NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP Report 422

Maintenance QA Program Implementation Manual

Transportation Research Board
National Research Council

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Report 422

Maintenance QA Program Implementation Manual

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

Note: The Transportation Research Board, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration, U.S. Department of Transportation.

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FOREWORD

By Staff
Transportation Research Board

The implementation manual contains guidance for highway agencies in the development and application of a maintenance quality assurance program. A quality assurance program not only is intended to assure the quality of accomplished work, but also ultimately helps provide acceptable and uniform levels of service throughout the highway system. The manual will be of great interest to maintenance engineers and to top managers and administrators of highway agencies. Top managers and administrators will be especially interested in the Executive Summary, which presents the general concepts, effort required, and expected benefits. The main text of the manual details the development and implementation of the quality assurance program. The supporting research is documented in the agency's final research report, which is available through the NCHRP world wide web site.

Highway agencies spend large sums of money to maintain their facilities, and assuring the quality of the products of these investments is important to an effective and efficient highway-maintenance program. Various industries, including highway and bridge construction, successfully use quality assurance (QA) programs to differing degrees. Although formal highway-maintenance QA programs are not generally in-place, highway-maintenance activities and end products do lend themselves to quality assurance and could benefit from such programs.

Consequently, research and development of an appropriate maintenance QA program would be helpful to many highway agencies. Quality assurance programs have to be capable of detecting insufficient maintenance efforts, poor material performance, and incorrect procedures when evaluating end-product performance. In their development and application, highway-maintenance QA programs must be integrated with other management-information systems and quality programs to derive mutual benefits.

Under NCHRP Project 14-12, "Highway Maintenance Quality Assurance," ERES Consultants, Inc., prepared guidance for developing and implementing a QA program for maintenance of highway facilities. In mid 1997, the basic research contract was completed and the agency's final research report made available as NCHRP Web Document 8. This final report can be accessed through the NCHRP homepage on the world wide web at http://www4.nas.edu/trb/crp.nsf "Web Documents."

An implementation manual was also developed and subsequently used in six workshops conducted by ERES across the country in early 1998. The six workshops took place in conjunction with cooperating state departments of transportation (DOTs) in Dubuque, Iowa; Lake Havasu City, Arizona; Bristol, Virginia; Galveston, Texas; Kansas City, Missouri; and Portland, Oregon. The assistance provided by the state DOTs was critical to the success of the workshops and was greatly appreciated by ERES and the NCHRP. At the time of publication, the Federal Highway Administration was considering further workshops using this NCHRP research project as the basis. The workshops were well received and provided input for further refinements to the manual. The version published as *NCHRP Report 422* incorporates the knowledge gained through these efforts.

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MAINTENANCE QA PROGRAM IMPLEMENTATION MANUAL

SUMMARY

Highway agencies spend large sums of money to maintain transportation facilities. Ensuring the long-term operation of these investments is important not only from a cost-effectiveness standpoint, but also from the standpoint of minimizing disruption to normal traffic flow caused by rehabilitation activities. An appropriate quality assurance (QA) program for the maintenance of highway facilities can be a vital component of this service, enabling an agency to provide a uniform level of service (LOS) throughout its highway system.

Generally speaking, highway agency officials act as the proxy for public benefit. Most of these officials feel that users of the transportation system are entitled to an adequate level of service (LOS), regardless of route or location. Achieving a stable, uniformly maintained system requires an objective evaluation technique for measuring the LOS provided at the activity, project, and network levels of maintenance. For it is only through measurement that a product or service can be improved.

NCHRP Project 14-12, "Highway Maintenance Quality Assurance," was conducted for the purpose of researching current quality management concepts, evaluating existing maintenance quality programs, and subsequently developing a state of the art maintenance QA program. The program would serve as a prototype that interested agencies could adopt to effect improved and more uniform highway maintenance.

In 1996, a prototype program was successfully developed which incorporated a combination of tried-and-true quality practices, augmented by sound quality management principles and statistical applications. Because of the variation in agency philosophies, structures, and styles, the program was cast in a framework of required and optional components, with each component having a certain degree of flexibility in the way it is established and used. Hence, the program is capable of functioning in a centralized or decentralized management environment, in large or small highway agencies, and in agencies having varying levels of contract maintenance.

The principals and procedures of the prototype QA program are formally presented in this implementation manual. The manual has been organized to be self-contained, in that no outside assistance should be necessary from persons experienced in the methodology. The manual is comprehensive and includes step-by-step instructions for agencies interested in developing, implementing, and routinely operating a customized ver-

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sion of the prototype QA program. Each step is represented as a component and each component has a stated objective, a clear concise description of how the objective is to be accomplished, and an illustrative example, where appropriate and possible.

All highway agencies should consider adopting at least some of the management practices outlined in this manual. Those that are interested in accomplishing the following objectives must consider undertaking the task of refocusing the direction of their maintenance operations:

- Determine the LOS expectations the traveling public is willing to pay for and assure them that the agency is meeting those goals.
- Develop the funding level needed to achieve a desired LOS.
- Develop a "priority strategy" to direct maintenance operations during periods of less- than-full funding.
- Achieve a uniform LOS throughout the agency by identifying excessively high or low areas of maintenance.
- Identify areas requiring additional employee skills or equipment to accomplish assigned tasks.

The establishment of a quality management program for an agency's maintenance operations requires a commitment by the Chief Executive Officer (CEO) and management staff to provide the necessary resources for achieving the objectives listed above. Fulfillment of these objectives will enable an agency to shift from a "fixing" mode to a "prevention" mode, thereby incurring the benefits for repairs that do not have to be repeated. Eventually, this culture shift may lead the way to greater levels of customer satisfaction, possibly at unit costs below those currently experienced by the agency.

BACKGROUND

The prototype QA program is based on information gleaned from an extensive literature review and the documented maintenance practices of various highway agencies. Key ideas identified in the literature and incorporated into the prototype program include the following:

- Make a commitment to quality from top management down to each employee.
- Build an awareness within the agency of the need and opportunity for continuous improvement.
- Create training and education opportunities for employees to help them accomplish work at the right time using the right procedures for the right reasons.
- Authorize employees to make more decisions and hold them accountable for the results of their decisions.
- Periodically assess quality, determine where problems lie, and take actions to correct the problems.
- Institute statistical sampling techniques to be used in the assessment of quality.
- Foster an environment of open communication between employees and managers.
- Involve agency employees in the establishment of LOS criteria.
- Establish quality goals and periodically report progress made toward achieving the established goals.

To supplement the pertinent information contained in the literature and to determine the extent and nature of maintenance quality programs currently being practiced by highway agencies, a series of surveys and field reviews of various state/provincial and city/county highway agencies were conducted under NCHRP Project 14-12. Though several agencies were noted as having instituted certain facets of quality, four agencies were given particular attention because of their LOS rating systems: the British Columbia Ministry of Transportation and Highways (MTH), the Florida DOT, the Maryland DOT, and the Oregon DOT-Region 4.

Each of these agencies has established LOS criteria for a host of routine maintenance activities and each performs periodic end-result assessments of randomly selected roadway segments to determine adherence to the LOS criteria. Moreover, each agency produces management reports that show network LOS results. British Columbia, Florida, and Maryland perform a formal agencywide quality control (QC) process on the LOS rating teams to ensure consistent, repeatable ratings from region to region. British Columbia supplements its LOS rating system with a well-documented QC process that rates work performance during and at the completion of each activity and it has an active QA/QC process for testing materials and procedures.

Table 1 summarizes the costs and scopes of the LOS rating systems operated by the aforementioned highway agencies. This information can be useful to agencies interested in installing their own customized LOS rating system and curious about the costs required to install it.

During the final stages of the NCHRP 14-12 project, it was learned that a few other highway maintenance agencies have, to varying extents, developed and operated LOS rating systems. One of the agencies, the Washington State DOT, instituted a comprehensive maintenance quality program in 1996, known as the Maintenance Accountability Process (MAP). An overview of this program, which contains many of the features of the NCHRP Project 14-12 prototype QA program, is provided in Appendix D of this implementation manual.

QUALITY MANAGEMENT

Although quality management can mean many things, the focus of study in this manual is on the "quality of management" rather than the "management of quality." Quality work is the product of quality management. The primary goal of a quality management

TABLE 1 Scopes and costs of various agencies' LOS rating programs

Highway Agency	Frequency of Inspections, number/year	Staffing Requirements, staff-years	Start-up Cost, $	Annual Cost, $	Amount of Highway Maintained, lane-miles	Maintenance Categories
Florida DOT	3	7	180,000	200,000	37,578	Roadway Roadside Traffic services Drainage Vegetation/aesthetics
Maryland DOT	1	2	288,000	110,000	15,954	Traveled roadway Shoulders Drainage Traffic control and safety Roadside
Oregon DOT, Region 4	4	2	100,000	75,000	1,900	Road surface Drainage Shoulder/roadside Maintenance for public safety Winter maintenance
British Columbia MTH	12	36	100,000	2,160,000	25,466	Surface Drainage Roadside Winter Bridges

1 mi = 1.61 km

program should be to improve quality and provide for the effective use of existing personnel, material, and equipment. Some of these concepts are as follows:

- Producing quality products and services,
- Eliminating waste,
- Avoiding rework, and
- Satisfying the agency's customers.

Toward this end, most organizations have established formal policies and procedures for improving the quality of the highway maintenance product. In general, these operational strategies currently include some form of QA, QC, continuous quality improvement (CQI), and statistical control process (SCP). It is important to recognize that, although each of these strategies is appropriate, they do not replace techniques for determining specifications and standards or for measuring conformance. They do, however, supplement or refine the strong traditional management approaches to problem solving and efficiency with a new emphasis on carefully defining and satisfying the requirements of the customer.

Many managers/administrators may view the prototype QA program as an opportunity to downsize and restructure their organizations. Although this may be a valid occurrence after the program has had an opportunity to operate for several years, agencies should not implement it for the purpose of reducing personnel. Quality management can be described as "doing the right thing at the right time for the right reason, and being able to recognize what actions are necessary to accomplish them." It is recommended that the agency initially concentrate on the resources required to produce a uniform LOS and then provide those resources to local managers.

To transition into a "quality organization," upper management must be willing to step back from daily involvement with products and services and concentrate on managing the resources (personnel, equipment, and materials) and the end results produced by field managers. Coincident with quantifying end results, local managers will now decide who, what, how, where, and when to use their resources in achieving the desired end results. In effect, local managers will be released to resolve daily decisions to ensure the desired end results are being achieved. Periodic assessments of these managers must be performed, and they should then be held accountable for the results that occur. Research has found that, when left to their own devices, the initiatives developed by these managers have proven to be very effective. It is equally important that managers who manage products and services also recognize they are being held accountable for those decisions they have been allowed to make.

OVERVIEW OF PROTOTYPE QA PROGRAM

The prototype QA program consists of a series of 24 components that represent actions to be taken by an implementing agency. The components are divided into two phases of work, as illustrated in Figure 1. The first phase, which contains components 1 through 10, is the preliminary work phase associated with developing a customized LOS rating system. The second phase, which contains components 11 through 24, is the field implementation and closed-loop operational phase. Though some components are optional or can be arranged differently in the program flow chart, the sequence of the components shown in Figure 1 provides agencies with a logical basis for guiding the development, implementation, and operation of a customized QA program.

Although these actions may represent a culture change from an agency's past business actions, it is necessary for all levels of management to support the changes in order for them to succeed. Many procedural and philosophical issues will be addressed as a function of this change, some of which are as follows:

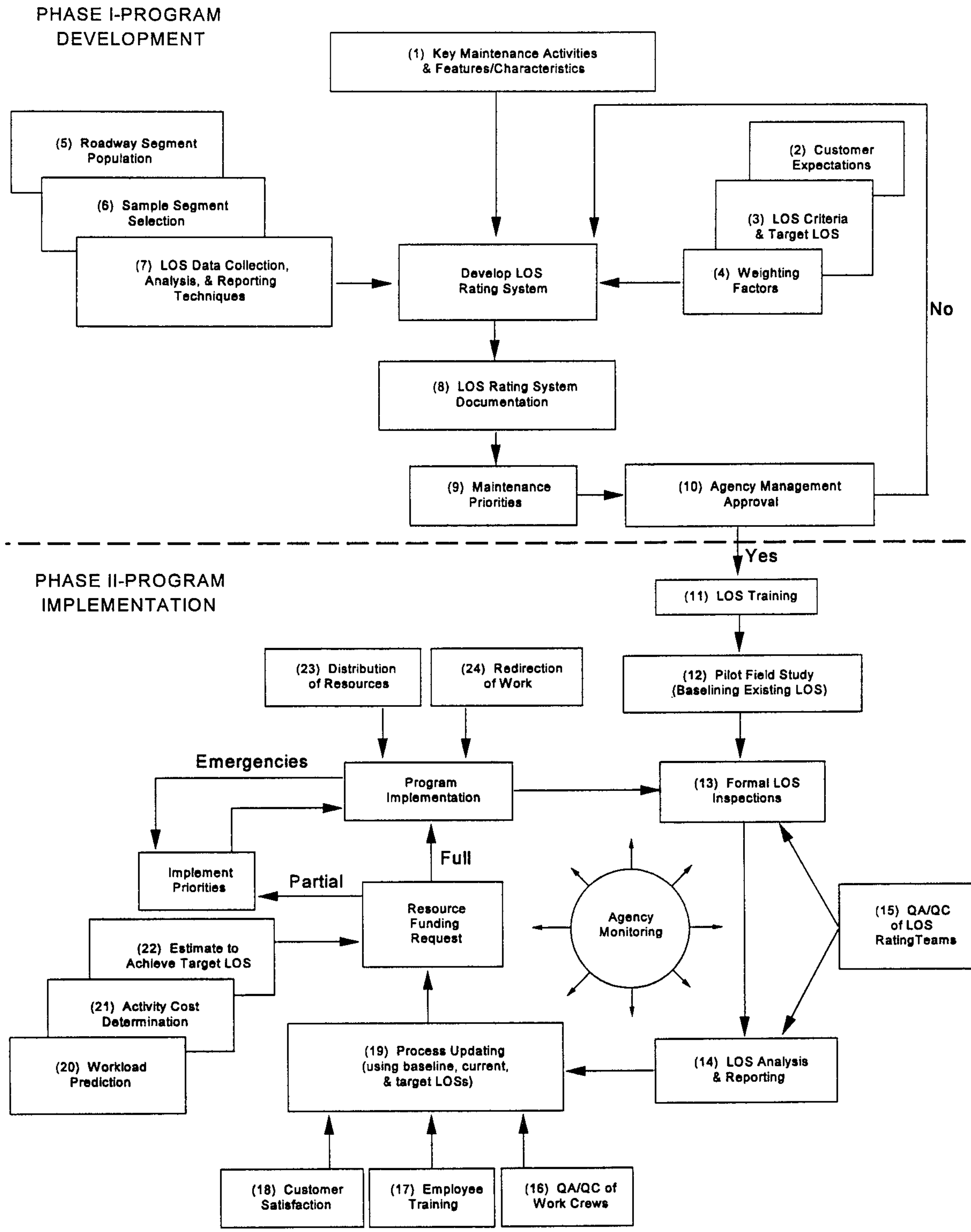

Figure 1. Prototype QA program flow chart.

- Determine customer expectations—One way to give customers quality is to know what they want. This, of course, requires that an agency know who its customers are, if they are internal (other units within the organization) or external (persons outside of the organization) and what part maintenance plays in satisfying these needs. In the past, most organizations have concentrated more effort on providing quality to internal customers than to external ones. It is recommended that agencies reverse this trend and devote more attention to the external customers.

- Establishing desired LOS—The term LOS, as described in this manual, is used to define the conditions that can be allowed to exist before a specific feature is considered not to meet the expectations of the agency. The LOS criteria may be established at different levels depending on the characteristics of the roadway (e.g., functional classification, rural or urban setting, traffic volume, environmental impact). Also to be considered is the answer to the question: "Are funding levels adequate to sustain the LOS being proposed?"
- Baselining existing LOS—Using this technique, management can determine where expectations have been met, substantially exceeded, or not met. Predictions can be made for more accurate budget requests, as well as the ability to distribute resources.
- Preparation of a zero-based budget—Developing annual agency budget requests to produce a predetermined LOS. When presented in the zero-based format, an agency commits to providing a service level to its customers for a fixed price. Although some locations (or activities) may be higher or lower than the desired level, the zero-based budget request should identify the total resources needed to achieve and maintain the desired LOS. Research suggests that when this point is reached, an agency should be more able to balance its resources in accordance with its identified needs.
- Authorizing or "releasing" employees to make daily operational decisions–In many instances, management is willing to let employees make their own decisions but is afraid to let go of control. When local managers make decisions concerning daily operations, management can pursue high-level policy issues that are beyond the ability of local managers to resolve. This also allows workers to concentrate on work projects.
- Improving administrative procedures—For the quality concept to succeed, a commitment to providing an optimal LOS will be required by all levels of agency management. If the cost of providing that level is higher than acceptable, then the LOS criteria must be revised. Eventually, however, a minimum level must be agreed upon and provided to the customers. Administrative procedures must be modified to enable agency employees to achieve the desired results. Of these, one of the most significant will be to establish the work accomplishment priorities. The recommended priorities are as follows:
  - Safety of the traveling public,
  - Preservation of investment,
  - User comfort and convenience, and
  - Aesthetics.
- QA/QC of work crews—A detailed process to inspect the quality of maintenance work as it is being performed. QC checks are typically performed by those supervisors that initially assign work to be accomplished. These inspections consist of a detailed review of how well crews are following agency-specified or agency-recommended practices and where improvements to agency practices can be made. QA checks are generally performed by central- or district/regional-office staff. These inspections are made randomly on crews throughout the agency or district/region in order to view the big picture concerning practices that are most or least effective or efficient. Information is then fed back to local supervisors.

BASICS TO IMPLEMENTATION

There are four major constraints on the use of the methodology that an implementing agency should have to successfully implement the features of the program. These constraints are as follows:

- An existing method of documenting work accomplishments, including production and productivity data;
- Reliable labor, equipment, and material costs associated with each work activity;
- An inventory of highway maintenance features to be maintained; and
- A basic understanding of quality management concepts.

None of these constraints should pose a problem for most transportation agencies, as maintenance management systems (MMSs) have been implemented to various degrees by many agencies within the last 20 years.

BARRIERS TO IMPLEMENTATION

One of the biggest obstacles in implementing any system is its being categorized as the "flavor of the month" by the employees within the agency. Management systems come and go regularly. Only those with practical value will survive within governmental agencies. The reason so many management systems have not succeeded in the past may be due to a coordinated lack of commitment by employees and management to want it to work. Most, if not all, agencies have experience with personnel who have tolerated an MMS but have been less than enthused about its results. A variety of reasons may be attributed to its lack of being of significant value, but one suspects the main cause is a lack of commitment from all levels.

Although the organizational makeup of governmental agencies will vary widely from location to location, essential to the successful use of the concept of quality management is a commitment to quality starting at the CEO level and extending through all levels of management. An agency that is seriously interested in providing a uniform LOS throughout the agency must require a change in attitude and psychology concerning the way the agency business is managed. This means that management must step back from direct involvement with a product or service and instead concentrate on the management of the people that produce the product or service. By authorizing or releasing lower-level managers to make their own decisions regarding how and when to accomplish work and holding them accountable for results, these managers will find innovative ways to prevent problems before they occur.

Other barriers likely to be encountered by an implementing agency include funding limitations, employee attitudes, special interests, privatization, and unions. Though not as critical as management commitment, they are serious impediments that must be properly addressed during the implementation process. Chapter 5 contains detailed discussions of each of the barriers mentioned.

BENEFITS OF IMPLEMENTATION

An agency that adopts the prototype QA program in its entirety should expect to achieve the following benefits or results:

- A stable uniformly maintained highway system;
- An understanding of the LOS at which the traveling public wants its highway system to be maintained;
- The ability to quantify a specific funding need, by activity, to produce an expected LOS;
- An understanding of the LOS that actually exists on an agency's highway system;
- The ability to move or acquire appropriate resources to accomplish LOSs that are not meeting expectations;
- The ability to reduce resources in areas or activities that significantly exceed LOS expectations;

- Crews that are better trained and equipped to accomplish workloads, when necessary, by applying the proper treatment at the proper time;
- Greater involvement and buy-in of employees with the agency's method of establishing LOSs;
- Increased productivity and repair effectiveness by allowing local managers to decide what, who, when, and how their resources are best applied to meet established LOS criteria;
- Increased ability of management to monitor LOS compliance by work units; and
- The ability to assess the benefits and savings of the QA program.

In closing, quality is a habit, not an act. Regardless of an agency's current status, if the philosophy of quality management is used properly, the prototype program should enable agencies to shift from a "fixing" mode to a "prevention" mode. As the trend toward prevention of problems increases, the need for less inspection will also follow, because improved techniques for procedures, materials, and construction will provide for greater customer satisfaction. The end result will be the realization of measurable improvements in quality for those who are willing to try.

CHAPTER 1

INTRODUCTION

BACKGROUND

*Quality assurance (QA)** in highway maintenance has been the subject of study and discourse for several years. It may best be described as the planned and systematic actions needed to provide adequate confidence that highway facilities meet specified requirements. Such requirements are usually defined by the highway agency but are intended to reflect the needs and expectations of the user.

First largely considered in the 1960s as part of the MMS concept, the issue of QA in highway maintenance has since remained an active topic because of increased work loads, greater maintenance demands, limited maintenance funds, and public perceptions of maintenance departments. The need for better *quality* maintenance has increased significantly within the last few years in recognition of the change in focus from infrastructure design and construction to maintenance and rehabilitation.

A number of major obstacles have stood in the way of true quality initiatives in highway maintenance. The primary hurdles have included substantial up-front costs associated with implementation of a quality program, lack of clearly documented benefits and simple reliable procedures for determining benefits, lack of any organized consistency for maintenance, fear and suspicion of the unknowns by maintenance personnel in all levels, and lack of a simple, objective procedure for evaluating quality. A few highway agencies have successfully chartered the choppy waters of *quality improvement (QI)*. None, however, has done so with a keen eye on how its programs meet the expectations of both the agency and the traveling public.

To advance the various concepts of quality in highway maintenance and build on the successes of current quality programs, the National Cooperative Highway Research Program (NCHRP)-sponsored Project 14-12, "Highway Maintenance Quality Assurance." Under this study, a prototype QA program was developed using both new and proven quality management practices that stem from a comprehensive literature review and extensive queries of several state and local highway maintenance agencies. The program consists of various interactive components, all of which have been carefully documented and organized and are presented in sequential fashion in this implementation manual.

* Italized words are defined in the Glossary.

OVERVIEW OF STATE OF THE ART

A substantial amount of information pertaining to quality, maintenance, and quality maintenance management was gathered under NCHRP Project 14-12. This section highlights the information found—through a comprehensive literature search and extensive investigations of several maintenance agencies—to be most pertinent in the development of the prototype QA program.

Quality

Modern quality management theories and techniques evolved from the work of several individuals. W. Edwards Deming, who began teaching statistical quality management methods in Japan in 1950, is probably the best known.

The Deming philosophy defines quality as "whatever the customer wants" (Miller and Krum 1992). However, not all customers want the same thing, and even a single customer's wants and needs may change over time. Therefore, it is necessary to continuously assess and measure customer satisfaction, thereby providing a map for improvement of processes and products.

Assessment and measurement are performed using statistical methods. Statistical methods are also used to collect data regarding work processes, and this information is then used to control the processes. Instead of looking at only the end result of a process, the Deming method calls for the examination of the work process itself to eliminate the root causes of defects in the final product.

Deming's techniques are summarized in his "14 Points for Management," which are as follows (Miller and Krum 1992):

1. Create constancy of purpose toward improvement of product and service.
2. Adopt the new philosophy. We can no longer live with commonly accepted levels of delays, mistakes, defective materials, and defective workmanship.
3. Cease dependence on mass inspection. Require instead statistical evidence that quality is built in.
4. End the practice of awarding business on the basis of price tag.
5. Find problems. It is the responsibility of the management to work continually on the system.
6. Institute modern methods of training on the job.
7. Institute modern methods of supervision of produc-

tion workers. The responsibility of foremen must be changed from numbers to quality.
8. Drive out fear, so that everyone may work effectively for the company.
9. Break down barriers between departments.
10. Eliminate numerical goals, posters, and slogans for the work force, asking for new levels of productivity without providing methods.
11. Eliminate work standards that prescribe numerical quotas.
12. Remove barriers that stand between the hourly worker and his right to pride of workmanship.
13. Institute a vigorous program of education and retraining.
14. Create a structure in top management that will push every day in the above 13 points.

Successful implementation of a QI system requires that these points be fully understood and embraced throughout an organization, from the top down. Often, this requires a radical change in philosophy and action from traditional management methods.

Maintenance Quality Management

The vast majority of highway agencies currently have some form of an MMS that helps them organize, plan, schedule, budget, control, and report highway maintenance activities. Many agencies also have performance standards that describe how individual maintenance tasks are to be performed, the resources required to carry out the task, the expected rate of production, and, occasionally, the desired level of quality.

Maintenance quality practices, on the other hand, are not as commonplace among highway agencies. Only a few agencies have instituted or are in the process of instituting maintenance QA programs. In general, these agencies take one of three approaches toward assuring quality maintenance work. Some strive to ensure that all work operations are done in accordance with the standards established by the agency. Others are mostly concerned with the long-term, end-result performance of the roadways that are maintained. Still others are concerned with both aspects and, as such, have established systems to monitor both.

Various quality concepts were identified among the maintenance agencies engaged in QA, and several of these concepts were used to develop the prototype QA program. The following is a list of key ideas that represent the state of the art in maintenance quality management:

- LOS rating system that measures long-term, end-result performance of field activities;
- Formal QA/QC reviews of LOS rating teams to ensure consistent, repeatable ratings from region to region;
- Detailed QA/QC process to rate work performance during and at the completion of each activity;
- Solicitation of customer input on the relative importance of various maintenance activities and the LOS expected from each activity;
- Solicitation of customer input on the degree of satisfaction with the maintenance being provided;
- Formal QA/QC process for testing materials and procedures;
- Release of employees to make daily operational decisions, but holding them accountable for results; and
- Continuous updating of QA process in accordance with customer satisfaction and anticipated funding levels.

OVERVIEW OF PROTOTYPE QA PROGRAM

The flow chart provided in Figure 1 shows the various components that a maintenance QA program should contain and the relationship of these components to each other. As seen in this figure, the QA program consists of two phases: the preliminary work phase associated with developing the LOS rating system and the field implementation and closed-loop operational phase. The main components of the QA program are briefly described below:

- **Key Maintenance Activities**—Grouping of key work activities into like categories for the purpose of evaluating maintenance quality.
- **Customer Expectations**—The one-time collection of highway users' expectations concerning the LOS at which an agency should maintain its highway system.
- **LOS Criteria**—Clear and measurable definitions concerning the points at which deficiencies cause *maintenance features* or *maintenance characteristics* no longer to meet expectations. LOS criteria are usually expressed in terms of amount and extent of deterioration (e.g., size and frequency of potholes, amount of litter per mile [kilometer]).
- **Weighting Factors**—Factors that (a) reflect the relative importance of individual maintenance features/characteristics that compose a *maintenance element* and (b) reflect the relative importance of individual maintenance elements that compose a highway facility, on the whole.
- **Maintenance Priorities**—Establishing the order in which work activities will be conducted in the event that a shortage of resources occurs. Each work activity is prorated according to the four fundamental maintenance objectives, prioritized as follows:
  1. Safety of the traveling public,
  2. Preservation of the investment,
  3. User comfort and convenience, and
  4. Aesthetics.
- **Baselining Existing LOS (Pilot Study)**—Determining the existing LOS of the maintenance of the agency's highway system using the components above.
- **Formal LOS Inspections, Analysis, and Reporting**—Periodic maintenance ratings stemming from random

inspections of statistically selected short segments of the highway system maintained by an agency.

- **Customer Satisfaction**—The periodic assessment of how satisfied highway users are with the LOS provided by a maintenance agency.
- **Workload Inventory**—Information on the type, location, and dimensions of key maintenance features that can be used to estimate workloads for maintenance activities.
- **Activity Cost Data**—Actual cost for performing a unit of work for a specific activity. For agencies that do 100 percent of their work using agency employees, this is usually readily available; however, for agencies that have a significant mix of in-house and contract maintenance forces doing the same activity, a proportional blend of the cost data will be required.
- **Zero-Based Budget**—Application of the activity cost data and field trial results to determine the costs required to produce a specific LOS established from customer expectation input.

The prototype QA program developed and presented in this manual encompasses the maintenance elements believed to be most common among highway agencies. These include traveled roadway (i.e., mainline pavement), shoulder (paved or unpaved), roadside, drainage features, traffic services, vegetation, and aesthetics. Recognizing that bridges and snow and ice control can also be substantial parts of an agency's maintenance program, a discussion of how the QA program can be applied to these elements has also been included in this manual. This discussion is contained in Appendix A, "QA Program Supplements."

ORGANIZATION AND USE OF MANUAL

This manual presents the principles and procedures of the prototype highway maintenance QA program developed under NCHRP Project 14-12. Its purpose is to recommend the actions necessary to implement the quality concepts that can effect considerable improvements in maintenance products and services.

The manual has been organized to be self-contained, in that no outside assistance should be necessary from persons experienced in the formal methodology. The manual is also comprehensive; the instructions cover all of the actions necessary for a maintenance agency to develop, implement, and routinely operate the QA program presented herein. A series of 24 well-defined components is presented, with each component having an objective, a clear concise description of how the objective is to be accomplished, and an illustrative example, where appropriate and possible.

This manual consists of six chapters, including this introductory chapter. Chapter 2 describes the various resources required for an agency interested in establishing the QA program. Chapter 3 describes the process for developing a customized LOS rating system designed to assess maintenance quality. Chapter 4 details how an agency-approved LOS rating system is applied in the field and how a continuous quality updating cycle is achieved. Chapter 5 addresses the many institutional barriers that can be expected during the establishment of the QA program. Lastly, Chapter 6 provides a summary of the QA program and the positive effects it can have on highway maintenance programs.

Four appendixes and a glossary are provided in support of this manual. Appendix A describes how the QA program can be applied to the maintenance areas of snow and ice control and bridge maintenance. Appendix B discusses the potential for use of data from various management information systems in the QA program. Appendix C provides illustrations of how the relationship between QA program outputs and long-term performance of highway elements can be monitored. Appendix D provides an overview of the Maintenance Accountability Process (MAP) recently enacted by the Washington State DOT. Finally, to give readers maximum comprehension of the QA program, a glossary has been included that contains a list of definitions for key terms used throughout the manual.

CHAPTER 2

RESOURCE REQUIREMENTS

QUALITY MANAGEMENT

Naturally, everyone is interested in achieving positive results—producing quality products and services, eliminating waste, avoiding rework, and satisfying customers. Toward this end, most organizations have established formal policies and procedures for improving the quality of the highway maintenance product. In general, these operational strategies currently include some form of QA, *quality control (QC)*, *continuous quality improvement (CQI)*, and *statistical control process (SCP)*.

It is important to recognize that, although each of these strategies is appropriate, they do not replace existing techniques for determining specifications and standards and for measuring conformance. They do, however, supplement or refine the strong traditional management approaches to problem solving and efficiency with a new emphasis on carefully defining and satisfying the requirements of the customer.

