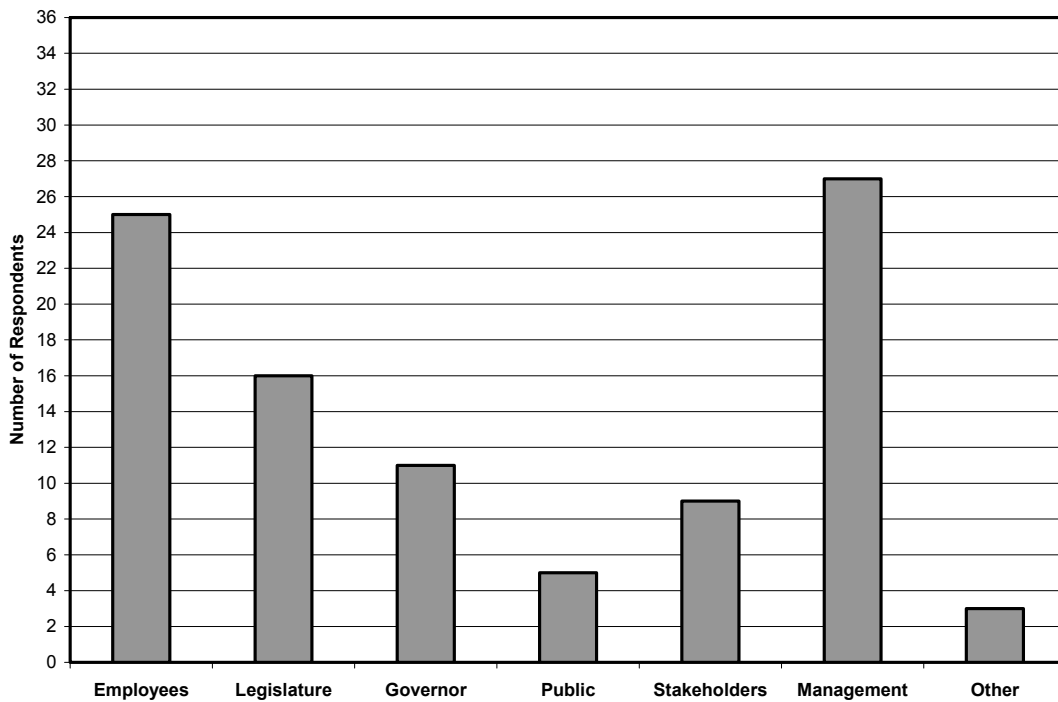


Figure 70. Groups who are provided the results of the condition assessment surveys (Question 31).

