MAINTENANCE QUALITY ASSURANCE– SYNTHESIS OF MEASURES

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16. Abstract Constrained budgets and reduced funding are causing state transportation agencies to re-evaluate spending and allocations for maintenance. Much attention is being placed on accounting for maintenance expenditures and justifying maintenance budgets. One approach is to relate highway maintenance to highway performance through maintenance quality assurance (MQA). MQA programs help decision-makers understand maintenance conditions, set priorities, and document the relationship between dollars spent and outcomes. There are guidelines available to assist in the creation of MQA programs, but no comprehensive resources on specific quantitative measures for maintenance quality. States that already have programs are interested in communication with others on how programs are used to improve expenditure decision and justify budgets. Additionally, states interested in establishing an MQA program want to know what measures to use and what others are doing. Two critical barriers for establishing and maturing MQA programs are the lack of a commonly understood set of terms for communication about MQA, and a lack of consensus on a set of commonly recognized maintenance features, characteristics and measures of maintenance performance. This report defines the essential terms necessary to discuss the concepts of highway maintenance quality assurance and presents a synthesis of the measures for maintenance quality assurance used by 26 state transportation agencies. It is expected that common terms and measures will enable agencies to better evaluate their own programs, the performance of their highways, improve communication among agencies and provide a basis for further development of MQA programs.			
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EXECUTIVE SUMMARY

Constrained budgets and reduced funding have caused states to re-evaluate spending and allocations for maintenance. Much attention is being placed on accounting for maintenance expenditures and justifying maintenance budgets. One approach is to relate highway maintenance to highway performance through maintenance quality assurance (MQA). MQA programs help decision-makers to understand maintenance conditions, set priorities, and to document the relationship between dollars and outcomes.

This report provides a synthesis of the measures for maintenance condition as used in maintenance quality assurance programs. The goals of this report are to provide a comprehensive list of measures used to quantify maintenance performance, and to highlight needs and next steps in the development of MQA programs.

The development of MQA programs comes in the midst of a national shift towards using measures to manage government. States practicing MQA want to know what other states are doing, what measures are being used, and what works. It is the expectation that a common understanding of MQA and measures will enable states to better evaluate their own programs, the performance of their highways, and improve state-to-state communication about MQA program development and the effectiveness of maintenance strategies.

This report is the result of a study funded by the Transportation Asset Management Pooled Fund Research Program. The study was completed in conjunction with the National MQA Peer Exchange held in Madison, Wisconsin in October 2004, and co-hosted by the Wisconsin DOT (WisDOT) and the Midwest Regional University Transportation Center (MRUTC) at the University of Wisconsin-Madison. The study began in December 2004 and concluded in August 2005. Representatives from the sponsoring states and the program committee for the National MQA Peer Exchange served as the advisory project committee.

The MQA Documents and Materials Library (http://www.mrutc.org/outreach/MQA/library/) was the primary source of information about MQA programs at state transportation agencies. The website has a comprehensive collection of field guides, rating manuals, reports, and field checklists that were submitted by many of the agencies that participated in the National Maintenance Quality Assurance Peer Exchange. Thirty-three transportation agencies including two Canadian provinces submitted documents to the library. The website is being updated and maintained by the MRUTC as agencies submit new documents. The contents of this report are limited to information available in December 2004.

The study accomplished two main objectives. The first was to assemble of set of common measures for maintenance quality by reviewing and synthesizing the measures used by individual agencies. The second objective was to evaluate consensus and evolution of maintenance quality measurement since the National Workshop on Commonly Recognized Measures for Maintenance held in Scottsdale Arizona in 2000.

As the work progressed it became clear that agencies use different and sometimes conflicting terms to describe aspects of their MQA programs. To facilitate communication and development of MQA program concepts and analysis, this report presents and defines a set of essential terms for MQA. The terms refine, extend and are consistent with terms defined in the glossary of the NCHRP Report 422 Maintenance QA Program Implementation Manual. The MQA terms

presented herein are the key scholarly contribution of this research effort. Clear and commonly understood definitions of terms like feature, characteristic, standard, measure, threshold, and target are essential for effective communication.

The process for identifying measures involved several steps. The first was to identify maintenance categories –logical groups of maintenance features based on their location or function along a highway. The second was to assemble an inventory of maintenance features – physical assets or activities whose condition is measured in the field, and maintenance characteristics –specific qualities/defects in a maintenance feature that are condition evaluated. In the third step, similar categories, features, and characteristics with different names were combined. Finally, measures and standards were identified for each feature and characteristic.

Overall states use very similar categories for organizing maintenance features and characteristics but not enough agreement exists on features and characteristics to allow for the identification of a set of common measures for each category. The reason for good agreement on maintenance categories (e.g. roadway, drainage, traffic management and bridges etc.) is that they are tied to maintenance budgeting and work activities. There is little agreement among the states on what particular features or characteristics are important to measure in each category.

When compared to results of Scottsdale meeting in 2000, MQA programs have evolved considerably. MQA is becoming a recognized business function at state transportation agencies. Terminology for MQA analysis and business has evolved significantly but no standard exists.

It is expected that the findings of this report will have far reaching implications in the area of highway maintenance. An agency beginning a program could use this to design measures; for agencies with established programs, this information can be used to expand their program to include new measures or to improve existing measures or to eliminate measures. The broader maintenance community can ultimately use these findings to launch the discussion about developing consensus on and adopting a set of common measures for MQA.

This report is available online at the MRUTC website (http://www.mrutc.org/outreach/MQA/). Notification of the report's availability was disseminated to the participants of the MQA Peer Exchange via email. The report was submitted to the AASHTO Transportation Asset Management Today website (http://assetmanagement.transportation.org/tam/aashto.nsf/home

1 INTRODUCTION

Constrained budgets and reduced funding have caused states to re-evaluate spending and allocations for maintenance. Much attention is being placed on accounting for maintenance expenditures and justifying maintenance budgets. One approach is to relate highway maintenance to highway performance through maintenance quality assurance (MQA).

The idea of quality in maintenance was first considered in the 1960's as a part of a maintenance management system concept (1). The notion of quality in highway maintenance has gained momentum in recent years as the national focus shifts from infrastructure design and construction to maintenance and rehabilitation (2). Performance measures are now being used in transportation maintenance to ensure quality, as is being done in other transportation fields such as transportation planning (3).

MQA is a process that uses quantitative quality indicators to assess the performance of maintenance programs. These programs are outcome based and provide statistically valid, reliable and repeatable measures of asset condition (4) Performance measures are at the foundation of an effective MQA program (5).

As the national focus shifts towards using measures to manage government, states are becoming increasingly interested in establishing MQA programs for a combination of reasons. The motivating drivers include legislative mandates, increased accountability, and improved maintenance program management. MQA data are being used for condition assessment, maintenance policy analysis, efficiency measurement, and/or maintenance funds allocation (6). Additional expectations from MQA programs are the detection of insufficient maintenance efforts, poor material performance, and incorrect maintenance procedures (1).

There are guidelines available to assist in the creation of MQA programs (1), but less on quantitative measures. States that already have programs are interested in communication with others on how programs are used to increase accountability and budget justification. Additionally, states interested in establishing an MQA program want to know what measures to use and what others are doing.

Two critical barriers for establishing and maturing MQA programs are the lack of a commonly understood set of terms for communication about MQA, and a lack of consensus on a set of commonly recognized maintenance features, characteristics and measures of maintenance performance. It is expected that common terms and measures will enable agencies to better evaluate their own programs, the performance of their highways, improve communication among agencies and provide a basis for further development of MQA programs.

This report is the result of a study funded by the Transportation Asset Management Pooled Fund Research Program and associated with the National MQA Peer Exchange held in Madison, Wisconsin in October 2004 that was co-hosted by the Wisconsin DOT (WisDOT) and the Midwest Regional University Transportation Center (MRUTC) at the University of Wisconsin-Madison. The study began in December 2004 and concluded in August 2005. Representatives from the sponsoring states and the program committee for the National MQA Peer Exchange served as the advisory project committee.

The MQA Documents and Materials Library (http://www.mrutc.org/outreach/MQA/library/) was the primary source of information about MQA programs at state transportation agencies. The

website has a comprehensive collection of field guides, rating manuals, reports, and field checklists that were submitted by many of the agencies that participated in the National Maintenance Quality Assurance Peer Exchange. Thirty-three transportation agencies including two Canadian provinces submitted documents to the library. The website is being updated and maintained by the MRUTC as agencies submit new documents. The contents of this report are limited to information available in December 2004.

1.1 Objectives

This report provides a synthesis of the measures used to quantify maintenance condition. The goals are to provide a comprehensive list of measures for quantifying maintenance performance, to present a set of essential terms for communicating about MQA measures, and to identify needs and next steps in the development of MQA programs. In addition, this report presents an evaluation of consensus and evolution of maintenance quality measurement since the National Workshop on Commonly Recognized Measures for Maintenance in Scottsdale Arizona held in 2000.

1.2 Methodology

The process for identifying measures for MQA involved several steps. The first step required that MQA programs at state transportation agencies be identified. Documents from 33 transportation agencies including 2 Canadian provinces were used to identify 26 agencies with MQA programs.

The second step was to compile an inventory of the maintenance categories, features and characteristics that are measured by each agency. Maintenance categories are logical groups of maintenance features and characteristics based on their location or function along a highway. Maintenance features are the physical assets or activities whose condition is measured in the field, and maintenance characteristics are the specific qualities/defects in a maintenance feature that are condition evaluated.

In the third step, similar categories, features, and characteristics with different names were combined. This step involved human judgment to match-up or distinguish between the words used to name the categories, features and characteristics in each agency's program. The descriptions and definitions in the agency's MQA documents were used in this step.

From the inventory of the maintenance categories, seven maintenance categories were identified as most frequently used to group maintenance features and characteristics. An inventory of maintenance features and characteristics was used to identify which are most frequently measured by agencies.

In the fourth step, measures and standards were identified for the features and characteristics in each maintenance category. The measures and standards reported are for the features and characteristics for which measures could be found in the state documents.

Finally, the categories, features, characteristics and measures compiled from the state agencies are compared to the ones identified in 2000 during the National Workshop on Commonly Recognized Measures for Maintenance held in Scottsdale, Arizona. The purpose of the comparison is to evaluate consensus among states and the evolution of MQA measures.

1.3 Related Studies

Several National Cooperative Highway Research Program (NCHRP) studies focus on related aspects of MQA. These studies focus on the use of performance based decision making throughout the transportation industry, the development of maintenance quality assurance programs nationally, and benchmarking initiatives for MQA programs.

- NCHRP Project 8-32(2): Multimodal Transportation: Development of a Performance-Based Planning Process developed a framework for performance-based transportation planning. The framework provides guidance in the identification and selection of performance measures. The results of this project are available in NCHRP Report 446: A Guidebook for Performance-Based Transportation Planning (7).
- NCHRP Project 14-12: Highway Maintenance Quality Assurance created an implementation manual that contains guidance for highway agencies on how to develop and implement an MQA program. The results of this project can be found in NCHRP Report 422: Maintenance Quality Assurance Program Implementation Manual (1), and in NCHRP Web Document 8, http://www.nap.edu/books/nch008/html/index.html.
- NCHRP Project 14-13: Customer Driven Benchmarking for Highway Maintenance Activities recognizes that continuous improvement in maintenance management is achieved by providing guidance for the establishment of levels of service or threshold values for acceptable condition of the highway system and its components. This study addresses guidelines for the establishment of benchmarks. The results of this project are published in NCHRP Report 511: The Guide and Primer for Customer Driven Benchmarking of Maintenance Activities (5) and in NCHRP Web Document 58, http://trb.org/publications/nchrp/nchrp_w58.pdf.