Modern-day quality advocates hold management responsible for a very high percentage of the quality problems that occur in manufacturing and various service-oriented industries. Though management may not be as major a hindrance in the highway maintenance industry, it is safe to say that quality work is the product of quality management. This manual is an outline for implementing a program that embraces the quality concepts discussed above.

Essential to the successful use of the concept of quality management is a commitment starting at the chief executive officer (CEO) level. Many procedural and philosophical issues will be addressed as a function of this process. Everything from budget preparation, to authorization of employees, to improving administrative procedures may represent a change from the old manner of doing business. As various individuals grow uneasy with the changes that are occurring, it is necessary for leadership to stand up and endorse the changes and raise the comfort level of those that are slower to believe in the value of the process (*Deming's Point No. 14—Create a structure in top management that will push every day on the first 13 points)*.

The primary goal of a maintenance QA program is to improve quality and provide for the effective use of existing resources. Agencies should not implement the prototype program for the purpose of reducing personnel requirements, even though many have lost personnel through the years and are faced with a critical need to maximize the productivity of existing personnel.

Quality management can be described as "doing the right thing at the right time for the right reason, and being able to recognize what actions are necessary to accomplish it." The concepts presented in this manual contain the state of the art in describing those actions to be implemented. In many instances, it will represent a culture change from the business-as-usual actions of the past, and it becomes critical that all levels of management support the process with their actions. It is equally important that employees who have been released to manage service delivery also recognize they are being held accountable for those decisions they have been authorized to make.

It can be said that transportation officials act as the proxy for public benefit. It can also be said that most officials believe that users of the transportation system are entitled to an adequate LOS, regardless of the route or location. To accomplish a stable, uniformly maintained system, it becomes imperative to institute an objective evaluation technique for measuring the LOS being provided by the transportation facilities. To do so, a user agency should have in existence the following basic management techniques prior to implementing the features described in the remainder of this manual.

- A method of documenting work accomplishments, including production and productivity;
- A method of determining labor, equipment, and material costs associated with each activity;
- An inventory of highway maintenance features, including a method of locating/referencing those features; and
- A basic understanding of quality management concepts and principles.

Although an agency can implement the features of a highway maintenance QA program without these techniques, the chances for success without them are significantly decreased.

In recognition of the many different organizational styles and structures in maintenance agencies, as well as agencies' varying size, this manual has been made flexible so that implementing agencies can create customized QA programs for the entire agency or for subgroups within the agency.

Once the QA program has been fully implemented, an agency should be able to shift from a "fixing" mode to a "prevention" mode, recognize improvements that have occurred since the program's inception, and identify additional improvements that are needed. Implementing agencies will also begin to move away from frequent second-guessing to a state of greater managerial confidence. In essence, they will be

- Doing the right thing by
  - Doing things the right way,
  - Doing things right the first time, and
  - Doing things on time.
- Delivering the right service by
  - Satisfying the customers' needs, and
  - Treating the customer with courtesy and respect.

To achieve these benefits, agencies must recognize that each manager, supervisor, and employee is responsible for the end result. Delegation of authority to get the job done includes the responsibility to make sure it is done the right way. Failure to do so allows the agency to become involved in confrontation, additional problem solving, repeat work, and occasional litigation. Not only are these matters time consuming, they will often occur several years after the fact, when employees have forgotten or even left employment with the agency. Quality management enables an agency to minimize these negative matters and focus its attention on meeting customers' expectations using long-term, cost-effective solutions.

MAINTENANCE MANAGEMENT

Work Accomplishments Documentation

The key in tying together work accomplishments is the development of performance standards for each activity and the inventory units of the specific road feature corresponding to that activity. These standards contain a measure for work accomplishments, a quantity standard or workload rate for each road class, and productivity values that define the production and productivity per labor hour expected from a typical crew. At this point, a program estimate can be developed for each work activity using the information contained in a feature inventory. Estimated work quantities, merged with daily crew production, can then produce an estimate of crew days by activity.

Management reports that can be produced from the reporting of actual work accomplishments can then be compared to estimated work quantities. Although the details in an agency's management system can vary, typical outputs usually consist of the following components:

- Work accomplishments reports, detailing performance summarized by activity, individual crew, area work location, district and statewide productivity rates.
- Equipment and materials utilized in performing the activities that produce the work units shown above.
- Performance budget information including the actual costs per unit of measure for each activity. Reports of this type will frequently contain a breakdown of these costs for labor, materials, and equipment.
- Resource usage reports comparing planned labor, equipment, and material requirements versus actual accomplishments or usage.
- Work production analyses comparing actual production versus the standard of average production rates.

Maintenance Costs Accounting

An economic analysis of maintenance requires models for estimating current and future agency costs. These models may be based on historical data or on predictions made by expert planners knowledgeable of future trends that will affect maintenance resources. Maintenance costs can be partly based on methods and standards (crew sizes, equipment types, materials needed, quantity standards, quality standards), but they must also consider the desired LOS to the user, emergency needs, condition surveys, proposed capital improvements (e.g., pavement, bridges, buildings), and user costs for delays in work zones.

Depending on their organizational structures, most agencies will not have cost accounting data available in a maintenance database. The actual information may reside in a personnel/payroll system, a mobile equipment system (including the cost of ownership as well as maintenance and repair costs), or a materials and warehousing system. Tying each of these databases into the maintenance performance reports, and ensuring that they are all compatible, is a task that should only be attempted by individuals knowledgeable with the specific attributes of each.

As mentioned in the previous section, properly developed performance standards will expedite the ability of an agency to consolidate its fiscal/financial information into a meaningful report that identifies the actual costs of doing work for any activity, crew, local area, district, or state. Information of this type can be invaluable to management in testing the comparative efficiency and cost-effectiveness of various work methods, types of equipment or materials, and size of crew.

Maintenance Features Inventory

A *maintenance features inventory* provides a physical basis for estimating annual maintenance work requirements by activity. Most inventories contain the following attributes:

- Allows the organization of data features in a manner that is compatible with work activities;
- Enables an agency to count maintenance features within a specific geographic boundary, milepost, route, maintenance unit, or district boundary; and
- Provides a basis for estimating annual or periodic maintenance work requirements.

Inventory data provide the basis for work program estimation by providing a physical measurement of road features that are considered important to maintenance activities. Although these inventory systems were generally designed to capture the quantities of each item, most did not initially reference the condition of these features. This was primarily because most work location identifications are based on specific deficiencies that may have developed after the inventory was initially taken and before the next update is conducted. This has been modified in the design of some of the newer inventory systems being implemented. Generally, these newer systems are beginning to collect feature and condition data simultaneously in order to determine the general status of an inventory feature on a highway system or network.

Quality Concepts and Principles

Many unique features can be used to outline the attainment of quality. Unfortunately, quality often lies in the eye of the beholder and not in a rational method of measurement. To further complicate this issue, one item being measured may vary widely from the criteria used to judge another, even if the two items are similar. In any given instance, no one definition will suffice, although most individuals will know it when they see it or will know when it is missing. In general terms, however, the concept of quality contains the following attributes (Miller and Krum 1992):

- Quality is conformance to requirements.
- Quality is the absence of defects.
- Quality is the fitness for use.
- Quality is meeting the customers' needs and expectations.

These attributes should cause one to ask the following types of questions: How is it to be measured? Under what conditions is it to be measured? Who will establish the requirements? What constitutes a defect? These and other questions will be answered in the remaining chapters of this manual.

QA PROGRAM INVESTMENT

To a large extent, the amount of money needed to implement and continuously operate the QA program will depend on the desired frequency of quality reviews. Naturally, the desired frequency will depend on the agency's need for information concerning the condition of certain functions, the level of control it intends for the information to play, and the cost it is willing to pay in acquiring the information.

Information on specific functions depends on the activity and the specific LOS criteria assigned to it. For instance, snow and ice control requires an immediate assessment of conditions and appropriate action, whereas mowing, which is usually much less critical, can be performed on a scheduled basis.

The level of control an activity requires may be the result of organizational characteristics of the agency. For many activities, the frequency of a review is less time critical and can be shown as the LOS evaluation for an activity on periodic highway network reports.

QA program costs should consider all activities required to perform a complete assessment of maintenance at the network, project, and activity levels, as well as the costs of program implementation, obtaining customer input, and training employees. Normally these items will include salaries, travel, equipment, report production and distribution, and the QA/QC of the LOS rating teams to ensure consistent results. A summary of the costs of the LOS rating systems in-place at four of the seven agencies reviewed under NCHRP Project 14-12 are contained in Table 1.

Staffing Requirements

In estimating the size of the staff required for the QA program, it is important that the implementing agency think through to the outcome and determine how it wishes to use the information produced. Table 1 will provide a few answers to the scope of how agencies with LOS rating programs have approached the variables to be considered in developing the program. One agency chose a yearly evaluation, whereas another (which fully contracted its maintenance functions with the private sector) opted to perform reviews on a continual basis, scheduling monthly performance review meetings with the contractor.

Depending on preferences, an agency should be able to develop a program to suit its unique needs. This manual contains general guidelines to help the implementing agency make decisions concerning the size and complexity of a program it wishes to implement. Following are some of the items to be resolved:

- Number of LOS inspections to be conducted during the year;
- Length of sections to be rated;
- Statistical requirements for the number of observations required to ensure accuracy in the LOS survey; and
- Proposed methods for using the data collected.

Generally speaking, QA program staffing will depend on the organizational structure of the implementing agency and the size of its highway system. A decentralized agency will be required to perform QA/QC on district/region compliance with the agency's LOS rating procedures, whereas a centralized agency will be required to perform the entire rating process itself. Similarly, an agency with a small highway system will likely desire to perform the entire LOS evaluation, whereas a large agency will need to have several teams to collect data in a timely manner. Table 2 lists the general skills required of the key QA program personnel.

Because the QA program is dynamic, it is recommended that an advisory panel, consisting of each district/regional maintenance manager/engineer and key central-office maintenance staff, provide broad overviews of development, implementation, revision, and operation of the QA/QC and LOS program criteria. Buy-in of these individuals is critical and their experience base is invaluable when establishing or modifying the program. The advisory panel should meet on a periodic (monthly, quarterly) basis; often enough to keep the system current but not so often that changes are made simply for the sake of change.

Sufficient clerical and computer support people will also be required on a periodic basis. These individuals will assist key personnel in transferring, processing, and analyzing data, preparing field supplies, and generating reports.

TABLE 2 General qualifications of key QA program staff persons

Central-Office Program Developer/Manager or District/Regional-Office Program Manager	Central-Office Supervisor or District/Regional-Office Supervisor	Central-Office LOS Rating Team Personnel or District/Regional-Office LOS Rating Team Personnel
1. Experience as an agencywide or district/regionwide manager of a large maintenance operation. 2. Computer literate. 3. Ability to work with complex formulas, numbers, and coding forms. 4. Good understanding of QA/QC concepts. 5. Ability to work with a variety of people, being able to disagree when necessary without becoming disagreeable. 6. Ability to train crews in the proper procedures to conduct LOS inspections. 7. Ability and willingness to travel for a moderate period of time.	1. Field experience in the supervision of constructing or maintaining highway features. 2. Generally computer literate. 3. Ability to work with complex formulas, numbers, and coding forms. 4. Ability to work with a variety of people, being able to disagree when necessary without becoming disagreeable. 5. Ability to train crews in the proper procedures to conduct LOS inspections. 6. Ability and willingness to travel for a moderate period of time.	1. Field experience with constructing or maintaining highway features. 2. Ability to reason, interpret written instructions, and make decisions regarding compliance with agency LOS criteria. 3. Ability and willingness to travel for extended periods of time.

Equipment and Supplies

Central and District/Regional Offices

Access through a local area network (LAN) to a central database for all maintenance management, inventory, fiscal/financial, mobile equipment, and warehousing and materials inventory information is highly desirable when developing an agency QA program. Additional support equipment, such as 486- or pentium-type processor computers equipped with Microsoft® Windows, LaserJet printers, copiers, and facsimile machines, will also be necessary.

Field

Depending on the size of the field rating team, each team will require access to a properly equipped survey vehicle. For a two- or three-person team, a compact station wagon or mini-van should be adequate. Teams of four or more individuals, however, will probably require a passenger van or comparable vehicle. Aside from the standard safety equipment, each survey vehicle should have a flashing amber safety light mounted on the roof and should be equipped with a distance measuring instrument (DMI) to accurately locate survey points. Communications devices (e.g., two-way radio, cellular phone) for safety purposes during late night inspections of signs and pavement markings should also be made available with the survey vehicles. With the accuracy of global positioning systems (GPSs)—satellite control and receivers used to determine the locations of persons or objects—continually being improved, agencies may consider using them in establishing sample segments. A more detailed listing of equipment and supplies needed in the field is contained in Chapter 3.

METHOD OF REPORTING

The organizational makeup of governmental agencies will vary widely from location to location, depending on the style of management preferred. One of the more widely accepted methods appears to be in a decentralized organization with a strong central administration that develops policies, procedures, standards, and rules of operation. All personnel within these agencies report to the CEO, who has the ultimate authority and responsibility for the success of the organization. Local managers do not report to the central-office maintenance managers, they report directly to the CEO. The central-office managers report to the CEO concerning the local manager's performance (actual LOS versus desired LOS) and subsequently revise the dynamics of the system that is in place. Local managers are then left to make their own decisions concerning daily operations while carrying out the agency's described methods of operation.

Daily decisions on what work to accomplish, when it should be accomplished, and the best way to accomplish it has been delegated to local managers. In this way, they are authorized to resolve daily decisionmaking to suit local conditions and produce cost-effective results without being delayed by bureaucratic ties to a central authority. Periodic *quality assessment* techniques are then performed to hold local managers accountable for the results they provide. When left to their own devices, the initiatives developed by the local managers have proven very effective, and there is a tendency to assist others by the sharing of solutions to common problems. To ensure adequate and equal LOSs, each management area is given the basic resources (personnel, equipment, materials) to accomplish the workload assigned to it.

CHAPTER 3

QA PROGRAM DEVELOPMENT

KEY MAINTENANCE ACTIVITIES AND FEATURES/CHARACTERISTICS

Component #1 Objectives: To identify the key routine maintenance activities representing approximately 80 percent of annual maintenance expenditures and to identify the maintenance features/characteristics primarily affected by those activities.

Using personal experience and a recent annual work accomplishments report, an implementing agency can begin to lay the foundation for a maintenance QA program by identifying the key maintenance activities to be monitored. Because the focus of the prototype QA program is on outcomes, the evaluations will not be of the performance of key activities, but rather the conditions that are largely affected by those activities.

The first step in the identification process is to examine the list of cost items in the most recent annual work accomplishments report and separate the routine roadway maintenance items from those items that are considered fixed obligations (e.g., administrative services, equipment and facilities maintenance, permits, utility bills). Summing the actual costs for each routine maintenance item will yield the total routine maintenance expenditure for that reporting year. Then, multiplying that dollar amount by 0.80 (i.e., 80 percent) will give the "target dollar amount" that represents 80 percent of the annual maintenance expenditure.

The next task is to identify the key routine maintenance items that come close to totalling the target dollar amount. It is suggested that the implementing agency concentrate on those activities that are the most visible and important to the highway user. There should be between 5 and 10 such items, each one falling under an umbrella of activities. The following are among the more common activity umbrellas, otherwise referred to as maintenance elements:

- Pavement or traveled roadway,
- Shoulders,
- Drainage,
- Traffic services or traffic control and safety, and
- Vegetation and aesthetics or roadside.

Other elements might include bridges, winter services (i.e., snow and ice control), and roadway facilities (i.e., rest stops).

The next step is to group similar activities and determine the total cost of each group. By summing the costs of various group combinations, comparisons can be made with the target dollar amount, and a set of key activities (generally, 20 or so) can be identified. During this process, it will be important to remember the centerline-out rule of maintenance feature priorities. That is, first concentrate on the costs of traveled roadway maintenance activities and then sequentially consider the costs of activities associated with traffic services, shoulders, drainage, roadsides, and vegetation and aesthetics.

Table 3 illustrates the key activities identification process. For a given agency, the routine maintenance activities performed are listed in the first column, followed by the corresponding annual costs of each activity in the second column. As can be seen, the total cost of all routine activities is \$2,639,589; hence, the target dollar amount when identifying the key maintenance activities is $0.80 \times \$2,639,589 = \$2,111,671$.

The group costs of similar activities are listed in the fourth column. It is from these costs that a conglomerate of activities is identified through a short trial-and-error process. In this illustration, maintenance activities associated with pavement patching and surface treatment, drainage improvement, and winter services make up 81.0 percent of the annual maintenance expenditure.

With the key activities identified, the next step is to determine the maintenance features/characteristics to be periodically evaluated. Such features/characteristics should be the responsibility of maintenance up until the time of rehabilitation, and they should be reflective of maintenance efforts, both in terms of evidence of maintenance (Has a treatment or repair been applied?) and effectiveness of maintenance (How well is the treatment or repair performing?).

For each key maintenance activity, list the maintenance features/characteristics that are improved as a result of performing the activity. For instance, street sweeping reduces the potential for drainage structures (e.g., inlets, pipes, manholes) to become clogged with leaves, dirt, and trash. Pavement milling restores surface quality and surface profile to roads exhibiting various distresses, such as bumps, rutting, corrugations, bleeding, raveling, and polishing.

A maintenance matrix, like the one given in Table 4, can be developed to show the ties between maintenance activities and the various features/characteristics. A matrix for each maintenance element will allow for quick identification of inadequate maintenance activities based on low LOS ratings of specific features.

TABLE 3 Work activities and annual costs

Maintenance Activity	Activity Costs, $	Maintenance Element	Costs of Grouped Activities, $	Costs of Key Activities, $
Pothole Patching	85,632	Pavement		
Hand Patching	3,461			
Temporary/Utility-Cut Repairs	18,661			
Full-Depth Repairs	80,909		188,663	188,663
Overlay Patching	348,965	Pavement	364,884	364,884
Milling	15,919			
Seal Coating	262,089	Pavement	263,668	263,668
Spot Sealing	1,579			
Spot Graveling	14,575	Unpaved Roads	59,198	
Regraveling Streets	44,623			
Joint and Crack Filling	92,413	Pavement	158,540	
Partial-Depth Spall Repair	66,127			
Street Sweeping	259,254	Drainage	330,305	330,305
Street Flushing	71,051			
Litter Pickup	28,120	Aesthetics	29,225	
Graffiti Removal	1,105			
Weed Spraying	10,002	Vegetation	31,036	
Mowing	21,034			
Plowing Streets	172,846	Winter Services		
Sanding Streets	230,479			
Spreading Deicing Agents	231,011			
Hauling Snow	167,695			
Miscellaneous Snow and Ice	189,471		991,502	991,502
Sign Repair and Replacement	17,453	Traffic Services		
Sign Cleaning	3,045			
Pavement Striping	48,322		101,813	
Pavement Marking	32,993			
Curb and Gutter Repair	20,847	Roadside	37,003	
Sidewalk Repair	16,156			
Ditch Cleaning and Shaping	31,321	Drainage	58,235	
Storm Drain Cleaning	26,914			
Sodding	8,612	Vegetation		
Tree Trimming and Removal	13,757		25,517	
Brush Removal	3,148			
	2,639,589	0	2,639,589	2,139,022

Total Number of Routine Activities = 34
Total Number of Key Activities = 15
Percent of Routine Expenditures = 2,139,022/2,639,589 = 81.0%

One key factor to remember in this process is to "inspect what you expect." The tendency to identify more characteristics than necessary is difficult to overcome *(Deming's Point No. 3—Cease dependence on mass inspection).* It is recommended that the following question be asked of each characteristic being considered: Is this information valuable in determining the status of customer expectations, or are we simply continuing business as usual?

The concept of quality management requires that all aspects of the program be evaluated for importance. The items chosen to be measured and reported will be the key to producing a quality assessment system. An agency should develop all of the characteristics it needs, but it must also use the data effectively, or much of the field data collection effort could be wasted. To keep the data collection time within reasonable limits, it is recommended that an agency's initial program

TABLE 4 Maintenance activity-characteristic matrix for asphalt concrete (AC) traveled roadway element

Quality	Characteristic	Maintenance Activity								
		Pothole Patching	Full-Depth Patching	Mechanized/ Overlay Patching	Spot Sealing	Surface Treatment	Base Repair	Crack Sealing/ Filling	Pavement Removal (Planing/Milling)	Sand/Chip Spreading
Structural Integrity	Alligator/Fatigue Cracking		✓	✓	✓	✓	✓			
	Block Cracking					✓		✓		
	Edge Cracking/ Raveling	✓								
	Longitudinal Cracking (including lane–shoulder separation)							✓		
	Transverse Cracking							✓		
	Potholes	✓	✓							
	Patch/ Patch Deterioration	✓	✓	✓	✓					
	Loss of Support (pumping)						✓			
Surface Deformation	Shoving		✓							
	Rutting			✓		✓			✓	
	Corrugations/Waves			✓			✓			
	Bumps/Heaves		✓						✓	
	Depression/ Settlement	✓		✓			✓			
Surface Quality	Bleeding/Flushing					✓			✓	✓
	Polished Aggregate					✓				
	Raveling/Stripping			✓	✓	✓			✓	
	Weathering			✓	✓	✓			✓	

size be limited to monitoring those maintenance conditions having practical significance. This recommendation should not be interpreted as "how little can I get away with," which is contrary to quality management ideals, but rather as an evaluation of the value of the data that field personnel are being asked to collect. In this case, more is not always better; ask for what you want, but be certain you want what you ask for.

CUSTOMER EXPECTATIONS

Component #2 Objective: To identify the highway user's perception of the relative importance of various maintenance features/characteristics and maintenance elements.

Perhaps one of the most profound statements concerning customers was made by Mr. Arnold W. Oliver, former Executive Director of the Texas DOT, when he said, "One way to give our customers quality is to know what they want" (FHWA 1992). This, of course, requires that an agency knows who its customers are, whether they are internal customers (other units within the organization) or external customers (persons outside of the organization), and what part maintenance plays in satisfying their needs.

In general, organizations tend to concentrate more on providing quality to internal customers than to external ones. It is important that agencies devote more attention to external customers by first asking them what they expect from the agency that provides highway maintenance, and later asking them how well the agency has fulfilled their previously stated expectations *(Deming's Point No. 1—Create constancy of purpose toward improvement of product and service).* In both cases, a short, well-constructed survey of a representative cross section of highway users can produce meaningful input for the highway agency.

A survey of highway users determines their basic perceptions of which features/characteristics and elements of a highway facility are of greater or lesser importance. Furnished with this information, the implementing highway agency can more precisely develop the following QA tools:

- Weighting factors that can be applied to individual maintenance features/characteristics and maintenance elements toward the calculation of an overall LOS rating; and
- Priority system for maintenance activities.

Survey Methods

Although there are several techniques for obtaining input from customers, only formal questionnaire surveys, conducted by mail or telephone, are deemed appropriate for determining highway users' expectations of service. These types of surveys, when properly constructed and administered on a statistical basis, yield the most reliable and representative customer inputs. Other feedback techniques, such as focus groups, public hearings, complaint and thank-you letters, and informal conversations, usually result in considerably biased, qualitative, or inadequate input. A third type of formal questionnaire survey—personal interviews—generally yields the most useful and reliable information, but involves extremely high costs and is therefore not recommended.

Table 5 highlights some of the important facets of two recent customer surveys: one conducted by the Minnesota DOT to determine both customer expectations and customer satisfaction and another conducted by the Pennsylvania DOT to determine customer expectations. This information is very useful because it reveals much about the resources an agency will need in order to obtain reliable customer input. It also illustrates some of the key differences between mail-in and telephone surveys, such as the cost of the surveys and the time and staffing needed to complete the surveys.

A couple of items are worth noting at this point. First, because neither survey type will yield a 100 percent response rate, it will be necessary to compensate for nonrespondents and unfit respondents by administering the survey to a larger number of individuals than designated by the sample size. To determine the approximate number of persons to contact to obtain the required sample size, divide the required sample size by the expected response rate. For example, if the required sample size is 100 and a telephone survey is expected to have a 70 percent response rate, then about 143 (100/0.70) individuals should be called. Naturally, if the number of responses is insufficient, then a few more randomly selected individuals will be needed until the sample size has been achieved.

Second, as the response rate decreases, the degree of nonresponse bias increases. Nonresponse bias is best described as a distortion of the survey results because of under representation of nonrespondents, the large majority of whom are lower- and upper-income people (these groups are less likely to respond, for one reason or another). Because of much lower response rates, mail-in surveys are likely to have a higher degree of nonresponse bias than telephone surveys. This should be kept in mind when deciding which approach to take.

Statistical Sampling

Defining the Survey Population

A *survey population* is the total set of individuals that make up a given market of interest. It is, in the business sense, a pool of customers. For a maintenance agency, the market of interest is highway service and the ideal survey population is "users of the highway facilities maintained by the agency." Because accessing this type of population is difficult—the user of a particular agency's highway can be a passenger, an unlisted person, or a driver from out of state—a slightly different target population must be considered. Two suitable targets are

TABLE 5 Key facets of Minnesota (SMS 1994) and Pennsylvania

	Minnesota	Pennsylvania
Time Conducted	November 1994.	April 1994.
Source Listing	Telephone listing.	Pennsylvania Driver's License database.
Pretest	Focus group.	
Sampling Type	Disproportionate stratified random sample (based on 1990 Census of Minnesota County populations and aggregated into eight maintenance districts).	Random sample (using random number generator).
Survey Type	Formal telephone questionnaire survey of customer expectations and customer satisfaction.	Formal mail-in questionnaire of customer expectations only.
Sample Size	1,200 originally proposed phone interviews (300 in each of 2 districts and 100 in each of 6 districts), 1,244 actual phone interviews. 10% of households contacted refused to participate, and less than 2% of the respondents terminated their participation in the survey midway.	4,800 mailed out (400 in each of 12 counties); 1,018 properly completed responses for 21.2% overall response rate.
Length of Survey	61 total questions, 15-minute phone time.	25 rating questions, 1 page.
Cost	$40,000 (approximately $32/respondent).	$20,000 (approximately $20/respondent).[a]
Time Frame and Staff	2 weeks using several telephone survey staff (responses entered directly into computer at time of survey).	1.5 months using three in-house individuals committed part time.[a]

[a] Pennsylvania conducted a customer satisfaction survey shortly after its customer expectations survey. The back-to-back surveys were conducted over a 3-month time frame at a reported combined cost of $40,000.

"licensed drivers residing within the jurisdiction of the maintenance agency" and "motor vehicle registrants residing within the jurisdiction of the maintenance agency."

A *sampling frame* is the source listing from which a sample of individuals is selected. In highway maintenance, various sampling frames can be used to represent the survey population. Several state highway agencies (SHAs), including Maryland, Oregon, and Pennsylvania, have used records from their Department of Motor Vehicles (DMV) or Driver's Licensing Bureau (DLB) as a basis for establishing the survey population. Such records typically include the names of individuals licensed to drive or operate vehicles within the state, along with the corresponding phone numbers and mailing addresses. Sorts on specific cities and counties can develop a listing of motorists residing in the area of interest.

Another sampling frame that may be used is telephone listings. Although this type of source listing is easier to access, it is considerably more biased than the two previous lists because of the potential for households with no telephone or with an unlisted number (it should be noted that random-digit dialing [RDD] is a technique that can be used to eliminate the bias associated with unlisted telephone numbers). In its 1994 survey of highway users, the Minnesota DOT, through a survey consultant, used a telephone listing to randomly select individuals throughout each district to be surveyed by phone (SMS 1994). To reach the right customers and limit bias, the phone interviewers asked to survey the licensed driver in the household with the most recent birthday. The approach was judged a success by both the DOT and the consultant, in terms of collecting data representative of the opinions and preferences of the people of Minnesota.

Type of Sampling

Two types of sampling are most conducive to performing surveys of highway customers: random sampling and stratified random sampling. In random sampling, a random number table or a computerized random number generator is used to determine which individuals are selected, based on their order of appearance on the source list. Random sampling ensures each individual in the population the same chance of being chosen for inclusion in the survey (Kopac 1991).

An agency having a special interest in the views of different groups of individuals will likely benefit from the stratified random sampling technique. This type of sampling calls for dividing the population into two or more strata and then drawing a random sample from each stratum (Kopac 1991). One instance in which this sampling technique might be desirable is for comparing the perspectives of urban and rural highway users on the importance of specific maintenance items.

Sample Size

Once a suitable sampling frame and sampling procedure have been identified, the sample size of individuals to be surveyed must be determined. Though a common practice in the past has been to select a certain percentage of the population (e.g., 5 percent or 10 percent) to serve as the sample size, this procedure often does not ensure the optimum sampling size (i.e., one large enough to yield statistically representative results, but not so large as to waste funds, delay the project, or achieve a needlessly high level of precision [Kopac 1991]).

The optimum sample size is largely dependent on the desired *confidence level* and the desired *precision,* or margin of error, of the results. Because the customer expectations survey will contain inquiries about the level of importance of various aspects of maintenance, the results of the survey will undoubtedly be averages of ratings, made in accordance with a specific rating scale (e.g., 1–10, 1–100). The optimum sample size is best determined using the following formula:

$$n = \frac{\left[0.25 \times (b-a)^2 \times z^2 \times N\right]}{\left[d^2 \times (N-1) + 0.25 \times z^2 \times (b-a)^2\right]} \quad (1)$$

where:

- n = sample size.
- a, b = lower and upper bounds of rating scale (e.g., for 1–10 rating scale, $a = 1$ and $b = 10$).
- d = precision (e.g., for precision of ±0.5 on a 1–10 rating scale, use 0.5).
- N = survey population size.
- z = z-statistic, standard normal variate associated with a particular confidence coefficient (for 95 percent confidence, $z = 1.96$).

As an example, assume that, for a population of 25,000 individuals, a 1–100 rating scale will be used and a precision of ±5 points is desired. For a 95 percent confidence interval, the required sample size is calculated as follows:

$$n = \frac{\left[0.25 \times (100-1)^2 \times 1.96^2 \times 25{,}000\right]}{\left[5^2 \times (25{,}000-1) + 0.25 \times 1.96^2 \times (100-1)^2\right]} = 371$$

Developing the Questionnaire

Deming's point that "quality has to be measured; it can't be guessed at" entails objectively measuring what is important. Surveys are used to measure a variety of concepts of interest, from personal habits and behaviors to awareness and recognition to attitudes and opinions. Though maintenance practitioners will have preconceived notions as to what aspects of maintenance are most important, the customer's assessment of importance is quite beneficial and can be obtained reliably through a properly designed questionnaire.

The most appropriate way to measure the importance of various maintenance-related issues is to use rating scale questions. Scales of 1–5, 1–10, and 1–100, with 1 representing "not important" and 5, 10, or 100 representing "very important," can be used effectively to measure the importance of conducting individual maintenance activities, as well as the importance of maintaining specific maintenance elements and distinct facility types.

When preparing such questions, it is important to think like the customer. This can be achieved by using terms the customer can relate to (e.g., potholes, smoothness, visibility) and by directing the list of questions to those areas that are clearly the responsibility of maintenance. Although an agency could gain from such information, it will serve no positive purpose to allow complaints about design or construction procedures to be mixed in with the results of a survey on maintenance customer expectations.

It is also important to refrain from including technical questions, such as "what degree of reflectivity is acceptable for striping?" The traveling public is most valuable in defining what it expects when traveling on the highway system, but it is the job of the professionals in the agency to work out technical issues. For instance, if the expectation of the public is to require major arteries into urban areas to be opened to traffic within 2 hours following a winter event, it is the job of the agency to determine what conditions should exist to meet this expectation. A minimum friction rating or a specific definition of bare pavement may be appropriate interpretations of what constitutes an "open highway" following a winter event.