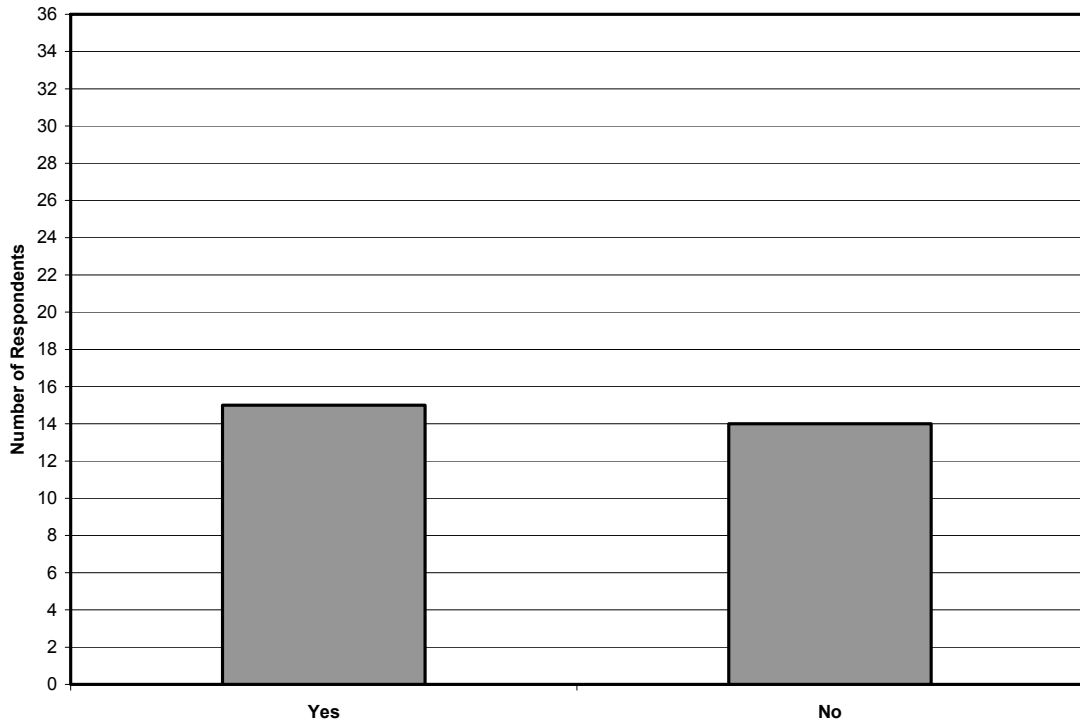


Figure 71. Availability of an educational component to familiarize the agency's employees with the condition assessment program (Question 32).

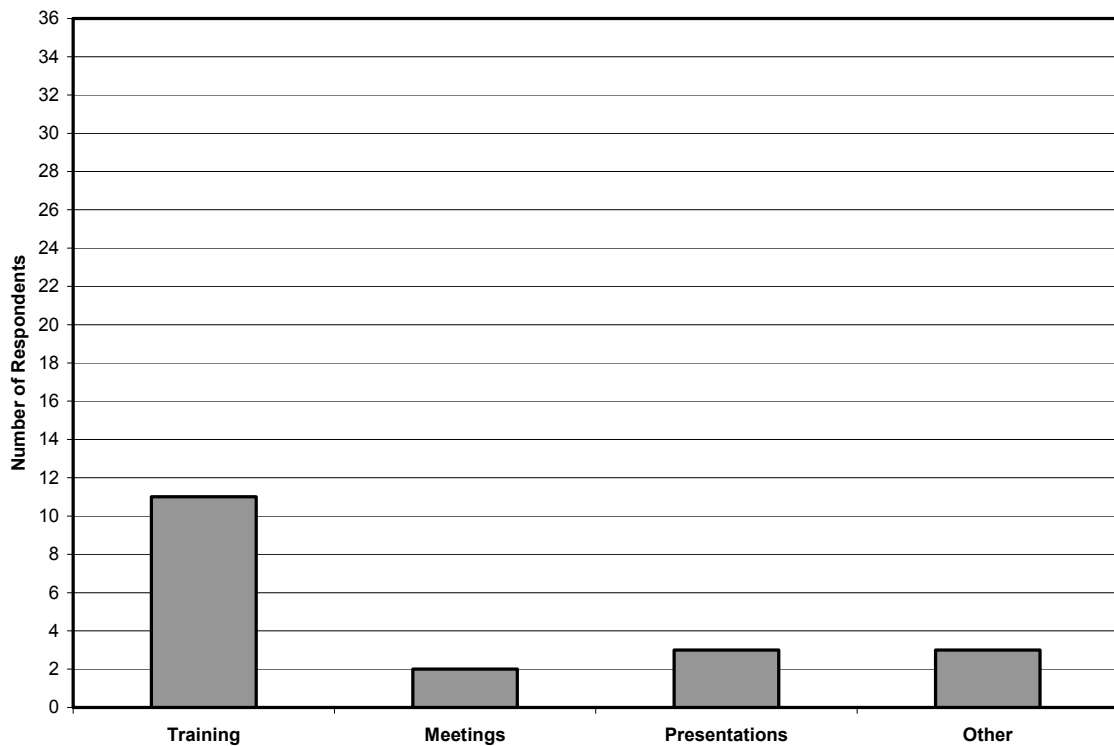


Figure 72. Education methods used by the agencies to familiarize their employees with the condition assessment program (Question 32).