This report builds upon results of two National MQA conferences. The National Workshop on Commonly Recognized Measures for Maintenance held in Scottsdale, Arizona, 2000 is the first known effort to identify commonly used measures for MQA. The Scottsdale workshop (8) set the stage for commonly used measures by promoting the development of maintenance quality assurance programs and spurring the exchange of information on the process. The National MQA Peer Exchange held in Madison, Wisconsin in October 2004 brought transportation officials together to share information and ideas of current MQA programs and practices and to define a national agenda for MQA program development (4). The identification of common measures for MQA was identified in the Peer Exchange's national agenda. In addition, a conference held in Whitefish, Montana is mentioned frequently in the content of MQA program development however conference materials or proceedings are not publicly available.

A survey conducted prior to the Madison MQA peer exchange also revealed a clear need for further research focused on performance measures (6). Survey responses were received from 36/50 states, and 3 of 10 Canadian Provinces. Another related survey conducted by the American Association of State Highway and Transportation Officials (AASHTO) on Performance Measure is relevant to this study. The AASHTO Survey (9) was issued in 2002 with the goal of identifying common measures to facilitate benchmarking, asset management and the development of measurement equipment.

Many states are thinking beyond what data to gather; they are concentrating on using information in decision-making. MQA programs include statistical analysis, and states are experimenting

with alternate reporting formats to effectively communicate to legislatures and the public. States are interested in guidance for selecting sample sections, data integration between maintenance management and other systems, and the incorporation of winter maintenance in an MQA framework (10) (11), (12). Microsoft Excel workbooks are now being used in MQA to provide low-risk and high-performance products for use by DOTs (12). In addition, some MQA programs incorporate information to quantify the agency's performance on environmental stewardship (13).

1.4 Organization of this Report

As the work progressed following the research steps described in Section 1.2, it became clear that agencies use different and sometime conflicting terms to describe aspects of their MQA programs. To facilitate communication and development of MQA program concepts and analysis, Chapter 2 presents and defines a set of essential terms for MQA. The terms refine, extend and are consistent with terms defined in the glossary of the NCHRP Report 422 Maintenance QA Program Implementation Manual. Clear and commonly understood definitions of terms like feature, characteristic, standard, measure, threshold, and target are essential for effective communication.

The other chapters in this report present results of research steps discussed in Section 1.2. Chapter 3 provides an indication of the states practicing MQA along with a detailed analysis of what is being measured. This chapter lists the categories, features and characteristics being measured in each agency's program. In addition, charts for each category indicate the frequency that features and characteristic are included in the MQA program.

Chapter 4 presents the actual measures that states use in the field to assess maintenance condition. The key findings of Chapter 4 are tabulated and presented in tables that provide a comprehensive resource on the current state of practice.

Chapter 5 of this report compares the findings in Chapters 3 and 4 to the results and outcomes of the National Workshop on Commonly Recognized Measures for Maintenance. The chapter includes a discussion on the progress and evolution of MQA terminology and measures since the Scottsdale Workshop in 2000.

Chapter 6 presents the findings and conclusions of this study. The chapter provides an overall picture of the state of practice and the common themes identified from program to program.

Chapter 7 provides recommendations for nest steps in the development of MQA concepts, programs and analysis.

2 MQA TERMINOLOGY

Based on review of individual agency documents, the terms used in the business of MQA are diverse and sometimes inconsistent. Many agencies use their own set of terms that are often poorly defined. Furthermore, among agencies, the same term is used to describe subtle but importantly different concepts. A lack of consensus on terminology makes it difficult for maintenance officials to communicate with themselves and with those outside the maintenance profession.

A set of terms for MQA were identified as part of NCHRP Project 14-12 (1). Some agencies have adopted those terms and the definitions in the NCHRP report provide an excellent basis for further development of a terminology for describing the artifacts and concepts of maintenance quality assurance. The following are a proposed set of terms and definitions for MQA. The definitions are consistent with yet refine and expand upon the definitions presented in the glossary of the NCHRP report on Highway MQA (1). In addition, the list includes definitions for terms like threshold and target that were not included in the NCHRP glossary. These definitions reflect the meaning of the terms used in this paper.

1) *Maintenance category* - A maintenance category is a logical grouping of maintenance features based on their location or function along a highway. Examples include roadway, drainage and traffic management. Categories are made up of features whose condition is measured with respect to a particular characteristic.

2) *Maintenance feature* - A maintenance feature is a physical asset or activity whose condition is measured in the field. There is one or more maintenance feature in each category. Collectively the maintenance features describe the maintenance quality of a maintenance category.

3) *Maintenance characteristic* – A specific quality/defect in a maintenance feature that is condition evaluated (example: signs can be evaluated with respect to retroreflectivity, appearance, sign height and other characteristics/deficiencies).

4) *Standards* - A tolerance level or criterion that helps to identify when a feature is not 'functioning as intended'; a tolerance level or criterion that helps to identify whether a characteristic requires maintenance attention or a characteristic's condition is unacceptable. A standard indicates when maintenance is needed.

5) *Measures* – Measures describe how to quantify the deficiency of a maintenance feature or characteristic. For example linear feet, percentage area, amount of deficiency.

6) *Thresholds* – Thresholds are predetermined system-wide maintenance levels for features and categories. Thresholds can be thought of as a grading scale or LOS indicator for MQA. Thresholds indicate how much or what percentage of the system is with or without deficiency. Thresholds also relate measures to customer satisfaction.

7) *Targets* – Targets relate thresholds to the maintenance budget. The target represents the expected threshold level that is attainable given the budget.

Figure 1 illustrates the hierarchical relationship between category, feature, and characteristic. A category is a group of related features. There are one or more characteristics for each feature. The distinction between feature and characteristic is important; features are physical assets while characteristics are the physical qualities or defects of the assets. Measures for maintenance quality are concerned with the physical quality of the assets. Yet maintenance quality measures tend to be defined for the feature. One must read the description of the measure to identify the particular characteristic of the feature that is being evaluated. The exception is for flexible pavement, rigid pavements and shoulder features. For these features agencies explicitly identify a set of characteristics and the corresponding measure for each.

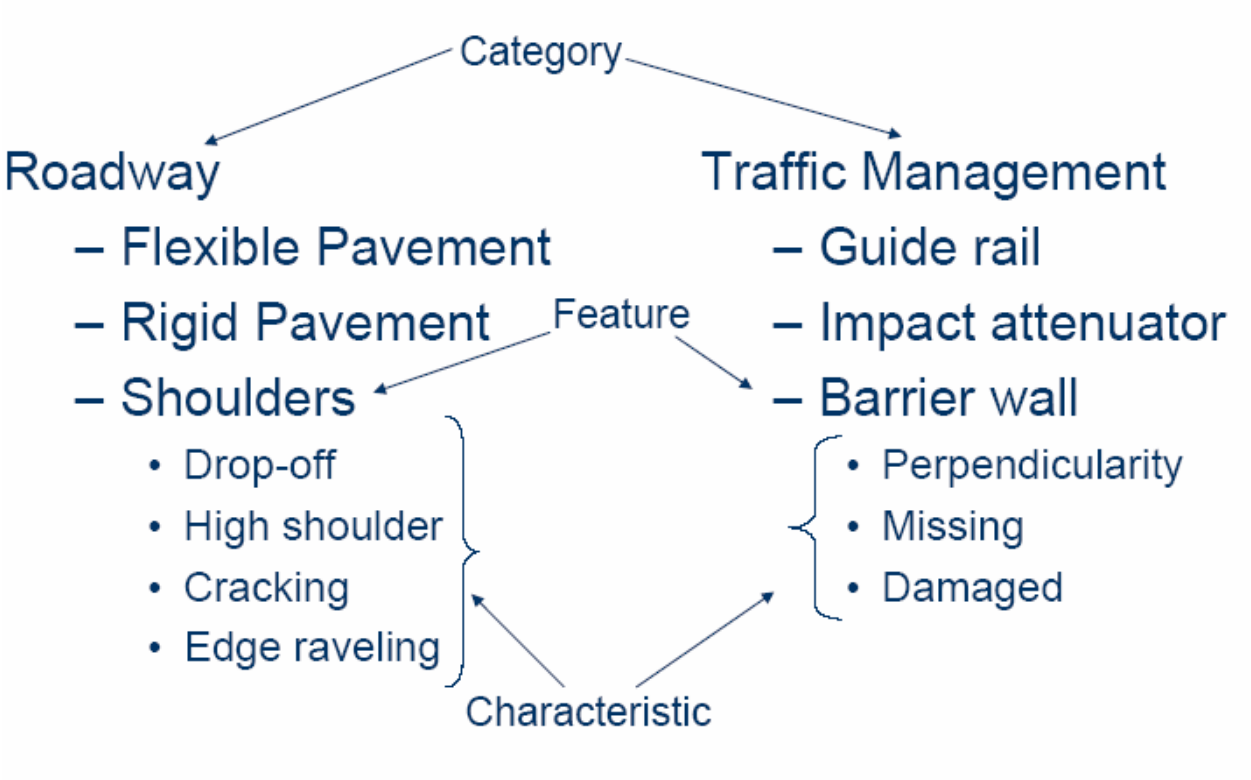

Figure 1. Relationship between Category, Feature and Characteristic

For flexible pavements, rigid pavements and shoulder features. Extensive condition assessment databases already exist. Agencies tend to take advantage of existing inventory and condition assessment databases for MQA. When these databases exist agencies tend to use the available condition information for multiple characteristics to assess the maintenance quality of a feature. For most features, inventory and condition data do not exist. It is thus necessary to collect data in order to assess maintenance quality. Agencies tend to use a random sampling strategy to collect data in the field. To minimize the workload agencies try to identify a single key measure for each feature.

3 MAINTENANCE CATEGORIES, CHARACTERISTICS, AND FEATURES

This chapter presents a snapshot of the maintenance categories, features, and characteristics included in MQA programs and the states that measure them. Specifically, the chapter presents:

- The maintenance categories most often used to group features and characteristics;
- The maintenance features and characteristics most often measured;
- The features and characteristics for which measures could be identified; and
- Details on who is measuring what, and what is being measured by whom.

The chapter draws from MQA program materials available on the MQA documents library. Particularly useful are the rating manuals, reports, and field checklists from 26 agencies. The results of this inventory are solely based on the documents submitted to the MQA Library. Other agencies may have MQA programs and the agencies listed herein may measure other features or characteristics.

Before a list of commonly used measures can be assembled it is important to identify what is measured. A maintenance inventory was completed to provide a better understanding of the maintenance categories, features and characteristics being included in MQA programs.
Agencies tend to group features and characteristic into maintenance categories which are related to the budget leading to the ability to evaluate budget trade-offs. Seven categories were identified from the agency's documents:

1. Roadway
2. Drainage
3. Traffic management
4. Roadside and vegetation
5. Snow and ice
6. Bridges
7. Rest areas

There is good consistency among the agencies regarding the maintenance categories in their MQA programs. The reason for good agreement on maintenance categories (e.g. roadway, drainage, traffic management and bridges, etc.) is that many states use similar maintenance budgeting categories.

There is little consistency among states on what particular features or characteristics are important to measure in each category. As a result a large number of features and characteristics were identified. The use of different features and characteristics makes it difficult to identify measures.

Some categories are more developed than others as seen by the number of MQA programs including a feature or characteristic and the number of features or characteristics for which measures could be identified. Table 1 provides an overview of each category, showing the largest, smallest and average number of features or characteristics measured in each maintenance category. For example, a minimum of 1, maximum of 7, and average of 3.9 drainage features are measured by state MQA programs. The last column in Table 1 identifies the state MQA programs that measure the largest and second largest number of features/characteristics in a

category. Traffic management tops the list of most often included categories followed by roadside and vegetation.