A good supplement to the rating scale questions is a resource allocation question. In this type of question, the respondent is provided with a total dollar figure for conducting the agency's routine maintenance activities and is then asked to assign percentages of that dollar amount to various maintenance elements. Space should be made available for write-ins, and respondents should be informed that the sum of the percentages they specify should equal 100 percent.

To maintain as high a response rate as possible and the highest degree of consideration for the questions, it is best to keep the questionnaire short and concise. A 1- to 3-page mail-in survey or a 5- to 10-minute phone survey is usually sufficient for asking the questions pertinent to customer's expectations. On mail-in surveys, it is recommended that sophisticated terms be defined clearly for the respondent and that the survey form itself be made attractive (proper text arrangement, spacing, and style), so participants are more receptive. Figure 2 contains an excerpt from the Minnesota customer survey; a similar, but more detailed, customer expectations survey is illustrated in Figure 3.

Occasionally, programs are mandated by others (Governor, Legislature, Secretary of Transportation), and the maintenance agency has no choice concerning the discontinuation of the program. Research should be conducted to identify such protected programs prior to mailing the survey to the public. It may even be important to the agency to do public service announcements (PSAs) as an educational tool about the program in question to ensure the purposes of the survey are being met without controversy.

Pretesting the Survey

As pointed out by Kopac (1991), "regardless of how carefully the questionnaire has been worded, it should not be

For the rest of this study, I would like you to focus on State roads and highways. Now, I would like to ask you about a series of issues relating to road maintenance. For each area I mention, I'd like you to tell me how important that issue is to you. To do this, we'll be using a scale from 1 to 10, where a score of "1" would mean that the issue is not all important to you, a score of "10" would mean that the issue is extremely important to you, and a score of "5" would be of middle importance to you.

NOT RANDOMIZED

13 First let me ask about MnDOT road maintenance: overall how important would you say Mn/DOT's road maintenance is to you?

RANDOMIZE REMAINING ISSUES; SCALE 1-10; 8888 DK; 9998 Not Applicable to Area; 9999 Refused

How important to you is it that...

ITEM	TEXT	RATING
14	roads be cleared of debris?	
15	the roads be cleared of ice and snow?	
16	roads be kept in similar condition statewide?	
17	road shoulders be in good condition?	
18	road surfaces be smooth and comfortable to drive on?	
19	all lanes on bridges be open year-round?	
20	weeds on the roadside be eliminated?	
21	the plants, grasses, and flowers by the roadside look good?	
22	litter and trash by the roadside be removed?	
23	stop lights and stop signs be clearly visible and working?	
24	highway signs be clearly readable?	
25	guardrails be in working condition (IF NECESSARY "undented and whole")?	
26	road stripes and markings be clearly visible?	
27	roadway lighting works?	
28	rest areas are safe, clean, and attractive?	
29	current information is provided on unplanned or emergency highway conditions?	

Figure 2. Customer expectations portion of Minnesota DOT survey (SMS 1993).

assumed that it will work well until it has been tested under field conditions." Informally pretesting the survey on nonprofessionals will provide useful feedback on the clarity, interpretation, and logical sequencing of the questions, as well as the length, receptiveness, and effectiveness of the survey.

Administering the Survey

The decision of how to administer the questionnaire survey will depend largely on costs and the availability of staff and other in-house resources. If sufficient staff and supplies are available, then an in-house mail-in survey may be the best option. In comparison with a professional marketing consultant, the costs of conducting an in-house survey will likely be lower—particularly if one or two individuals with survey experience can be acquired to lead the effort.

If an outside marketing consultant is necessary and survey results are desired in a short time, then a telephone survey is recommended. Firms specializing in telephone interviewing can be contracted to carry out the survey and provide the complete results in computer format. Such firms may use tens or hundreds of professionally trained and computer-assisted interviewers to conduct the survey in a matter of a few days or weeks.

Regardless of which type of survey is chosen, consideration must be given to the following items when administering the survey:

- Establish an appropriate time for conducting the survey—Try to avoid times that may significantly bias the results, such as peak construction times or times of substantial snowfall.
- Explain the purpose and importance of the survey—For mail-in surveys, convey both of these items in the cover

CUSTOMER EXPECTATIONS SURVEY

PART A

The *(enter agency name)* is interested in determining the level of maintenance it should be providing on its highway system, a system that consists of *(specify types of roads/streets)*. Please review each work activity and specify the level of importance of the activity using a scale of 1 to 10, with 1 representing unimportant and 10 representing very important.

Work Activity	Level of Importance
• Patching potholes in asphalt or concrete pavement	________
• Removing dips, bumps, or irregularities on asphalt pavement	________
• Leveling drop-offs or ruts at edge of pavement and shoulder	________
• Maintaining adequate warning signs (e.g., stop, yield, curve)	________
• Maintaining adequate informational signs (e.g., speed limit posting, destination, mileage, no parking, school zone)	________
• Maintaining adequate pavement symbols (arrows, left, right) considering daytime and nighttime appearance	________
• Maintaining adequate pavement stripes (e.g., centerline, no-passing, lane dividers), considering daytime and nighttime appearance	________
• Maintaining adequate reflective pavement markers	________
• Removing debris (e.g., sand, stone, sticks) on pavement or in gutters	________
• Removing litter from pavement and roadside in **urban** areas	________
• Removing litter from pavement and roadside in **rural** areas	________
• Controlling vegetation (e.g., grass, weeds) in **urban** areas	________
• Controlling vegetation in **rural** areas	________
• Maintaining wildflowers in **rural** areas	________
• Providing satisfactory landscape appearance in **urban** areas	________
• Providing satisfactory rest area appearances (e.g., buildings, sidewalks, parking areas)	________
• Providing clean restroom and picnic facilities at rest areas	________
• Removing snow and ice from **urban** roads during winter events	________
• Removing snow and ice from **rural** roads during winter events	________

How important is it that features (pavement, shoulders, vegetation, signs) on Interstate highways (I-57, I-72, et al.) be kept in good condition? ________
How important is it that features on **major highways** (US 45, US 51) be kept in good condition? ________
How important is it that features on **minor highways** (IL 9, IL 136) be kept in good condition? ________

PART B

Please enter the dollar amounts you feel should be spent for maintenance of the *(enter agency name)* highway system in the following categories.* Assume that a **total** of $100 million is available and is to be divided among the following activities according to your spending priorities:

• Pavement maintenance	$______ million
• Signs and pavement markings	$______ million
• Litter and debris removal	$______ million
• Mowing and weed control	$______ million
• Wildflower and landscape activities	$______ million
• Rest area maintenance	$______ million
TOTAL*	$ 100 million

* Snow and ice removal is not shown due to its wide variability from year to year.

Figure 3. Example questionnaire for obtaining customer expectations input.

letter and in the survey form itself. For telephone surveys, explain these items at the beginning of the conversation.

- Express assurance of confidentiality and appreciation for survey participation—Assure the individuals being surveyed that the information provided will be kept confidential. Thank them for their participation in the survey.
- Provide clear instructions to survey respondents—For mail-in and telephone surveys, clearly describe or explain how to respond to the questions. For mail-in surveys, provide clear and concise instructions on how, when, and where to return the completed survey form. Also, include a self-addressed and stamped envelope for mail-in surveys.

DESIGNING THE LOS RATING SYSTEM

Once an agency has identified the work activities it plans to monitor and has obtained the perspectives of its customers (if so desired) regarding the importance of those activities, it can begin to formulate its LOS rating process. Key components in designing the LOS rating system include the following:

- Establishing LOS criteria that allow determinations to be made of the acceptability of maintenance conditions;
- Developing weighting factors that reflect the importance levels of the various work activities and that can be used to generate an overall rating of maintenance;
- Defining the pool of roadway segments that can be sampled for LOS in the field;
- Establishing a statistical-based method for periodically selecting roadway segments to evaluate; and
- Developing the set of techniques for collecting, analyzing, and reporting LOS data.

Each of these components is discussed in detail in the following sections.

LOS Criteria

Component #3 Objective: To establish maintenance condition standards for various maintenance features, which can be used for field determinations of acceptable or unacceptable LOSs.

Although LOS has been defined in various ways, from statements about the required frequency of an activity to written descriptions of results to be achieved, its use in this manual is most comparable to threshold conditions. Threshold conditions are the conditions that can be allowed to exist before a specific maintenance feature is considered not to meet the expectations of the agency, and when corrective action should be taken to improve the situation. Naturally, the desire is to have conditions better than or exceeding threshold conditions, because this is an indication that maintenance has done its job.

The first item of business in this process is to identify a committee of 25 to 30 people consisting of approximately 75 percent field personnel and 25 percent central-office personnel. The primary objective of this committee is to decide what maximum conditions or defects may exist for each activity before the activity is considered unacceptable. When these LOS criteria have been finalized, local managers should be informed of the criteria that will be used to measure the LOS within their area of responsibility. Local managers should also be informed that they will now have the opportunity to decide who, what, where, when, and how to use their resources in achieving the desired end results. In effect, upper management will have stepped back from being involved with daily decisions and will be concentrating on providing the training and resources requested by local managers to accomplish the work.

The LOS rating system, which is the heart of the prototype QA program, entails field inspections of maintenance features along randomly chosen road segments to determine whether the desired conditions of the features are being met. Each feature is condition-evaluated by trained personnel and given a pass (P) or fail (F) rating, with pass representing acceptable LOS and fail representing unacceptable LOS. A third rating, not applicable (NA), is used when a particular feature/characteristic does not exist along the inspection segment. For instance, if there is no guardrail within a given inspection segment, then an assessment of whether or not the guardrail meets the desired condition cannot be made, and the NA rating is given.

To the degree possible and practical, condition standards should be expressed in quantitative terms. That is, numerical thresholds should be set for both the severity and extent (amount or number) of a deficiency in a given maintenance feature. For instance, in the condition standard "no pothole shall exist that is greater than 0.5 ft^2 (0.05 m^2) in area and 1.5 in. (38.1 mm) deep," the severity level is given by the threshold dimensions of the pothole (0.5 ft^2 [0.05 m^2] in area and 1.5 in. [38.1 mm] deep) and the extent is given by the threshold number of potholes (none).

Quantitative condition standards give rise to the need for measurements which, in turn, lead to objective assessments of quality. This is an important point, for as stated by MacLean (1993) in his publication, *Documenting Quality for ISO 9000 and Other Industry Standards,* "if you can't measure it, you can't improve upon it. If you don't measure it, you won't even try to improve it."

In some cases, measuring extents and severities of maintenance deficiencies can be too costly and time-consuming, thereby justifying a more subjective assessment of conditions. The condition standards in these cases are more qualitative, often pertaining to whether a particular feature is functioning as intended. For instance, impact attenuators might be assessed for functionality based on apparent damage. The apparent damage may be minor or significant, which leaves room for interpretation by the rater.

Tables 6 through 12 list the various feature/characteristic condition standards used by Florida, Maryland, and Virginia for individual maintenance elements. For each of the key maintenance activities identified in the initial stages of development, it is the implementing agency's task to determine the appropriate threshold conditions and develop a suitable condition standard. By knowing what the original highway design standards are, what the general highway conditions are, and what is acceptable to the customer with respect to conditions, a preliminary set of standards can be developed (and can be modified later, as appropriate) through a LOS training program.

Threshold conditions can be set at different levels according to various maintenance characteristics, such as functional classification (controlled or uncontrolled access, arterial or collector), funding source classification (National Highway System [NHS], non-NHS, or toll facilities), environmental setting (rural or urban), and traffic volume. For example, to

(text continues on page 32)

TABLE 6 Condition standards for flexible roadway element (Florida DOT 1994; Maryland DOT 1994; and Virginia DOT 1996)

Distress Characteristic	Condition Standard		
	Florida (0.1-mi section)	Maryland (0.5-mi section)	Virginia (0.1-mi section)[a]
Potholes	No defect >0.5 ft² in area and 1.5 in. deep. Pervious base must not be exposed in any hole.	State highway system is free of potholes ≥ 4 in. wide and 2 in. deep, or any potholes that present a safety or tire hazard.	Asphalt-paved lanes • No ruts > 0.5 in. • No unsealed cracks > 0.25 in. over 95% of roadway surface. • No potholes > 3 in. x 4 in. x 1 in. deep. • Bleeding, raveling < 50 ft². • Patching - even, and < 0.5 in. higher or lower.
Cracking	99% of roadway is free of unsealed Class III cracking.	95% of the roadway surface is free of unsealed cracks ≥ 0.25 in.	
Bleeding/ Flushing	—	95% of the pavement surface is free of bleeding and flushing.	
Shoving	The shoved area should not exceed a cumulative 25 ft².	Rutting/Shoving Shoved areas ≥0.75 in. high does not exceed 25 ft².	
Rutting	Rutting areas are not >0.5 in. average depth, with no one measurement exceeding 0.75 in.	90% of pavement surface is free of ruts ≥0.5 in.	
Depressions/ Bumps	No measurement varies more than 0.5 in. within the initial 10-ft increments or plus 0.375 in. for each additional 10-ft increment.	—	
Patching	—	—	
Raveling/ Stripping	95% of roadway surface is free of stripping or delamination.	Surface/Edge Raveling 90% of pavement surface is free of evidence of dislodging of aggregate particles.	
Edge Raveling	90% of total roadway edge is free of raveling. No continuous section of edge raveling ≥ 4 in. wide exceeds 25 ft in length.	90% of total roadway edge is free of raveling. No accumulated section of edge raveling ≥4 in. wide exceeds 25 ft in length.	—

[a] For interstate roadways only. PCI and skid index criteria also established by Virginia DOT, but are not shown.
1 mi = 1.61 km
1 in. = 25.4 mm
1 ft = 0.305 m

TABLE 7 Condition standards for rigid roadway element (Florida DOT 1994; Maryland DOT 1994; and Virginia DOT 1996)

Distress Characteristic	Condition Standard		
	Florida (0.1-mi section)	Maryland (0.5-mi section)	Virginia (0.1-mi section)[a]
Potholes	No defect >0.5 ft^2 in area and 1.5 in deep. Pervious base must not be exposed in any hole.	State highway system is free of potholes ≥ 4 in wide and 2 in deep, or any potholes that present a safety or tire hazard.	Concrete-paved lanes • No unsealed cracks > 0.25 in over 95% of roadway surface. • < 0.5 in faulting at joints and otherwise. • < 10% of each joint is missing material or needs repair. • No potholes > 3 in x 4 in x 1 in deep. • Patching: < 0.5-in elevation differential.
Spalls		90% of roadway surface is free of spalls >3 in wide.	
Cracking	90% of roadway slabs have no unsealed cracks wider than 0.125 in.	95% of the roadway surface is free of unsealed cracks ≥ 0.25 in.	
Joints	85% of length of transverse and longitudinal joint material appears to function as intended.	90% of the section has joint material functioning as intended.	
Faulting	—	90% of all highway systems are free of differences in elevation between slabs of >0.5 in high or longitudinal joint separation of >0.5 in wide.	
Patching	—	—	
Depressions/ Bumps	No measurement varies more than 0.5 in within the initial 10-ft increments or plus 0.375 in for each additional 10-ft increments.	—	—
Roadway Void	90% of slabs exhibit no evidence of pumping.	—	—

[a] For interstate roadways only. PCI and skid index criteria also established by Virginia DOT, but are not shown.
1 mi = 1.61 km
1 in = 25.4 mm
1 ft = 0.305 m

TABLE 8 Condition standards for shoulders (paved) element (Florida DOT 1994; Maryland DOT 1994; and Virginia DOT 1996)

Distress Characteristic	Condition Standard		
	Florida (0.1-mi section)	Maryland (0.5-mi section)	Virginia (0.1-mi section)[a]
Shoulder/ Joint	75% of the joints appear to function as intended by restricting the intrusion of water and incompressibles.	90% of the lane–shoulder joint separation or edge joint cracks do not exceed 0.25 in in width and joint material is functioning as intended.	Paved shoulders • < 10% edge drop-off that is > 1.5 in. • < 10% separation that is > 0.5 in. • No false ditch (i.e., shoulder buildup causing water to drain back onto pavement). • < 10% pavement distress (i.e., cracking, raveling, bleeding, rutting). • No potholes that cause the shoulder to be unsafe.
Drainage	—	100% of the shoulder is free of any evidence of severe flooding, ponding, pumping, or erosion, and there is no occurrence of a level or negative slope.	
Potholes	No defect is greater than 0.5 ft^2 in area and 1.5 in deep. Pervious base is not exposed in any hole.	State highway system is free of potholes ≥ 4 in wide and ≥ 2 in deep, or any potholes that present a safety or tire hazard.	
Cracking	80% is free of unsealed Class III cracking (asphalt) or unsealed cracks > 0.125 in wide.	95% of the paved surface has no unsealed cracks ≥ 0.25 in.	
Raveling	—	—	
Bleeding	—	—	
Rutting	—	—	
Drop-off/ Buildup	Measurement of each depressed/raised area is made in both directions. No measurement varies more than 1 in within the initial 100-ft increments or plus 0.375 in for each additional 100-ft increments.	90% of the drop-off from the shoulder to the roadside or buildup does not exceed 1.5 in.	
Vegetation Growth	—	100% of the shoulder is free of vegetation growth.	—
Distortion	—	90% of the elevation difference between the traffic lane and the shoulder does not exceed 1 in.	—
Edge	75% is free of raveling. No continuous section of edge raveling ≥ 4 in wide exceeds 50 ft in length.	—	—

[a] For interstate roadways only.
1 mi = 1.61 km
1 in = 25.4 mm
1 ft = 0.305 m

TABLE 9 Condition standards for shoulders (unpaved) element (Florida DOT 1994; Maryland DOT 1994; and Virginia DOT 1996)

Distress Characteristic	Condition Standard		
	Florida (0.1-mi section)	Maryland (0.5-mi section)	Virginia (0.1-mi section) [a]
Drainage	—	95% of the shoulder is free of any evidence of severe flooding, ponding, pumping, or erosion, and there are no occurrence of a level or a negative slope.	Unpaved shoulders • < 10% drop-off that is > 1.5 in. • < 10% shoulder causes water to drain back onto the pavement.
Drop-off	No shoulder drop-off exceeds 3 in deep within 1 ft of the pavement edge for a continuous 25 ft.	90% of the edge drop-off or buildup between the shoulder and the roadside does not exceed 1.5 in.	
Buildup	—		—
Distortion	No deviations across shoulder width exist > 5 in below or 2 in above the design template. No washboard areas exist having a total differential greater than 5 in from the low spot to the high spot.	90% of the edge drop-off or buildup between the traffic lane and the shoulder does not exceed 1 in.	—

[a] For interstate roadways only.
1 mi = 1.61 km
1 in = 25.4 mm
1 ft = 0.305 m

TABLE 10 Condition standards for drainage element (Florida DOT 1994; Maryland DOT 1994; and Virginia DOT 1996)

Distress Characteristic	Condition Standard		
	Florida (0.1-mi section)	Maryland (0.5-mi section)	Virginia (0.1-mi section)[a]
Roadside Ditch	The ditch bottom is ≥ _____ ft below the nonpaved outside edge of pavement and/or functions as intended. rural limited access: 3 rural arterial: 3 urban limited access: 2.5 urban arterial: 2.5	75% or more of roadside and outfall ditches are unobstructed by soil or impermeable material and functioning as intended. 90% of all paved ditches are structurally functioning as intended.	Unpaved ditches • Grade drains. • Minimal erosion. • Outfalls functional. • No obstruction to flow of water that requires action. Paved ditches • < 1 in settlement. • No undermining or undercut requiring action. • < 25% spalled. • No obstruction to flow of water that requires action.
Outfall Ditch	The ditch bottom is at or within the lower 1/3 of the distance between natural ground and the design flowline.		
Median Ditch	The ditch bottom is ≥ 2 ft below the inside nonpaved edge of pavement and/or functions as intended.		
Culverts/ Pipes	90% (storm drain), 60% (side drain) and 60% (cross drain) of the cross-sectional areas are not obstructed.	75% or more of the culvert openings are unobstructed and functioning as intended.	Cross pipes and box culverts (< 36 ft^2) • < 10% deteriorated barrel. • > 90% diameter open, or meets environmental permitting. • Drains. • Joints intact. • No evidence of flooding. • Minimal erosion at ends. • End protection intact. • No dip in road over pipe, indicating structural problems.
Catch Basins/ Drop Inlets	90% (curb inlet) and 85% (other inlets) of the opening of each inlet is not obstructed.	75% or more of the cavity of each structure is free of debris and operating as intended.	• > 90% open. • No evidence of flooding. • < 0.5-in settlement if inlet is part of a sidewalk section, 1 in otherwise. • Grate unbroken.
Under/Cross Drains	—		• Opening "open" (not crushed). • Opening clear. • End protection intact.
Curb/Gutter	Material accumulation is ≤ 0.75 in deep for more than a continuous 1 ft in the traveled way or shall not exceed 2.25 in in depth for more than a continuous 1 ft in any gutter. (Classified as "roadway sweeping")	90% of curb and gutter areas are free of structural distresses and 100% free of obstructions that would severely impede the drainage flow. 90% of pavement/gutter joint will be flush or filled with joint material.	• < 1 in settlement or misalignment. • Minimal obstruction. • No unsealed cracks > 0.25 in. • No spalling > 0.25 in deep. • < 25% of surface spalled. • Minimal undermining.
Sidewalk/ Ramps	*Evaluated under "Vegetation and Aesthetics" element.*	—	• No settlement > 0.5 in. • No unsealed cracks > 0.25 in. • < 25% of surface spalled.
Storm water Management Ponds	—	—	• Clean. • Connections (pipes, weirs, etc.) intact and clean. • Fencing present and intact.

[a] For interstate roadways only. 1 mi = 1.61 km 1 in = 25.4 mm 1 ft = 0.305 m

TABLE 11 Condition standards for traffic control and safety element (Florida DOT 1994; Maryland DOT 1994; and Virginia DOT 1996)

Distress Characteristic	Condition Standard		
	Florida (0.1-mi section)	Maryland (0.5-mi section)	Virginia (0.1-mi section)[a]
Signs	Warning signs: 95% are functioning as intended. Regulatory signs: 95% are functioning as intended. Information signs: 85% are functioning as intended.	Regulatory signs: 95% are functioning as intended. Other signs: 90% are functioning as intended.	• Meet reflectivity standards (i.e., clear and reflective at 120 ft). • 100% clear of obstruction. • 95% surface free of damage. • Placement works for motorist at posted speed. • Height - 7 ft urban, 5 ft rural, 17 ft bridges, 19 ft cantilever.
Overhead Signs (i.e., sign structures and supports)	—	—	• Structurally sound. • Foundation sound. • Properly assembled and strong sign hangers.
Pavement Markers/ Symbols	Raised markers: 70% of the required markers are functional (reflective). No more than 120 ft of continuous centerline or lane line is without a reflective marker. Symbols: 70% of existing symbols function as intended.	100% of existing pavement markings function as intended.	Markers (raised and recessed) • 70% present, placement meets constructed standards. • Two consecutive markers are not missing. • 100% clear of debris. • Reflectivity meets standards (i.e., clear and reflective at 120 ft). Symbols/messages • Reflectivity meets standards (i.e., clear and reflective at 120 ft). • 100% clear of debris. • < 10% of surface damaged.
Pavement Striping	70% of each line functions as intended.	90% of lines are functioning as intended.	• Reflectivity meets standards (i.e., clear and reflective at 120 ft). • 100% clear of debris. • < 5% of surface damaged. • Placement meets industry standards.
Object and Delineator Markers	80% of markers are functioning as intended.	—	• 90% reflective. • Properly mounted.
Luminaires	Sign lighting: 75% of each installation is functioning as intended. Highway lighting: 90% of the installation is functioning as intended.	—	• 90% work, no two consecutive out. • Signs are illuminated. • 100% of access panels present and secured.
Barrier Wall	99% of an installation functions as intended.	100% of all concrete barriers do not have missing sections and are properly aligned, 95% of all barriers are painted and have no severe cracks.	*Evaluated under "Vegetation and Aesthetics (Roadside)" element.*
Guardrail	Each single run functions as intended.	95% of all guardrail is functioning as intended and free of excessive rust and dents (standard height to top of w-beam is 27±2 in).	• No dents that decrease structural integrity. • Posts in good condition. • No rust that adversely affects structure or component integrity. • 25- to 29-in height strong post. • 28- to 32-in height weak post. • Cables taut and properly secured (according to standard).
Impact Attenuators	Each device functions as intended.	100% is functioning as intended.	• No missing parts, properly aligned. • Undamaged.
Truck Ramps	—	—	• Bladed. • Material is in place.
Glare Foils	—	—	• Present. • < 10% damaged.

[a] For interstate roadways only. 1 mi = 1.61 km 1 in = 25.4 mm 1 ft = 0.305 m

TABLE 12 Condition standards for vegetation and aesthetics (roadside) element (Florida DOT 1994; Maryland DOT 1994; and Virginia DOT 1996)

Distress Characteristic	Condition Standard		
	Florida (0.1-mi section)	Maryland (0.5-mi section)	Virginia (0.1-mi section)[a]
Mowing/ Grass	Roadside: no more than 2% of vegetation exceeds _____ in high. rural limited access: 24 rural arterial: 18 urban limited access: 18 urban arterial: 12 Slope: no more than 2% of vegetation exceeds 24 in high.	Mowing is done in accordance with latest mowing standards.	• Grass height ≤ 12 in. • Sight distance is clear in intersections, passing zones, curves, and interchanges. • Neat around guardrail, headwalls, paved ditches. • Adequate cover.
Litter/ Debris	The volume of litter does not exceed 6 ft^3/acre excluding all roadway pavement.	Less than 100 pieces/mile for multi-lane facilities and less than 50 pieces/mile for two-lane facilities.	• Roadside appears neat and clean.
Bush & 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.	100% free of encroachment of tree limbs 15 ft vertically. 100% of right-of-way free of hazardous, leaning, or dead trees capable of falling onto roadway. 100% of signs are visible with no obstructions by tree limbs.	• No sight distance or sign obstructions. • Vertical clearance of at least 15 ft over roadways, 7 ft over sidewalks. • No illegal signs or structures. • No trees present a "leaning" hazard.
Graffiti	—	Area is 100% free of graffiti.	—
Fence	—	100% is functioning as intended.	• < 10% of the fencing needs repair or replacement. • No damage that allows access. • No leaning vegetation over the fence.
Sidewalks	There is no encroachment of grass and debris ≥ 6 in onto the curb or sidewalk for more than a continuous 4 ft, or no deviation of soil of more than 4 in above or 2 in below the top of curb or sidewalk for more than a continuous 4 ft.	—	*Evaluated under "Drainage" element.*
Slopes	—	No ruts or washouts greater than 6 in deep. Slope management is in accordance with latest guidelines.	• Minimal erosion, and no erosion showing a pattern that will endanger the stability of the slope.
Landscaping	Vegetation is maintained in a healthy, attractive condition.	90% of the landscaped area on all highway systems appear healthy, attractive, and free of weeds. Necessary pruning, trimming, or mulching has been done.	• Overall appearance is neatly maintained.
Turf	Turf in the mowing area is 75% free of undesired vegetation.	—	—
Concrete Barriers	—	—	• Minimal misalignment (1 in). • Minimal settlement (1 in).
Sound Barriers	—	—	• No settlement indicating structural distress. • Free of damaging vegetation. • < 10% of any applied sound retardant material is damaged. • No graffiti.

[a] For interstate roadways only. 1 mi = 1.61 km 1 in = 25.4 mm 1 ft = 0.305 m 1 acre = 4,047 m^2

ensure optimum safety and comfort for the majority of highway users, an agency might set the required percentage of functional reflective markers at 95 percent for interstate highways, 90 percent for primary highways, and 85 percent for secondary highways. This approach gives a real sense of the level of quality achieved for a given highway type. However, it is recommended that the number of features having alternative standards be limited, to avoid confusion of the threshold values by LOS rating personnel.

The following are other items that an implementing agency should consider when establishing LOS criteria:

- What are the environmental impacts of the proposed criteria?
- Are funding levels adequate to sustain the LOS being proposed?
- What are the consequences of not establishing/funding a quality level for an activity?
- Should "benchmarking" be done for each activity by comparing current performance to the "best in the class" techniques used by other agencies?

Because of the obvious legal considerations that may accompany them, care should be taken when establishing LOS criteria not to refer to them as the point where the situation is considered unsafe. For instance, if it has been determined that the height of vegetation for a safe stopping sight distance is 24 in. (610 mm), then the LOS for vegetation might best be described as "not more than 10 percent should exceed 18 in. (457 mm) in height."

By setting a strict LOS for safety conditions, the maintenance organization should have time to identify noncompliant areas and react before they become legal problems. Although establishing the point at which a condition becomes unsafe may be difficult, it should be easier to reach a conclusion before a lawsuit forces the agency to do so. A check with the Florida DOT legal office indicated no significant changes in the rate of tort liability claims were due to the LOS standards implemented in 1985. Discussions with other SHAs indicated that the establishment of LOS criteria in their agencies would probably not result in a substantial increase in lawsuits.

Weighting Factors

Component #4 Objective: To establish weighting factors that properly reflect the relative importance of individual maintenance features/characteristics and maintenance elements in the computation of an overall LOS segment rating.

Because some maintenance features/characteristics are of greater or lesser importance than others, a weighting system must be developed that will enable rational calculation of an overall LOS segment rating. Although one set of weighting factors for all features/characteristics could serve this purpose, a more useful system consists of two sets of weighting factors: one set that accounts for the importance of individual features/characteristics within a given maintenance element and another set that accounts for the importance of individual maintenance elements. This two-set system reveals deficiencies among features/characteristics and it shows which maintenance elements are deficient.

In the two-set weighting system, both feature/characteristic weightings ($W_{F/C}$) and element weightings (W_E) are developed. The feature/characteristic weighting is based on an ascending scale of importance of 1–10. For instance, in the traveled roadway element, the very important characteristic of potholes might be assigned a weighting of 8 or 9, whereas the less important characteristic of raveling might be given a weighting of 6 or 7.

As illustrated in Table 13, the weighting established for each feature/characteristic is multiplied by the corresponding rating value (0 for fail, 1 for pass) to generate a rating score for that feature/characteristic. Likewise, each feature/characteristic weighting is multiplied by the corresponding rating code to generate a total possible score for that feature/characteristic. The rating code indicates whether a particular feature is present and can be rated or whether a particular characteristic is or has the potential to be present and can be rated. For instance, on AC-surfaced highways, each of the seven characteristics shown in Table 13 has the potential to be present and can therefore be rated.

Once the rating score and total possible score have been calculated for each feature/characteristic, an element rating score

TABLE 13 Example of application of feature/characteristic weighting factors

Characteristic	Rating Code (0=No, 1=Yes)	Rating (0=Fail, 1=Pass)	Feature/Characteristic Weighting ($W_{F/C}$)	Total Possible Score (Rating Code × $W_{F/C}$)	Rating Score (Rating × $W_{F/C}$)
Cracking	1	1	9	9	9
Patching	1	0	8	8	0
Potholes	1	1	9	9	9
Depression/Bump	1	1	8	8	8
Bleeding/Flushing	0	NA	7	0	NA
Shoving/Pushing	0	NA	7	0	NA
Raveling	1	1	7	7	7
Total	5	4		41	33

and an element total possible score can be produced by summing the individual feature/characteristic scores within the element. The element LOS rating (LOS_E) is computed by dividing the element rating score by the element total possible score, and then multiplying by 100 percent. In the example in Table 13, LOS_E equals 80 percent ([33/41] × 100% = 80%).