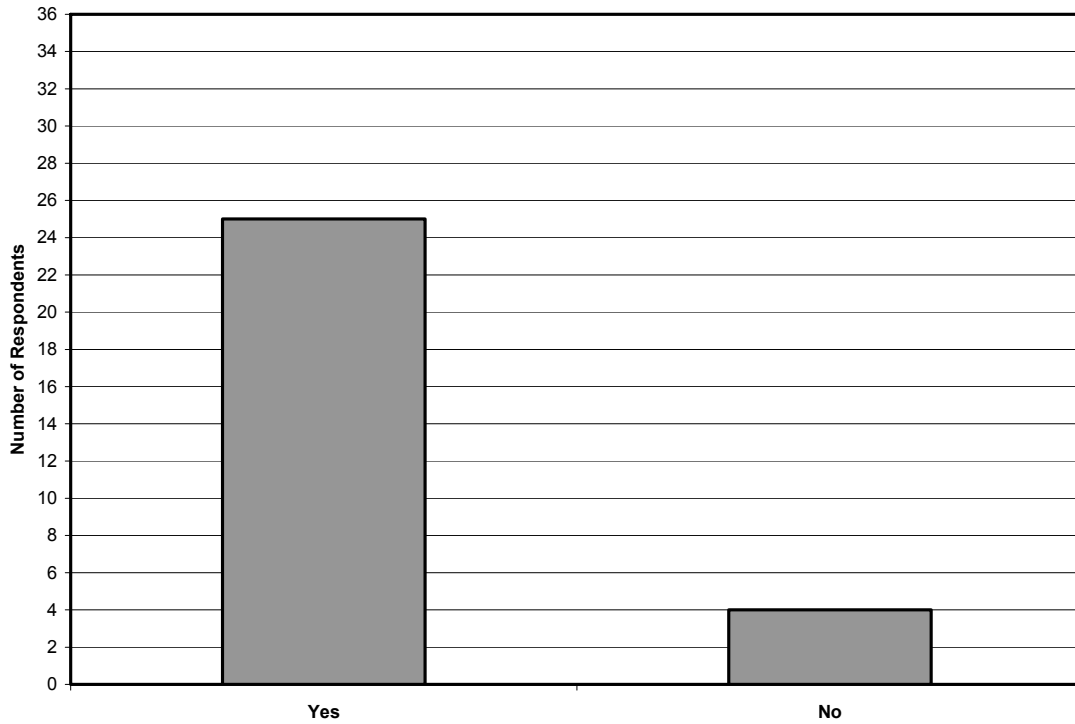


Figure 73. Distribution of the agencies' responses to whether their condition assessment system helped to identify maintenance priorities on a statewide basis (Question 33).

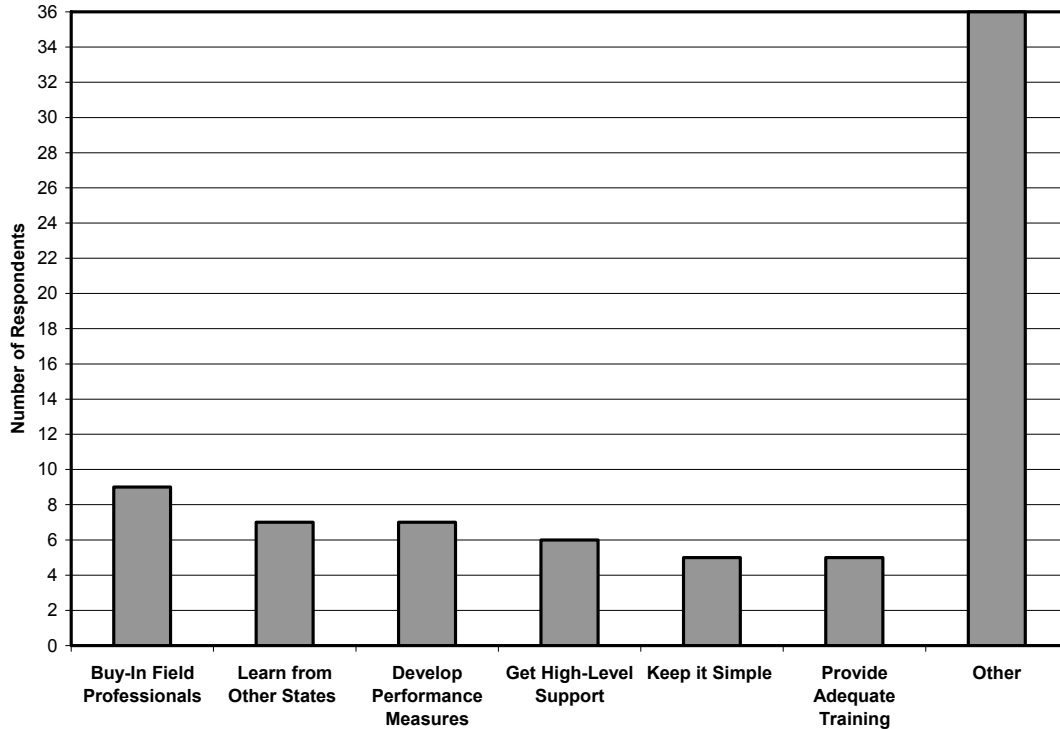


Figure 74. Advice to an agency just starting the development of its condition assessment techniques (Question 34).