Table 1. Summary of Inventory Results

Category	Features/Characteristics			States Measuring most Features & Characteristics
	Min.	Max.	Average	
Roadway				
- Flexible Pavement	4	10	6.6	Iowa and Missouri
- Rigid Pavement	2	7	4.5	Missouri and North Carolina
- Shoulders	1	8	4.3	Maryland and Missouri
Drainage	1	7	3.9	Tennessee and Kansas
Traffic Management	1	10	7.55	Colorado, Washington D.C. Mississippi and Missouri
Roadside and Vegetation	3	9	5.9	Tennessee, Texas and Wisconsin
Snow and Ice	1	2	1.2	Tennessee
Bridges	1	4	2.1	Washington D.C. and Missouri
Rest Areas	1	5	3	California, New York and South Dakota

It is important to note that Table 1 counts only the features and characteristics for which measures could be identified. MQA documents include other features and characteristics but without clear indication of the associated measures.

The subsections that follow list the characteristics and features in each category. Each category includes five to twenty features or characteristics. Inventory tables, Tables 2 – 9, show which features or characteristics are measured by each state. Bar charts, Figures 2 - 10 show the percentage of states that measure each characteristic or feature in a given category. It is important to note that the tables and charts include only the features and characteristics for which measures could be identified.

3.1 Roadway

The roadway category consists of three main features – flexible pavement, rigid pavement, and shoulders. To evaluate the maintenance quality of these roadway features, agencies tend to define measures for characteristics (quality defects that are condition assessed). These characteristics are measured in the field to determine the overall maintenance condition of each roadway feature. The roadway category is unique in this respect; for all other categories agencies tend to define measures for features.

Most, if not all states that assess maintenance quality of pavements use data from their pavement management programs. Consequently, for most states MQA of pavement maintenance is in documents other than those submitted to the MQA Document Library. As a result, not all states provided documents detailing pavement measures to this study.

Table 2 lists fourteen flexible pavement characteristics and eleven rigid pavement characteristics identified from ten state MQA programs. The number of flexible pavement characteristics ranges from four to ten; the number of rigid pavement characteristics ranges from three to seven. Missouri and North Carolina lead the way in measuring both the flexible and rigid pavement characteristics. Missouri measures 64% of the flexible pavement characteristics and 64% of the

rigid pavement characteristics. North Carolina measures 55% of the rigid pavement characteristics. Iowa measures 71% of the flexible pavement characteristics while Texas measures only 29% of the characteristics. Nevada measures only 18% of the rigid pavement characteristics.

Figure 2 and Figure 3 show the percentage of states measuring each of the flexible and rigid pavement characteristics. Potholes and cracks are among the most frequently measured characteristics of both the flexible and rigid pavement features. Among the flexible pavement characteristics, rutting is measured by 100% of the MQA programs. Potholes, cracking and surface raveling are each measured in 70% of the MQA programs inventoried, while surface oxidation and longitudinal cracks are only measured in 20% of the programs. Among the rigid pavement characteristics, spall/popouts and joints are each measured in 80% of the MQA programs. Cracking and potholes are measured in 70% and 60% of programs respectively, while rutting, ride quality and longitudinal cracks are only measured in 10% of the programs including rigid pavement.

As shown in Table 3, nineteen of the MQA programs measure shoulders characteristics. These programs included one to eight of the ten characteristics listed. Missouri and Maryland each measure 80% of the shoulder characteristics. Wisconsin measures 70%, while Ohio and Mississippi each measure 10% of the shoulder characteristics. Shoulder drop-off was the most frequently measured shoulder characteristic; it is measured in 84% of the MQA programs. As in the flexible and rigid pavement features, cracking and potholes are measured most frequently, 63% and 58% respectively. The least measured shoulder characteristics are shoulder cross slope and vegetation growth.

Figure 4 shows the percentage of states measuring each shoulder characteristic. Shoulder drop-off is the most frequently measured shoulder characteristic; 85% of MQA programs measures shoulder drop-off. Portholes and cracking are each measured in approximately 65% of programs while vegetation growth and shoulder cross slope are only measured in approximately 25% of programs.

Table 2. Inventory of Characteristics for Flexible and Rigid Roadway Pavement Feature

Feature	Characteristic	State									
		CA	IA	IN	KS	MD	MO	NC	NE	TN	TX
Flexible Roadway Pavement	Alligator Cracks	x	x					x	x	x	
	Bleeding/Flushing	x	x			x	x	x		x	
	Cracking	x		x	x	x	x			x	x
	Depressions/Bumps		x	x	x		x				
	Edge break up (edge raveling)		x	x			x				
	Longitudinal Cracks		x						x		
	Patching						x	x			x
	Potholes	x	x	x	x	x	x			x	
	Raveling/ Stripping (surface)		x	x		x	x	x	x	x	
	Rideability / Ride quality	x						x			x
	Rutting	x	x	x	x	x	x	x	x	x	x
	Shoving			x	x	x	x				
	Surface Oxidation		x					x			
	Transverse Cracks		x					x	x		
Rigid Roadway Pavement	Cracking	x	x	x		x	x			x	x
	Depressions/Bumps		x	x			x				
	Faulting				x	x	x	x	x		
	Joints (seal)	x	x	x	x	x	x	x		x	
	Longitudinal Cracks							x			
	Patching						x	x			x
	Potholes		x	x	x	x	x			x	
	Rideability / Ride quality										x
	Rutting										x
	Spalls/Popouts	x	x	x	x	x	x	x		x	
	Transverse Cracks							x	x		

*AB, CO, DC, KY, MS, NY, OH, SC measure pavement characteristics but do not separate characteristics for flexible and rigid pavements.

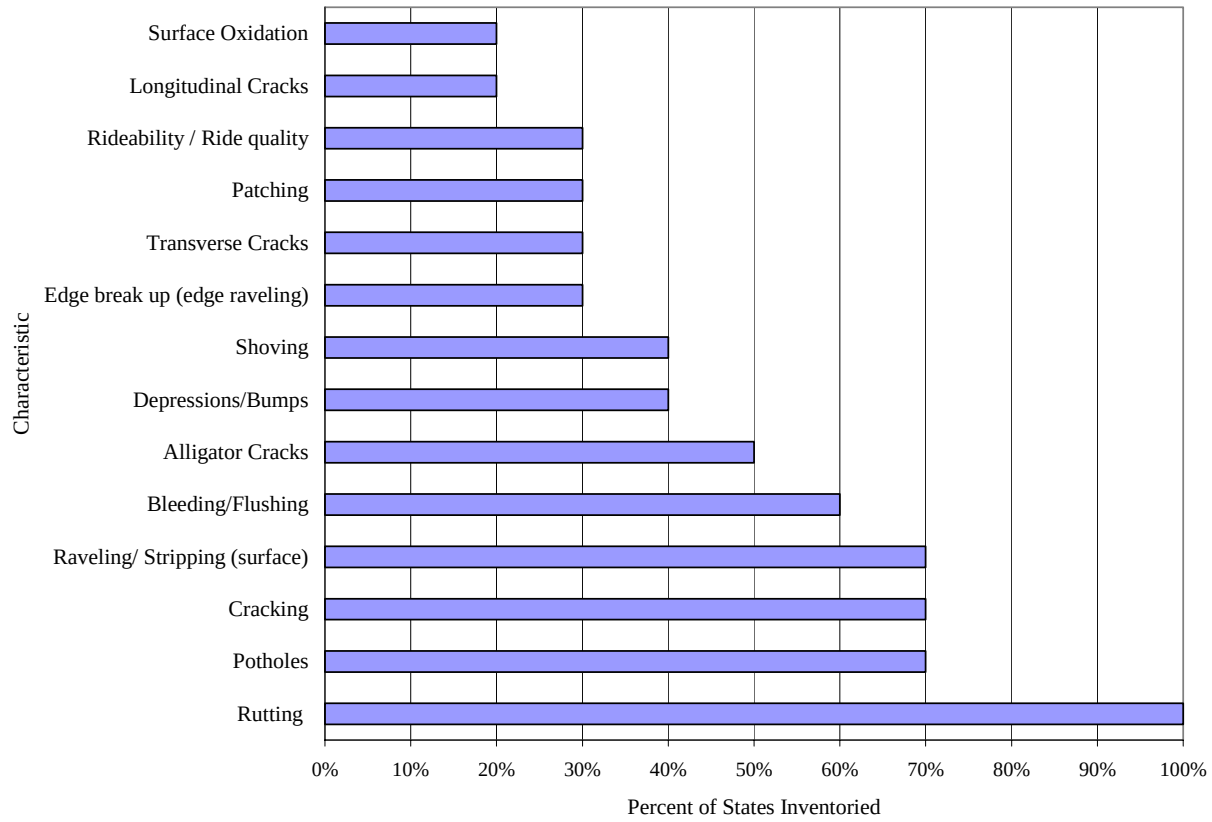

Figure 2.Common Flexible Pavement Characteristics

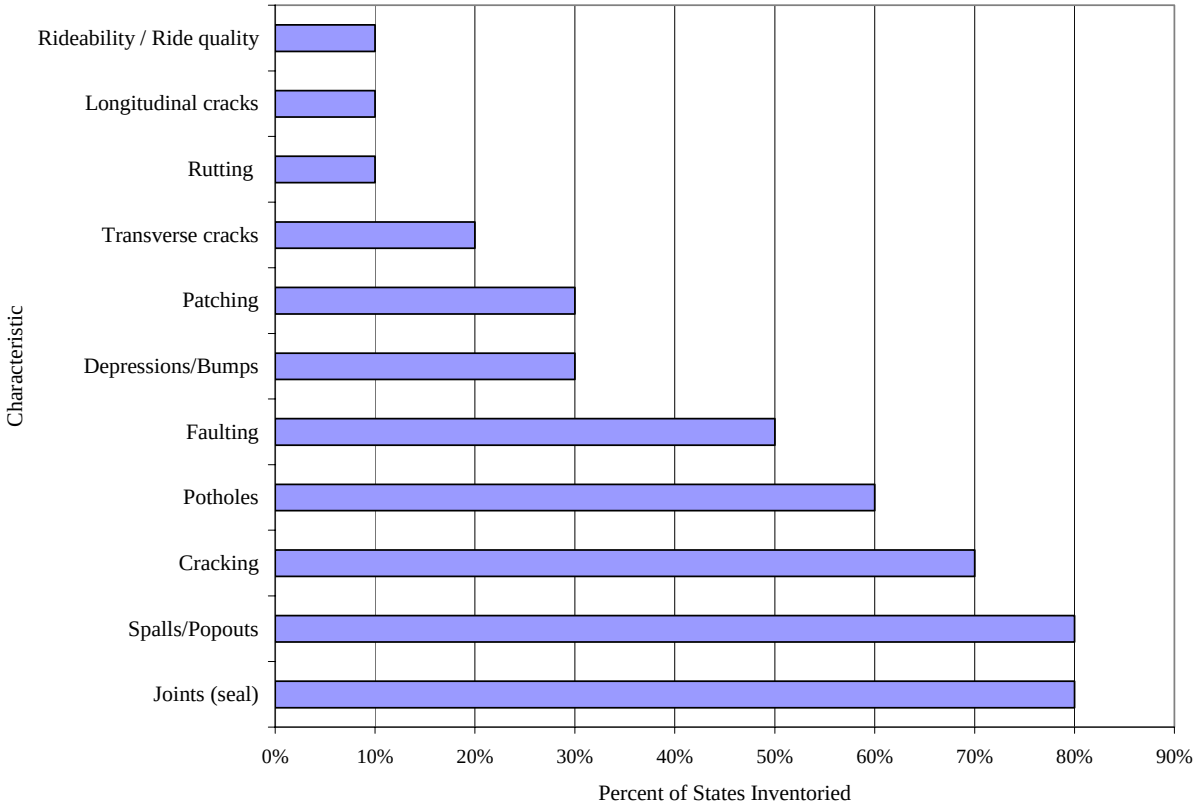

Figure 3. Common Rigid Pavement Characteristics

Table 3. Inventory of Characteristics for Shoulder Roadway Features

	State or Province																			
Characteristic	AB	CA	CO	IA	IN	KS	KY	MD	MO	MS	NC	NE	NY	OH	SC	TN	TX	VA	WA	WI
Cracking	x	x		x	x	x		x	x			x				x		x	x	x
Distortion							x	x	x		x				x			x		
drainage					x	x		x	x			x				x			x	x
Pavement drop-off to shoulder			x	x	x		x	x	x			x		x		x	x			
Potholes		x		x	x	x	x	x	x							x	x	x	x	x
Rutting	x	x		x		x												x		x
Shoulder cross slope				x	x								x						x	x
Shoulder drop off to ground			x	x	x	x	x	x	x	x	x	x	x		x	x		x	x	x
Surface-edge raveling		x						x	x							x		x	x	x
Vegetation growth						x		x	x			x								