Element weightings are best expressed as percentages, and the sum of the percentages assigned to each element must total 100. Naturally, the more important the element is, the higher the percentage it should be given. For instance, traveled roadway, which is important from the standpoints of safety and preservation, should receive a considerably higher weighting than vegetation and aesthetics, which is important primarily from an aesthetics standpoint. In this way, the higher weighted elements have more priority than lower weighted elements, but the numeric target is still the same for each.

The element weightings are used in conjunction with element LOS ratings to generate an LOS rating of a particular sample segment. The weightings and LOS ratings of each individual element are multiplied together, and the resulting products associated with all elements are summed to produce the segment LOS rating (LOS_S). This process is illustrated in Table 14.

As one might expect, different weightings may be necessary or appropriate for facilities that have different functional classifications or locations. For instance, landscaping would be more beneficial in urban settings than country settings because it would offset the more mundane environment of metropolitan areas and would be seen and appreciated by more users. As another example, vegetation height would be much less critical on rural facilities than on urban facilities because it is not as apparent on high-speed rural facilities and adjacent property owners are usually less concerned in rural areas.

Element weightings may also vary by functional class or location. Placing added importance on the traveled roadway element of major arterials, for example, would be justifiable, so as to delay the need for rehabilitation and the user delay costs associated with such work.

As illustrated by the above examples, the professionals within an agency can assign a weight for each characteristic and element to be rated. These weightings represent the relative value of each feature/characteristic to the value of others or of each element to the others. It is recommended that weighting development be done by 20 to 25 individuals who are knowledgeable of highway maintenance and safety techniques. The results of the exercise can then be averaged to determine a best-fit weighting for each feature/characteristic or element.

The Florida DOT has prepared alternative feature/characteristic weightings and element weightings for each of four facility types: rural limited access, urban limited access, rural arterial, and urban arterial. Summaries of these different weightings are given in Tables 15 and 16. As seen in Table 15, "Roadway Sweeping" on rural limited access facilities was assigned by the Florida DOT a weighting of 5, whereas on urban arterial facilities it was given a weighting of 7. Similarly, in Table 16, Florida assigned a weighting of 0.19 to the "Vegetation and Aesthetics" element on rural limited access facilities, whereas a weighting of 0.17 was used for the same element on urban limited access facilities.

Roadway Segment Population

Component #5 Objective: To determine the inventory of roadways to be monitored and establish the roadway segment population.

At this stage in the development process, the establishment of LOS rating criteria and weighting factors (based on clear, unbiased input from the traveling public) should be complete. The focus must now shift to establishing the pool, or population, of fixed-length roadway segments from which a small portion can be randomly selected to serve as samples for LOS inspections.

The starting point in this task is the roadway features inventory. This fundamental component should be reviewed carefully to ensure accurate information about the location (e.g., mileposts or reference points, county, district) and characteristics (e.g., road class, traffic, pavement type, length, number of lanes) of each highway section and bridge in the agency's jurisdiction. By taking time initially to make sure the data are accurate and complete, many problems pertaining to LOS field inspections and data analysis and reporting can be avoided.

The main interest in the features inventory is the total amount of centerline miles (divided and undivided) maintained by the agency and included in the LOS rating system.

TABLE 14 Example of application of element weighting factors

Element	Element Weighting (W_E)	Element LOS Rating (LOS_E)	Rating Score ($LOS_E \times W_E$)
Traveled Roadway	0.27	80	21.6
Paved Shoulder	0.16	68	10.9
Roadside	0.10	71	7.1
Traffic Services	0.16	78	12.5
Drainage	0.22	64	14.1
Vegetation & Aesthetics	0.09	70	6.3
Total	1.00		72.5

TABLE 15 Florida's LOS factors for characteristics by facility types (Florida DOT 1993)

	Facility Type			
	Type 1 Rural Limited Access	Type 2 Rural Arterial	Type 3 Urban Limited Access	Type 4 Urban Arterial
ROADWAY				
Pothole	9	9	9	8
Joint	8	7	8	7
Pavement Void	8	7	8	8
Edge Raveling	5	7	5	5
Rutting	8	7	7	6
Cracking	7	6	7	6
Depression	6	6	6	6
Stripping	3	3	3	3
Shoving	5	6	5	6
Shoulder-Paved	5	5	5	5
ROADSIDE				
Shoulder-Soil	9	9	9	9
Front Slope	6	7	6	7
Turnout	0	7	0	7
Sidewalk	0	7	0	7
Bike Path	0	7	0	7
Fence	7	0	6	0
TRAFFIC SERVICES				
Pavement Marker	9	9	9	9
Striping	8	8	8	8
Symbol	7	7	7	8
Guardrail	9	9	9	9
Attenuator	9	9	9	9
Barrier Wall	9	8	8	8
Warning Sign	9	9	9	9
Regulatory Sign	8	8	8	8
Info Sign	8	8	8	8
Object/Guide	7	7	7	7
Sign Lighting	8	8	8	8
Highway Lights	8	8	8	8
DRAINAGE				
Storm Drain	6	7	8	8
Side Drain	7	7	7	7
Cross Drain	7	7	7	7
Roadside Ditch	4	4	4	4
Median Ditch	4	4	4	4
Outfall Ditch	6	6	6	7
Curb Inlet	9	9	9	9
Other Inlet	6	7	7	7
Misc Drainage	5	5	5	6
Roadway Sweeping	5	4	7	7
VEGETATION & AESTHETICS				
Roadside Mow	7	7	7	7
Slope Mowing	6	6	6	6
Landscaping	4	4	5	5
Tree Trimming	6	6	7	6
Curb-S/W Edge	6	6	6	7
Litter Removal	3	3	4	4
Turf Condition	6	6	7	7

TABLE 16 Florida's LOS factors by facility by element (Florida DOT 1993)

	Type 1 Rural Limited Access	Type 2 Rural Arterial	Type 3 Urban Limited Access	Type 4 Urban Arterial
Roadways	25	24	25	24
Roadsides	14	18	13	17
Traffic Services	27	27	30	29
Drainage	15	14	15	13
Vegetation/Aesthetics	19	17	17	17
Total	100	100	100	100

This total centerline mileage is divided into many small segments of equal length, the collection of which serves as the roadway segment population. For example, if the total centerline mileage in a highway network is 2,762 mi (4,447 km) and 0.5-mi (0.81-km) segments are desired, then the roadway segment population would be 5,524 (2762 mi/0.5 mi = 5,524 [4447 km/0.81 km = 5,524]).

The length used to subdivide the highway network is that length deemed appropriate by the agency for conducting LOS inspections. The primary considerations in selecting this length are as follows:

- Cost,
- Number of segments required to be statistically correct, and
- Minimum length needed to produce a representative sampling of many activities.

Florida and Virginia use 0.1-mi (0.16-km) segments in their rating systems, whereas Maryland uses 0.5-mi (0.81-km) segments and British Columbia uses 1.24-mi (2-km) segments.

Sample Segment Selection

Component #6 Objective: To develop a method for randomly selecting the required number of sample segments to be inspected for LOS.

Simple random sampling of the total roadway segment population assures each individual segment in the population the same chance of being chosen for field inspection. By numbering the entire population of roadway segments, the basis for random sampling is set. A random number generator function, like the one available in Microsoft® Excel or other computerized spreadsheets, can be used to generate random numbers which, in turn, are linked to roadway segments. Simply specify the number of random numbers required (a formula for determining the required number of samples based on a desired confidence level and precision rate is provided below), along with the lower and upper number boundaries (1 and 5,524, respectively, in the previous example), and the function will return the desired number of random numbers.

The sample size required to achieve the desired precision and confidence level is computed using the following formula:

$$n = \frac{z^2 \times s^2}{d^2} \qquad (2)$$

where:

n = required sample size.
s = standard deviation of the ratings from the pilot study (see Chapter 4 section "Pilot Field Study").
d = precision (e.g., for precision of ±5 on a 1–100 scale, use 5.0).
z = z-statistic (for 95% confidence, $z = 1.96$).

As can be seen from this formula, the necessary sample size increases as the desired precision increases. That is, if one wants more precise results (smaller value of d), then a larger sample size is required.

Two considerations in the random sample selection process include what to do about selected segments that are located along bridges or other structures and how to avoid selection of the same segments from inspection round to inspection round. In the first matter, it is recommended that an additional 10 segments be selected to serve as alternate sample segments. If 25 segments must be inspected and 3 of the segments within the first 25 selected fall on bridges, then the 26th, 27th, and 28th selections can be used as replacements for the bridge segments (assuming, of course, that the alternates are not located on bridges).

In the second matter, it is recommended that segments inspected in previous rounds be withdrawn from the population to be sampled. That is, any time a segment is selected and inspected, it should be removed as a candidate from future lists. This is referred to as random sampling without replacement. Although a concern with this procedure might be that the population size will be seriously depleted over time, the ratio of sample size to population size will usually be small enough (less than 10 percent) that depletion only becomes a consideration after several years. However, if this becomes a critical issue, the original population can be restored on a more frequent and desirable basis with little effect on the randomness.

Stratification

To obtain a greater degree of representation, implementing agencies can divide the total roadway segment population into homogeneous subsets or strata. These strata may be according to geography (e.g., district, residency, maintenance unit) or facility type (e.g., functional class, highway system), whatever is deemed important by the implementing agency.

Although numerous strata can be created, it is recommended that the number be limited to about 10. Strata in excess of 10 will generally give little added benefit in comparison with the added cost of increased sample sizes. Subdividing by facility type should be satisfactory for both state and local agencies, as the number of facility types within a given agency will usually be below 10. As for geographic strata, larger states are probably best off subdividing by district, whereas smaller States might be able to subdivide by residency or even maintenance unit. Local agencies will usually have little problem subdividing by maintenance unit.

The Virginia DOT stratifies by highway system (e.g., interstate, primary, secondary highways), and the Maryland DOT stratifies by county (23 total). Interestingly, the Florida DOT stratifies by maintenance unit (30 total) and functional class (urban limited access, rural limited access, urban arterial, rural arterial), which results in 120 total possible strata ($30 \times 4 = 120$). Because not all maintenance units have roadways belonging to each of the four facility types, the net number of strata in Florida is 93.

Once the strata have been defined, Equation 2 must be used to determine the required sample size for each stratum. As a minimum, 25 segments per stratum should be sampled, regardless of the number of segments calculated using the sample size equation. Moreover, in performing the calculation for a given stratum, it is important to use the standard deviation computed for that stratum during the LOS pilot study, since each stratum will have a unique sampling error.

LOS Data Collection, Analysis, and Reporting Techniques

Component #7 Objective: To formulate the procedures for recording and processing field ratings, analyzing those ratings, and preparing reports that present the results of the analyses.

The next step in designing the LOS rating system is to develop the preliminary strategies for recording the ratings in the field, processing and analyzing the ratings data, and reporting the results in such a manner that effectively serves the various levels of maintenance. The development of a customized rating form for rating teams to record feature/characteristic ratings in the field is the first consideration here. Such a form should be designed to include general information about the sample segment that is to be evaluated (date, district, county, cost center, highway number, facility type, beginning and ending mileposts) and a listing of the features/characteristics that are to be rated, with spaces given for reporting the rating. If room permits, it is a good idea to include the threshold values of the extents and severities associated with each feature/characteristic. An excellent example of a rating form is illustrated in Figure 4. Developed and used by the Maryland DOT, this form includes separate columns for yes-no (i.e., pass-fail) ratings, not just for one sample segment, but for three. It should be noted that the amount of paper required in the field by using the sample form could be cut in half by having inspectors use one column per sample segment instead of two, as shown. The inspectors would simply specify a "Y" or "N" for each feature/characteristic.

It is highly recommended that a team or multiple teams be formed to conduct the LOS evaluations, with each team consisting of at least two individuals. Because consistency from year to year is vital to the program's success, LOS raters should be encouraged to continue in their rating capacity for as many years as possible. To the extent possible, each two-person team should have at least one rater who is a carryover from the previous year.

The individuals within the rating team should perform independent evaluations of a given sample segment and, at the conclusion of their inspections, should reach a consensus as to which features/characteristics were rateable along the segment and which of the rateable ones met the condition standards. The results of the consensus for the sample segment should be recorded on-site using a hard copy rating form or, if available, a rating form contained on a portable computer. In this way, the data are ready for manual processing and analyses (using a calculator) or for subsequent entry into the office computer, or are already computerized and ready for processing and analysis.

Once the collected field data have been entered into the computer, they should be reviewed for accuracy and completeness. Spot checks of the data will provide a good indication of whether the data are satisfactory for analysis or if a complete review and correction effort is required.

Data processing is the series of steps taken to transform the individual feature/characteristic ratings into LOS_E and LOS_S ratings for each sample segment. It is, essentially, the application of the previously developed feature/characteristic and element weightings to the corresponding feature/characteristic and element ratings. Although data processing can be done manually using a calculator, it is highly recommended that a computerized spreadsheet or computer program be used, because these tools will allow for quick calculations of LOS_E and LOS_S for a particular sample segment. Setting up a computerized spreadsheet or writing a computer program that will automatically calculate these types of ratings will require some additional up-front time, but it will save considerable time in future processing.

The extent to which data analyses are performed and the analysis results are reported should be carefully considered. All levels of maintenance will be interested in knowing the quality levels they are producing, so that changes can be made to effect positive results. However, the implementing agency will need to determine the types of ratings that will be of most value to both network-level managers and field-level personnel. The following two sections briefly discuss the types of

PEER REVIEW FOR QUALITY HIGHWAY MAINTENANCE

	SITE NUMBER:								REVIEWER:
DATE	RTE TYPE (I-P-S)								
DISTRICT	ROUTE/RTE. NO.								Placing a checkmark in the shaded area indicates that the element observed does not meet "Desired Maintenance Condition" criteria.
COUNTY	DIRECTION/LANES								
CATEGORY	B/E MILEPOINT								
	Maintenance Element	LIMIT	MEETS DESIRED CONDITIONS						
TRAVELLED ROADWAY			YES	NO	YES	NO	YES	NO	COMMENTS
Flexible	Cracking=>1/4"	<5%							
	Surface/Edge Raveling	<10%							
	Rutting/Shoving=>½"	<10%							
	Bleeding/Flushing	<5%							
	Potholes=>4"W	NONE							
Rigid	Cracking=>1/4"	<5%							
	Spalling=>3"W	<10%							
	Joint Material Defects	<10%							
	Faulting=>½"	<5%							
	Potholes=>4"W	NONE							
SHOULDERS									
Paved	Shldr Joint Sep=>1/4"	<10%							
	NonPositive Drainage	NONE							
	Vegetation Growth	NONE							
	Potholes=>4"W	NONE							
	Cracking=>1/4"	<5%							
	Distortion	<10%							
	Dropoff/Buildup=>1.5"	<10%							
Unpaved	NonPositive Drainage	<5%							
	Distortion=>1"	<10%							
	Dropoff/Buildup=>1.5"	<10%							
DRAINAGE									
	Ditches	<10%							
	Culverts	<25%							
	Catch Basin/Inlets	<25%							
	Curb/Gutter	<10%							
TRAFFIC CONTROL AND SAFETY									
Signs	Regulatory	<5%							
	Other	<10%							
	Pvmnt Mrkings/RPM's	0%							
	Linestriping	<10%							
Barriers	Concrete	<5%							
	W-Beam	<5%							
	Impact Attenuators	0%							
ROADSIDE									
	Mowing	0%							
	Litter	50/25							
	Brush & Tree Control	0%							
	Graffiti	0%							
	Fence	0%							
	Slopes	0%							
Form FR-1	Landscaping	<10%							
REV:3/11/94	Debris=>1"	<5%							

Figure 4. Maryland DOT peer review program rating form (Maryland DOT 1994).

ratings that would be beneficial and of interest to maintenance personnel at these two maintenance levels. Details on how the various ratings can be calculated are provided in Chapter 4, "LOS Analysis and Reporting."

Network Level

To aid their management functions, network-level maintenance bureaus (i.e., central office, district/regional office) must be informed of the LOSs being achieved throughout the agency and within each district/region. They must be furnished with the mean LOS and corresponding confidence interval for various network scenarios. At the central office, the most important rating statistics would probably be those associated with the following scenarios:

- All facility types, agencywide;
- Individual facility types, agencywide;
- All facility types, districtwide/regionwide;
- Individual facility types, districtwide/regionwide;
- Individual elements, all facility types, agencywide; and
- Individual elements, individual facility types, agencywide.

At the district/regional office, the rating statistics of most value might include those pertaining to the following scenarios:

- All facility types, agencywide;
- Individual facility types, agencywide;
- All facility types, districtwide/regionwide;
- Individual facility types, districtwide/regionwide;
- Individual elements, all facility types, districtwide/regionwide;
- Individual elements, individual facility types, districtwide/regionwide;
- Individual maintenance units, all facility types, all elements, districtwide/regionwide;
- Individual maintenance units, all facility types, individual elements, districtwide/regionwide; and
- Individual maintenance units, individual facility types, all elements, districtwide/regionwide.

Simple statistical analyses, such as calculating the mean (or average), standard deviation, and confidence interval using the appropriate series of LOS_E or LOS_S data, are sufficient for data analysis at the network level. These descriptive statistics provide a real sense of the true quality levels being achieved. Although such statistical analyses can be performed using a scientific calculator, computerized spreadsheets or databases are often equipped with the above statistical functions and can make the calculations very fast. If the individuals who will be performing the statistical calculations are not experienced with computers, but a computer and spreadsheet software are available, it is highly recommended that those individuals take the time initially to learn the software and its statistical functions. Again, this will require some additional up-front time, but it will save considerable time in future analyses, because the same expedient analysis process will be used.

Field Level

Some network-level quality statistics, such as the agency's overall rating, the district's/region's overall rating, or each maintenance unit's overall rating, will be of interest to field-level maintenance divisions (i.e., maintenance units and maintenance crews) and should be included in the reports distributed to them. However, more vital to the interest of field-level maintenance personnel will be information on the quality levels of individual elements, individual features/characteristics, and specific highways within their domain. The results of analyses directed toward these areas will point to specific deficiencies or overwork at both the project and activity levels.

At the project level, for instance, the LOS_S ratings along various stretches of highway within the maintenance unit's jurisdiction will be very telling of where future concentrations of work should be. For example, if the LOS for Rt. 9, MP 12–28 is found to be very deficient and the other stretches of highway within the maintenance area are generally found to be adequate, then the specific features/characteristics causing the low LOS for that highway section can be identified and steps can be taken to improve the conditions there.

At the activity level, the overall ratings for the various elements and features/characteristics within a given maintenance unit will indicate which crews are providing substandard quality and which ones are overachieving. Naturally, it is then the responsibility of the maintenance unit's supervisor to determine whether the crews are accountable for the deviations or if other factors, such as resource allocation and work directing, are involved.

The simple statistical methods used to compute network-level ratings can also be used to generate ratings for various projects and elements in a maintenance area. Again, the appropriate series of LOS_E or LOS_S data must be used.

The calculation of individual feature/characteristic ratings within a maintenance unit requires no statistical analysis; rather, it involves computing the percentage of sample segments in which a given feature/characteristic met the desired maintenance condition. Further details and an illustration of this type of analysis are provided in Chapter 4, "LOS Analysis and Reporting."

LOS RATING SYSTEM DOCUMENTATION

Component #8 Objective: To prepare detailed and comprehensive manuals describing the proposed methods of assessing maintenance quality in the field and generating management-level assessments of LOS.

It is highly recommended that the complete LOS rating process developed by agency staff be put into document form so that the ultimate approval authority can review it and make appropriate comments or suggestions. Though one manual may be sufficient for this purpose, eventually separate manuals for conducting the field surveys and for analyzing and reporting management-level ratings may be needed or prove useful. An executive's manual that summarizes the complete LOS process may also be desirable.

A field survey manual should contain a complete listing of the maintenance condition standards and any supplemental rating procedure descriptions. It should also include the customized rating form developed for LOS rating teams and a complete list of the equipment, supplies, and safety items needed by the rating teams.

An analysis and reporting manual should describe in detail how field data are to be transferred to a computer and checked for accuracy, how they are to be processed to create rolled-up management-level ratings, and how they are to be analyzed for statistical validity. It should also present the plan for reporting the rolled-up ratings to the full spectrum of maintenance managers and supervisors.

MAINTENANCE PRIORITIES

Component #9 Objective: To establish the priorities of routine maintenance activities using a systematic weighting process to account for the various highway maintenance considerations (e.g., safety, preservation of investment).

The adoption of a priority system for maintenance is of vital importance when determining reduction of work activities to be made in case of funding shortfalls or for determining which work should be performed first in emergency situations. These decisions, which can best be guided by a careful analysis of what is most important, should be done during routine working conditions without the pressures associated with deadlines. In this way, management can carefully review the proposed scenario and give approval before implementation begins.

Historically, maintenance has taken a "centerline-out" approach toward priority, with the most important activities centering around the pavement and the least important activities being those done near the edge of the right of way. In theory, each maintenance activity can be weighted according to the four main objectives or considerations of maintenance, listed below in general order of importance:

1. Safety—Highway features and characteristics that provide users with a clear sense of freedom from danger, injury, or damage;
2. Preservation of investment—Actions taken to help a highway element obtain its full potential service life;
3. User comfort and convenience—Highway features and characteristics, such as ride quality, proper signing, lack of obstructions, and rest-stop facilities, that provide a state of ease and quiet enjoyment for highway users; and
4. Aesthetics—The display of natural or fabricated beauty items, such as landscaping or decorative structures, located along a highway corridor.

The first step is to thoroughly analyze each key maintenance activity to determine under which consideration it falls. More than likely, two or more considerations will be applicable to an activity, depending on the variety of situations that could occur. For example, the activity "mowing" is generally done for aesthetics, but not performing this activity for an extended period could restrict sight distance, a safety consideration. Similarly, although pothole patching is typically done to preserve the pavement investment and restore user comfort, the presence of excessively large potholes makes safety the prime consideration.

By creating a six-column table that lists the key maintenance activities (preferably grouped by element) along the first column and gives headings of "safety," "preservation of investment," "comfort and convenience," "aesthetics," and "total" for each of the next five columns, a weighting chart can be developed to reflect the maintenance priorities of each activity. An example chart is given in Table 17. In this chart, the percentage of the total workload that each consideration

TABLE 17 Illustration of maintenance priorities table

Routine Maintenance Activity	Consideration				Total
	Safety	Preservation of Investment	Comfort and Convenience	Aesthetics	
Pothole Patching	20	55	25	0	100
Seal Coating	23	65	10	2	100
Joint and Crack Filling	0	100	0	0	100
Mowing	15	55	10	20	100
Snow Plowing	50	0	50	0	100
Litter Pickup	10	0	20	70	100
Sign Repair and Replacement	25	35	35	5	100
Ditch Cleaning and Shaping	10	50	35	5	100
Guardrail Repair	95	5	0	0	100

represents for a given activity is estimated. For instance, for guardrail repair, 95 percent of the total workload is for safety purposes, while the remaining 5 percent of the workload is for preservation of the investment. Note that the sum of the percentages for all four priority considerations should always total 100.

At least one agency (Florida) has chosen to build its annual maintenance budget showing the estimated workload for each activity. The proposed budget converts the applicable percentage for each priority column into the theoretical units of work to be done, and subsequently, the estimated cost for each priority within that activity.

Funding shortages as a result of emergencies or inadequate appropriations will occasionally occur. A well-thought-out priorities table tells how the agency will reduce its work accomplishments to ensure funding is available for the highest priorities. Using Table 17 as an example, reductions in up to 20 percent of the mowing workload and up to 70 percent of litter pickup would be required before reducing any of the next priority level (comfort and convenience). Reductions in the workload should be accomplished in locations that do not affect the work assigned to the next higher level of priority. This type of managerial action should continue until a balance between funding and the remaining workload is achieved.

AGENCY MANAGEMENT APPROVAL

Component #10 Objective: To obtain agency management approval of the rating system developed and a notice to proceed with its implementation.

Because many of the ideas being implemented may be a significant departure from existing agency management techniques, it is important that these changes not be confused with current fads (e.g., downsizing, right-sizing, re-engineering, teambuilding) being embraced by many corporations. Although this prototype QA program does recognize the advantages of decentralization, it is designed to be functional over a range of management philosophies. The prototype program is primarily designed to provide better information for decision-making by suggesting an agency ask its customers what they expect, decide what measures will best describe the customers' expectations, and produce periodic reports measuring the success in meeting these objectives.

As a spin-off benefit from this process, a performance-based budget can also be prepared to estimate the resources necessary to produce the target LOS. At no time should this process be suggested as "doing more with less." Although that may be a long-term result, the task of determining what the customer wants and finding a way to measure what is provided may result in doing more of some activities and less of others. The bottom line will be a systematic method of measuring results and being able to know when and where the agency is providing these results.

At this point, the agency should be ready to present for management approval the LOS system it has developed. Most organizations have a CEO, who is recognized as the individual that can make or break any program. The CEO's endorsement of and commitment to the QA program being proposed by the agency is essential *(Deming's Point No. 2—Adopt the new philosophy).* It is recommended that consideration be given for CEO endorsement in the form of an agency administrative procedure. In this way, the program can continue without concern that it will be dropped because of confusion or a lack of understanding, since most agency procedures also require periodic audits to ensure compliance.

It should also be recognized at this point that it will not be uncommon to have management suggest several revisions or to request the development of additional information to support the recommendations being made. One of the most likely changes may be a request to reduce or increase the LOS criteria for certain activities, thus causing a change in the annual cost of providing the service. Making these changes to meet management wishes can be a trial and error process until agreement is finally reached. Some of the suggestions contained in Chapter 4, "Process Updating," may be of use when performing this procedure.

It is important that once management adopts these recommendations, it understands the program's content and, perhaps most important, fully supports the program. This can be especially valuable during difficult times, when the tendency may be to follow "seat of the pants" actions instead of a carefully thought out long-term direction. Although no system will be able to resolve all situations, care should be taken to develop the program so that it can resolve most field-related issues without further research. Failure to "bulletproof" the program before it reaches the management approval stage may result in a lack of confidence by management.

Credibility or the lack of it will likely be one of the biggest factors in developing the new program. A well-thought-out approach, one that shows the customers' expectations, including a reliable, repeatable, and realistic method of displaying the level being achieved, can be the best feature of the new system. Similarly, a lack of these same qualities can doom all efforts to being ineffective at best, and may result in hardening management against changes of any type in the future.

CHAPTER 4

QA PROGRAM IMPLEMENTATION

Once the LOS rating system has been designed and sufficiently modified so as to receive the initial blessings of management, it can be tested in the field and worked into existence. The first step in this process is to instruct—through a field-training session—the designated individuals on how to perform LOS inspections. Such a training session will also provide an opportunity to fine-tune the established rating procedures, resulting in greater consistency in official ratings. The second step is to conduct a pilot field study, in which the rating teams are tasked with performing their first set of real inspections. This enables the agency to determine the inherent variability in ratings and, in turn, establish a proper sampling rate for formal inspections.

Beyond the field testing period, the implementing agency will work itself into the continuous quality loop, depicted in the bottom portion of Figure 1. In that loop, an agency routinely assesses the quality of maintenance, makes sure that the actual quality being achieved is continually moving in the direction of the target quality, and redirects work, reallocates resources, and implements priorities to achieve higher quality maintenance.

The maintenance quality ratings (LOS) generated by the QA program are end-result assessments of the quality at the activity, project, and network levels. These assessments give managers at all levels of maintenance, from supervisor to CEO, the ability to make more informed decisions concerning allocating resources, identifying effective and economical maintenance procedures and equipment, and prioritizing work activities. The sections presented in this chapter describe in detail the initial field testing and the components of the quality improvement cycle.

LOS TRAINING

Component #11 Objective: To train LOS rating personnel in the proper methods of viewing and rating the various maintenance features/characteristics.

Paramount to implementing the agency-approved LOS rating system is the formal training of selected personnel in the field rating process. The focus of this training must be on making sure that raters look at the same features in each case and arrive at the same basic conclusions concerning their evaluations. Having a good description or specification of when a feature/characteristic meets or exceeds desired conditions is a key factor in this phase. Success in establishing this criterion will enable an agency to begin establishing the credibility of its QA system, whereas a lack of proper descriptions may have the opposite effect and cause further efforts to be ineffective.

The training course should be scheduled at a time and location convenient to all participants. It is only appropriate that the key personnel responsible for developing the rating system serve as the instructors of the course. Their duties will include the following:

- Coordinating the training activities, including providing sufficient copies of rating manuals and forms and locating the segments to be rated;
- Discussing the required supplies and safety aspects for conducting the LOS inspections (see "Formal LOS Field Inspections");
- Training the raters in the basic principles of LOS inspections, including establishing the sample segment, determining which features/characteristics are rateable and which meet standards, and recording the rating results;
- Conducting independent inspections of the selected sample segments; and
- Identifying any legitimate suggestions for improving the rating process.

In general, between 5 and 10 sample segments, representative of different strata, should be sufficient for conducting the LOS training phase. Ideally, there should be at least the same number of segments as there are rating teams. The training process is expedited this way, as each team can rate a different segment at the same time.

During an inspection, each member of a team must conduct independent evaluations of maintenance conditions. Upon completion, the team members will discuss their observations and reach consensus on the features/characteristics present within the segment and those that passed the LOS criteria. Rotating from segment to segment, each team will eventually complete an evaluation of each segment. At that point, copies of each team's rating forms can be made by the instructors, and the results can be placed on a blackboard or flip chart. The instructors should be certain not to identity the teams so the class will concentrate on results and not on which teams may have been in error.

Each feature/characteristic should be discussed in detail to ensure the group understands what rating should have been given to each one and why it was given, as well as what was not rated and why. It is not uncommon to have some teams insist that characteristics did not exist on certain sites and other teams to insist that they did. Because the original rating forms are retained by each team, the raters will learn how their ratings compare to the rest of the group.

Team training should be repeated using the same teams and new sites to see if the results improve and if consistency is achieved. It is highly recommended that no ratings be produced for official use until consistency has been achieved in the test site results. Consistently erroneous or poor quality data can usually be attributed to improper or incomplete training of the individuals involved. However, if consistency cannot be accomplished in two or three groups of sites, the agency may wish to consider modifying the LOS criteria of characteristics where consistent results are not being achieved. This may require a review of the descriptors of what "meets" or "does not meet" the expected or desired end results, possibly changing the wording in the descriptions (this should not be construed as meaning that the LOS criteria should be increased or decreased), or providing photographs to guide the team members in achieving consistent evaluations.

PILOT FIELD STUDY/BASELINING LOS

Component #12 Objective: To evaluate the variability of rating teams' first unsupervised set of LOS inspections and establish a baseline of existing maintenance conditions.

Following successful completion of the training program, rating teams should be instructed to perform a trial run of LOS inspections on sample segments in their assigned geographic areas. The segments to be rated in the pilot study should be selected in accordance with the procedures presented in Chapter 3, "Sample Segment Selection." It is recommended that a sample size of 25 segments per stratum be selected for the pilot study, because this number ensures that the estimated variance will be reasonably accurate for computing the required number of sample segments to be rated during the formal inspection process

Using the concepts and procedures acquired in the training program and documented in the final rating manual, rating teams can begin the pilot LOS inspections. Each team must evaluate the 25 randomly selected segments per stratum and then submit the results to the key program administrators, so that the variability (i.e., sample variance) of each team's ratings for a given stratum can be determined (the section in this chapter, "LOS Analysis and Reporting" describes and illustrates how the sample variance [s^2] is calculated). The resulting sample variances are then reported back to the rating teams so that they may compute the number of samples required in formal inspection rounds using Equation 2. If serious problems in the rating process are identified during the pilot field study, then the agency should take immediate action to correct or minimize the effects of the problems.