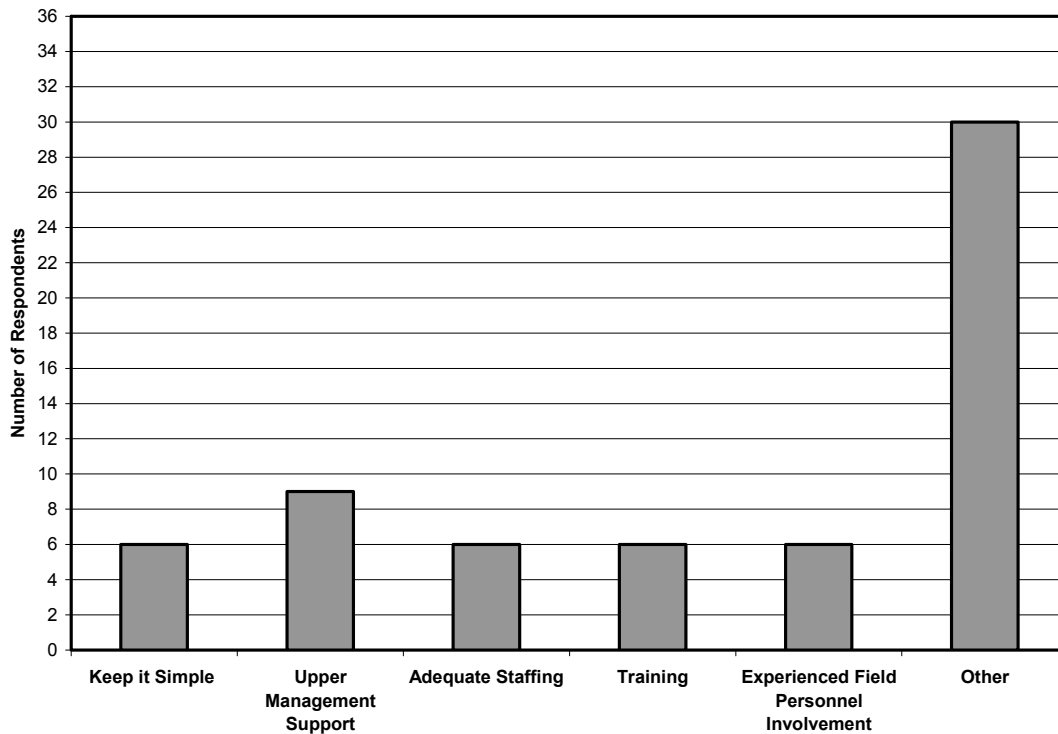


Figure 75. Factors that contribute to the success of the condition assessment system (Question 35).