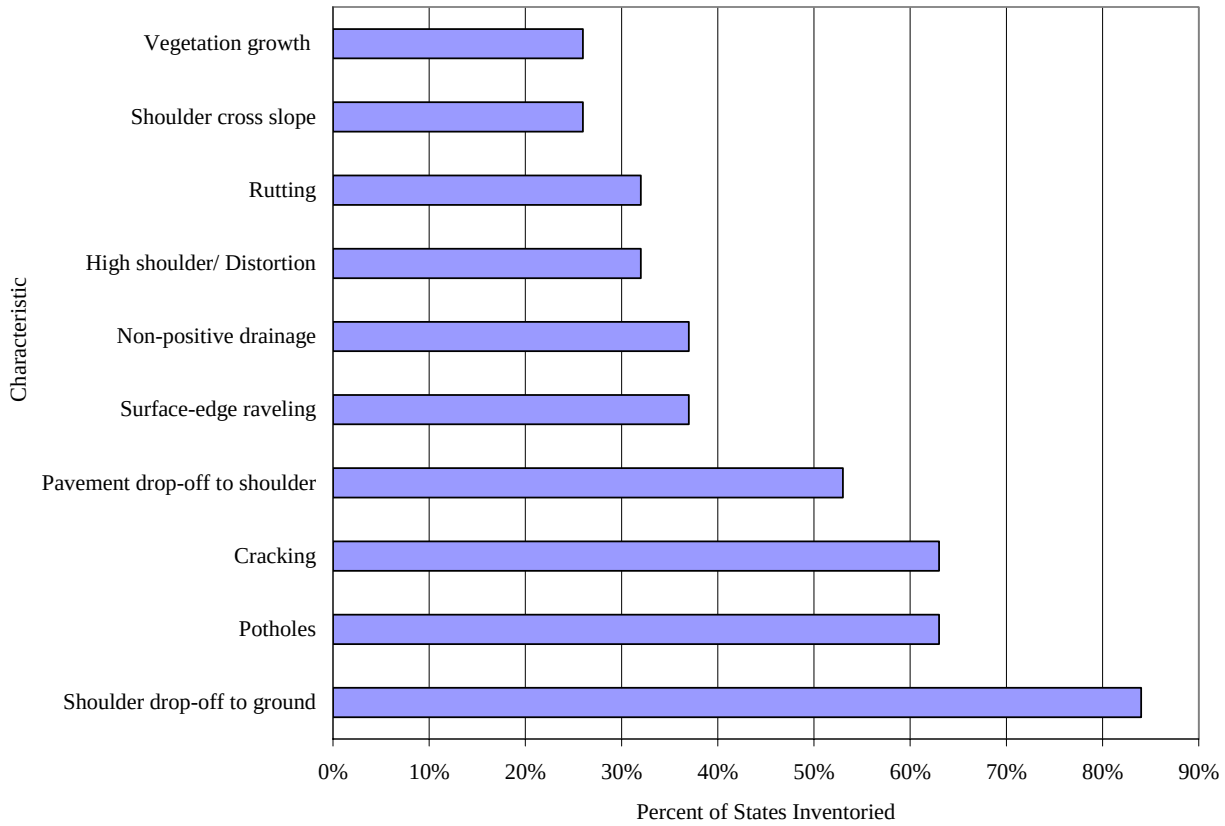

Figure 4. Common Shoulder Characteristics

3.2 Drainage

Table 4 lists nine drainage features identified from twenty state MQA programs. The number of drainage features measured by an individual state MQA program ranges from one to seven. Tennessee leads the way in measuring the drainage features, measuring seven out of nine or 78%. Wisconsin and Kansas each measure 67% of the drainage features. Washington D.C., Iowa and Ohio each measure 22% of the drainage features. The Colorado MQA program measures the fewest number of drainage features, measuring 11% of features.

Figure 5 shows the percentage of states measuring each of the drainage features. Ditches are the most frequently measured drainage features. Among the drainage features, ditches are measured by 85% of the MQA programs. Curb and gutter, and drop inlets are each measured by 60% of programs. The least measured drainage features are pipes and storm drains, each measured by 20% of programs.

3.3 Roadside and Vegetation

Table 5 lists fourteen roadside and vegetation features identified from twenty-one state MQA programs. The number of roadside and vegetation features measured by an individual state MQA program ranges from three to nine. Tennessee, Texas and Wisconsin each measure 64% of the roadside and vegetation features. Missouri measures 47% of features, while Kentucky measures only 21% of the features.

Figure 6 shows the percentage of states measuring each of the roadside and vegetation features. Litter/debris is the most frequently measured roadside and vegetation feature. Liter/debris is measured by 76% of state MQA programs. Mowing and fences are each measured by 71% of programs, while brush and tree control is measured by 67% of programs. The least frequently measured features, hazardous debris/roadkill and curb trees/sidewalk edge, are measured by 9% and 14% of programs respectively.

Table 4. Inventory of Drainage Features

Feature	State																			
	CA	CO	DC	IA	IN	KS	KY	MD	MO	MS	MT	NC	NY	OH	SC	TN	UT	VA	WA	WI
Catch basins/ Drop inlets			x		x	x		x	x			x			x	x	x	x	x	x
Culverts				x	x	x	x	x	x							x			x	x
Curb/Gutter					x	x	x	x	x			x	x		x	x	x	x		x
Ditches	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Drainage structure			x				x			x	x		x							
Pipes												x			x	x		x		
Slope failures/ Washouts	x	x		x		x				x	x								x	
Storm drains									x	x						x				x
Subsurface drainage					x	x		x						x		x		x	x	x

Table 5. Inventory of Roadside and Vegetation Features

Feature	State																			
	CA	CO	DC	IA	IN	KS	KY	MD	MO	MS	MT	NC	NY	OH	SC	TN	TX	UT	VA	WA	WI
Brush and tree control	x		x	x	x	x	x	x	x			x	x		x		x			x	x
Curb trees /Sidewalk edge			x	x						x											
Fences	x	x	x	x	x	x	x	x	x		x		x			x		x	x		x
Graffiti	x							x	x							x				x	x
Hazardous debris/Roadkill					x											x					
Landscaping		x					x	x		x		x		x		x	x		x		
Litter/Debris	x	x		x	x	x		x	x		x	x		x	x	x	x	x		x	x
Litter removal (vegetated areas)	x									x			x	x		x	x				x
Mowing		x	x	x	x			x	x	x	x	x			x	x	x	x	x		x
Noxious weed		x		x	x						x		x	x			x			x	x
Retaining walls	x		x														x				x
Sidewalks/Curb			x						x		x				x	x	x		x		
Slopes						x		x	x	x	x	x		x		x	x	x	x	x	x
Turf condition									x	x		x			x						