Generally speaking, the results of the pilot field study can be used as part of the first round of inspections. If the number of samples required for the formal LOS program turns out to be smaller than the number of samples rated as part of the pilot study, then the pilot study may be used as the first formal round of LOS inspections. By the same token, if the number of samples required for the formal LOS program turns out to be larger than the number of samples rated as part of the pilot study, then the pilot samples may be supplemented with additional samples to satisfy the required sample size for formal inspections.

The results of the pilot inspection round serve as a baseline of existing maintenance conditions. They are, in essence, a snapshot of maintenance conditions before the establishment of quality management principles and procedures. An implementing agency will use the baseline conditions to measure the amount of improvement made over time in the quality of maintenance.

FORMAL LOS FIELD INSPECTIONS

Component #13 Objective: To have the LOS rating team(s) perform routine LOS inspections of the roadways designated for maintenance quality monitoring.

Formal LOS inspections must be carried out according to the periods and frequencies established by the agency at the outset of the QA program. Individuals participating in the LOS inspection process should prepare their work schedules around planned routine inspections.

Because the locations of sample segments will change during each inspection round, the time required by each rating team to inspect the required number of segments may vary. Before setting out to do the inspections, rating teams are encouraged to map the segments to be inspected and prepare an inspection schedule that minimizes the amount of time spent in the field. Consideration should also be given at this time to any segments that might present hazards or situations that require special precautions. The following sections provide details on the equipment and supplies needed to conduct the inspections, as well as essential safety items and procedures that should be considered by field inspection personnel.

Equipment and Supplies

The following is a list of equipment and supplies necessary or recommended for the efficient and safe collection of survey data (Florida DOT 1994).

- DMI installed on survey vehicle,
- Clipboard, pencils, and erasers,
- Rating manual,

- Rating forms or handheld devices,
- Maps of the segments to be sampled,
- Measuring wheel or measuring tape,
- Pocket calculator,
- Reflective marking tape,
- Small measuring ruler (6 in. [152 mm]),
- Metal or wood straightedge (5 to 8 ft [1.5 to 2.4 m]),
- Leveling device (carpenter's level or string level),
- Stringline (100 ft [30.5 m]),
- Hammer and nails (12D or larger),
- Heavy-duty pry bar (for removal of manhole covers and inlet grates), and
- Containers/boxes (for measuring litter).

Agencies that are fairly well progressed technologically are encouraged to consider the use of laptop computers or pen-based handheld data collection devices in the field inspection process. The laptops can be used to store the rating data collected each day in the field. Either immediately after an inspection or at the end of the day, inspectors can enter the data into a database program contained on the laptop computer system. As mentioned in Chapter 3, with the appropriate software programs, ratings for each site can be quickly generated once the field data has been entered into the computer.

Handheld data collection devices are being used more and more often in the highway and other "on-the-go" industries. The Apple® Newton MessagePad equipped with Leverage for Pavements software (Figure 5), for instance, is currently used by a few state and local governmental agencies for pavement distress survey purposes and has proven to be a very reliable and efficient method of data collection (ERES 1996). It includes a Microsoft Windows-based data exchange system for data transfer between the handheld device and a PMS installed on a microcomputer. It allows easy and convenient collection and storage of pavement distress data (Figure 6), and users can upload network topology information directly from the PMS to the MessagePad for accurate identification of sections (Figure 7). The software of this device uses pen-based data entry technology, and data entry is simplified by pick-up lists, numeric keypads, and character recognition features. The handheld data collection device holds great potential for use in recording maintenance quality rating information, and the technology exists for redesigning the software into the rating format described in this manual.

Figure 5. The Apple® handheld data collection device.

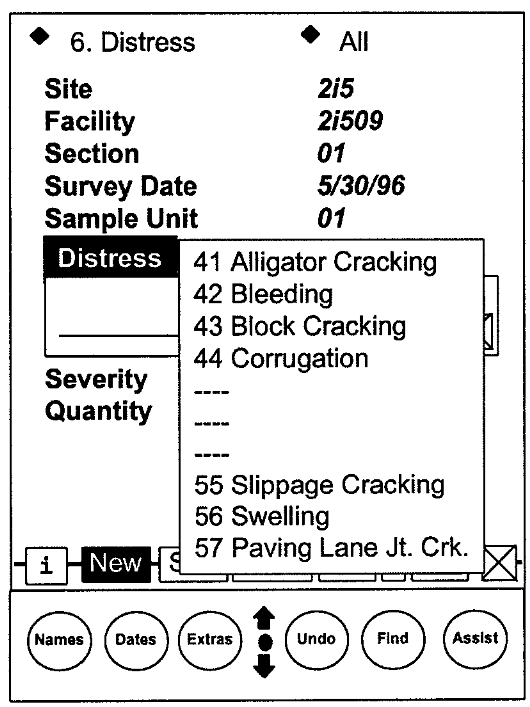

Figure 6. Sample screen showing distress data recording.

Safety

It is mandatory that the implementing agency's first responsibility be the safety of the traveling public and LOS inspection crews. Although the task at hand is important, its worth does not outweigh the lives and personal well-being of motorists, pedestrians, and agency personnel. Some of the safety items that inspection teams should be equipped with are as follows (Florida DOT 1994):

- Survey vehicles—Four-way flashing lights, at least one yellow/amber strobe light mounted on vehicle's roof, cellular phones or two-way radios to facilitate safety and operational communications, triangular safety signs mounted inside rear doors so they are visible when the doors are open, first-aid kit, and fire extinguisher.
- Individuals—Orange reflectorized safety vests, Underwriter's Laboratory (UL) approved safety glasses or safety prescription glasses (optional).

Basic safety precautions that should be followed by field inspection personnel include the following (Florida DOT 1994):

- Provide all signing and flagging required by the agency and the *Manual of Uniform Traffic Control Devices (MUTCD).*
- Survey vehicle should be safely parked along the side of the road.
- Survey vehicle strobe lights and four-way flashers should be activated at the worksite and remain activated until work is completed.
- Inspectors should observe traffic in both directions on undivided highways and should face oncoming traffic on divided highways.
- Inspectors should not attempt to stop or divert traffic.
- Inspectors should use discretion regarding their safety in hazardous situations that result from dense fog, heavy rains, and lightning prevalent conditions.

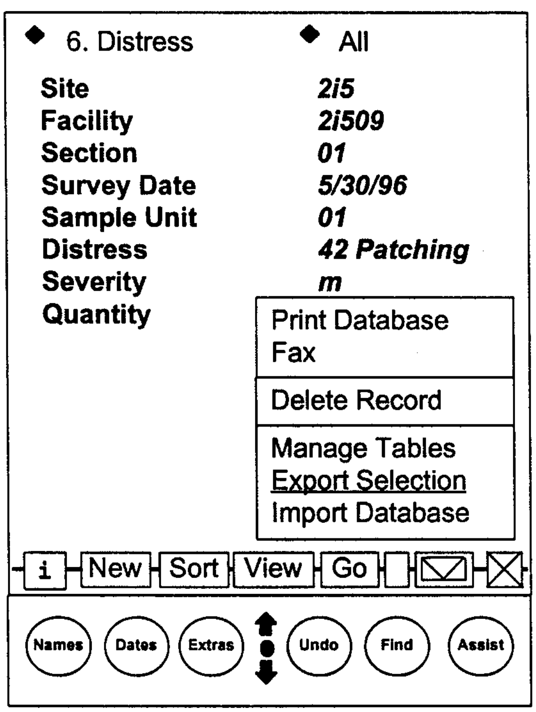

Figure 7. Sample screen showing database exporting.

Occasionally, it may be necessary to schedule the survey of some segments with high-traffic volumes so that it occurs during low-traffic periods. Doing so will provide increased safety to the inspection team and decreased disruption to traffic. It may also be necessary from time to time to request special traffic control items (flaggers, cones, signs, directional arrows) during an inspection.

LOS ANALYSIS AND REPORTING

Component #14 Objective: To compile, process, and statistically analyze the results of the LOS field inspections, and to develop customized reports of the findings for examination by all levels of maintenance.

At this point, the first formal round of field inspections will have been conducted and the rating data for each sample segment will exist either on paper or on a computer. Now, the job is to analyze the data and report the findings in such a manner that all maintenance levels are made fully aware of the quality of maintenance of the areas that pertain to them.

Network Level

Calculation of the various network-level rating statistics desired by the agency requires the use of the LOS values computed for each sample segment. The following sequence of statistical calculations can be performed to determine the mean segment LOS and corresponding 95 percent confidence interval or, if desirable, the mean element LOS and corresponding 99.5 percent confidence interval.

Step 1. Calculate the mean LOS—Add the individual segment LOS values and divide by the number of sample segments.

$$\overline{LOS_S} = \frac{\sum LOS_{Si}}{n} \tag{3}$$

where:

$\overline{LOS_S}$ = mean segment LOS.
LOS_{Si} = individual segment LOS values for n sample segments.
n = number of sample segments.

$$\overline{LOS_E} = \frac{\sum LOS_{Ei}}{n} \tag{4}$$

where:

$\overline{LOS_E}$ = mean element LOS.
LOS_{Ei} = individual element LOS values for n sample segments.
n = number of sample segments.

Step 2. Calculate the sample variance—Subtract the mean LOS from each of the individual LOS ratings. Square each of these values and then sum the squares. Divide the sum of the squares by $n - 1$.

$$s^2 = \frac{\sum\left(LOS_{Si} - \overline{LOS_S}\right)^2}{n-1} \tag{5}$$

where:

s^2 = sample variance of segment LOS ratings.
LOS_{Si} = individual segment LOS values for n sample segments.
$\overline{LOS_S}$ = mean segment LOS.
n = number of sample segments.

$$s^2 = \frac{\sum\left(LOS_{Ei} - \overline{LOS_E}\right)^2}{n-1} \tag{6}$$

where:

s^2 = sample variance of element LOS ratings.
LOS_{Ei} = individual element LOS values for n sample segments.
$\overline{LOS_E}$ = mean element LOS.
n = number of sample segments.

Step 3. Calculate the standard deviation—Take the square root of the sample variance calculated in Equation 5 or Equation 6.

$$s = \sqrt{s^2} \tag{7}$$

where:

s = standard deviation of segment or element LOS ratings.
s^2 = sample variance of segment or element LOS ratings.

Step 4a. Form 95 percent confidence interval around mean segment LOS rating—Multiply 1.96 (z-statistic for 95 percent confidence level) by the segment LOS standard deviation and divide by the square root of n (this is the plus-or-minus term, and it is a measure of the precision). The plus-or-minus term is then applied to the mean segment LOS to give the 95 percent confidence interval, as shown below.

$$\overline{LOS_S} \pm 1.96s\ \sqrt{n} \tag{8}$$

where:

$\overline{LOS_S}$ = mean segment LOS.
s = standard deviation of segment LOS ratings.
n = number of sample segments.

Step 4b. Form 99.5 percent confidence interval around mean element LOS rating—Multiply 2.8 (z-statistic for 99.5 percent confidence level) by the element LOS standard deviation and divide by the square root of n. The plus-or-minus term is then applied to the mean element LOS to give the 99.5 percent confidence interval, as shown below. A higher level of confidence (i.e., larger confidence interval) is required for element LOS analysis than for segment LOS analysis.

$$\overline{LOS_E} \pm 2.08s\ \sqrt{n} \tag{9}$$

where:

$\overline{LOS_E}$ = mean element LOS.
s = standard deviation of element LOS ratings.
n = number of sample segments.

With the 95 percent confidence interval established for segment LOS analysis, an agency can be 95 percent sure that the "true" LOS_S is located within the 95 percent confidence interval.

If the 95 percent confidence interval contains the desired or target LOS (Scenario 1 in Figure 8), then the target level is obviously being achieved (subject to the precision attached to the rating procedure at the outset), and no particular remedial action would be indicated. If the 95 percent confidence interval lies entirely below the target LOS (Scenario 2 in Figure 8), then with 95 percent confidence an agency can conclude that the "true" LOS_S is below the target value and remedial action should be considered. If the 95 percent confidence interval lies entirely above the target LOS (Scenario 3 in Figure 8), then with 95 percent sureness an agency can conclude that the "true" LOS_S is above the target value and that resources can be shifted to other needs while still achieving the target LOS.

To exert more control in obtaining more uniform maintenance, an implementing agency can adopt a twofold maintenance quality requirement, consisting of a target (mean) LOS and a maximum allowable variation from that target. For instance, if a target LOS of 80 is used, an agency may also choose to specify that the standard deviation of LOS ratings be no greater than 5 or that no more than 15 percent of the samples be below 75. Calculation of the standard deviation was illustrated in Equation 7. Calculation of the percentage of segments below a specified LOS is done simply by dividing the number of sample segments with LOSs below the specified LOS by the total number of sample segments, and then multiplying by 100 percent.

Regardless of whether an agency chooses to specify simply a target LOS or a target LOS in conjunction with a variation parameter, it is recommended that the agency routinely examine the overall distribution of LOS ratings by constructing a histogram. A histogram, as illustrated in Figure 9, is a two-dimensional bar graph in which LOS is plotted on the horizontal axis and frequency (i.e., number of sample segments with LOSs in a given LOS range) is plotted on the y-axis. It provides a general indication of whether the sample LOS ratings are normally distributed (Case 1 in Figure 9), bimodally distributed (Case 2 in Figure 9), skewed left (Case 3 in Figure 9), or skewed right (Case 4 in Figure 9).

Figure 10 provides an example of how network-level LOS statistics are computed. In this example, the LOS ratings from 30 sample segments, representing rural interstate highways within District 1, are analyzed. With 95 percent confidence, it is found that the "true" districtwide LOS_S for this facility type is between 68.81 and 73.39, and that the "true" districtwide traveled-roadway LOS_E for this facility type is between 66.57 and 74.03. Depending on the information desired, similar calculations could be made for other elements (e.g., drainage,

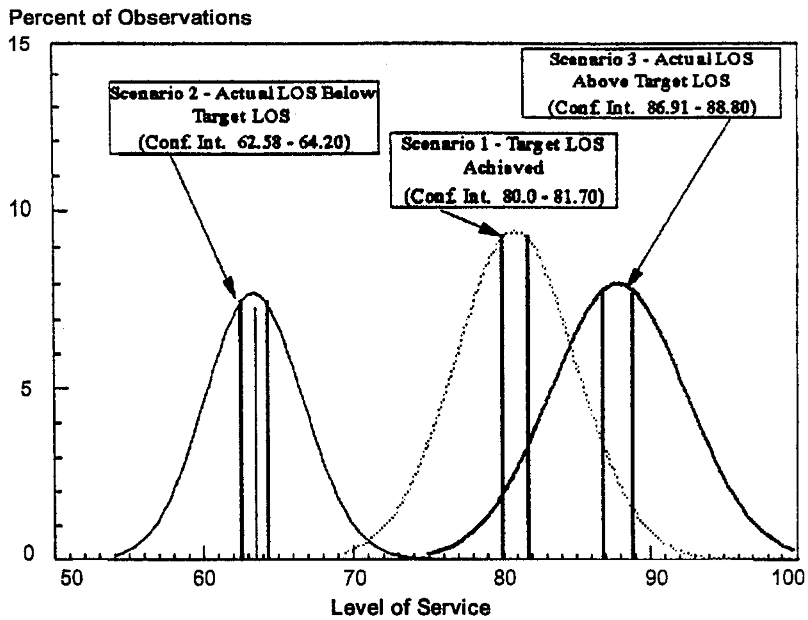

Figure 8. Case scenarios for determining whether target LOS has been achieved.

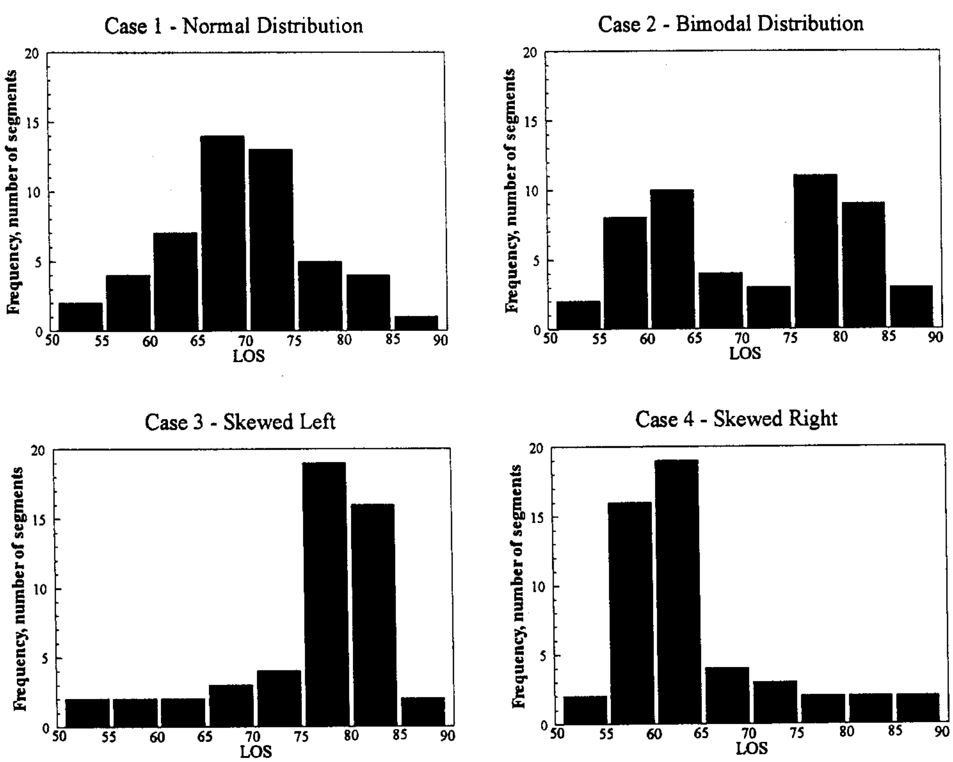

Figure 9. Types of LOS frequency distributions.

District 1 Ratings—Rural Interstate Facility Type

Highway	MP	LOS_S	LOS_E*	Highway	MP	LOS_S	LOS_E*
I-57 NB	107.5	80.6	76.6	I-34 EB	101.0	76.1	80.1
I-57 NB	118.6	85.1	84.3	I-34 EB	133.6	74.6	77.9
I-57 NB	123.4	74.5	78.6	I-34 EB	138.4	65.7	60.6
I-57 NB	132.5	68.4	73.2	I-34 EB	145.7	57.1	59.4
I-57 NB	136.7	75.8	72.6	I-34 EB	159.5	66.5	58.5
I-57 NB	144.4	72.9	67.5	I-34 WB	70.3	72.4	60.7
I-57 NB	150.2	64.5	70.6	I-34 WB	111.8	66.7	64.3
I-57 NB	156.9	85.8	82.2	I-34 WB	129.5	62.5	61.6
I-57 SB	108.7	75.4	78.8	I-34 WB	142.7	71.4	73.4
I-57 SB	119.3	84.3	69.0	I-34 WB	157.7	60.2	69.2
I-57 SB	123.3	71.1	58.7	I-69 NB	31.4	65.7	65.6
I-57 SB	127.6	73.5	63.9	I-69 NB	44.2	72.3	67.7
I-57 SB	148.4	74.1	69.3	I-69 SB	24.3	68.6	73.1
I-34 EB	79.5	71.0	71.7	I-69 SB	32.7	68.1	75.2
I-34 EB	83.1	63.0	62.2	I-69 SB	46.7	71.6	78.3

* Traveled Roadway Element

Step 1. Calculate the mean LOS.

Mean Segment LOS

$$\overline{LOS}_S = \frac{80.6+85.1+....+71.6}{30} = 71.3$$

Mean LOS of Traveled Roadway

$$\overline{LOS}_E = \frac{76.6+84.3+....+78.3}{30} = 70.2$$

Step 2. Calculate the sample variance.

Variance of Segment LOS's

$$s^2 = \frac{(80.6-71.3)^2+(85.1-71.3)^2+....+(71.6-71.3)^2}{30-1} = 48.46$$

Variance of Traveled Roadway LOS's

$$s^2 = \frac{(76.6-70.2)^2+(84.3-70.2)^2+....+(78.3-70.2)^2}{30-1} = 56.23$$

Step 3. Calculate the standard deviation.

Std. Deviation of Segment LOS's $\quad s = \sqrt{48.46} = 6.96$

Std. Deviation of Traveled Roadway LOS's $\quad s = \sqrt{56.23} = 7.50$

Steps 4a and 4b. Form 95-percent confidence interval around mean segment LOS and 99.5-percent confidence interval around mean element LOS.

Segment $\quad 71.3 \pm 1.96 \times 6.96/\sqrt{30} = 71.3 \pm 2.49$ or 68.81 to 73.79

Traveled Roadway $\quad 70.2 \pm 2.8 \times 7.50/\sqrt{30} = 70.2 \pm 3.83$ or 66.37 to 74.03

Figure 10. Illustration of how mean LOS and corresponding confidence interval are calculated.

traffic services) within this focus group or for other facility types in this district.

To compute ratings that transcend all possible facility types, such as an overall district/region rating or the overall agency rating, it will be necessary to apply weightings to the individual facility types. This is done by multiplying the mean LOS ratings of the individual facility types by the corresponding centerline mileage values of those facility types, summing the mathematical products calculated for each facility type, and dividing that sum by the total centerline mileage. Table 18 illustrates this procedure using individual district ratings for each of three highway systems. As can be seen, overall LOS ratings have been computed for each district, as well as for the entire agency.

The format selected for final reporting of survey results can be tailored to suit a variety of needs, depending on the infor-

TABLE 18 Example computation of district/regionwide and agencywide LOS ratings

District	Interstate System			Primary Highway System			Secondary Highway System			All Systems		
	LOS	CL[a] Miles	Product (LOS×Miles)	LOS	Miles	Product (LOS×Miles)	LOS	Miles	Product (LOS×Miles)	Total Miles	Sum of Products	Overall LOS Rating
1	72	20.3	1,461.6	77	124.9	9,617.3	69	354.7	24,474.3	499.9	35,553.2	71.1
2	—	0.0	0.0	80	180.6	14,448.0	72	431.1	31,039.2	611.7	45,487.2	74.4
3	69	73.4	5,064.6	66	118.0	7,788.0	71	358.6	25,460.6	550.0	38,313.2	69.7
4	67	56.7	3,798.9	72	155.5	11,196.0	70	567.2	39,704.0	779.4	54,698.9	70.2
5	73	44.5	3,248.5	74	101.9	7,540.6	75	499.0	37,425.0	645.4	48,214.1	74.7
6	83	59.5	4,938.5	75	73.4	5,505.0	77	327.5	25,217.5	460.4	35,661.0	77.5
All Districts, All Systems										3,546.8	257,927.6	72.7

[a] Centerline mileage.
1 mi = 1.61 km

mation desired. The Florida DOT, for instance, generates two key summary tables following each inspection round. The first table displays, by facility type, the mean LOS results for individual maintenance units, districts, and the entire agency. The other table shows, by facility type, the mean LOS results for each of the five maintenance elements. Samples of these reports are provided in Tables 19 and 20.

The Maryland DOT displays its year-to-year network ratings in both table and bar chart format. Table 21, for instance, lists the individual highway system ratings and the overall network ratings for the years 1992 through 1994. Figure 11 shows the individual element ratings and the overall network ratings for 1993 and 1994. It should be noted that Maryland's "category" term is the equivalent to the "element" term used in this manual.

The significance of network-level reports, such as those provided in Tables 19 through 21 and Figure 11, is that middle- and top-level managers can readily identify areas of excessive or deficient maintenance and track the progression of quality over time. For instance, in Table 19, a chief engineer can examine how each district is performing overall and how performing on specific facility types. Similarly, a district engineer can examine how each maintenance unit is performing overall and how it is performing on specific facility types. By considering both the time-series LOS trends of a specific interest area (e.g., district-by-district trends for all facilities, element-by-element trends for rural expressways) and the past funding levels, maintenance managers can better forecast LOS and take the appropriate actions to bring about improved and more uniform maintenance. Moreover, top-level managers will be better prepared to advise their funding bodies of the consequences of various funding levels.

Network-level reports containing the results of each round of surveys should be given wide distribution in a timely manner. A recommended distribution list for this type of report is as follows:

- District/regional-office managers,
- Middle management personnel at the central office,
- Top management personnel at the central office,
- Planning and budget personnel, and
- Legislative staff personnel who review budget requests.

Field Level

The same statistical formulas previously used to produce network-level statistics can be used to generate rating statistics for each element in a maintenance area. For instance, a table similar to Table 20, which lists element ratings by facility type, could be developed for each maintenance unit instead of for the entire state network.

Moreover, with some additional analysis work, the element rating statistics for individual highways within a maintenance unit can be computed and then reported in a format similar to that shown in Table 22. This type of analysis and reporting gives clear indications of which highways—and, more specifically, which elements within those highways—need more attention and which ones can get by with less.

If, in the example shown in Table 22, the target LOS was 80 and the confidence interval was ±3.0 percentage points, then Rt. 101 would be seriously deficient and Interstate 17 and U.S. 65 would be slightly deficient; the other two routes would be right on target. Interestingly, if these were all the roads maintained by the maintenance unit, then the unit as a whole would be deficient, because the calculated LOS is 73.

Using the inspection results for each segment sampled in a given maintenance unit, individual feature/characteristic ratings can be calculated that will shed further light on out-of-tolerance work activities. These calculations are performed by dividing the number of sample segments in which a given feature/characteristic has met desired conditions by the total number of segments where that feature/characteristic was

TABLE 19 Level of maintenance summary from Florida's maintenance rating program—first period, fiscal year 1992–1993 (Florida DOT 1992)

MAINTENANCE AREA	RURAL LIMITED/ARTERIAL		URBAN LIMITED/ARTERIAL		ALL FACILITIES
	LIMITED	ARTERIAL	LIMITED	ARTERIAL	
Bartow	76	86	73	80	82
Ft. Myers/Labell/Naples	90	86	88	77	84
Sarasota/Arcadia	92	78	74	75	79
District 1	**86**	**83**	**78**	**78**	**81**
Gainesville/Chiefland	—	75	—	74	75
Lake City	68	78	—	78	76
Perry	92	69	—	80	72
Jacksonville	82	66	72	64	68
St. Augustine	—	74	—	72	74
District 2	**81**	**73**	**72**	**74**	**74**
DeFuniak	69	75	—	76	75
Panama City	—	84	—	76	82
Tallahassee	74	83	—	74	81
Marianna	81	82	—	68	80
Pensacola/Milton	69	69	68	66	68
District 3	**74**	**78**	**68**	**72**	**77**
Ft. Pierce	81	75	—	70	75
Ft. Lauderdale	88	79	89	71	76
West Palm Beach	—	80	72	72	76
District 4	**85**	**78**	**81**	**71**	**76**
Cocoa	83	78	—	83	82
Deland	82	86	—	75	83
Leesburg	96	94	—	89	93
Oviedo	—	77	86	80	81
Orlando	83	73	81	74	75
Ocala	89	87	—	83	86
District 5	**87**	**82**	**83**	**81**	**83**
South Dade	—	—	—	—	—
North Dade	—	—	—	—	—
Marathon	—	—	—	—	—
District 6	—	—	—	—	—
Tampa	85	73	82	73	76
Dade City	90	81	—	78	81
Pinellas	81	82	84	75	77
District 7	**85**	**79**	**83**	**76**	**78**
Turnpike	**89**	—	**89**	—	**89**
Statewide	**84**	**79**	**81**	**74**	**78**

Note: No ratings are listed for maintenance units in District 6 because the ratings in those areas for that time period were suppressed as a result of emergency maintenance efforts surrounding the destruction left by Hurricane Andrew.

TABLE 20 Maintenance rating summary of Florida highways—fiscal year 1992–1993 (Florida DOT 1992)

	Expressways		Arterial Highways		All
Element	Rural	Urban	Rural	Urban	Roads
Roadway	88	90	90	87	89
Traffic Serv	82	71	74	71	75
Roadside	75	72	66	61	68
Drainage	94	91	86	81	87
Veg/Aesth	85	83	81	75	80
Statewide	**84**	**81**	**79**	**74**	**78**

TABLE 21 Summary of 1992–1994 LOS for Maryland highway systems (Maryland DOT 1994)

Highway System	1992 (pilot)	1993	1994
Interstate Highways	83.1	91.6	92.0
Primary Highways	86.1	89.2	88.4
Secondary Highways	83.7	89.2	86.6
Statewide	84.0	89.4	88.2

applicable, and then multiplying by 100. For instance, if 27 of 30 total segments inspected in maintenance unit "A" were rated for informational signs—that is, informational signs were present at 27 of 30 sites—and this feature passed the LOS criteria at 18 segments, then the feature/characteristic rating would be 67 percent (18/27 × 100 = 67%). The remaining feature/characteristic ratings are calculated in the same manner, and the results can then be displayed in the field-level report using a summary table or graph.

For any given activity, the number assigned as the target LOS represents the percentage of random samples in which the maintenance condition standard corresponding to the activity is to be met or exceeded. For instance, an activity with an LOS rating of 97 means that 97 percent of the segments sampled met the condition standard. In Florida's case (target LOS = 80), this value would indicate that either the activity is being overmaintained or the condition standard is too easy to meet.

When an agency has established the level it wants to achieve, then it must decide what actions to take to ensure compliance. For example, if the LOS being provided is considered too high, then resources should be redirected. If the level is considered adequate, then the maintenance condition standard should be raised to make it more difficult to achieve. A combination of both redirection and raising the condition standard can also be undertaken.

An agency will have the flexibility to establish its condition standards at any level it wants and the flexibility to decide when that level has been achieved. If it wishes to establish a broad band that is above or below the target LOS, it can. The number of possible scenarios is limitless, depending on the ingenuity and desires of the agency to provide a specified LOS to its customers.

Table 23 shows the Florida DOT's summary table. The number symbol (#) in the second column of this table designates the total number of sample segments where each feature/characteristic was applicable; the YES term in the third column signifies the number of segments in which desired conditions were achieved; and the asterisk (*) in the fourth column is the resulting percentage of passing segments. Recalling that Florida's target LOS is 80, it can be seen in this table that there are numerous deficient features/characteristics (shoulders, curb, turf, striping, regular signs, object markers) as well as several features/characteristics that exceed the

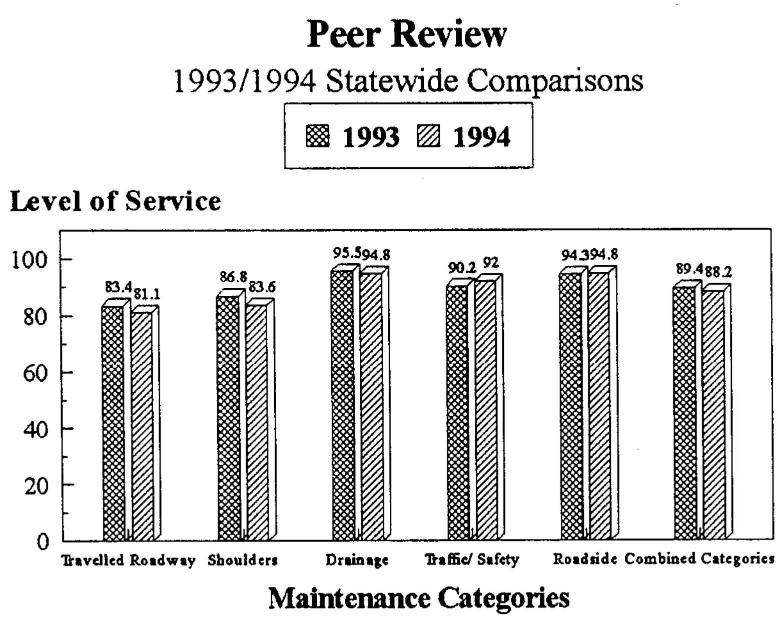

Figure 11. Statewide comparisons of Maryland maintenance category ratings (Maryland DOT 1994).