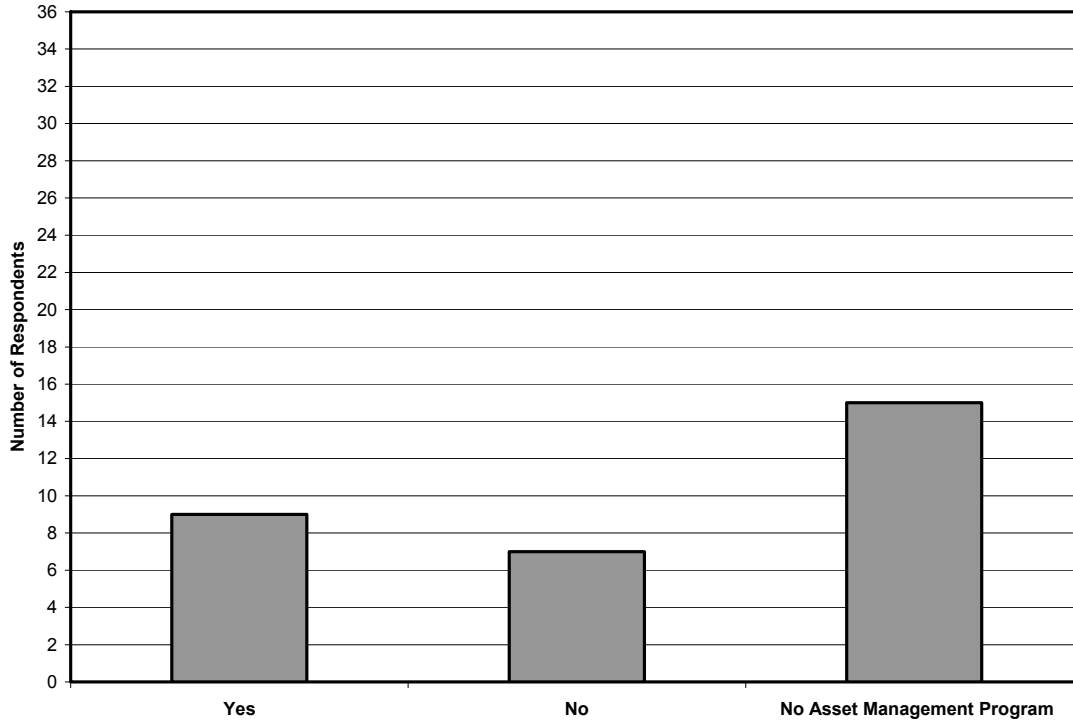


Figure 76. Distribution of the agencies' responses to the question whether their condition assessment system is a part of an overall Asset Management Program (Question 36).

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

Maintenance activities are essential if transportation agencies are to continue to provide a safe, smooth, and efficient road network to the traveling public. As competition for maintenance dollars has increased in recent years, transportation agencies have seen the number of unfunded projects increase while staff sizes have decreased. As a result, agencies are being forced to find ways to improve operational efficiency and to better link maintenance priorities to their performance objectives. The use of maintenance condition assessment systems (CAS) as part of a maintenance management program has emerged in recent years as a key factor in enabling agencies to set maintenance performance targets and to translate those targets into an effective maintenance program.

Today's operational environment is forcing many transportation agencies to make changes to their existing maintenance management practices so they can take advantage of enhanced technological capabilities, but more importantly so they can better respond to customer expectations and political demands. For some agencies, this has meant developing enhanced capabilities within their existing maintenance management program. However, a number of other agencies have initiated new processes and procedures that are more customer-oriented, outcome-focused, and integrated with other existing systems. This report, and the accompanying Guide, focuses on the development of CAS that provide the information needed to effectively manage the maintenance and operations of today's transportation agencies.

Characteristics of Effective Condition Assessment Systems

The most effective CAS being used today provide the information maintenance and operations managers need to report existing asset conditions, identify maintenance needs, set maintenance priorities, and evaluate trade-offs in resource allocation. Although there are several commonalities to the types of CAS being used in transportation agencies today, there is a great deal of variability in the attributes that are being measured and the way that the condition assessment surveys are conducted. Table 8 summarizes the most commonly measured attributes in practice today.

The condition attributes are typically evaluated as part of a scheduled maintenance quality assurance survey by district or regional personnel. While many agencies collect the information annually, there are a number of agencies who collect condition information on some assets more frequently to account for seasonal variations. Most agencies collect some condition information using 0.1-mile representative samples that allow them to extrapolate conditions across the entire network. Where sampling is used, it is most common when rating the condition of paved shoulders, guardrail, litter, and ditches. Since maintenance work programs are based on the results of the condition surveys, procedures to ensure the quality of the data are very important. Agencies responding to the survey emphasized the importance of annual training of the raters and independent checks of 5 to 10 percent of the data collected. Agencies emphasized the importance of adequate resources to support the CAS and reported that the surveys require 1 to 2 man-months of effort in smaller States, or more than 6 man-months of effort in larger States. Regardless of the size of the network collecting data, it is important that the CAS be designed to be manageable over time with the resources available.

Developments in CAS

The majority of transportation agencies that participated in the survey of practice reported that they have Maintenance Activity Guidelines in place that outline the work methods and resource requirements (in terms of equipment, materials, and personnel) for the maintenance activities most commonly performed using in-house forces. These guidelines are useful for estimating resource needs and for scheduling maintenance activities based on the resources available. However, these guidelines assume a certain level of service is being produced and provide limited assistance in helping transportation agencies estimate the consequences of changing the level of service to meet customer demands and/or agency initiatives. Therefore, a number of agencies are building on these initial efforts to provide the information needed to evaluate different investment strategies.

The survey results identified four significant areas of development with respect to CAS: (1) the use of CAS information to establish performance targets that are linked to resource requirements, (2) the use of automated systems to estimate budgets and/or evaluate the impacts of different investment strategies, (3) the use of CAS results to schedule maintenance activities, and (4) the establishment of stronger links between work priorities and customer expectations. A significant number of agencies are developing these capabilities according to the survey results.