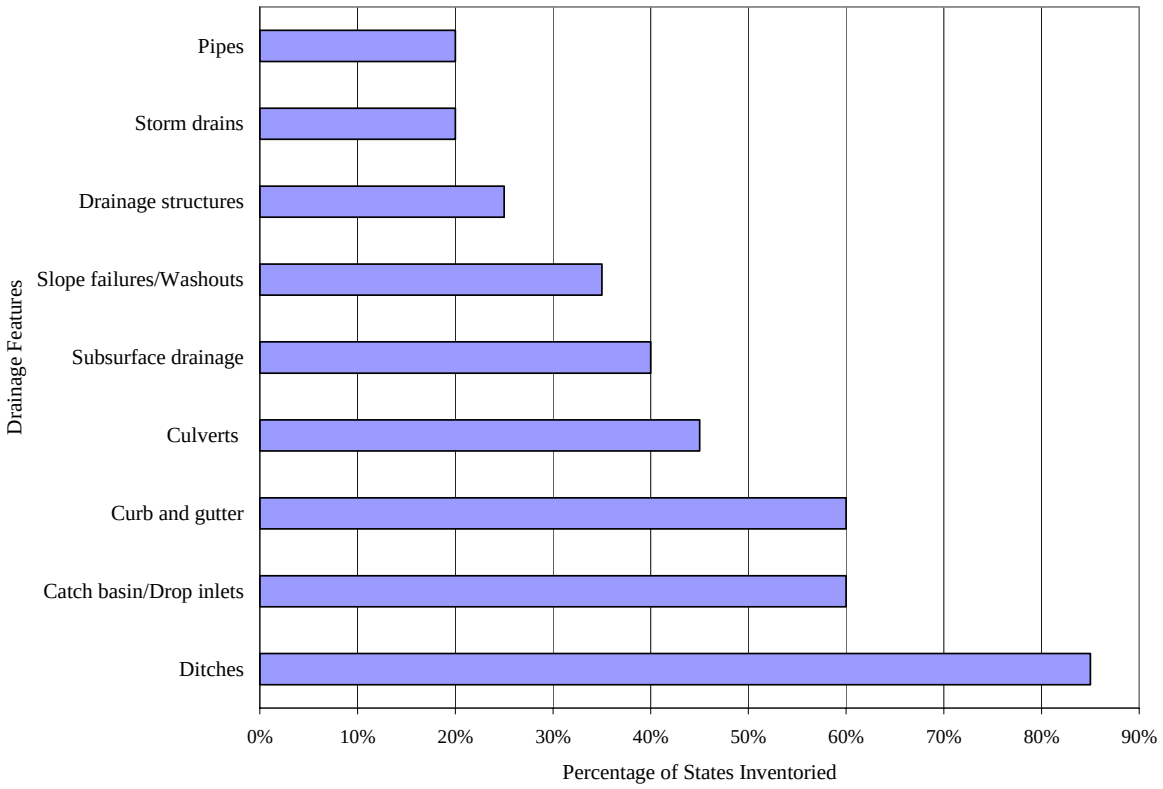

Figure 5. Common Drainage Features

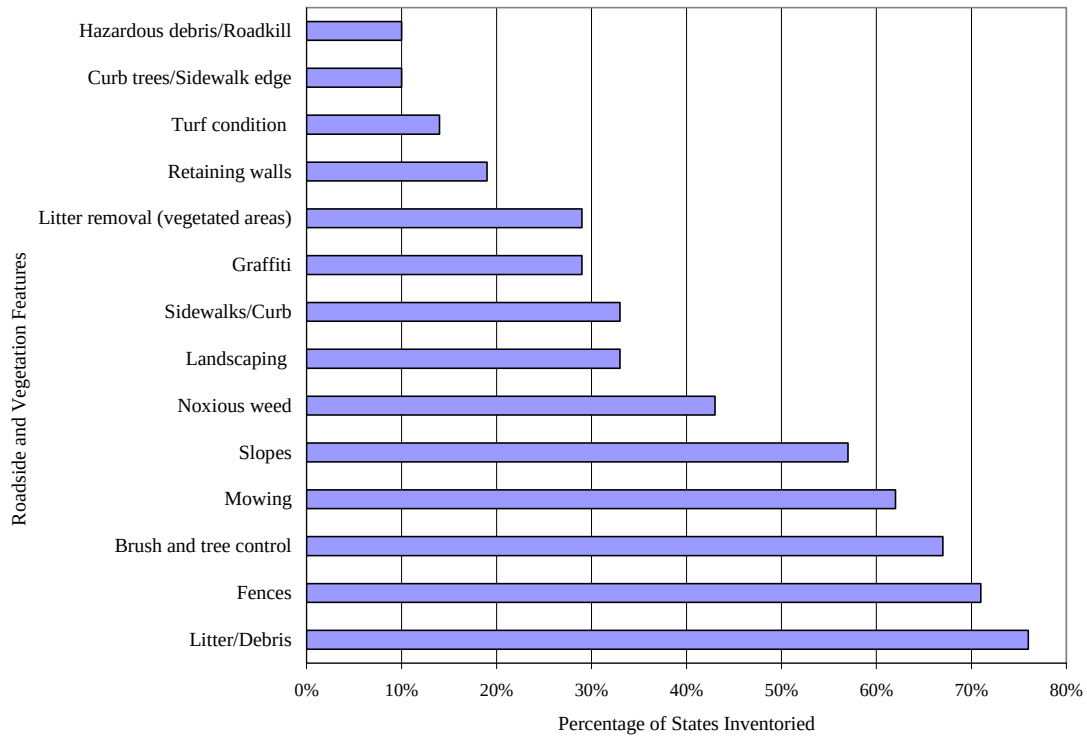

Figure 6. Common Roadside and Vegetation Feature

3.4 Traffic Management

Figure 7 shows the percentage of states measuring each of the traffic management features. Signs are the most frequently measured traffic management features. Signs are measured by 91% of state MQA programs. Guiderail/guardrail and pavement markings are each measured by 82% and 86% of states respectively. IT, object markers and traffic signals are measured by less than 15% of state MQA programs.

Table 6 lists fourteen traffic management features identified from twenty-one state MQA programs. The number of traffic management features ranges from one to ten. Colorado, Washington D.C., Missouri and Mississippi lead the way in measuring traffic management features, each measuring 71% of features. Five other state MQA programs measure 64% of traffic management features. Based on the documentation submitted, Washington State measures 21% of features while Minnesota measures 7% of the features.

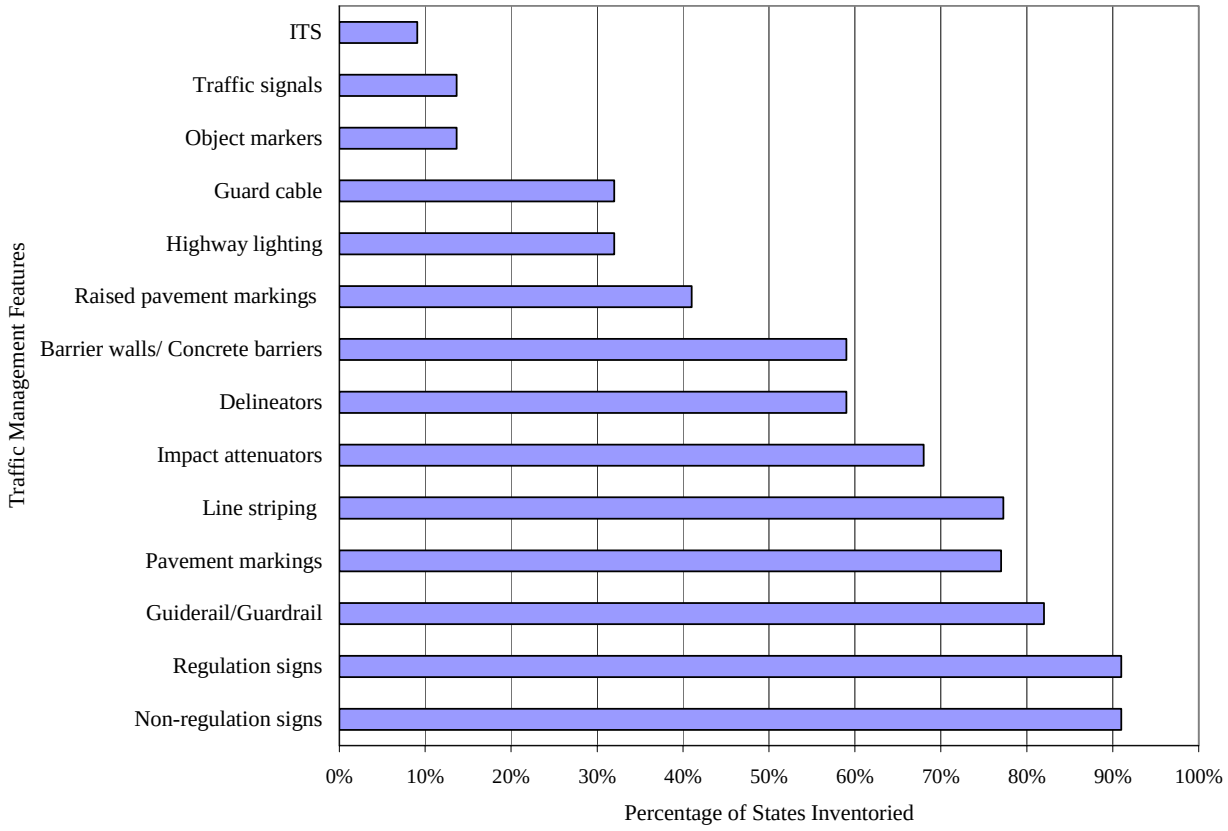

Figure 7. Common Traffic Management Features

Table 6. Inventory for Traffic Management Features

Feature	State																					
	CA	CO	DC	IA	IN	KS	KY	MD	MN	MO	MS	MT	NC	NY	OH	SC	TN	TX	UT	VA	WA	WI
Barrier wall/Concrete barriers	x		x	x	x	x	x	x		x	x	x					x			x		x
Delineators		x	x	x	x	x		x		x	x	x	x					x	x			x
Guard cable				x						x				x	x	x				x		x
Guide / Guard rail	x	x	x	x	x	x	x	x		x	x		x	x	x	x	x	x	x	x	x	
Highway lighting		x	x	x						x	x	x								x		
Impact attenuators	x	x	x		x	x	x	x		x	x		x		x	x	x	x				x
ITS Systems		x										x										
Line striping	x	x	x	x		x	x	x	x		x	x	x	x		x		x	x	x		x
Non-regulation signs	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x
Object markers				x		x				x												
Pavement markings	x	x	x		x	x		x		x	x	x	x	x	x	x	x		x	x	x	x
Raised pavement markings	x		x		x						x					x		x		x	x	x
Regulation Signs	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x
Traffic Signals		x										x					x					

3.5 Snow and Ice

Table 7 lists three snow and ice features identified from six state MQA programs. The three features identified include – hours to bare lane, plowing activity and statewide salt usage. Each state MQA program with the exception of Tennessee measures 33% of the snow and ice features. Tennessee measures 67% of features.

Figure 8 shows the percentage of states measuring each snow and ice feature. Hours to bare lane is the most frequently measured feature. Five of six states measure hours to bare lane. 83% of state MQA programs measure hours to bare lane.

Table 7. Inventory of Snow and Ice Features

	State					
Feature	CO	MN	NC	ON	TN	WI
Hours to bare lane		x	x	x	x	x
Plowing activity					x	
Statewide salt usage	x					

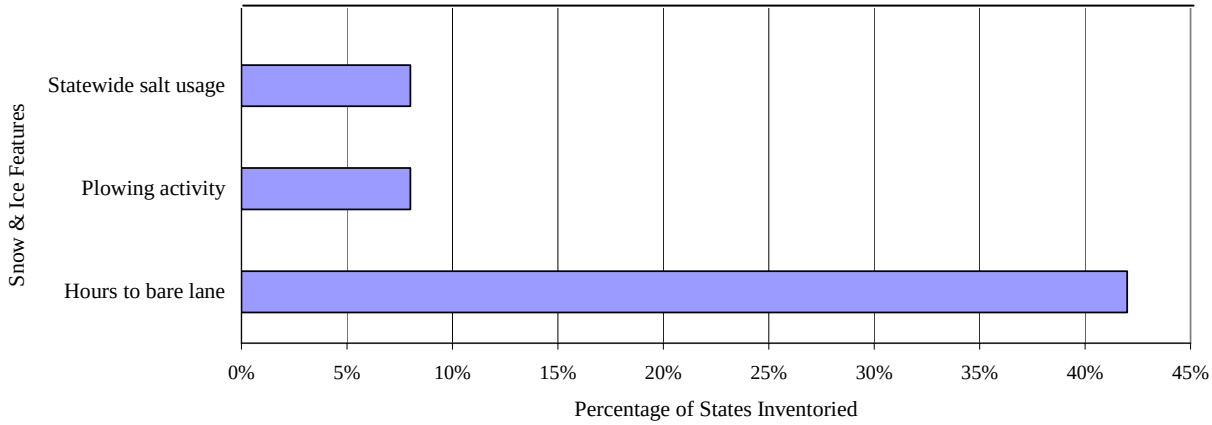

Figure 8. Common Snow and Ice Features

3.6 Bridges

Table 8 lists seven bridge features identified from nine state MQA programs. The number of bridge features measured by a given program ranges from one to four features. Approximately 50% of programs only measure a single feature. The other 50% of states measure three or more features.

Figure 9 shows the percentage of states measuring each of the bridge features. Bridge deck and bridge railing are the most frequently measured bridge features; each is measured by 44% of state MQA programs. Painting is only measured in 11% of MQA programs.

Table 8: Inventory of Bridge Features

	State								
Feature	DC	MS	NC	NY	TN	TX	UT	WA	WI
Bridge approach	x				x				
Bridge deck	x		x				x	x	
Bridge railings	x	x			x	x			
Bridge structure	x			x					
Drain holes		x					x		x
Joints		x			x		x		
Painting		x							

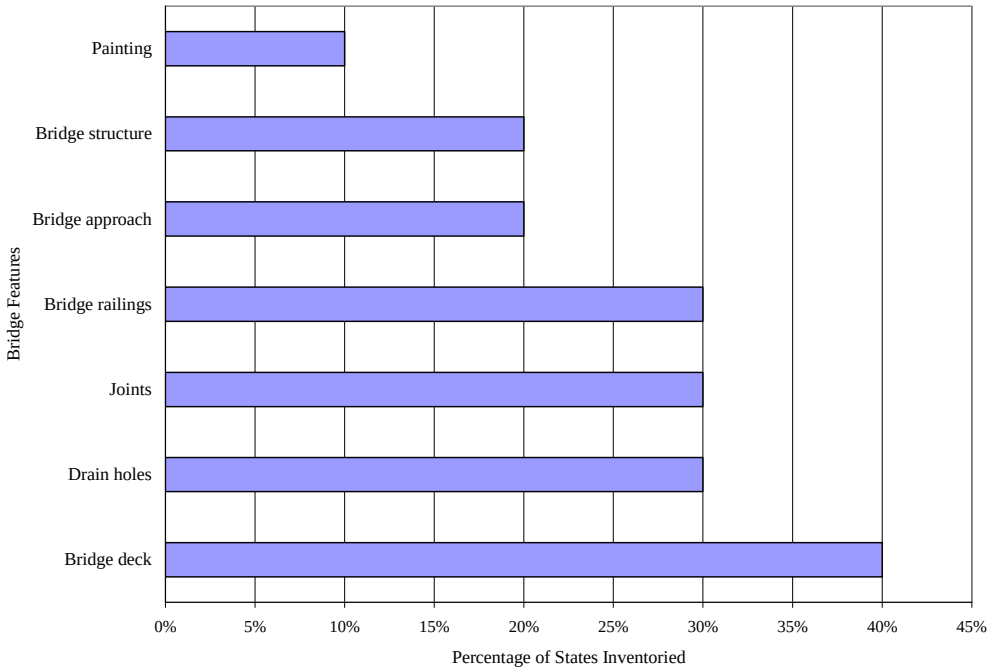

Figure 9. Common Bridge Feature

3.7 Rest Areas

Table 9 lists five rest area features identified in eight state MQA programs. The number of rest area features measured by a given program ranges from one to five. California, New York and South Dakota, each measure 100% of the rest are features. Colorado measures 80% of the features while the remaining state MQA programs measure fewer than 40% of features.