TABLE 22 Example summary table of element ratings for various highways within a maintenance unit

Element	Rt. 43 (24 mi)	Rt. 86 (16 mi)	Rt. 101 (34 mi)	US 65 (20 mi)	I-17 (10 mi)	All Roads (104 mi)
Traveled Roadway	68	81	60	77	75	70
Traffic Services	82	61	54	71	69	66
Roadside	70	79	66	81	78	73
Drainage	94	91	76	75	72	82
Vegetation/ Aesthetics	65	80	71	85	84	75
Unitwide	77	79	65	76	74	73

1 mi = 1.61 km

target LOS of 80 (pavement void, rutting, shoving, roadside mowing, barrier wall).

As with network-level reports, field-level reports should be given wide distribution in a timely manner. Recipients of these reports should be district/regional office managers, maintenance unit managers and supervisors, and maintenance crew personnel.

QA/QC OF LOS RATING TEAMS

Component #15 Objective: To ensure that LOS rating teams are providing accurate rating results (QA) and are complying with the agency-specified rating and safety procedures (QC).

Agencies that need or choose to use multiple LOS rating teams to survey segments located within separate districts/

TABLE 23 Example summary table of feature/characteristic ratings (Florida DOT 1994)

ROADWAY	#	YES	*
Pothole	60	58	97
Joint-Conc	39	37	95
Pavt Void	39	39	100
Edge Ravel	11	11	100
Rutting	22	22	100
Cracking	60	50	83
Depression	60	55	92
Stripping	22	21	95
Shoving	22	22	100
Paved Shoulder	56	38	68

ROADSIDE	#	YES	*
Shoulder-Soil	54	27	50
Front Slope	60	29	48
Turnout	2	1	50
Sidewalk	1	0	0
Bike Path	0	0	0
Fence	50	43	86

VEGETATION - AESTHETICS	#	YES	*
Roadside Mowing	59	59	100
Slope Mowing	23	15	65
Landscaping	8	6	75
Tree Trimming	50	46	92
Curb/SW Edge	22	6	27
Litter Remove	60	38	63
Turf Condition	60	16	27

TRAFFIC SERVICES	#	YES	*
Raised Marker	60	42	70
Striping	59	7	12
Pavt Symbol	27	15	56
Guardrail	30	21	70
Attenuator	0	0	0
Barrier Wall	17	17	100
Warning Sign	16	11	69
Regulatory Sign	20	8	40
Info Sign	34	28	82
Object Marker	41	17	41
Sign Lighting	18	16	89
Hwy Lighting	46	31	67

DRAINAGE	#	YES	*
Storm Drain	23	23	100
Side Drain	19	14	74
Cross Drain	27	24	89
Roadside Ditch	44	40	91
Median Ditch	46	45	98
Outfall Ditch	1	0	0
Curb Inlet	19	10	53
Other Inlet	39	16	41
Misc Drain St	32	18	56
Rdwy Sweeping	58	50	86

regions will find it very important to perform periodic QA and QC checks on their teams. These checks will help identify any inconsistencies in the way features/characteristics are evaluated, any significant differences in rating results, and any departures from standard evaluation practices. Subsequently, corrective actions can be taken to control the level of quality of the overall rating process.

QA Checks

The QA checks should be performed by a central-office, "true" rating team, consisting of the individuals responsible for developing the program and those who served as instructors in the LOS training course. The central-office team should perform QA checks on each district/regional "satellite" team at least once a year, with more frequent attention given to teams having persistent problems in producing accurate (i.e., consistent and unbiased) ratings.

QA Based on Overall Ratings

To begin the QA process, the central-office team should ask the supervisor of the satellite team to be reviewed for a complete listing of the sample segments selected for inspection during a given inspection round. From that listing, a minimum of 25 segments—representive of all facility types—should be randomly selected for inspection by the central-office team. The central-office team should then coordinate with the satellite team, so that the selected segments can be independently evaluated at the same time by the two teams.

Upon completion of the 25 (or more) QA inspections, the central-office team should first review the individual rating forms to determine if the satellite team has evaluated the proper features/characteristics. Next, the central-office team must perform some statistics to determine the accuracy of the satellite team's segment LOS ratings. The steps in this process are described below.

Step 1. For each sample segment, compute the segment LOS ratings derived from both the satellite team's inspection and the central-office team's inspection.

Step 2. For each sample segment, compute the difference between the two segment LOS ratings.

$$\Delta LOS_{Si} = LOS_{Si,CO} - LOS_{Si,S} \qquad (10)$$

where:

ΔLOS_{Si} = difference in LOS_S ratings for a given sample segment.
$LOS_{Si,CO}$ = segment LOS rating derived by central-office team.
$LOS_{Si,S}$ = segment LOS rating derived by satellite team.

Step 3. Calculate the mean value of the LOS_{Si} differences—Add the individual ΔLOS_{Si} values and divide by the number of sample segments.

$$\overline{\Delta LOS_S} = \frac{\sum \Delta LOS_{Si}}{n} \qquad (11)$$

where:

$\overline{\Delta LOS_S}$ = mean value of the LOS_{Si} differences.
ΔLOS_{Si} = difference for an individual sample segment.
n = number of sample segments.

Step 4. Compute the variance of the LOS_{Si} differences—Subtract the mean difference from each of the n differences and square each of these n differences. Add each of the n squared values and divide by n–1.

$$s^2 = \frac{\sum \left(\Delta LOS_{Si} - \overline{\Delta LOS_S}\right)^2}{n-1} \qquad (12)$$

where:

s^2 = sample variance of the LOS_{Si} differences.
ΔLOS_{Si} = difference for an individual sample segment.
$\overline{\Delta LOS_S}$ = mean value of the LOS_{Si} differences.
n = number of sample segments.

Step 5. Compute the standard deviation of the LOS_{Si} differences—Take the square root of the variance that was calculated using Equation 12.

$$s = \sqrt{s^2} \qquad (13)$$

where:

s = standard deviation of the LOS_{Si} differences.
s^2 = variance of the LOS_{Si} differences.

Step 6. Compute the z-statistic—Multiply the mean value of the LOS_{Si} differences by the square root of n and divide by the standard deviation calculated using Equation 13.

$$z = \frac{\overline{\Delta LOS_S} \times \sqrt{n}}{s} \qquad (14)$$

where:

z = z-statistic.
$\overline{\Delta LOS_S}$ = mean value of the LOS_{Si} differences.
n = number of sample segments.
s = standard deviation of the LOS_{Si} differences.

If the z-statistic is greater than +1.96, then the conclusion is that the satellite team is producing ratings that are significantly higher than those of the central-office team. If the z-statistic is smaller than −1.96, then the conclusion is that the satellite team is producing ratings that are significantly lower than those of the central-office team. If z is between −1.96 and +1.96, then there is no significant difference between the ratings produced by the two teams. The z-statistic cut-off values of −1.96 and +1.96 correspond to a 95 percent confidence level.

Figure 12 contains an example problem, in which the ratings of the satellite team and the central-office team are tested for significant differences. Note that steps 1 and 2 in this example have been completed and are shown at the top in the three right-hand columns. In this example, the z-statistic is computed to be −0.851. Because this value is between −1.96 and +1.96, it can be concluded that no significant difference exists between the ratings produced by the two teams.

QA Based on Element Ratings

A second set of checks should also be done to ensure the accuracy of individual element ratings (LOS_E). The same 6-step statistical comparison procedure is used, with the following two exceptions:

- Instead of using the differences between two overall ratings, the differences between two ratings corresponding to a given element are used.

Sample Segment	Central-Office Rating, $LOS_{Si,CO}$	Satellite Team Rating, $LOS_{Si,S}$	Difference in Ratings, ΔLOS_S
1	74.3	88.9	-14.6
2	83.6	88.7	-5.1
3	82.3	78.4	3.9
4	85.0	82.3	2.7
5	86.9	86.3	0.6
6	86.1	91.0	-4.9
7	81.1	83.9	-2.8
8	79.6	84.8	-5.2
9	86.1	82.1	4.0
10	86.4	83.4	3.0
11	92.4	89.6	2.8
12	85.5	89.1	-3.6
13	87.2	85.5	1.7
14	85.5	88.8	-3.3
15	90.7	87.5	3.2
16	88.1	88.5	-0.4
17	92.7	91.0	1.7
18	91.6	92.7	-1.1
19	92.2	92.3	-0.1
20	88.3	95.2	-6.9
21	90.3	88.7	1.6
22	78.0	83.9	-5.9
23	85.7	79.3	6.4
24	75.3	68.5	6.8
25	72.2	77.6	-5.4

Steps 1 and 2 already completed.

Step 3. Calculate the mean value of the LOS_{Si} differences.

$$\overline{\Delta LOS_S} = \frac{(-14.6)+(-5.1)+....+(-5.4)}{25} = -0.836$$

Step 4. Compute the variance of the LOS_{Si} differences.

$$s^2 = \frac{(-14.6-(-0.836))^2+(-5.1-(-0.836))^2+....+(-5.4-(-0.836))^2}{25-1} = 24.118$$

Step 5. Compute the standard deviation of the LOS_{Si} differences.

$$s = \sqrt{24.118} = 4.911$$

Step 6. Compute the *z*-statistic.

$$z = \frac{-0.836 \times \sqrt{25}}{4.911} = -0.851$$

Figure 12. Example problem illustrating the test for significant differences between central-office and satellite team ratings.

- The z-statistic cut-off values of −1.96 and +1.96 are replaced with −2.8 and +2.8. These larger cut-off values are needed because more than one comparison is being made and therefore a higher degree of confidence (i.e., larger confidence interval) is required (99.5 percent instead of 95 percent). These cut-off values assume that there are no more than 5 or 6 elements under consideration.

Significant differences that occur at the element level will help narrow the focus in identifying problem areas. Should a particular element be found to have significantly different ratings, the individual feature/characteristic ratings constituting that element can be examined to pinpoint the feature(s)/characteristic(s) causing the variation.

If significant variations from the central-office team ratings are noted, consideration should be given to suppressing the ratings produced by the satellite team for the most recent inspection round. Immediate training should be given by the central-office team to ensure that accuracy is restored.

QC Checks

To help ensure that acceptable survey quality is being achieved, the satellite rating team supervisor should conduct at least one QC check during each inspection round. QC checks are essentially field reviews of the satellite teams to see if they are following the agency-specified inspection procedures. A QC form, much like the one presented in Figure 13, can be used in this process. This particular form is used by the Florida DOT as part of its maintenance rating program (MRP). Results of each QC check should be discussed with the satellite team, and differences or problems should be resolved in a positive format.

Updating Variance Estimates of LOS Rating Teams

Because the variability of each team's ratings will change with time, it is recommended that the central-office team

QUALITY CONTROL (QC) - MRP TEAMS

	YES	NO
1. Does the MRP survey team have adequate tools to do the job?	___	___
2. Does the team carry the necessary reference materials with them (MRP manual, Help Manual, SLDs, Standard Specifications, MUTCD, RCI listing for outfall and landscaping locations mowing guide, etc.)?	___	___
3. Does the team have the necessary safety equipment (safety vests, hard hats, safety cones, etc.)?	___	___
4. Does the survey vehicle have the necessary safety equipment (warning lights, first aid kit, fire extinguisher, etc.)?	___	___
5. Has the survey route been logically planned for efficiency?	___	___
6. Are the MRP points appropriately:		
a) Measured by DMI or odometer to determine location?	___	___
b) Measured from the center point with a measuring wheel to determine beginning and ending points?	___	___
c) Marked at center, beginning, and ending locations?	___	___
7. Have all the characteristics in the sample point been included in the team's survey coding sheet?	___	___
8. Have all the characteristics been evaluated according to MRP standards?	___	___
9. Does the team practice maximum safety procedures?	___	___
10. Is the MRP field survey data entered into the computer on a timely basis?	___	___
11. Are logical checks made against the data to find errors?	___	___
12. Has survey team attended the Statewide MRP training?	___	___

Comments: ______________________________

Date of quality control: ______________________________

Quality control conducted by: ______________________________

Figure 13. Typical QC form for evaluating rating teams (Florida DOT 1994).

compute an updated estimate of variance for each satellite team following each set of annual QA reviews. This can be done by obtaining the complete set of ratings produced by each team in the latest inspection round and then performing the first three statistical steps presented in the section, "LOS Analysis and Reporting." As with the pilot field study, a sample variance for each stratum evaluated by a given team must be computed. The resulting variances can then be used to determine future sampling requirements for each team for each stratum.

QA/QC OF WORK CREWS

Component #16 Objective: To ensure that work activities performed by maintenance crews are done in accordance with agency-specified or agency-recommended practices.

Several maintenance agencies engage in a process of assessing the quality of work as it is being performed or immediately after it is completed by maintenance crews. The evaluations are typically made by area supervisors, and any deficiencies in the materials, equipment, or work practices are identified so that corrective actions can be made right away. This is, by definition, QC at the activity level, and it is an important part of a quality management program.

Some agencies have instituted a quality assessment process in which independent inspectors, either from the central office or district/regional office, evaluate the quality of each step performed by work crews as part of a specific work activity. Rating scores are given for individual items, from which an overall activity rating is produced. This type of process is QA at the activity level, with focus on in-process or recently completed work, instead of on end results. Examples of the work items commonly reviewed as part of this process are listed in Figure 14.

A few agencies, most notably British Columbia and Pennsylvania, have instituted a quality assessment process, in which independent inspectors evaluate the quality of each step performed by work crews as part of a specific work activity. Rating scores are given for individual items, from which an overall activity rating is produced. This type of process is QA at the activity level, with focus on in-process or recently completed work instead of on end results.

The Pennsylvania DOT has a County Accreditation Review System (CARS) in which internal independent evaluations are made of the effectiveness and efficiency of the state's many county maintenance organizations. The objective of the program is to monitor four major categories—equipment, personnel, field operations, and office operations—involving approximately 22 work functions. One such function is the QA of maintenance activities. As illustrated in Figures 15 and 16, individual items (e.g., cleanliness of joint faces, appropriateness of sealant material) in a given activity are rated, and the rating scores are then summed and divided by the number of items rated to generate an overall score for the activity. The ratings of three evaluations (covering different activities) are then averaged, and the results are discussed with county supervisors.

The British Columbia MTH, which contracted all of its highway and bridge maintenance with private industry, conducts QA of all in-process and end-product maintenance work activities as part of its MAP. In general, contractors are totally responsible for the control of quality; however, area managers within the MTH perform periodic QA reviews to ensure compliance with the agency's policy standards.

Yes	*No*	
10	0	1) Does crew have work order?
5	0	2) Does work order provide adequate site location information?
10	0	3) Is crew working where work order requires?
5	0	4) Does crew arrive at work site in a reasonable time?
10	0	5) Is the work to be performed scheduled from work needs survey?
15	0	6) Is the work being performed the best long-range solution?
10	0	7) Does crew have proper tools to do the job?
10	0	8) Does crew have proper equipment to do the job?
5	0	9) Are tools in good condition?
10	0	10) Is equipment in good condition?
15	0	11) Does crew have the right kind and amount of materials to do the job?
15	0	12) Does crew follow work standards and guidelines?
10	0	13) Is crew staffed properly to do assigned work?
10	0	14) Are crew members productive at worksite?
10	0	15) Do employees wear proper personal protective safety items?
15	0	16) Does traffic control adhere to Department work zone standards?
10	0	17) Is completed work properly measured and recorded?
5	0	18) Are time charges made correctly?
5	0	19) Are material charges made correctly?
5	0	20) Are equipment charges made correctly?
5	0	21) Is crew adhering to Department work break regulation?

Figure 14. Florida DOT's quality assessment review (Miller 1989).

Bureau of Maintenance and Operations
Quality Assurance Evaluation

Concrete Pavement Joint Sealing (711-7147) - 4/92

EVALUATOR ______________ COUNTY ______ # ______
DATE ______________ ASSISTANT ______ # ______
SR ______ SEG ______ SEG ______ FOREMAN ______ # ______
CONCRETE PAVEMENT TYPE (CIRCLE ONE) 1 2 3

	SCORE	COMMENTS
1. CLEANING EQUIPMENT	____	____________
2. CLEAN VERTICAL FACE	____	____________
3. DRY VERTICAL FACE	____	____________
4. SEALING EQUIPMENT	____	____________
5. MATERIAL	____	____________
6. PAVEMENT TEMPERATURE	____	____________
7. MATERIAL TEMPERATURE	____	____________
8. BACKER ROD/BOND BREAKER	____	____________
9. FILLING	____	____________
10. ADHERENCE	____	____________
11. MATERIAL MIX RATIO	____	____________

SCORING SUMMARY	TOTAL	NO. ITEMS RATED	AVG SCORE	

FINAL SCORE ____________

ACTIVITY RATING			
	4.75 - 5.00	VERY GOOD	__
	3.65 - 4.74	GOOD	__
	2.30 - 3.64	MINIMUM ACCEPTABLE	__
	LESS THAN 2.30	UNSATISFACTORY	__

THE ACTIVITY IS UNSATISFACTORY IF ANY OF THE SCORES ABOVE ARE LESS THAN THREE.
PERSONAL SAFETY COMMENTS:

Figure 15. Pennsylvania's QA evaluation form for concrete joint sealing (Pennsylvania DOT 1994).

Figure 17 illustrates the agency's inspection form used by area managers to evaluate the in-process/end-product work quality provided by contractors. As can be seen, many different items (e.g., work procedure, smoothness, clean-up) are rated, and the rating points are tallied and divided by total possible points to produce an overall inspection rating.

EMPLOYEE TRAINING

Component #17 Objective: To instill in employees the proper skills in and knowledge of the newest maintenance technologies.

In an age of constantly evolving technologies, training and educating employees is essential if continuous improvement is to be sustained. Deming's sixth point, *Institute modern methods of training on the job,* and thirteenth point, *Institute a vigorous program of education and training,* mean equipping employees with the proper skills and knowledge to do their jobs correctly.

Although resistance to change must be anticipated from some employees, it is important to recognize that those who resist change often do so because they lack the appropriate skills. Although a poor attitude may be part of the problem, it is more likely that these types of employees wish to do a good job but lack the knowledge or tools to accomplish it.

In the educational process, it is important that employees familiarize themselves with the work issues so they can understand the logic of and need for improvements. Cooperation should increase significantly once workers know the change will improve the process and that their jobs will be secure. While training employees in the proper methods to accomplish the desired results, opportunities should be given for suggestions from the employees. When workers understand what needs to occur and what does not need to occur, they can often become the source of excellent ideas for significant improvements.

Similar results may also be achieved by studying the differences between the target LOS and the one actually achieved, and subsequently identifying the critical items

CONCRETE PAVEMENT JOINT SEALING 711-7147
QUALITY ASSURANCE EVALUATION INDICATORS

TYPE 1 & 2 PAVEMENTS

A1. CLEANING EQUIPMENT
- 1. Compressor
- 3. Hook, wire brush, & compressor
- 5. Saw/sandblast & compressor or waterblast & compressor

A2. CLEAN VERTICAL FACE
- 1. Not clean
- 3. Most joints clean
- 5. All joints clean

A3. DRY VERTICAL FACE
- 1. Damp or wet vertical faces
- 3. Most vertical faces dry
- 5. All vertical faces dry

A4. SEALING EQUIPMENT
- 1. Incorrect equipment for material used
- 3. Direct-fired kettle with full-sweep agitation
- 5. Correct equipment for material used

A5. MATERIAL
- 1. Any other sealant
- 3. AC with rubber with District approval
- 5. D-3405 sealant or better (D-1190 sealant or better Type II pavement)

A6. PAVEMENT TEMPERATURE
- 1. <40 degrees
- 5. 40 degrees or greater

A7. MATERIAL TEMPERATURE
- 1. Not within mfgr's recommendations
- 5. Within mfgr's recommendations

A8. BACKER ROD/BOND BREAKER
- 1. Not used
- 5. Used

A9. FILLING
- 1. Material overbands joints
- 5. ¼" - ½" below pavement surface, no overbanding

A10. ADHERENCE
- 1. Non adherence to vertical face, <90%
- 3. 90% - 99% adherence
- 5. 100% adherence

A11. MATERIAL MIX RATIO
- 1. Rubber <1-½ lbs per gal
- 3. Rubber 1-½ to 2 lbs per gal
- 5. Rubber 2 lbs per gal or greater, or pre-packaged material

TYPE 3 PAVEMENT

A1. CLEANING EQUIPMENT
- 1. No cleaning equipment
- 3. Compressor only
- 5. Compressor plus additional equipment (hook and/or wire brush)

A2. CLEAN VERTICAL FACE
- 1. Not clean
- 3. Most joints clean
- 5. Clean

A3. DRY VERTICAL FACE
- 1. Damp or wet vertical faces
- 3. Most vertical faces dry
- 5. Dry vertical face

A4. SEALING EQUIPMENT
- 1. Incorrect equipment for material used
- 5. Correct equipment for material used

A5. MATERIAL
- 1. Any other sealant
- 5. AC with rubber or AC with fiber

A6. PAVEMENT TEMPERATURE
(Not applicable)

A7. MATERIAL TEMPERATURE
- 1. Not within mfgr's recommendations
- 5. Within mfgr's recommendations

A8. BACKER ROD/BOND BREAKER
(Not applicable)

A9. FILLING
- 1. Spalls >½ sq ft filled with sealant
- 5. Spalls >½ sq ft repaired with cold mix or layered patching

A10. ADHERENCE
- 1. Non adherence to vertical face
- 3. 80% to 100% adherence to vertical face
- 5. 100% adherence

A11. MATERIAL MIX RATIO
- 1. Fiber <4% per gal; rubber <1-½ lbs per gal
- 3. Fiber 4 to 5% per gal; rubber 1-½ to 2 lbs per gal
- 5. Fiber 5% per gal or greater; rubber 2 lbs per gal or greater

Figure 16. Pennsylvania's joint sealing evaluation indicators (Pennsylvania DOT 1994).

requiring change. The best efforts of even trained individuals will fall short of expectations if the appropriate tools and equipment are not provided. One should not underestimate the value of training, because it is critical to the ultimate achievement of the elusive quality goal being sought. Only by clearly defining agency goals and providing the proper attitude, environment, training, and tools can the desired improvements in quality occur. Some of the items to consider are as follows:

- Skills training to enable employees to adequately make cost-effective and timely decisions concerning daily job challenges. Determining the capabilities of the agency's workforce will be necessary to tailor the training for the best results. Basic math and reading skills may be appropriate in some situations, whereas more advanced subjects, such as introduction to computers or a course in dealing with the public, may be appropriate.
- Procedures and methods for conducting work activities in accordance with agency policies and best practices will always pay dividends in the long run. Not only will this enable employees to do the job right the first time, but it may also help the agency avoid costly, and some-

Province of British Columbia — Ministry of Transportation and Highways

Quality Assurance Program

SURFACE (3) / DRAINAGE(5) / ROADSIDE(6) INSPECTION

ITP3/5/6

Location: ____________________

Inspection Date	C A / M / S	Highway Number	Start Landmark	Offset
Y Y M M D D				

Activity No. ______ - IN PROCESS ☐ - END PRODUCT ☐ INSPECTION ______

			N/A	Good	Fair	NTS.
Traffic Control	IP	100 - ~~360~~ 440				
Site or Base Preparation	IP	100 - 260				
Visual Inspection of Material	IP	100 - 260				
Work Procedure	IP	100 - 260				
Specified Quantity Utilized	IP	100 - 260				
Backslope Condition	IP	250 - 260				
Site Distance Cleared	EP	360				
Distance From Shoulder	EP	360				
Specified Height	EP	360				
Unimpeded Drainage	EP	360				
~~Workmanship~~ Quality of Work	IP.EP	100 - 440				
Specified Location	IP.EP	360 - 440				
Smoothness (Rideability)	EP	100 - 170				
Crowns/Drains Properly	EP	100 - 170				
Impermeable Compaction	EP	100 - 170				
Loose Surface Material	EP	100 - 170				
Dust Free	EP	100 - 170				
Appropriate Location	EP	100 - 170				
Ditch Cross-section	EP	250				
Ditch Gradient	EP	250				
Shoulder Clean Up	EP	250				
Debris Removed	EP	250				
Culvert Ends Clean	EP	250				
Rock Ditches Clean	EP	250				
Specified Type and Size	EP	440				
Work Site Clean Up	EP	100 - 440				

N.C.R. Number

Defect Notice

ACTIVITY REFERENCE TABLE

SURFACE: applies to 100, 130, 170 and 100M through 160N.

DRAINAGE: applies to 250M 260M 250N and 260P.

ROADSIDE: applies to 440 M, 440N and 440P. (Signs and Delineators) 360 (Brushing)

Installation Request #

Accomplished as stated in work reports (Circle one) (Y/N/NA)

Material sample taken (Y/N) ☐

Amount (quantity) inspected ______

Weather: ______

Comments ______

Area Manager's Signature ______

H-903 (92/07) M39 3881

Figure 17. QA form used by British Columbia for evaluation of maintenance activities (British Columbia MTH 1991).

times embarrassing, mistakes. In today's environmentally sensitive climate, using the right equipment and materials in the wrong place or using the wrong methods can cause an agency to expend a significant portion of its resources to correct problems. The cost of training employees so as to avoid these problems is occasionally far less than the cost of correcting the problem.

- Equipment and materials purchases to match the job and its conditions to the value of the projects that are to be designed. Bigger is not always better, and a low first cost is not always the most cost-effective in the long run. Training in this area may involve specification writers as well as foremen, superintendents, maintenance engineers and others to ensure that each one understands the agency's mission for maintenance and the most cost-effective solutions for the overall objective. Examples might include weedeaters instead of slingblades, tractors with backblades for work on driveways and tight areas instead of large motorgraders, more costly but longer lasting thermoplastic for line striping instead of shorter lasting water-based paints, and environmental considerations. Although this list is directed primarily at the management and operations leaders, it will also prove cost-effective for the employees conducting the work. Each of these new opportunities requires that updated skills and methods training be provided to keep pace with new developments.

CUSTOMER SATISFACTION

Component #18 Objective: To assess the highway user's satisfaction with the LOSs provided by the agency in key maintenance activities.

It can be said that agency officials act as the proxy for public opinion once the public's expectations have been identified. Even though maintenance forces are in close contact with the public on a daily basis, it is important not to let complaint calls be an indicator of public satisfaction or dissatisfaction. There is no substitute for the value obtained in acquiring a random sample of the expectations of the public, and then following a carefully designed program to meet those expectations. Florida found that rest area condition complaint letters sent to the Governor's Office dropped significantly when comment cards were made available at each rest area location. Even more valuable was the tabulation of results that showed the overwhelming majority of patrons were very satisfied with the LOS being delivered at rest areas. Until these results were received, past perceptions were based on complaint calls, representing only a small percentage of the total users.

After an agency has had its LOS rating system in place for a substantial period, for example, between 18 and 24 months, it is recommended that the public be asked to rate how satisfied they are with agency performance in key maintenance activities. As with the customer expectations survey, the easiest way to do this is to prepare a short questionnaire and administer it by mail or phone to a representative cross section of highway users.

For simplicity sake, the level of importance questions used in the customer expectations survey can be recast into performance satisfaction questions. For instance, if the question "On a scale of 1–10, how important is that roads be cleared of debris?" was used in the customer expectations survey, it can be changed to "On a scale of 1–10, how well do you think we are clearing roads of debris?" Similarly, the question "On a scale of 1–10, how important is visible line striping?" can be changed to "How would you rate the quality of line striping?" An alternative method would be to ask the survey participants for their bottom-line assessment of each key maintenance activity (i.e., are expectations being met?). An example of this type of survey is presented in Figure 18.

The same process used for the customer expectations survey of choosing an appropriate sampling frame, determining the sample size, pretesting the survey, and conducting the survey, can be used for the customer satisfaction survey. The statistical results of the customer satisfaction survey can be used to verify the LOS ratings being achieved, as well as identify any areas where adjustments in LOS criteria are warranted. For instance, if the LOS rating for potholes is at the target level of 80 and the customer satisfaction survey indicates that the agency is not meeting the traveling public's expectations for potholes, then the condition standard for this characteristic will need to be tightened.

Generally speaking, customer satisfaction surveys should be conducted every 3 to 4 years, following the first customer satisfaction survey. This frequency level is quite appropriate considering the slow rate of change in customers' expectations over time.

PROCESS UPDATING

Component #19 Objective: To periodically review and modify the LOS rating system in accordance with changes in agency standards/policies and customer needs/expectations.

Deming's first point, *Create constancy of purpose toward improvement of product and service,* means never-ending improvement, and this is the essence of process updating. To improve the product or service being provided to the traveling public, the entire rating process must be reviewed and modified. The act of continual improvement requires that cyclic feedback be an integral part of the system and that changes be implemented in a timely fashion.

Historically, cost data have often been the controlling factor in instituting change. Although cost is important, the implementing agency must always focus on the paramount goal of the QA program, to provide the desired LOS. With that said, the cost to accomplish a given LOS is a good starting place in analyzing potential areas to be modified. In general, the following nine cost and LOS scenarios are possible:

CUSTOMER SATISFACTION SURVEY

PART A

The ___(enter agency name)___ is interested in obtaining your opinion concerning how well it is performing routine maintenance tasks on its highway system, which consists of ___(specify types of highways/roads/streets)___. Please review the following list of work activities and specify whether the average highway condition, with respect to each activity, is:

1. Below your expectations.
2. Meets your expectations.
3. Exceeds your expectations.

Work Activity	Level Achieved
• Patching potholes in asphalt or concrete pavement	______
• Removing dips, bumps, and other irregularities on asphalt pavement	______
• Leveling drop-offs or ruts at edge of pavement and shoulder	______
• Maintaining adequate warning signs (e.g., stop, yield, curve)	______
• Maintaining adequate informational signs (e.g., speed limit posting, destination, mileage, no parking, school zone)	______
• Maintaining adequate pavement symbols (e.g., arrows, left, right) considering daytime and nighttime appearance	______
• Maintaining adequate pavement stripes (e.g., centerline, no-passing, lane dividers) considering daytime and nighttime appearance	______
• Maintaining adequate reflective pavement markers	______
• Removing debris (e.g., sand, stone, sticks) on pavement or in gutters	______
• Removing litter from pavement and roadside in **urban** areas	______
• Removing litter from pavement and roadside in **rural** areas	______
• Controlling vegetation (e.g., grass, weeds) in **urban** areas	______
• Controlling vegetation in **rural** areas	______
• Maintaining wildflowers in **rural** areas	______
• Providing satisfactory landscape appearance in **urban** areas	______
• Providing satisfactory rest area appearances (e.g., buildings, sidewalks, parking areas)	______
• Providing clean restroom and picnic facilities at rest areas	______
• Removing snow and ice from **urban** roads during winter events	______
• Removing snow and ice from **rural** roads during winter events	______
• Obtaining uniformity in the level of maintenance throughout the ___(enter agency name)___ highway system	______

How well do you think features (pavement, shoulders, vegetation, signs) on **Interstate highways** (I-57, I-72, et al.) are being maintained (please check one)?
Below my expectations ______
Satisfies my expectations ______
Exceeds my expectations ______

How well do you think features on **major highways** (US 45, US 51) are being maintained (please check one)?
Below my expectations ______
Satisfies my expectations ______
Exceeds my expectations ______

How well do you think features on **minor highways** (IL 9, IL 136) are being maintained (please check one)?
Below my expectations ______
Satisfies my expectations ______
Exceeds my expectations ______

Figure 18. Example questionnaire for obtaining customer satisfaction input.