Condition Assessment Guide

To assist agencies with the implementation of CAS that support the use of the information in establishing maintenance priorities and budget requirements, a stand-alone Guide was developed under this project. The Guide provides more detail on establishing a method of assessing the condition of transportation assets. In addition, the Guide introduces the concept of levels of service (LOS) and the use of this information for setting performance targets. Finally, the Guide illustrates the use of this information for estimating budget needs and for developing maintenance programs. The Guide provides examples from SHA and introduces the lessons learned by agencies who have implemented these programs. The Guide also provides a list of resources that might be helpful as an agency moves forward with enhancements to its maintenance practices.

Benefits to Enhanced CAS

Agencies have reported a number of benefits to the use of the enhanced CAS, which are discussed more fully in the Guide. For instance, more than 75 percent of the individuals who responded to the survey indicated that the use of a CAS helped them obtain more consistent conditions on a statewide basis. Improvements in consistency are most likely the result of a better understanding of maintenance conditions by maintenance personnel and the use of performance targets to set statewide maintenance priorities.

Perhaps one of the greatest benefits to the use of a CAS is its role in helping maintenance and operations personnel establish maintenance priorities. The outcome-based performance measures that are used in today's CAS are more customer-oriented than the output-based performance measures used in the past. For example, performance is measured in terms of the number of hours until a road has been cleared after a winter storm rather than the amount of salt used or the number of hours worked. As a result of these changes, maintenance personnel are

able to establish work programs that place a priority on the issues that are of most concern to the traveling public. By linking the CAS to budgeting and resource planning tools, transportation agencies are also better equipped to respond to customer inquiries about raising the level of service being provided in one or more areas. With the establishment of these links, agencies can better report the consequences associated with shifting resources from one area to another.

Research Needs

The results of this research clearly indicate that agencies are transitioning from the output-based maintenance management practices of the past into the more outcome-based, customer focused maintenance management practices required today. This research study was initiated because of the scarcity of resources available to assist agencies through this transition. The resulting Guide provides information needed to assist agencies interested in enhancing their existing CAS so they are better able to link the survey results to budget requirements and maintenance priorities.

However, additional research activities are warranted in this area. The following maintenance suggestions are offered to further assist agencies as they strive to establish stronger links between condition information and maintenance planning activities:

- **Integrating pavement management systems with maintenance management activities.** Pavement management systems are well established in most transportation agencies for assessing pavement conditions and prioritizing preservation needs. However, there are traditionally very weak links between maintenance and pavement management recommendations. Stronger links would enable more coordinated decisions that could lead to improved efficiency in both maintenance and rehabilitation practices.
- **Developing guidelines in the use of statistical applications to support CAS.** Statistics play an important role in determining the number of samples to include in each condition assessment survey for the results to be statistically valid. Additionally, the aggregation of scores from samples to determine overall levels of service requires a sound application of statistical measures. Agencies would benefit from guidance in this area to ensure that the results of the surveys are statistically valid from year to year.
- **Establishing tools to automatically estimate budget requirements and evaluate strategies.** Few agencies responding to the survey have automated tools in place to assist them in estimating budget requirements associated with the various levels of service that might be provided. Ideally, these tools would enable agencies to quickly evaluate the consequences associated with different investment strategies by predicting expected outcomes so reasonable performance targets can easily be established.

Table 8. Commonly used attributes in condition assessment systems.

Asset Type	Attributes
Drainage	
Culverts	Clogged or interrupted flow Structural deterioration
Curb and Gutter	Structural damage or deterioration Settlement Interrupted flow
Ditches	Inadequate drainage due to settling or debris Eroded flowline
Drop Inlets	Blockage Broken/missing grate Structural deterioration
Underdrains	End protection damage Pipe blocked or crushed
Roadside	
Fence	Length of fence (or fabric) damaged Length of broke posts
Grass	Grass height
Brush	Obstructions Encroachment on travelway
Litter	Volume within a certain length Appearance
Pavements	
Paved Shoulders	Drop-off Structural distress
Unpaved Shoulders	Drop-off Build up
Paved Surfaces	Structural distress Cracking Faulting Functional distress Roughness
Traffic Items	
Signs	Post or panels damaged Pole or post plumb (or orientation) Visibility at a standard distance (or legibility)
Pavement Markings	Day visibility Missing or damaged marking Night retroreflectivity
Pavement Markers	Number of missing, damaged, or non-reflecting Obstruction

Asset Type	Attributes
Guardrail	Post or rail damage Orientation Functionality
Guardrail End Treatments	Post or rail damage Length functioning as originally intended Structural integrity
Impact Attenuators	Damage Functionality Percent operational
Special Facilities	
Rest Areas	Graffiti Facilities working properly Appearance Mowing Landscaping Odor Cleanliness

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