Figure 10 shows the percentage of states measuring each of the rest area features. Parking area is the most frequently measured rest area feature. 88% of states measure parking area. All remaining features are measured in at least 38% of programs, but by no more than 63% of programs. Restroom interior, which is measured in 38% programs, is the least measured feature.

Table 9. Inventory of Rest Area Features

Feature	State							
	CA	CO	NY	OH	SD	TN	WA	WI
Condition of buildings	x	x	x		x		x	
Condition of grounds	x	x	x		x	x		
Condition of restrooms	x	x	x		x			
Parking area	x	x	x	x	x		x	x
Restroom interior	x		x		x			

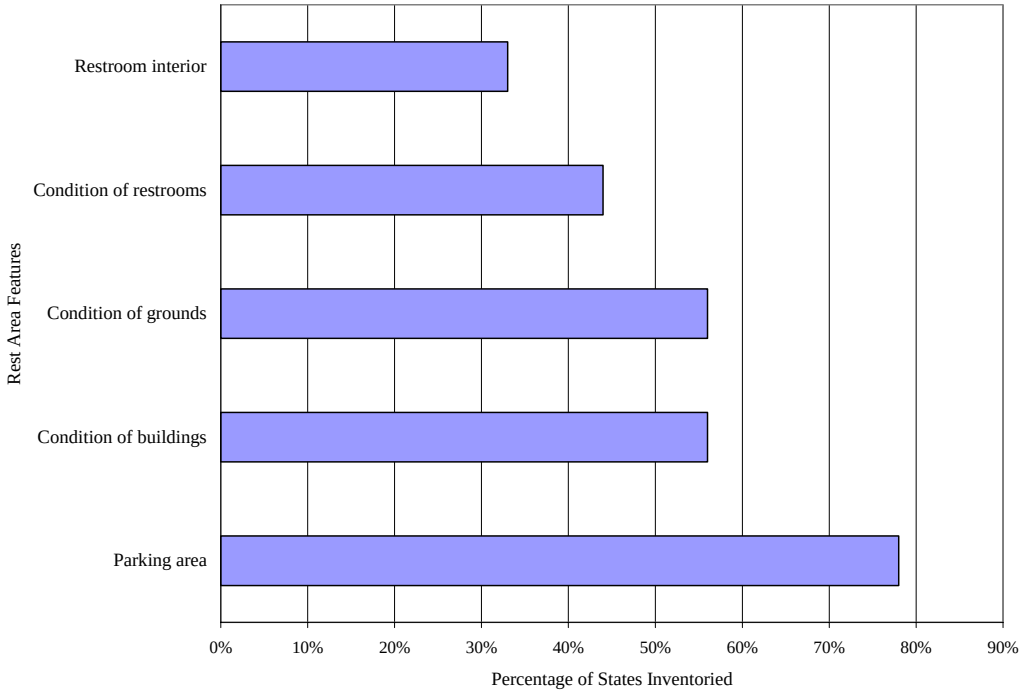

Figure 10. Common Rest Area Features

4 MEASURES FOR MQA

This chapter presents measures and standards for evaluating the maintenance quality of the features and characteristics highlighted in chapter 3.

- A measure is a description of how to quantify the deficiency of a maintenance feature or characteristic;
- A standard is a tolerance level or criterion that helps to identify when a feature is not 'functioning as intended'; a tolerance level or criterion that helps to identify whether a characteristic requires maintenance attention or a characteristic's condition is unacceptable. A standard indicates when maintenance is needed.

The information presented herein is based on documents available in the MQA Library as of December 2004. The measures presented below are for features and characteristics for which measures could be identified. As a result, states may in fact include features and characteristics not listed in this section.

The measures identified are expressed in several ways including, as a total number, in terms of area, length, height and depth, or simply as a ratio. There is no consistency between states on how the maintenance of a specific feature is quantified or how a need for maintenance is determined. Tables 10 through 18 list multiple measures for most features and characteristics because many states use different measures and some states use more than one measure to express the deficiency of a single feature or characteristic. This lack of consistency even applies to features/characteristics that states measure commonly; standards and measures even tend to vary for these features/characteristics. Each state uses a different measure, and some states use more than one measure to express the deficiency of a single feature or characteristic. The use of different measures makes it difficult to compare and rank order states based on maintenance work and progress.

In addition, the tables list the standards or tolerance levels used to identify whether a feature is functioning as intended. States have different standards, even where they have similar features and characteristics. There is little or no consistency among the agencies on how the need for maintenance is determined. This makes it very challenging to compare.

The measures for characteristics of the three main roadway features – flexible pavement, rigid pavement, and shoulders are listed in Tables 10, 11, and 12. Agencies tend to define measures for characteristics (quality defects that are condition assessed) of roadway features. The roadway category is unique in this respect; for all other categories agencies tend to define measures for features. The most likely reason is that most, if not all states that assess maintenance quality of pavements use data from their pavement management programs. Pavement management programs include characteristics and measures that have been well developed.

Table 10. Measures for Roadway Flexible Pavement Maintenance Quality

Characteristic	Standards	Measures per Segment
Rutting	Ruts in excess of the allowed depth require attention	▪ Depth of ruts ▪ Number of ruts ▪ Average rut depth
Potholes	Potholes in excess of the allowed depth or area require attention	▪ Area of potholes ▪ Number of potholes

Characteristic	Standards	Measures per Segment
Cracking	Cracks in excess of the allowed width, depth or length require attention	▪ Length of cracks ▪ Number of unsealed cracks ▪ Area of cracking ▪ Percent of cracking
Raveling/ Surface stripping	Any cumulative raveling greater the allowed length or area requires attention	▪ Percent of surface with raveling ▪ Area of raveling
Bleeding/ Flushing	Bleeding/flushing in excess of allowed area requires attention	▪ Area of bleeding/flushing
Alligator cracking	Cracks in excess of the allowed length, depth or area in square feet require attention	▪ Area of cracking ▪ Width of cracking ▪ Percent surface with cracking
Depressions/ Bumps	All areas of depressions/bumps in excess of the allowed size in square feet require attention	▪ Height of depressions/bumps ▪ Width of depressions/bumps ▪ Area of depressions/bumps
Shoving	All shoving greater than the allowed depth requires attention	▪ Depth of shoving ▪ Area of shoving
Edge break-up/ Edge raveling	Edge break up in excess of the allowed depth requires attention	▪ Depth of break-up ▪ Length of break
Transverse cracks	Cracks in excess of the allowed length dept or area require attention	▪ Length of cracking ▪ Width of cracking ▪ Separation of blocks with cracking ▪ Percent of pavement with transverse cracking ▪ Number of unsealed cracks ▪ Number of slabs with cracking
Patching	All patches larger than the allowed area in square feet must be repaired	▪ Area needing repair ▪ Number of patches per lane
Ride ability / Ride quality (composite)	▪ Any travel way where it is difficult to maintain speeds requires attention ▪ Surfaces where cracks cause unevenness require repair ▪ Surfaces that are cracked, worn or torn away require attention	▪ IRI (roughness) index
Longitudinal cracks	Cracks in excess of the allowed length, depth or area require attention	▪ Length of cracking ▪ Width of cracking ▪ Percent of pavement with cracking ▪ Number of slabs with cracking
Surface oxidation	▪ Surfaces where texture is worn by more than the allowed require repair ▪ Surfaces with extensive large popouts require attention	▪ Percent of pavement surface with unwanted deficiencies or oxidized surface

Table 11. Measures for Roadway Rigid Pavement Maintenance Quality

Characteristic	Standards	Measures per Segment
Joints (seal)	▪ All unsealed joints require attention ▪ Joints require attention if unable to keep out water	▪ Percent of joints not functioning as intended ▪ Length of unsealed joints
Spalls/ Popouts	Spalls/Popouts greater than a specified area in square feet or depth require attention	▪ Area of spalling ▪ Depth of spalls ▪ Number of slabs with spalls
Cracking	Cracks in excess of the allowed length, depth or area require attention	▪ Length of cracks ▪ Number of unsealed cracks ▪ Area of cracking ▪ Percent of pavement with cracking
Potholes	Potholes in excess of the allowed depth or area in square feet require attention	▪ Area of potholes ▪ Number of potholes
Faulting	Faults greater than the allowed depth require attention	▪ Width of faulting ▪ Average area of faulting
Depressions/ Bumps	All areas of depressions/bumps in excess of the allowed size in square feet require attention	▪ Height of depressions/bumps ▪ Width of depressions/bumps ▪ Area of depressions/bumps
Patching	All patches larger than the allowed must be repaired	▪ Area needing repair ▪ Number of patches per lane
Transverse cracks	Cracks in excess of the allowed length, depth or area require attention	▪ Length of cracking ▪ Width of cracking ▪ Separation of blocks with cracks ▪ Percent of pavement with cracking ▪ Number of slabs with cracking
Rutting	Ruts in excess of the allowed depth require attention	▪ Depth of rut ▪ Number of ruts ▪ Average rut depth
Longitudinal cracks	Cracks in excess of the allowed length, depth or area require attention	▪ Length of cracking ▪ Width of area of cracking ▪ Percent of pavement with cracking ▪ Number of slabs with cracking
Ride ability / Ride quality (composite)	▪ Any travel way where it is difficult to maintain speeds requires attention ▪ Surfaces where cracks cause unevenness require repair ▪ Surfaces that are cracked, worn or torn away require attention	▪ IRI (roughness) index

Table 12. Measures for Roadway Shoulder Maintenance Quality

Characteristic	Standards	Measures per Segment
Shoulder drop-off to ground/ Mainline drop-off/ Build-up	Shoulder drop-off requires attention when lower than travel way (e.g. 0.5 - 2 inches lower)	▪ Longitudinal length where drop-off is lower than warranted ▪ Drop-off height where deficient ▪ Number of occurrences of deficient drop-off ▪ Percent of shoulder with deficient drop-off
Potholes	▪ All potholes greater than a specified depth (e.g. 0.5- 4 inches) require attention ▪ All potholes greater than a specified area require attention	▪ Depth of potholes ▪ Area of potholes ▪ Number of deficient potholes
Cracks	▪ Cracks greater that the allowed width (e.g. 0.25-1.0 inch) require attention ▪ All unsealed cracks require attention	▪ Length of cracking
Pavement drop-off to shoulder/ Pavement shoulder joint	▪ Pavement drop-off greater than the allowed length requires attention ▪ Pavement drop-off requires attention when a certain percentage of the joint or drop-off has failed	▪ Longitudinal length of drop-off ▪ Number of uncorrected defects ▪ Height of pavement to shoulder drop-off
Surface-edge raveling	▪ Raveling requires attention when greater than allowed size in square feet (e.g. 1 - 2 inches) ▪ Raveling requires attention when the width of deficient area is greater than allowed (e.g. 1- 4 inches)	▪ Area of raveling ▪ Percent of pavement surface with raveling
Non-positive drainage	Drainage requires attention when standing or ponding water evident	▪ Area of non-positive drainage
High shoulder/ Distortion	Shoulder requires attention if height relative to travel-way is greater than allowed (e.g.0.5-2.0 inches)	▪ Height of distorted/ high shoulder ▪ Longitudinal length of distorted/high shoulder
Rutting	Ruts in excess of the allowed depth require attention	▪ Width of rutting ▪ Length of rutting
Shoulder cross slope	▪ Cross slope requires attention if grade of cross slope does not meet requirements (usually expressed as a percentage) ▪ Slope needs attention if flooding or ponding is observed ▪ Slope requires attention if negative slope is observed	▪ Length of deficiency
Vegetation	None found	▪ Area of vegetated cover

Tables 13 to 18 list the measures for the drainage, traffic management, roadside and vegetation, snow and ice, bridges, and rest areas categories. For these categories states assign measures to features; the characteristics are implied by the description of the measure. For example, in the traffic management category, signs are listed as a feature. The measures provided describe the ways in which post alignment, sign height and sign reflectivity are quantified. Though not expressed explicitly these are the characteristics or quality defects that help to define the deficiency of a sign.