- Scenario A—Total cost of providing the service is low and the LOS is **below** standards.
- Scenario B—Total cost is low and the LOS **meets** standards.
- Scenario C—Total cost is low and the LOS **exceeds** standards.
- Scenario D—Total cost of providing the service is acceptable and the LOS is **below** standards.
- Scenario E—Total cost is acceptable and the LOS **meets** standards.
- Scenario F—Total cost is acceptable and the LOS **exceeds** standards.
- Scenario G—Total cost of providing the service is high and the LOS is **below** standards.
- Scenario H—Total cost is high and the LOS **meets** standards.
- Scenario I—Total cost is high and the LOS **exceeds** standards.

Scenario B is the ideal situation, followed closely by scenario E; however, the actual results will most likely fall into one of the other categories. For instance, in scenarios A, D, and G, where the LOS is low, modifications to work programs in the form of resource changes should be considered. Resources can be diverted from activities in which LOS exceeds the standard (scenarios C, F, and I) to activities having low LOSs.

By determining which of these nine scenarios each maintenance activity falls under, it is possible to develop a priority list of the activities. For this purpose, it is recommended that the following priority sequence be utilized (1 is the highest priority, 9 is the lowest):

1. Scenario A (deficient LOS and low cost)—Good value for the public, but need to consider diverting resources to improve LOS ratings.
2. Scenario G (deficient LOS and high cost)—Consider cost-reduction strategies and alternate ways of accomplishing the same end result.
3. Scenario I (excessive LOS and high cost)—Consider reducing LOS and diverting resources.
4. Scenario D (deficient LOS and acceptable cost)—Consider increasing resources.
5. Scenario C (excessive LOS and low cost)—Good value for the public. More resources are needed to improve LOS in other areas.
6. Scenario F (excessive LOS and acceptable cost)—Good value for the public. More resources are needed to improve LOS in other areas.
7. Scenario H (acceptable LOS and high cost)—Consider cost-reduction strategies and alternate ways of accomplishing the same end result.
8. Scenario E (acceptable LOS and cost)—Good situation.
9. Scenario B (acceptable LOS and low cost)—Ideal situation.

Regardless of the scenario that each activity falls under, the LOS criteria and corresponding rating procedures established for each feature/characteristic should be periodically reviewed for adequacy. It is entirely possible for the LOS criteria of a given feature/characteristic to be too stringent or too lax, thereby causing ratings to be consistently significantly higher or lower than ratings for other features/characteristics. Moreover, LOS criteria should be closely examined in conjunction with the results of customer surveys. Any major discrepancies between current LOS criteria and customer satisfaction indicate changes needed in condition standards.

Many times, new programs are considered to be "just another central-office mandate," and gaining a "buy in" by district/regional and field forces is difficult. One method of gaining acceptance *(Deming's Point No. 9—Break down barriers between departments)* is by appointing teams onsisting of a high-placed district/regional manager and several field-level experts from other districts/regions to review the LOS criteria. Not only does this relieve the central office of the initial workload, it allows field-level personnel, who are closest to the public, to input their knowledge. It is recommended that each team also have one central-office member with equal voting rights. Implementing the process in this way allows it to become the district's/region's program, in which the central office provides an overview.

As has been mentioned in earlier chapters, care must be taken to ensure accurate results, both agencywide and over time. Toward this end, it is important that the original LOS criteria be verified as the desired or target level **before** implementation is complete. Although some deviations in LOS criteria can be tolerated during the first 18 to 24 months, any changes made to the criteria beyond this period should be made with extreme care. In allowing last year's poor ratings to become next year's good ratings (via slackening LOS criteria)—especially if no actual changes occurred in the field—the ability to track real improvements over time is lost.

Before instituting a change in LOS criteria, it is highly recommended that the overall effect of the change be investigated. This can be done by comparing the approximate agencywide rating based on actual data with approximate agencywide ratings generated as a result of the proposed changes in LOS criteria. Tables 24 and 25 illustrate such an investigation, in which changes in the LOS criterion for the rutting characteristic are the focus.

In this example, the approximate rating for the traveled roadway element is first calculated for three different scenarios. The first scenario represents the actual current results, given that 522 of the 672 total segments inspected received passing ratings. The second scenario represents the projected results if the LOS criteria for rutting were so stringent that none of the 672 segments could receive passing ratings. The third scenario represents the projected results if the LOS criteria for rutting were so lax that all of the 672 segments could meet the desired standards. For each scenario, the approximate element rating is calculated as follows:

1. For each characteristic, separately multiply the characteristic weighting ($W_{F/C}$) by the number of passing sites and by the total number of sites to produce passing points and total points.
2. For all characteristics, individually sum the passing points and the total points to give overall passing points and overall total points for the element.
3. Divide the overall passing points by the overall total points to give the approximate element rating.

Next, the approximate ratings based on actual data are calculated for the remaining maintenance elements. Each of the approximate element ratings is multiplied by the corresponding element weightings (W_E), and the resulting element points are summed to produce the approximate agencywide rating, as demonstrated in Table 25. In this example, the maximum effects of changing the LOS criterion for rutting are for the approximate element ratings to decrease from 86.6 to 75.0 or to increase from 86.6 to 89.9. Subsequently, the approximate agencywide ratings either drop from 81.8 to 78.9 (scenario 1 → scenario 2) or jump from 81.8 to 82.6 (scenario 1 → scenario 3).

This type of analysis can be conducted on an annual basis, as deemed necessary by the implementing agency. It is suggested that no more than 2 features/characteristics per element be considered for LOS criteria changes in any given year, to maintain consistent trends over time. Moreover, it is recommended that the maximum allowable change in

TABLE 24 Calculation of approximate traveled roadway element ratings for three LOS criteria scenarios

Characteristic	Scenario 1-Actual		Scenario 2-Tightened LOS Criteria		Scenario 3-Slackened LOS Criteria	
	Segment Count (Passing/Total)	Points (Passing/Total)	Segment Count (Passing/Total)	Points (Passing/Total)	Segment Count (Passing/Total)	Points (Passing/Total)
Potholes ($W_{F/C}$=9)	815/838	7,335/7,542	815/838	7,335/7,542	815/838	7,335/7,542
Joints ($W_{F/C}$=8)	173/173	1,384/1,384	173/173	1,384/1,384	173/173	1,384/1,384
Pavement Voids ($W_{F/C}$=8)	171/171	1,368/1,368	171/171	1,368/1,368	171/171	1,368/1,368
Edge Raveling ($W_{F/C}$=5)	426/426	2,130/2,130	426/426	2,130/2,130	426/426	2,130/2,130
Rutting ($W_{F/C}$=8)	522/672	4,176/5,376	0/672	0/5,376	672/672	5,376/5,376
Cracking ($W_{F/C}$=7)	551/836	3,857/5,852	551/836	3,857/5,852	551/836	3,857/5,852
Depression ($W_{F/C}$=6)	685/838	4,110/5,028	685/838	4,110/5,028	685/838	4,110/5,028
Stripping ($W_{F/C}$=3)	640/673	1,920/2,019	640/673	1,920/2,019	640/673	1,920/2,019
Shoving ($W_{F/C}$=5)	671/673	3,355/3,365	671/673	3,355/3,365	671/673	3,355/3,365
Paved Shoulder ($W_{F/C}$=5)	300/381	1,500/1,905	300/381	1,500/1,905	300/381	1,500/1,905
Approximate Element Rating		31,135/35,969 = 0.866 (86.6%)		26,959/35,969 = 0.750 (75.0%)		32,335/35,969 = 0.899 (89.9%)

approximate element ratings, as a consequence of changing the LOS criteria for 1 or 2 features/characteristics, be 1 percentage point, because this will ensure adequate stability of LOS trends over time. Thus, in the above example, LOS criteria changes associated with scenario 2 (where all segments failed) would be unacceptable, whereas the changes associated with scenario 3 (where all segments passed) would be acceptable.

The information generated by a successful LOS rating system can be combined with information contained in an MMS or accounting system to generate a fiscal/financial quality picture of the agency's maintenance program, as was done by the Florida DOT. A fiscal/financial quality summary report, like the ones depicted in Tables 26 and 27, presents many opportunities for changes in the next planning cycle. Specifically, this type of information enables an agency to accomplish the following:

- Revise its planning and prediction techniques.
- Investigate specific areas or conditions that may have contributed to the end results achieved.
- Move resources, as required, to obtain a proper ratings balance (i.e., more uniform maintenance).

As can be observed in the last row of Table 26, $88 million of the $125 million estimated need for FY 1991–1992 was expended on the MRP activities shown, and the annual agencywide LOS (designated MRP 80 rating) increased from 73 in FY 1990–1991 to 74 in FY 1991–1992. Similarly, in Table 27, $129 million of the $149 million allocated for FY 1995–1996 was expended, and the annual agencywide LOS (designated MRP 80 rating) increased from 83 in FY 1994–1995 to 84 in FY 1995–1996. With its target LOS set at 80, Florida has been able to monitor more closely the quality of and spending for network and individual work activities. By performing this

TABLE 25 Calculation of approximate agencywide ratings for three LOS criteria scenarios

Maintenance Element	Scenario 1-Actual		Scenario 2-Tightened LOS Criteria		Scenario 3-Slackened LOS Criteria	
	Approximate Rating	Element Points	Approximate Rating	Element Points	Approximate Rating	Element Points
Traveled Roadway (W_E=0.25)	86.6%	21.7%	75.0%	18.8%	89.9%	22.5%
Roadside (W_E=0.14)	85.3%	11.9%	85.3%	11.9%	85.3%	11.9%
Traffic Services (W_E=0.27)	69.9%	18.9%	69.9%	18.9%	69.9%	18.9%
Drainage (W_E=0.15)	90.9%	13.6%	90.9%	13.6%	90.9%	13.6%
Vegetation/Aesthetics (W_E=0.19)	82.8%	15.7%	82.8%	15.7%	82.8%	15.7%
Approximate Agencywide Rating		81.8%		78.9%		82.6%

TABLE 26 Florida maintenance allocation versus expenditure—FY 1991–1992 (Florida DOT 1992)

ACTIVITY	DESCRIPTION	ALLOCATION	TOTAL DOLLARS EXPENDED	DIFFERENCE BETWEEN EXPENDED & ALLOCATED	PERCENT EXPENDED VERSUS ALLOCATED	ANNUAL 1990/91 MRP 80 RATING	ANNUAL 1991/92 MRP 80 RATING
411	Plant Mix Patching (Manual)	$4,100,206	$4,788,632	($688,426)	116.79%	94	96
412	Plant Mix Patching (Mech.)	$2,935,879	$2,216,699	$719,180	75.50%	88	88
414	Base Repair	$1,268,581	$811,328	$457,253	53.96%		
421	Slabjacking	$523,458	$262,562	$260,896	50.16%	88	87
423	Concrete Pavement Joint Repair	$1,353,738	$50,651	$1,303,087	3.74%	69	63
424	Concrete Slope Pavt. Joint Repair	$1,631,221	$72,529	$1,558,692	4.45%		
425	Concrete Pavement Surface Repair	$1,165,355	$76,564	$1,088,791	6.57%	86	86
431	Motor Grader Operation	$382,728	$178,584	$204,144	46.66%		
432	Rep N-paved Shld, Slopes, Ditches (Man)	$6,276,313	$2,076,597	$4,199,716	33.09%	66	69
433	Sodding	$5,292,394	$430,409	$4,861,985	8.13%	25	26
435	Seeding, Fertilizing, and Mulching	$10,551,663	$1,416,103	$9,135,560	13.42%	25	26
436	Reworking Shoulders	$4,884,414	$4,976,359	($91,945)	101.88%	59	63
437	Misc. Slope and Ditch Repair	$1,826,607	$860,479	$966,128	47.11%	87	88
451	Clean Dra Str (Mech)	$1,510,641	$674,602	$836,039	44.66%	69	71
454	Clean Dra Str (Man)	$1,060,166	$641,853	$418,313	60.54%	69	71
456	Repair or Replace Storm Dr., Side Dr., X-Dr.	$1,995,656	$643,517	$1,352,139	32.25%	74	79
457	Concrete Repair	$1,396,821	$1,263,172	$133,649	90.43%	64	64
459	Concrete Sidewalk Repair	$4,377,042	$2,021,958	$2,355,084	46.19%	33	38
461	Roadside Ditches - Clean & Reshape (Mech)	$4,278,859	$2,418,953	$1,859,906	56.53%	95	95
462	Outfall and Roadside Ditches - Clean & Repair (Man)	$582,363	$874,812	($292,449)	150.22%	81	88
463	Outfall Ditches Clean & Repair (Mech-Haul)	$521,589	$249,435	$272,154	47.82%	81	88
464	Outfall Ditches Clean & Repair (Mech-Spread)	$541,397	$226,044	$315,353	41.75%	81	88
471	Large Machine Mowing	$5,704,694	$7,155,129	($1,450,435)	125.43%	82	81
482	Slope Mowing	$829,333	$708,015	$121,318	85.37%	70	74
484	Intermediate Machine Mowing	$997,365	$934,339	$63,026	93.68%	82	81
485	Small Machine Mowing	$1,066,089	$1,089,094	($23,005)	102.16%	82	81
487	Weed Control (Manual)	$266,524	$1,374,141	($1,107,617)	515.58%	82	81
488	Weed Control (Mech)	$1,832,289	$1,606,574	$225,715	87.68%	82	81
489	Wildflowers	$185,086	$107,285	$77,801	57.97%		
490	Fertilizing - Bulk	$1,104,796	$900,430	$204,366	81.50%	25	26
491	Fertilizing	$2,046,414	$64,473	$1,981,941	3.15%	25	26
492	Tree Trimming and Removal	$1,470,595	$2,155,026	($684,431)	146.54%	66	71
493	Landscape Area Maintenance	$1,020,669	$1,059,213	($38,544)	103.78%	78	79
494	Chemical Weed and Grass Control (Mech)	$2,186,402	$2,239,196	($52,794)	102.41%	25	26
495	Chemical Weed and Grass Control (Man)	$26,007	$200,489	($174,482)	770.89%	25	26
496	Selective Weeding (Wiping) Large Machines	$838,058	$17,119	$820,939	2.04%	25	26
497	Selective Weeding (Broadcast)	$1,365,039	$1,154,908	$210,131	84.61%	25	26
520	Signs (Ground Signs 30 sf or less)	$4,458,157	$5,520,372	($1,062,215)	123.83%	59	61
521	Signs (Ground Signs over 30 sf & All Overlane)	$281,992	$638,719	($356,727)	226.50%	63	65
522	Sign Cleaning	$311,521	$66,247	$245,274	21.27%	59	61
526	Guardrail Repair	$2,907,936	$2,148,900	$759,036	73.90%	51	58
527	Fence Repair	$2,341,219	$1,019,511	$1,321,708	43.55%	92	93
530	Attenuator Inspect. & Serv.	$330,148	$220,670	$109,478	66.84%	86	92
531	Attenuator Repair	$1,460,764	$528,013	$932,751	36.15%	86	92
532	Pavement Striping (Large Machine)	$8,540,384	$5,888,590	$2,651,794	68.95%	54	54
533	Line and Symbol Removal	$272,837	$226,980	$45,857	83.19%	61	66
534	Pavement Marking (Small Machine)	$2,948,281	$3,300,209	($351,928)	111.94%	61	66
537	Raised Pavement Marker Replacement	$3,046,818	$2,373,052	$673,766	77.89%	61	67
540	Graffiti Removal	$78,405	$164,443	($86,038)	209.73%		
541	Roadside Litter Removal	$4,010,116	$5,138,120	($1,128,004)	128.13%	88	91
542	Road Sweeping (Manual)	$308,650	$165,258	$143,392	53.54%	79	82
543	Road Sweeping (Mech.)	$3,154,339	$2,141,963	$1,012,376	67.91%	79	82
544	Rest Area Maintenance	$5,334,568	$5,878,879	($544,311)	110.20%		
545	Edging and Sweeping	$1,896,330	$1,746,042	$150,288	92.07%	79	82
787	Highway Lighting Maintenance	$4,707,976	$3,255,077	$1,452,899	69.14%	70	72
Total		$125,786,893	$88,418,318	$37,368,575	70.29%	73	74

TABLE 27 Florida maintenance allocation versus expenditure—FY 1995–1996 (Florida DOT 1996)

ACTIVITY	DESCRIPTION	ALLOCATION	TOTAL DOLLARS EXPENDED	DIFFERENCE BETWEEN EXPENDED & ALLOCATED	PERCENT EXPENDED VERSUS ALLOCATED	ANNUAL 1994/95 MRP 80 RATING	ANNUAL 1995/96 MRP 80 RATING
411	Plant Mix Patching (Manual)	$5,361,085	$5,145,406	$215,678	95.98%	92	95
412	Plant Mix Patching (Mech.)	$2,722,384	$1,644,839	$1,077,545	60.42%	92	96
414	Base Repair	$1,254,202	$467,930	$786,273	37.31%	92	96
421	Slabjacking	$635,003	$373,002	$262,001	58.74%	95	85
423	Concrete Pavement Joint Repair	$1,092,894	$130,377	$962,516	11.93%	79	90
424	Concrete Slope Pavt. Joint Repair	$512,513	$360,504	$152,009	70.34%		
425	Concrete Pavement Surface Repair	$354,198	$453,457	($99,259)	128.02%	89	93
431	Motor Grader Operation	$423,035	$81,089	$341,946	19.17%		
432	Rep N-paved Shld, Slopes, Ditches (Man)	$7,072,654	$2,089,603	$4,983,051	29.54%	80	77
433	Sodding	$1,993,662	$2,140,102	($146,440)	107.35%	88	86
435	Seeding, Fertilizing and Mulching	$3,383,413	$1,199,255	$2,184,157	35.45%	88	86
436	Reworking Shoulders	$7,708,242	$5,997,027	$1,711,215	77.8%	77	77
437	Misc. Slope and Ditch Repair	$2,519,038	$1,995,136	$523,902	79.2%	77	73
451	Clean Dra Str	$1,404,728	$2,110,992	($706,264)	150.28%	86	83
456	Repair or Replace Storm Dr., Side Dr., X-Dr	$2,174,568	$1,213,068	$961,500	55.78%	89	85
457	Concrete Repair	$865,889	$2,757,938	($1,892,049)	318.51%	84	82
459	Concrete sidewalk Repair	$3,869,028	$2,673,212	$1,195,816	69.09%	92	92
461	Roadside ditches - Clean & Reshape	$4,827,934	$4,031,429	$796,505	83.5%	95	91
464	Outfall Ditches Clean & Repair	$923,327	$640,722	$282,605	69.39%	95	89
471	Large Machine Mowing	$8,689,359	$9,050,085	($360,726)	104.15%	88	88
482	Slope Mowing	$3,576,439	$2,729,355	$847,083	76.31%	88	85
484	Intermediate Machine Mowing	$1,298,367	$1,107,738	$190,629	85.32%	88	88
485	Small Machine Mowing	$1,340,390	$2,578,727	($1,238,338)	192.39%	88	88
487	Weed Control (Manual)	$992,782	$4,706,860	($3,714,078)	474.11%	88	87
489	Wildflowers	$299,825	$119,095	$180,730	39.72%		
490	Fertilizing	$2,697,139	$1,662,910	$1,034,228	61.65%	88	86
492	Tree Trimming and Removal	$2,419,532	$7,297,773	($4,878,241)	301.62%	71	71
493	Landscape Area Maintenance	$2,422,331	$687,785	$1,734,545	28.39%	86	78
494	Chemical Weed and Grass Control	$2,469,448	$2,263,700	$205,748	91.67%	81	81
497	Chemical Weed and Grass Control Selective Weeding	$506,845	$111,140	$395,705	21.93%	88	87
519	Delineators	$1,093,131	$1,297,697	($204,566)	118.71%	76	79
520	Signs (Ground Signs 30 sf or less)	$5,753,445	$7,721,020	($1,967,575)	134.20%	77	73
521	Signs (Ground Signs over 30 sf and all overlane	$975,401	$2,330,371	($1,354,970)	238.91%	78	93
522	Sign Cleaning	$359,529	$104,706	$254,822	29.12%	78	77
526	Guardrail Repair	$2,361,775	$3,686,306	($1,324,531)	156.08%	72	76
527	Fence Repair	$3,153,101	$1,993,194	$1,159,907	63.21%	95	95
530	Attenuator Inspect. & Serv.	$1,013,306	$486,154	$527,152	47.98%	90	96
531	Attenuator Repair	$2,153,143	$1,145,290	$1,007,853	53.19%	90	96
532	Pavement Striping (Large Machine)	$15,612,867	$8,699,043	$6,913,825	55.72%	74	86
534	Pavement Marking (Small Machine)	$6,676,638	$4,607,052	$2,069,586	69.00%	80	86
537	Raised Pavement Marker Replacement	$4,478,191	$2,287,856	$2,190,335	51.09%	78	79
540	Graffiti Removal	$106,955	$427,569	($320,614)	399.76%		
541	Roadside Litter Removal	$7,158,885	$7,842,720	($683,834)	109.55%	96	97
542	Road Sweeping (Manual)	$248,794	$205,764	$43,030	82.70%	87	88
543	Road Sweeping (Mech.)	$4,757,058	$3,643,874	$1,113,184	76.60%	87	88
544	Rest Area Maintenance	$8,689,102	$6,937,557	$1,751,545	79.84%		
545	Edging and Sweeping	$2,713,758	$3,433,098	($719,341)	126.51%	54	64
787	Highway Lighting Maintenance	$6,081,101	$4,882,012	$1,199,089	80.28%	72	73
Total		$149,196,431	$129,551,542	$19,644,889	86.83%	83	84

type of exercise, an implementing agency can minimize many critical comments, strengthen the credibility of the data presented, and greatly increase the chances for the success of the QA program.

WORKLOAD PREDICTION

Component #20 Objective: To develop an estimate of the annual workload expected for each maintenance activity using converted inventory techniques.

Knowing where an agency is in achieving a defined LOS is a major step in the management of the tremendous investment the taxpayers have made in their highway and bridge system. The next step in having a complete process is to estimate how much work is required to produce the desired LOS.

It was recommended in Chapter 1 that an agency have an inventory of highway maintenance features that would serve as a basis for estimating predicted workloads. Several agencies are in the process of developing Geographic Information System (GIS) databases using automated data collection techniques for many of the inventory features. These techniques use multiple video cameras and GPS receivers (for latitude and longitude) to collect inventory features at highway speeds. Not only does this provide a permanent baseline concerning highway conditions (including pavement), but it enables an agency to review the data safely at a work station instead of having survey crews in the field. Regardless of the degree of sophistication an agency uses, converting an inventory to a workload can be accomplished using the technique described below.

Converting the inventory requires the development of a formula for each desired maintenance feature. Figure 19 is a sample of Florida's formula for estimating the guardrail repair workload. The area represented by the inventory may be as small or as large as necessary (for a county, maintenance unit, district, or statewide) depending on the planned usage of the data. It should be noted that Florida has chosen to make predictions at the maintenance-unit level, which are used to distribute resources (see section, "Distribution of Resources," presented later in this chapter). The larger the area represented by the inventory, the more accurate the prediction will be.

The factors shown in Figure 19 were derived from past history of guardrail damages that required repairs. When completed, the annual workload calculation should approximate the total amount (in linear ft) of work done by state forces or contractors during a 1-yr period (providing the desired LOS has been achieved, otherwise this estimate must be increased or decreased). The "planning value" is the estimated amount of repair work that can be accomplished by a guardrail repair crew (in this case, a 4-person crew) in an 8-hr day. Care should be taken not to violate Deming's tenth point, *Eliminate numerical goals, posters, and slogans for the work force, asking for new levels of productivity without providing methods.*

This type of workload prediction process lends itself to being automated by programming a computer database to do the annual workload calculation using the formulas provided. Table 28 shows a sample printout of the annual estimate for several work activities performed by the Florida DOT.

In this table, the total workload is the complete inventory, whereas the annual workload is the amount of that total inventory that is estimated to require work in the next year. For instance, for guardrail repair, the annual workload is estimated to be less than 3 percent of the total inventory, yet for small machine mowing the annual workload is 700 percent of the total inventory. This simply means that only a small portion of the existing guardrail is estimated to be damaged each year, but the entire acreage of small machine mowing is expected to be mowed 7 times.

It should be emphasized that the percentage of work must be adjusted for each of the four maintenance priorities, as shown in Table 17. For guardrail repair, this is fairly easy because all work is considered as safety; however, for large machine mowing, the percentage must be divided into its respective priorities (15 percent for safety, 55 percent for preservation of investment, 10 percent for comfort and convenience, and 20 percent for aesthetics; see Table 17). By dividing the planning value for guardrail (70.35 linear ft/8-hr day [21.45 linear m/8-hr day]) into the number of estimated feet requiring repair (40,401 ft [12,322 m]), an estimate of 574 crew-days is obtained (40,401 ft/70.35 ft = 574 [12,322 m/21.45 m = 574]). Then, by dividing the 574 crew-days by 5 (i.e., 5 crew-days/week), the number of weeks required for the activity is calculated to be 115 (574/5 = 115).

RCI CONVERTED INVENTORY FORMULA
MMS STANDARD 526
GUARDRAIL REPAIR

Unit = Linear Feet

TOTAL WORKLOAD = (Length of Standard Guardrail + Length of Miscellaneous Guardrail + Length of Double-Faced Guardrail) × 5280

ANNUAL WORKLOAD = [(((Length of Standard Guardrail) + (Length of Miscellaneous Guardrail) + (Length of Double-Faced Guardrail × 1.3)) × (0.042 for roadways with ADT ≥ 10,000/lane-mile))) + (((Length of Standard Guardrail) + (Length of Miscellaneous Guardrail) + (Length of Double-Faced Guardrail × 1.3)) × (0.017 for roadways with ADT < 10,000/lane-mile)))] × 5280

FACTORS:	5280	=	Converts miles to feet.
	0.042	=	Equivalent to 220 feet/mile for urban.
	0.017	=	Equivalent to 90 feet/mile for rural.
	1.3	=	Work effort for double-faced guardrail is 1.3 times that of single-face guardrail.
NOTES:	RCI	=	From feature 271 (STDGRAIL, SPCGRAIL, AND DBLGRAIL)

PLANNING VALUE = 70.35 linear feet/8-hr day

RCI = Roadway characteristics inventory. 1 ft = 0.305 m 1 mi = 1.61 km

Figure 19. Example of converted inventory formula for guardrail repair (Florida DOT 1992).

TABLE 28 Florida DOT converted RCI (Florida DOT 1992)

District	Area No-Name	Road System	Unique Model No.	Rural/Urban	Model Type	No Lanes	Co No-Name	Section
		All	All	All	All	All	87 Dade	All

ACT NO.	ACTIVITY DESCRIPTION	ACTIVITY TYPE	TOTAL WORKLOAD	ANNUAL WORKLOAD	UNIT OF MEASURE	WEEKS REQ'D	REMARKS
484	Inter Machine Mowing	R/U	1,016	7,115	Acres	365	RCI Generated Workload
485	Small Machine Mowing	R/U	733	5,132	Acres	546	RCI Generated Workload
487	Weed Control-Manual	R/U	178	712	Acres	81	RCI Generated Workload
489	Wildflowers	R/U	97	97	Acres	9	RCI Generated Workload
490	Fertilizing	R/U	748	748	Tons	14	RCI Generated Workload
492	Tree Trim and Remove	R/U	6,276	6,276	ManHour	46	RCI Generated Workload
493	Landscape Area Maint	R/U	602,822	2,411,288	Sq Yd	705	RCI Generated Workload
494	Chem Weed Control	R/U	112,811	225,622	Gals	163	RCI Generated Workload
497	Chem Weed-Brdcst/Wip	R/U	4,853	2,426	Acres	10	RCI Generated Workload
519	Delineators	R/U	17,084	8,542	Units	29	RCI Generated Workload
520	Sign-Grnd-LT 30 sq ft	R/U	41,602	31,201	Units	283	RCI Generated Workload
521	Signs-Overlane-GT 30 sq ft	R/U	8,285	2,071	Units	38	RCI Generated Workload
522	Sign Cleaning	R/U	32,086	32,086	Units	47	RCI Generated Workload
526	Guardrail Repair	R/U	1,411,172	40,401	Ft	115	RCI Generated Workload
527	Fence Repair	R/U	1,509,097	78,668	Ft	86	RCI Generated Workload
530	Atten Inspec & Serv	R/U	203	2,436	Each	156	RCI Generated Workload
531	Attenuator Repair	R/U	203	609	Each	33	RCI Generated Workload
532	Pavt Striping-Large	R/U	3,242	3,942	Lane Mi	59	RCI Generated Workload
534	Pavement Symbols	R/U	890,405	690,904	Sq Ft	216	RCI Generated Workload
537	RPM Replacement	R/U	396,452	135,334	Each	105	RCI Generated Workload
540	Graffiti Removal	R/U	58,471	58,471	Sq Ft	35	RCI Generated Workload

R/U = Rural/urban 1 ton = 1.10 Mton 1 ft = 0.305 m 1 acre = 4,047 m^2
1 gal = 3.785 L 1 yd^2 = 0.84 m^2

ACTIVITY COST DETERMINATION

Component #21 Objective: To develop a budgetary unit cost for each maintenance activity and compute the total monetary need for the activity, based on the estimated annual workload and budgetary unit cost.

Once the workload determination has been completed, developing a cost for each activity is required to estimate budget requirements. This can be done using historic cost data or by developing "engineered cost." Figure 20 shows how the engineered unit cost for guardrail repair is calculated by the Florida DOT. The advantage to using an engineered cost is that many times crews do not use standard methods in making repairs, which may cause actual cost data to be different—in many instances, greater—than if a standard crew and equipment were used.

A sample summary of Florida's proposed 1995–1996 unit prices for various maintenance activities is provided in Table 29. In this example, the proposed 1995–1996 unit prices are calculated by first multiplying the engineered unit price by the percent estimated to be accomplished by in-house forces, then adding the product of the contract unit price and the percent estimated to be accomplished by contract, and finally dividing by 100. Significant differences in the estimated unit prices for agency and contract forces are likely due to imbalances in the type of work being assigned (e.g., mowing on rural interstate right of way is contracted, whereas the more difficult to contract urban arterial system is done in-house). By combining these elements onto a single sheet, the total needs can be determined, as illustrated in Table 30. This table represents many of the routine maintenance activities performed in Florida.

ESTIMATE TO ACHIEVE TARGET LOS

Component #22 Objective: To evaluate the effects of various funding levels on predicted LOS.

To the dismay of most top management officials in a governmental agency, what appear to be minor budget cuts generally have a significant effect on the performance of routine maintenance. This is because activities and costs associated with fixed obligations (e.g., bridge tending, utility bills) often cannot be reduced until many routine activities (e.g., mowing, litter pickup, landscape) are significantly reduced or stopped entirely.