Each category describes features that perform unique functions. The drainage category contains features that help to remove water from highways. The roadside and vegetation category contains features that are located along the roadside and within the mowing limit of roadways. The traffic management category contains features specific to maintaining safety along the travel way. The bridge category contains features specific to maintaining the quality of bridge structures. The snow and ice category contains activities relevant to snow and ice removal along a highway. The rest area category contains features located within a rest area and adjoining property (e.g. parking lot and picnic areas).

Three dominant geometries of features have been identified in this study. The features as they relate to roadway segments are continuous linear (e.g. line striping), discontinuous linear (e.g. ditches or fences) or point (e.g. signs). A continuous linear feature/characteristic is one that has a linear geometry, appears in consistent locations, and is continuous within a highway segment; line striping is an example of a continuous linear feature. A discontinuous linear feature is one that has a linear geometry, but does not appear continuously within a highway segment. Instead these features appear at individual locations along a highway segment and are ordered in a linear pattern. Other examples of discontinuous linear features are a guardrail, or a concrete barrier. The final type of geometry identified is the point. These features are not uniformly distributed along a highway segment and demonstrate no pattern or density. An example of a point feature is a sign. The discussion in this paragraph focuses mainly on features. However, characteristics may also exhibit these geometries.

For many features states use different measures that are parametrically related. For example, some states record the total length of a feature and the length that is defective, while other states simply record the percent deficient. The deficiency of a uniform linear feature is often expressed as per mile or as a percentage of segment sampled; the deficiency of a discontinuous linear feature is often expressed in terms of the length or linear feet of damage; and the deficiency of a point feature is often expressed in terms of the total number deficient.

Table 13. Measures for Drainage Maintenance Quality

Feature	Standards	Measures per Segment
Ditches	▪ Ditches require attention when percent of ditch accumulation is greater than allowed ▪ Ditches require attention when blocked by a certain amount ▪ Ditches require attention when depth of standing water in pipe is greater than allowed	▪ Length or percent of ditch debris ▪ Length or percent of blocked ditches ▪ Percent of ditch debris accumulation ▪ Length of ditch scour ▪ Length or percent of ditch segment to be cleaned
Catch basin/Drop inlets	Inlet requires attention when full by more than the allowed amount (e.g. 25 – 50%) (expressed as a percentage of total inlet capacity)	▪ Number of inlets and catch basins ▪ Number of deficient inlets and catch basins
Curb and gutter	▪ Curb and gutter requires attention if blocked by more than the allowed percentage (e.g. 25-75%) ▪ Curb and gutter requires attention when functioning at less than the allowed percentage of design capacity (e.g. 50-90 %)	▪ Length of blocked curb and gutter
Culverts	Culverts require attention when blocked by more than the allowed percentage (e.g. 25%)	▪ Number of culverts ▪ Number of obstructed or blocked culverts
Subsurface drainage	Subsurface drainage requires attention if functioning at less than a given percentage of design capacity (e.g. 90%)	▪ Length of subsurface drainage ▪ Length of deficient subsurface drainage ▪ Percent of inhibited flow area
Slopes / Slope failures/ Washouts	Slope requires attention if a slide or erosion jeopardizes structural integrity; slide blocks shoulders or travel lanes	▪ Number of slope failures (degree of slope (foreslope) measured to determine potential for damage)
Drainage structures	Drainage structures require attention if the percentage of inhibited flow area is greater than allowed	▪ Number of drainage structures ▪ Number of deficient drainage structures ▪ Percent of inhibited flow area
Storm drains	▪ Drains require attention if a given percentage of cross-sectional area is restricted ▪ Drains require attention if functioning at a less than optimal percentage of the design capacity	▪ Number of drains ▪ Number of deficient drains
Pipes	Pipes require attention if blocked by a percentage that is not allowed (e.g. 25-50%), or if damaged or obstructed	▪ Number of pipes ▪ Number of blocked, damaged or obstructed pipes

Table 14. Measures for Traffic Management Maintenance Quality

Feature	Standards	Measures per Segment
Non-regulatory Signs and regulatory signs	Signs require attention if there is insufficient reflectivity, worn or missing characters in message, incorrect sign height, incorrect lateral clearance, or a deviation of post alignment from vertical is evident	▪ Number of signs ▪ Number of signs deficient ▪ Number of signs with poor reflectivity ▪ Number of missing, damaged, illegible signs ▪ Number of signs with incorrect sign height ▪ Number of non-perpendicular signs ▪ Number of signs with worn or missing characters ▪ Number of signs with incorrect lateral clearance
Guiderail / Guardrail	Count as deficient any guardrail that is functionally or structurally impaired	▪ The longitudinal length of any guardrail that is not functioning as designed or has been damaged ▪ Percent damaged as a function of original design capacity
Pavement markings	▪ Markings require attention if extent to which worn is greater than desired ▪ Marking requires attention if distance of line from original location is greater than desired	▪ Number of markings ▪ Number of deficient markings ▪ Amount (length) of line damage ▪ Distance of pavement markings from original location ▪ Retroreflectivity of markings
Line striping	▪ Requires attention when percentage of paint missing from line exceeds allowed amount ▪ Line requires attention if line is not visible from the required distance ▪ Line requires attention if distance of line from original location is greater than desired	▪ Length of lines in segment ▪ Length of worn, missing or damaged striping ▪ Distance of line striping from original location ▪ Retroreflectivity of line striping
Impact attenuators	Attenuators require attention if functioning at less than allowed percentage of design capacity	▪ Number of attenuators needing repairs ▪ Length of deficient attenuators ▪ Percent of attenuators free of defects
Delineators	▪ Delineators require attention if a given percentage of reflectivity is missing, or worn ▪ Delineator requires attention if vertical height alignment or perpendicularity varies by more than	▪ Number of delineators that should be present ▪ Number of delineators missing or defective

Feature	Standards	Measures per Segment
	allowed amount	
Barrier wall/ Concrete barrier	Walls require attention once deficient or not functioning as originally intended	▪ Number of crash barriers ▪ Number of crash barriers deficient or malfunctioning barriers
Raised pavement markings	Raised markings require attention if a given percent of original installation is deficient or not functioning as intended	▪ Number of RPM's that should be present in the segment ▪ Number of deficient RPMs
Highway lighting	▪ Lighting requires attention if a given percentage of installation is not functioning ▪ Lighting requires attention if the structural integrity of the lighting is compromised	▪ Number of highway lights ▪ Number of highway lights deficient ▪ Percentage of lights along segment that are functional/ not functional
Guard cable	▪ Cable requires attention if damaged to the point of functional deficiency ▪ Cable requires attention if there is deviation of horizontal alignment from design height	▪ Length of cable ▪ Length of deficient cable ▪ Number of cables not functioning as intended
Object markers	Markers require attention if consecutively non-functional markers observed	▪ Number of consecutive non-functional markers
Traffic signals	Signals require attention if not working properly	▪ Number of signals with lamp outages, improper signal operation or damage ▪ Percent of traffic lights with bulbs not working, structural damage or non functioning loops
Intelligent transportation systems	ITS requires attention if the percentage of non-functioning systems is more than allowed	▪ Percent of ITS systems not working

Table 15. Measures for Roadside and Vegetation Maintenance Quality

Feature	Standards	Measures per Segment
Litter/ debris (roadside)	▪ Litter needs removal if visible at posted speed ▪ Litter larger than an identified dimension (e.g. fist size) requires removal ▪ Litter visible as one walks along roadside requires removal	▪ Length of litter ▪ Number of pieces of litter counted ▪ Percent of site with litter
Fences	Fence requires attention if it fails to provide a positive barrier, missing or damaged	▪ Length of fence ▪ Percentage of fence requiring repair ▪ Length of deficient fence

Feature	Standards	Measures per Segment
Brush and tree control	▪ Brush requires attention if obstructing vision, obstructing sight distance, or obstructing clear zone ▪ Brush requires attention if encroaching upon travel way or blocking signage	▪ Number of instances of trees in the clear zone ▪ Number of vegetation obstructions per segment ▪ Percent of travel way free of encroachment
Mowing	Grass requires mowing once a given percentage of grassy area exceeds the allowed height	▪ Percentage of vegetated area mowed to standard ▪ Average grass height over a specific length ▪ Length of grassy area that is above the allowed height
Slopes	▪ Slopes require attention if the width of erosion is greater than allowed ▪ Slopes require attention if the depth of observed ruts or washouts is more than allowed	▪ Length of slopes ▪ Length of deficient slopes
Noxious weeds	▪ Weeds require removal if visible clumps are present ▪ Weeds require removal if the percentage of infestation is more than allowed	▪ Length of highway where noxious weeds are present ▪ Percentage of noxious weeds present per segment ▪ Area of roadside ▪ Area of infestation
Landscaping	Landscaping requires attention once area is no longer maintained at its original condition	▪ Area of landscaping ▪ Area of poor landscaping ▪ Percentage of landscape that is poorly maintained
Sidewalks/ Curb	Sidewalk requires attention once the percentage of sidewalk under visible distress exceeds allowed amount	▪ Area of sidewalk ▪ Area of sidewalk that needs repair ▪ Length of sidewalk ▪ Length of non-functioning sidewalks
Graffiti	Graffiti requires attention if visible at posted speed	▪ Area with graffiti ▪ Percent of surface free of graffiti ▪ Number of hours following notification of deficiency that graffiti is removed
Litter removal (vegetated areas)	▪ Litter requires removal when visible at posted speeds ▪ Litter requires removal when present within mowing limit or located at an unacceptable	▪ Number of pieces of litter

Feature	Standards	Measures per Segment
	distance from mowing limit	
Retaining walls	Wall requires attention when undermining of rip-rap slope, paved ditch slope, or pavement is evident	▪ Percent of weep holes with blocked drainage ▪ Linear feet of wall ▪ Linear feet of deficient wall
Turf condition	Turf requires attention if no longer maintained at its original condition	▪ Longitudinal length of with poor sod ▪ Percentage of turf maintained at below healthy condition
Curb trees/ Sidewalk edge	Sidewalk requires attention if there is an encroachment of grass or vegetation along sidewalk	▪ Length of sidewalk ▪ Longitudinal length of deficient sidewalk
Hazardous debris/Roadkill	Carcasses on shoulder, visible from the roadway or in roadway require removal	▪ Percentage of carcass removed following notification ▪ Time taken to remove carcass

Table 16. Measures for Snow and Ice Maintenance Quality

Feature	Standards	Measures per Segment
Hours to bare lane	None found	▪ Number of hours taken to achieve bare pavement
Plowing activity	No roadway ice or snow accumulations shall be present 12 hours after the local state supervisor is notified	▪ Number of hours after storm that plowing is completed
Statewide salt usage	None found	▪ Number of hours after storm that salting is completed ▪ Amount of salt required to achieve pre-storm conditions

Table 17. Measures for Bridge Maintenance Quality

Feature	Standards	Measures per Segment
Bridge Deck (composite)	▪ All deficiencies larger than the allowed depth or length require attention. (e.g. minimum size 6" x 6" x 1" depth or larger) ▪ Deck requires cleaning if sand or debris is present. ▪ Sand or debris requires removal if flow of water or drainage on bridge deck is adversely affected	▪ Percent of deck surface with deficiencies ▪ Total square feet of deficient deck ▪ Total square feet of sand or debris
Drain holes	▪ Blocked drain holes require attention ▪ Drain holes functioning at less than a given percentage (e.g. < 90%) of design capacity require	None found

Feature	Standards	Measures per Segment
	attention	
Joints	▪ Joints functioning at less than an allowable percentage (e.g. < 90%) of functional capacity require attention ▪ Joints require attention once a given percentage (e.g. 95%) of joint is blocked by debris or dirt ▪ Joints require attention if unable to inhibit the longitudinal movement of the superstructure	None found
Bridge railing	▪ All damaged rails require attention ▪ Railing requires attention if a given percentage does not function as intended (e.g. < 90%) ▪ Out of place rails require attention	None found
Bridge approach	Approach requires attention if elevation difference is greater than allowed (e.g. > 1.5 inches)	None found
Bridge structure	▪ All dents that impact structural integrity require attention ▪ Erosion that would have an adverse effect on thru roadway or structure requires attention ▪ Graffiti requires removal if more than the allowed percentage of structure is covered ▪ Graffiti requires removal if present	▪ Percentage of structure covered with graffiti ▪ Percentage of graffiti removed within the required time following report
Painting	Steel structures exceeding the "non-deteriorated" range by more than a given percentage of rust (e.g.1%) require attention	None found

Table 18. Measures for Rest Areas Maintenance Quality

Feature*	Measures per Segment
Parking area	Condition of parking area
Condition of buildings	Appearance of building exterior
Condition of grounds	Appearance of grounds (landscaping, litter, etc.)
Condition of restrooms	Functionality of plumbing and dryers in restrooms
Restroom interior	Cleanliness & appearance of building interior

** No standards were identified for the rest area category*

Trends noted between feature geometry and measures used are mere guidelines for the use of measures when assessing the deficiency of a given type of feature. As was noted previously, there is very little consensus on the use of measures to quantify deficiency, or on the types of measures to be used when assessing a particular feature/characteristic. As a result there were several cases observed where the deficiency of a continuous linear feature was expressed in terms of the number deficient or length deficient. For many continuous linear features percent deficient is adequate because the quantity of the feature is implied by the segment length. For discontinuous linear and point features it may be best to record the quantity (area or length or number of) the feature along with the quantity that is defective. By recording both values, absolute (magnitude of the backlog) and relative measures are known. These values become particularly important if those interpreting measures wish to calculate average deficiency over a region. It is expected that in time, using the trends highlighted herein, greater uniformity will be brought to the selection of measures to quantify maintenance deficiency.

5 RELATIONSHIP TO SCOTTSDALE WORKSHOP FINDINGS

In June 2000, a National Workshop on Commonly Recognized Measures for Maintenance was held in Scottsdale Arizona (8) with the objective to reach consensus on a set of common measures for the delivery of maintenance services and products. Representatives from 25 states and 18 organizations participated in the Workshop which was sponsored by the AASHTO Subcommittee on Maintenance with funding from the Federal Highway Administration (FHWA).

The Scottsdale workshop represents the first major attempt to identify measures for maintenance quality assurance and provides a basis for comparisons with current terminology and measures. Since the Scottsdale event, MQA terminology has evolved considerably. The participants of the workshop made little distinction between measures and features. Terms like characteristic, quality defect, standard, target, and threshold were not used in the proceedings of the Scottsdale event.

Table 19 shows the results of the Scottsdale workshop labeled and organized to allow for a comparison with measures in use today. For consistency, the terms – maintenance element, commonly recognized measures, and discussion/issues – used in the Scottsdale report were replaced with the appropriate terms used in this report. From the table it can be seen that the participants identified a number of relevant features but few actual measures.

At the time of the Scottsdale event, agencies organized measures into “categories” apparently related to availability of information. Since then, the concept of a category has evolved to reflect spending categories and maintenance work activities. Although there are more categories in use today, some of the categories identified at the Scottsdale event are today widely used (e.g., Drainage, Snow and Ice, Pavement Surfaces, Shoulders).

It is interesting to note that all of the features and measures identified at the Scottsdale Workshop were adopted unanimously by the participants with the exception of potholes. Today rutting and potholes are the most widely measured pavement characteristics.

The scope of the Scottsdale workshop included customer satisfaction. Since the Scottsdale event, the measurement of customer satisfaction has evolved independently of the measurement of maintenance quality assurance. Today agencies tend to consider customer satisfaction as related to but separate from their MQA programs. The agencies’ MQA Library documents contain very little on customer satisfaction. Today measures are often linked to a grading scale (threshold levels) that is designed to reflect customer satisfaction. The threshold levels for each measure are used to relate customer satisfaction to the maintenance being done which enables comparison of between features and categories based on customer perceived maintenance quality.

Table 19. Reinterpretation of Scottsdale Workshop Findings

Maintenance Category	**2000 Scottsdale Workshop**		
	Features	***Characteristics***	***Measures***
Roadway Pavement	Roughness (IRI)	-	Ride Quality Index or International Roughness Index
	Rutting	-	-
	Friction	-	-
	Potholes	-	-
Traffic Management	Signs	Retroreflectivity	Standard measurement procedures
	Pavement markings	Physical appearance - Contrast - Color fade - Legibility	Attributes and measurement procedures not fully defined
		Sign post condition	
		Retroreflectivity	Standard measurement procedures
		Physical appearance - Contrast - Presence	Not fully defined
	Attenuators	Functioning as intended	-
	Guardrail	Functioning as intended	-
	Guardrail end treatment	Functioning as intended	-
	Customer satisfaction	-	Surveys
			Focus groups
Roadway Shoulders	Clear zone	Horizontal distance from edge	Vertical clearance applies to clearance over vehicles using roadway. Needs to be defined
		Vertical clearance distance	
	Obstruction	Yes/No	Vegetative obstruction of guardrail , signs, etc
	Vegetation (grass)	Height in inches	-
	Noxious weeds	Yes/ No	Presence or absence of noxious weeds
	Litter count (per segment)	-	Method of counting litter needs to be defined
	Edge variance (drop-	-	Methods need to be defined

Maintenance Category	**2000 Scottsdale Workshop**		
	Features	***Characteristics***	***Measures***
	off & build-up)		
	Customer satisfaction	-	Surveys
			Focus groups
Drainage	Culverts, Cross drains	Percent blocked/damaged	-
	Open ditches	Percent blocked/damaged	The total length of the ditch in feet should also be determined
	Curb, gutters, and barrier walls	Percent blocked/damaged	The total length of the drainage in feet should also be determined
	Catch basins and inlets	Percent blocked	-
	Subsurface drainage	Percent blocked	-
Snow and Ice	Road closures	-	Duration traffic volume impacted
			Number of closures
	Bare Pavement indicator	-	Duration of loss of bare pavement
			Duration of time to recover from the end of event
	Customer satisfaction	-	Surveys
			Focus groups
Customer Satisfaction	Survey questions	-	Methods for maintenance that is not visible to the public needs to be defined

* Dashes signify locations where Scottsdale tables did not provide data

6 DISCUSSION AND CONCLUSIONS

This document provides a helpful framework for measuring and for creating and grouping measures. An agency beginning a program could use this to design measures. For agencies with established programs, the information can be used to expand their program to include new measures or to refine existing measures. The findings are essential to the broader maintenance community to launch the discussion about developing consensus on and adopting a set of common measures for MQA.

Overall states use very similar categories for organizing maintenance features and characteristics. The reason for good agreement on maintenance categories (e.g. roadway, drainage, traffic management, and bridges, etc.) is that they are tied to maintenance budgeting and work activities. There is little agreement among the states on what particular features or characteristics are important to measure in each category. Additionally, there were features identified as being measured for which little information on measures were not available. Though a comprehensive list of measures was identified, there is still much opportunity for the expansion of this list. For example, pavement and bridge condition are managed by well developed and mature asset management systems. As a result measures for pavement and bridge maintenance are less likely to be included in state MQA documents.

When compared to results of Scottsdale meeting in 2000, MQA programs have evolved considerably. MQA is becoming a recognized business function at state transportation agencies. Terminology for MQA business has evolved significantly but no standard exists. With out commonly understood terms agencies will not be able to efficiently communicate on the development of their programs. It is expected that the terminology developed and steps outlined in this report will assist in the development of future MQA programs and the identification of measures for those features less commonly used by states to assess the performance of highways. In addition, it was discovered that the measurement of customer satisfaction and maintenance quality has evolved independently.

Most states are beyond gathering information and now concentrate on using the information in decision making. Programs now include statistical analysis, and states are experimenting with alternate reporting formats to effectively communicate to legislatures and the public. As a consequence, a common understanding of terms like thresholds and targets will be essential to the future development of this field.

To the maintenance community, thresholds are predetermined system-wide maintenance levels for features and categories. Thresholds can be thought of as a grading scale or LOS indicator for MQA that relates measures to customer satisfaction. A threshold indicates how much or what percentage of the system is with or without deficiency. As statistical techniques become more widely used clearly defined thresholds will facilitate comparisons between programs, counties and districts. Some but not many MQA programs integrate thresholds into the assessment of maintenance work. States have different standards and thresholds, even where they have similar features and characteristics. These disparities make it difficult for maintenance officials to compare maintenance results.

7 RECOMMENDATIONS

Several actions are required by the broader maintenance community to further the development of MQA programs. Foremost is the adoption of a consistent terminology to facilitate the development of MQA programs and concepts. It is recommended that common measures be identified for maintenance features and characteristics for which there appears to be consensus e.g. rutting of pavement, retro-reflectivity of striping, and retro-reflectivity of signs. Action should also be taken to adopt consistent terminology to facilitate the development of MQA programs and concepts. There should also be an effort to expand upon the comprehensive list of measures, and to develop consensus on measures for less commonly used features and characteristics

Next, there must be agreement on common standards as a first step towards common measures. States have different standards, even where they have similar features. Agreement on common standards and measures are both essential for states to engage in dialog and information exchange regarding the effectiveness of various maintenance activities. The obvious features and characteristics for dialogue on common measures include rutting of pavement and retro-reflectivity of striping and signs. A common understanding of terms like thresholds and targets will be essential to the future development of this field. (Thresholds are the grading scale indicator of maintenance deficiency at the county, district or system-wide level. Targets represent the allowable/acceptable backlog and the expected threshold level that is attainable given the available budget).

Finally, discussions should be held to ascertain whether or not the maintenance community is in fact interested in moving towards common measures, that is a set of standardized measures, for use in all MQA programs. If in the future, maintenance officials are unable to reach consensus on common measures for MQA it is recommended that steps be taken to identify clearly articulated definitions of how measures are achieved in different states.

Clearly articulate definitions would allow maintenance officials to make comparisons across programs. From an outside perspective the ability to make such comparisons appears to be useful. However, at some point in the future the maintenance community will need to determine whether creating a system for comparison is in fact the ultimate goal for the use of measures in MQA.

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