Table 31 helps illustrate this point. The total estimated expenditures in Florida for FY 1995–1996 consisted of $129,406,930 (46.8 percent) in fixed obligations and $147,343,581 (53.2 percent) in routine maintenance. A 5 percent

LABOR:	1 HMTS	=	$12.74/hr × 8 hr	=	$101.92
	3 HMT 1	=	$9.35/hr × 8 hr	=	$224.40
	Daily Cost			=	$326.32
Labor Cost Per Foot		=	$326.32/70.35	=	$4.64
EQUIPMENT:	One 2-ton Crew Cab				
	Avg Daily Util.	=	71 mi × $0.41	=	$29.11
	Daily Rental Rate			=	$18.05
	Daily Cost			=	$47.16
Equip Cost Per Foot		=	$47.16/70.35	=	$0.67
MATERIALS:	1 lin ft of Guardrail			=	$1.99
	Miscellaneous Hardware Per Foot			=	$0.70
	Guardrail Post Per Foot			=	$0.52
Material Cost Per Foot				=	$3.21
Total Cost to Maintain Guardrail Per Foot				=	**$8.52**

HMTS = Highway maintenance technician supervisor
HMT = Highway maintenance technician

1 ft = 0.305 m
1 ton = 1 Mton

Figure 20. Example of the development of engineered unit cost for guardrail repair (Florida DOT 1992).

reduction in total expenditures of the maintenance budget equates to $13,837,525 ($276,750,511 × 0.05 = $13,837,525). If the routine maintenance budget were to incur this entire cut amount, the real reduction in funding for routine maintenance would be 9.4 percent ($13,837,525/$147,343,581 × 100% = 9.4%).

The summary table given in Table 31 can be used by an implementing agency in formulating a budget request based on a predetermined LOS. When expressed as a pro-rata share of the routine maintenance portion, the end result LOS rating can be estimated according to a specific budget reduction scenario. For instance, in the example described above, the effect of a 9.4 percent reduction can be calculated as follows:

$$\text{Estimated LOS} = \text{Target LOS } 80 \times [(\$147{,}343{,}581 - \$13{,}837{,}525)/\$147{,}343{,}581] = 72.5$$

Knowing the predicted consequences of LOS for a given funding level will tend to make budget reductions less palatable for many budget managers; therefore, these managers are less likely to reduce funding once they know the end results. This process is a reinforcement of Deming's fourth point, *End the practice of awarding business on the basis of price tag.* It should be noted, however, that routine maintenance funding variations (either up or down) will not show up immediately but will be reflected in the LOS ratings within 9 to 12 months following the changes. This is due to the large workload within an agency, the long lead time for features to deteriorate, and the time it takes to improve enough of it to be reflected in the LOS ratings.

DISTRIBUTION OF RESOURCES

Component #23 Objective: To balance the availability of resources among locations in accordance with workloads.

Agencies that have progressed to the point of being able to do workload predictions and some form of needs-based budget requests should now be able to balance resources in accordance with their identified needs. Balancing resources will enable an agency to provide the desired LOS to its customers through reductions in activities that are in excess of the established target and increases in activities that are deficient.

Using the total estimated workload, as previously described in the "Workload Prediction" section of this chapter, enables resources (personnel, equipment, materials, inmate labor, funding for maintenance contracts) to be assigned to accomplish identified workloads. One of the simplest ways of developing the proper balance of each type of resource within a location is to express all workloads in "dollar equivalents" and let each location establish the resource balance best suited for its specific conditions.

This approach is perhaps best illustrated by Table 32, which is a maintenance needs summary for a district in Florida. As can be seen in this table, the dollar subtotals for each of the resources are given, with "Salaries and Benefits" representing personnel, "Pay CSS" (Central Support Services) representing equipment, and "TM & E" (Transportation Materials and Equipment) representing materials. Since this is an estimate of the resources required to produce a specific LOS, what actually exists within the district may be

TABLE 29 **Proposed 1995–1996 unit prices for Florida maintenance activities (Florida DOT 1996)**

				BASED ON REPORTED 92/93 INFORMATION		PROPOSED 95–96 UNIT PRICES
ACTIVITY NUMBER	DESCRIPTION	UNIT	ENGINEERED UNIT PRICES	CONTRACT UNIT PRICES, $	PERCENT [a] CONTRACTED	
411	Plant Mix Patching (Manual)	tons	$177.72	—	0.00%	$177.72
412	Plant Mix Patching (Mech.)	tons	$84.27	43.05	40.00%	$67.78
414	Base Repair	tons	$40.82	59.27	60.00%	$51.89
421	Pressure Grouting	cubic ft.	$16.92	—	0.00%	$16.92
423	Concrete Pavement Joint Repair	linear ft.	$0.93	—	0.00%	$0.93
424	Concrete Slope Pavt. Joint Repair	linear ft.	$0.70	—	0.00%	$0.70
425	Concrete Pavement Surface Repair	sq. ft.	$18.08	12.50	95.00%	$12.78
431	Motor Grader Operation	shoulder mi.	$55.69	—	0.00%	$55.69
432	Rep N-paved Shld, Slopes, Ditches (Man)	sq. yd.	$2.35	—	0.00%	$2.35
433	Sodding	sq. yd.	$3.67	1.82	35.00%	$3.02
435	Seeding, Fertilizing and Mulching	acres	$287.95	—	0.00%	$287.95
436	Reworking Shoulders	acres	$594.68	—	0.00%	$594.68
437	Misc. Slope and Ditch Repair	cu. yd.	$12.48	—	0.00%	$12.48
451	Clean Dra Str	lin. ft.	$2.32	2.63	15.00%	$2.37
456	Repair or Replace Storm Dr., Side Dr., X-Dr.	lin. ft.	$33.29	—	0.00%	$33.29
457	Concrete Repair	cu. yd.	$269.88	220.50	15.00%	$262.47
459	Concrete Sidewalk Repair	sq. yd.	$53.41	20.98	75.00%	$29.09
461	Roadside Ditches - Clean & Reshape	lin. ft.	$2.15	1.41	5.00%	$2.11
464	Outfall Ditches Clean & Repair	lin. ft.	$2.73	—	0.00%	$2.73
465	Mitigation Area Maintenance	acres	$19.32	—	0.00%	$19.32
471	Large Machine Mowing	acres	$15.88	11.36	50.00%	$13.62
482	Slope Mowing (LGG Tractor)	acres	$135.82	106.40	50.00%	$121.11
484	Intermediate Machine Mowing	acres	$63.51	69.70	20.00%	$64.75
485	Small Machine Mowing	acres	$110.61	124.32	70.00%	$120.21
487	Weed Control (Manual)	acres	$240.45	—	0.00%	$240.45
489	Wildflowers	acres	$212.01	—	0.00%	$212.01
490	Fertilizing - Bulk	acres	$227.29	204.32	75.00%	$210.06
492	Tree Trimming and Removal	manhour	$24.00	27.72	10.00%	$24.37
493	Landscape Area Maintenance	sq. yd.	$0.56	—	0.00%	$0.56
494	Chemical Weed and Grass Control (Mech)	gals	$1.98	1.40	50.00%	$1.95
497	Selective Weeding (Broadcast)	acres	$11.78	—	0.00%	$11.78
519	Delineators	units	$3.70	—	0.00%	$3.70
520	Signs (Ground Signs 30 sf or less)	units	$21.78	—	0.00%	$21.78
521	Signs (Ground Signs over 30 sf and all Overlane	units	$70.68	431.54	5.00%	$88.72
522	Sign Cleaning	units	$1.38	—	0.00%	$1.38
526	Guardrail Repair	lin. ft.	$8.48	6.14	30.00%	$7.78
527	Fence Repair	lin. ft.	$2.97	4.37	50.00%	$3.04
530	Attenuator Inspect. & Serv.	each	$85.99	—	0.00%	$85.99
531	Attenuator Repair	each	$625.85	1150.93	20.00%	$730.87
532	Pavement Striping (Large Machine)	line mi.	$192.91	— [b]	15.00%	$192.91
534	Pavement Marking (Small Machine)	sq. ft.	$0.97	1.06	40.00%	$1.01
537	Raised Pavement Marker Replacement	each	$2.79	2.80	80.00%	$2.80
540	Graffiti Removal	sq. ft.	$0.74	0.56	50.00%	$0.65
541	Roadside Litter Removal	cu. yd.	$50.40	— [b]	35.00%	$50.40
542	Road Sweeping (Manual)	curb mi.	$238.16	—	0.00%	$238.16
543	Road Sweeping (Mech.)	curb mi.	$40.33	47.25	65.00%	$44.83
545	Edging and Sweeping	edge mi.	$434.21	336.00	30.00%	$404.75
781	Weight Station Maintenance	units	$8.54	—	0.00%	$8.54
805	Bridge Joint Repair	lin. ft.	$6.13	— [b]	15.00%	$6.13
806	Bridge Deck Maintenance and Repair	sq. ft.	$17.04	—	0.00%	$17.04
810	Bridge Handrail Maintenance and Repair	lin. ft.	$22.70	—	0.00%	$22.70
825	Superstructure Maintenance and Repair	units	$20.04	— [b]	10.00%	$20.04
845	Substructure Maintenance and Repair	units	$18.33	—	0.00%	$18.33
859	Channel Maintenance	units	$13.73	—	0.00%	$13.73
861	Routine Bridge Electrical Maintenance	units	$21.59	—	0.00%	$21.59
865	Routine Bridge Mechanical Maintenance	units	$20.42	—	0.00%	$20.42
869	Movable Bridge Structural Maintenance	units	$16.50	—	0.00%	$16.50
896	Ferry Slip Maintenance and Repair	units	$16.11	—	0.00%	$16.11

[a] Excludes Memorandum of Agreement (MOA) and Department of Corrections (DC) information.
[b] Type of work performed by contract or units reported not comparable to in-house activity.
1 yd^2 = 0.837 m^2

1 ton = 1.10 Mton
1 ft = 0.305 m
1 acre = 4,047 m^2
1 gal = 3.785 L

TABLE 30 Florida DOT's FY 1995–1996 maintenance budget needs (Florida DOT 1996)

Activity Number	Description	Unit of Measure	Annual RCI Workload Units	Annual MRP 80 Workload Units	Salaries & Benefits, $unit	Equipment, $unit	Materials, $unit	Total Needs, $
519	Delineators	units	125,377	97,167	4.27	0.98	6.00	1,093,130.72
520	Signs (Ground Signs 30 sf or less)	units	340,854	264,162	8.54	5.62	7.62	5,753,445.09
521	Signs (Ground Signs over 30 sf and all Overlane)	units	14,186	10,994	38.89	13.07	36.76	975,400.99
522	Sign Cleaning	units	260,528	260,528	1.17	0.21	0.00	359,528.64
526	Guardrail Repair	lin. ft.	303,570	303,570	4.22	0.61	2.95	2,361,774.60
530	Attenuator Inspect. & Serv.	each	11,784	11,784	56.69	15.07	14.23	1,013,306.16
531	Attenuator Repair	each	2,946	2,946	102.91	14.85	613.11	2,153,143.02
532	Pavement Striping (Large Machine)	lane mi.	52,408	52,408	38.81	14.10	245.00	15,612,867.28
534	Pavement Symbols	sq. ft.	5,257,195	5,257,195	0.56	0.11	0.60	6,676,637.65
537	Raised Pavement Marker Replacement	each	1,599,354	1,599,354	1.25	0.30	1.25	4,478,191.20
Group Total								39,384,294.63
437	Misc. Slope and Ditch Repair	cu. yd.	201,846	201,846	5.88	6.01	0.59	2,519,038.08
451	Clean Drainage Structures	lin. ft.	911,865	592,712	1.40	0.97	0.00	1,404,728.03
456	Repair or Replace Storm Dr, Side Dr, X-Dr	lin. ft.	66,951	66,951	15.37	11.01	6.10	2,174,568.48
457	Concrete Repair	cu. yd.	3,299	3,299	151.51	68.85	42.11	865,888.53
461	Roadside Ditches-Clean and Reshape	lin. ft.	3,050,827	2,288,120	0.84	1.27	0.00	4,827,933.73
464	Outfall Ditches-Clean and Repair	lin. ft.	541,144	338,215	0.41	2.32	0.00	923,326.95
542	Roadsweeping (Manual)	curb mi.	1,229	1,045	212.93	25.23	0.00	248,793.84
543	Roadsweeping (Mech.)	curb mi.	124,867	106,137	24.43	20.39	0.00	4,757,058.10
Group Total								17,721,335.74
471	Large Machine Mowing	acres	850,647	637,985	6.66	6.96	0.00	8,689,359.11
482	Slope Mowing	acres	39,374	29,531	69.17	51.94	0.00	3,576,438.86
484	Intermediate Machine Mowing	acres	33,420	20,052	41.97	22.78	0.00	1,298,367.00
485	Small Machine Mowing	acres	18,584	11,150	92.82	27.39	0.00	1,340,389.58
487	Weed Control (Manual)	acres	7,507	4,129	184.82	55.63	0.00	992,781.98
489	Wildflowers	acres	2,357	1,414	78.32	82.94	50.75	299,824.54
490	Fertilizing	tons	19,022	12,840	13.76	7.10	189.20	2,697,138.89
493	Landscape Area Maintenance	sq. yd.	7,864,710	4,325,591	0.47	0.07	0.02	2,422,330.68
494	Chemical Weed and Grass Control	gals	2,026,214	1,266,384	0.67	0.23	1.05	2,469,448.31
497	Chemical Weed and Grass Control (Broadcast/Wiping)	acres	59,346	43,026	4.01	1.26	6.51	506,844.51
Group Total								24,292,923.47

1 ft = 0.305 m
1 acre = 4,052 m^2
1 yd^2 = 0.837 m^2
1 gal = 3.785 L

more or less than the dollar amounts shown. In instances where the district personnel costs are greater than the amount shown, then transfers of personnel (or vacant positions) to another district having less than the amount required should be considered. This same logic also will suffice when a need for balancing equipment and materials is determined. Naturally, the same system can be used within a district/region when balancing the capability of a maintenance unit to the identified needs of that unit.

Because this approach is a significant change to daily operations, it will cause a great amount of politicizing on an individual basis to minimize its impact. However, in those locations where contract maintenance is a significant portion of the ability of a district/region to accomplish work, the transfer of contracting dollars can be more easily reassigned than personnel, equipment, and materials.

Of particular concern to an implementing agency trying to balance resources is minimizing the impact to employees. Unless workers are willing to move, a reassignment can cause a major disruption to them and their families. For this reason, when balancing capability with needs, it is highly recommended that resource transfers be limited to nonpersonnel items, such as contract maintenance dollars, vacant positions, equipment, and materials.

TABLE 31 Florida maintenance needs summary—updated May 1994 (Florida DOT 1996)

	Amount	Units	Total Needs FY 95–96, $
Fixed Obligations			
Utilities-Mov Bridges	106	Each	509,648
-Standard Lights	44,942	Each	4,272,636
-High Mast Lights	8,050	Each	3,826,487
Ferry Operations	1	Each	1,423,933
Tunnel Maintenance	1	Tunnels	180,724
Bridge tending	90	Bridges	9,184,500
Fairbanks Operations	1	Each	1,736,000
Local Govt. Br. Inspect.	$10,750,000	W.P. $Amt	10,750,000
N.P.D.E.S	$5,533,000	W.P. $Amt	5,553,000
Motorist Aid Call Boxes	2,441	Each	1,159,060
In-House Supv. & Contract Adm.			29,288,544
Adm. & Adm. Support Personnel			16,515,788
Permits-Utility	5,398	Each	2,481,123
-Access	2,425	Each	2,534,966
-Drainage	922	Each	474,640
-House Moving	643	Each	76,842
-Road Closure	566	Each	75,073
-Special	2,178	Each	652,139
Bridge Insp.-Routine	3,346	Bridges	2,996,800
-Long Structure	802	Bridges	1,435,548
-Moveable Br.	107	Bridges	521,742
-Cable Stay	2	Bridges	357,782
-Steel & Conc. Box	57	Bridges	203,906
-Underwater	1,292	Bridges	626,089
-Light Pole Insp.	378	Poles	135,520
-Sign Insp.	1,978	Structures	1,020,860
Hazardous Material			1,012,987
Hgwy. Lighting-Standard	44,942	Each	3,758,050
-High Mast	8,050	Each	2,356,495
Rest Area Maint-RA w/ Fac.	81	Each	7,492,500
-RA w/o Fac. & Toll Fac.	179	Each	978,083
-Wayside Parks	50	Each	218,515
Rest Area Security	79	Each	9,875,000
Additional Workload	835	Lane Miles	4,836,212
Mitigation Areas	1,055	Acres	895,739
Total Fixed Obligations			129,406,930
Routine Maintenance			
Total Safety			57,238,650
Total Preservation			48,340,803
Total Routine			30,540,484
Total Aesthetics			11,223,644
Total Routine Needs			147,343,581
Total Budget Needs			276,750,511

1 mi = 1.61 km
1 acre = 4,052 m^2

REDIRECTION OF WORK

Component #24 Objective: To redirect resources within a specific location from work activities that have exceeded the target LOS to work activities that are below the target LOS.

Although not specifically identified as being examples of redirection of work, the discussion given earlier in the "Process Updating" section contained many possibilities to redirect work. Depending on the LOS currently being provided versus the target LOS, management at all levels within an agency must accept responsibility for providing a uniform LOS to customers *(Deming's Point No. 7—Institute modern methods of supervision of production workers).*

Obtaining uniformity is a desirable goal to ensure that taxpayers are getting equal value. The end result must be such that travelers are not aware of a significant change in highway features as they cross from one maintenance jurisdiction to another. Ensuring consistency is also desirable when

TABLE 32 Maintenance needs summary of a Florida maintenance district (Florida DOT 1996)

	Amount	Units	Salaries & Benefits, $	Expenses, $	Pay CSS, $	TM & E, $	Data Processing, $	OPS, $	HRD, $	Consultant Fees, $	OCO, $	Total Needs FY 95–96, $
Fixed Obligations												
Utilities-Mov Bridges	18	Each		74,734			11,810					86,544
-Standard Lights	947	Each					90,031					90,031
-High Mast Lights	1,518	Each					721,566					721,566
Ferry Operations	0	Each	0	0								0
Tunnel Maintenance	0	Tunnels	0	0	0			0				0
Bridge tending	15	Bridges	1,425,000	6,000	750	9,000		90,000				1,530,750
Fairbanks Operations	0	Each	0	0		0				0		0
Local Govt. Br. Inspect.	$1,800,000	W.P. $Amt								1,800,000		1,800,000
N.P.D.E.S	$354,000	W.P. $Amt								354,000		354,000
Motorist Aid Call Boxes	378	Each	90,327		39,323	49,836						179,486
In-House Supv. & Contract Adm.			2,804,038	196,283	462,666	14,020	56,081		14,020		28,040	3,575,148
Adm. & Adm. Support Personnel			1,542,567	107,980	254,524	7,713	30,851	30,851	7,713		15,426	1,997,624
Permits-Utility	718	Each	258,839	18,119	42,708	1,294	5,177		1,294		2,588	330,020
-Access	381	Each	312,374	21,866	51,542	1,562	6,247		1,562		3,124	398,277
-Drainage	142	Each	57,334	4,013	9,460	287	1,147		287		573	73,101
-House Moving	58	Each	5,436	381	897	27	109		27		54	6,931
-Road Closure	80	Each	8,322	583	1,373	42	166		42		83	10,611
-Special	214	Each	50,256	3,518	8,292	251	1,005		251		503	64,076
Bridge Insp.-Routine	0	Bridges	0	0	0	0	0		0		0	0
-Long Structure	0	Bridges	0	0	0	0	0		0		0	0
-Moveable Br.	0	Bridges	0	0	0	0	0		0		0	0
-Cable Stay	0	Bridges	0	0	0	0	0		0		0	0
-Steel & Conc. Box	0	Bridges	0	0	0	0	0		0		0	0
-Underwater	0	Bridges	0	0	0	0	0		0		0	0
-Light Pole Insp.	0	Poles	0	0	0	0	0		0		0	0
-Sign Insp.	0	Structures	0	0	0	0	0		0		0	0
Hazardous Material			93,053	6,514	15,354	465	1,861		465	9,305	931	127,948
Hgwy. Lighting-Standard	947	Each	31,213		6,032	41,943						79,188
-High Mast	1,518	Each	173,553		37,525	231,404						442,482
Rest Area Maint-RA w/ Fac.	9	Each	643,500		96,300	92,700						832,500
-RA w/o Fac. & Toll Fac.	7	Each	22,949		7,650	7,650						38,249
-Wayside Parks	18	Each	39,323		19,671	19,671						78,665
Rest Area Security	6	Each	600,000		75,000	75,000						750,000
Additional Workload	90.00	Lane Miles	285,238		98,355	137,660						521,252
Mitigation Areas	358	Acres	189,901		75,960	37,980						303,842
Total Fixed Obligations			8,633,224	439,989	1,303,383	1,551,911	102,644	120,851	25,661	2,163,305	51,322	14,392,291
Routine Maintenance												
Total Safety			2,760,888		1,102,930	2,854,474						6,718,292
Total Preservation			3,361,091		1,795,629	1,414,440						6,571,160
Total Routine			2,213,731		1,133,518	574,746						3,921,995
Total Aesthetics			1,024,961		240,597	133,562						1,399,120
Total Routine Needs			9,360,671		4,272,674	4,977,222						18,610,567
Total Budget Needs			17,993,895	439,989	5,576,057	6,529,133	102,644	120,851	25,661	2,163,305	51,322	33,002,858

1 mi = 1.61 km
1 acre = 4,052 m^2

Anticipated Cost Increases (3%)		$990,086
Anticipated Inventory Increases (2%)		$372,211
Total MRP 80 Budget Need	$34,365,156	

funding distribution occurs. If all maintenance jurisdictions are provided equal funding to achieve their specific workload, good managers will achieve or exceed the minimum LOS requirements, whereas others may not.

It is the responsibility of the agency to provide the environment that enables employees to capitalize on opportunities that exist. Redirection of work should not result in a fear of failure when reducing an LOS that far exceeds the desired range nor should it cause an overreaction when trying to improve a lower than desired LOS. If the agency has done the proper preparation in developing LOS criteria and obtaining management approval, then achieving the desired levels can be accomplished by redirecting work without concern for being overruled by others.

Once an objective is established, then the resources needed to achieve that objective can be identified and appropriately directed. If an agency's performance is rated on the percentage of the desired LOS that has been met, then other concerns will become secondary to achieving the desired objective. When this occurs, the variability within the system will be reduced, along with waste and inefficiency, thereby allowing a quality product to be produced.

CHAPTER 5

INSTITUTIONAL BARRIERS

One of the biggest obstacles for an agency attempting to implement a new system is having the system labeled as the "flavor of the month." New systems come and go; only those with any practical values will survive within governmental agencies. Much of this attitude has been brought about by successive layers of managers who, with the inevitable changes in administration, rotate in and out of an agency, leaving the new programs without proper support.

Managing for quality must succeed if the United States is to continue as a world leader. To accomplish the transition into a quality organization, management must step back from direct involvement with a product or service and concentrate on the management of the people that produce the product or service. Instead of micromanaging the operation, which is what many managers do, the focus must turn to establishing the desired end result while allowing the individuals doing the work to be responsible for achieving the desired results using the training and tools provided by management.

Another reason that many past "flavor of the month" programs have not succeeded has been a lack of commitment by employees. Most agencies have experienced personnel who have tolerated an MMS but have not really been interested in the results it produces. Although many reasons have been given for its lack of real value, one suspects the main cause was a lack of commitment from all levels.

The QA program presented in this manual can succeed if managers are seriously interested in providing a minimum LOS uniformly throughout the agency. This will likely require a change in the attitude and psychology of most agencies concerning the way their businesses are managed, but for those committed to long-term quality, the means are now available.

Maintenance agencies are quite familiar with the barriers raised against the implementation of a new program. Depending on the composition, philosophy, and structure of the agency, adoption of the QA program will likely encounter the following institutional barriers:

- Lack of commitment by all levels of management,
- Funding limitations,
- Employee attitudes,
- Special interests,
- Privatization and
- Unions.

The following sections discuss the nature of each of these barriers and how an implementing agency can work to overcome them.

MANAGEMENT COMMITMENT

Many managers/administrators may view the QA program described in this manual as an opportunity to downsize and restructure the organization. Although this may be a valid occurrence after the system has had an opportunity to operate for several years, the initial direction must be to determine the resources required to produce an LOS and to provide those resources to work units. Determining what is required to provide the desired LOS may require an increase in resources and should not be approached from the standpoint of "doing more with less." In many instances, unfortunately, an agency's highway/street maintenance bureau is asked to defer its operations so that a balance of design and construction projects can also be accomplished.

If the quality concept is to succeed, a total commitment to providing the optimal LOS will be required by all levels of management. Unfortunately, what an optimal level of quality means is an optimal level of defects to be allowed on an agency's highway system. If the cost of providing that level is higher than acceptable, then the LOS criteria must be revised. Eventually, a minimum level must be agreed upon and provided to the customers. As was stated earlier in this manual, quality is a habit, not an act; this will undoubtedly be a culture change for many agencies.

Leadership in management should have as its primary goal the motivation of people to work to their maximum levels of performance. Under the concepts of this manual, innovative field managers, who are accountable for end results, are authorized or "released" to make their own decisions regarding how and when to accomplish work. After all, these field managers, who are closest to where the work occurs, will have a much better chance of discovering and eliminating hidden waste and inefficiency. Realizing that others are being given the same resources to accomplish similar work assignments will spur the truly innovative manager to excel. As they begin to seek ways to obtain maximum benefits from resources, these released field managers will begin to generate savings by finding ways to prevent problems and defects before they occur, which is also a major objective of the prototype QA program.

Of all the institutional barriers, obtaining the commitment of top management and administrators to stay the course will be the most difficult. It is important that these individuals be fully aware of the principles involved, of how work priorities will be accomplished should funding levels be lowered, and of the impact of reduced funding on the LOS that can be provided.

FUNDING LIMITATIONS

The issue of funding limitations is one of the most important. In his summary of remarks to the National Quality Initiative (NQI) Partnerships for Quality seminar held in Dallas in 1993, Mr. Francis B. Francois, then Executive Director of the American Association of State Highway and Transportation Officials (AASHTO), stated, "The public is willing to pay for quality. If you can show them what they are going to get, it's been shown in state after state that they are willing to pay for it, provided that they know they are going to get a good return on their dollars." Understanding this statement and applying its meaning is very difficult for most managers/administrators who are being pressured by many special interests to fund their programs.

Highway agencies spend large sums of money to maintain their facilities. Implementing a QA program will require the funding of repairs necessary to keep these facilities operating at the optimum level to prevent deterioration and provide safety and convenience to the public. In effect, this means recognizing the importance of funding maintenance activities. This will be a necessary feature of the program in order for the agency to convince the public that it is obtaining the maximum potential life of existing (as well as future) highway and bridge features, while at the same time providing minimum acceptable safety and convenience items.

Should funding limitations occur, they will most likely be the result of one of the three scenarios shown below:

- Unwillingness within the agency to request adequate funding to provide the desired LOS. When this occurs, it will be necessary to revisit the LOS criteria and either modify the LOS to be provided on each activity or to revise the methods and cost estimates of producing the end result.
- Failure of the final approval authority to fund the agency request. The only course of action in this case is to implement the priorities scenario, which was developed for this purpose. It is more difficult for an approval authority to deny agency requests when the agency has adequately explained the principles of a QA program, the LOS desired, the LOS resulting from the proposed funding limitation, and the method of implementing priorities.
- Funding shortages during the fiscal year caused by emergencies (e.g., heavier-than-usual snowfall, earthquakes, hurricanes, flooding, wildfires). Generally, the course of action in this event is similar to that discussed above. Unless funding increases are granted by the final approving authority, it will be necessary to implement the priorities scenario that was developed. Even if additional funding is approved, this is usually well after the incident occurs, and the priorities scenario will have to be started to ensure funding for high-priority activities is available during the remainder of the fiscal year.

EMPLOYEE ATTITUDES

American workers have been bombarded in the last several decades with a variety of techniques and strategies that are supposed to make them work smarter, not harder. In recent years, terms such as re-engineering, empowerment, downsizing, team building, coaching, decentralization, and other management fads have been embraced by agencies in an attempt to improve performance. All of these are good and valuable concepts when implemented in the right way and for the right reasons. Unfortunately, many organizations have focused on the cost part of the equation and have ignored the fact that growth is occurring, which increases overall costs in spite of the best efforts of employees. The end result may be that many of these concepts have been endured by employees who have played the good soldier to keep from being marked as against progress. Some employees may also resist the proposed system because it represents change. Change can mean the potential loss of job security, or it can promote fear in workers that they will not be able to understand what management wants or cannot obtain the skills necessary to succeed in the new environment.

To implement a successful QA program, management must create a clear statement of purpose or picture of what the end result should be. Many of the concepts touted in previous systems were valid but lacked the forethought to properly complete the image they wanted. For instance, most lower level employees will agree that management meddles in daily operations far too much. Management must allow field employees to make their own decisions about how to best accomplish LOS objectives. Doing this may relieve managers to pursue issues at a higher level than most field forces can effectively handle. Issues, such as labor relations, personnel matters, equipment purchases, arranging for appropriate training courses to be taught, and so on, may be causing difficulties for field operations. These are things that management can and should do.

SPECIAL INTERESTS

Many well-meaning special-interest groups will be affected by the LOS criteria being proposed by an agency. These organizations will do their best to ensure that the legislative and administrative leaders of an agency recognize the importance of their causes. Many times, the information gathered in the customer expectations phase of program implementation will enable an agency to identify the customers' wishes and still accommodate some of the requests of special-interest groups. This will require careful examination of the issues to determine what impact these requests may have on the customers' desired LOS. Although special-interest groups are also customers, the reason for statistical random sampling when determining customer expectations is to ensure that the needs of the majority are identified.

In each case, an estimate should be made to ensure the results of the approved lobbying efforts of these special-interest organizations are considered in workload predictions, budget requests, and the distribution of resources (see Chapter 4). Some of the organizations that may be encountered are as follows:

- Environmental
- Highway beautification,
- Sales personnel,
- Utilities,
- Truckers and haulers,
- Unions,
- Contractors, and
- Trade associations.

PRIVATIZATION

To agency employees, the topic of privatization may equal in importance all other issues combined. Not only does the title suggest getting rid of jobs and employees, the very mention of it can excite union leaders into action. When applied properly, however, using private corporations to perform activities historically assigned to routine maintenance forces can be a cost-effective alternate to using agency crews. Careful selection of activities, preparing clear and concise specifications for the end result to be achieved, and "inspecting what you expect" has resulted in savings of more than 10 percent in the Florida DOT's contract maintenance program, as compared to the cost of performing the same work with agency employees.

Florida's experience has been documented during the past 15 years of contract maintenance. Currently, approximately 55 percent of all highway maintenance expenditures that could be privatized have been let to contract. This is an amount in excess of $110 million, which does not include resurfacing and major bridge rehabilitation or replacement. After the completion of a study done by a consulting firm researching the cost-effectiveness of contract maintenance within the state, Florida adopted a goal of 65 percent of highway maintenance to be contracted within the next 2 years. Even though this percentage was a major portion of the routine maintenance workload, it was accomplished by requiring that all increases in maintenance workload be taken up through privatization contracts. In recent years, vacant maintenance positions have been transferred to other divisions within the agency, with little or no impact to existing employees because of privatization. Although the initial reaction by the field managers was negative, they soon witnessed a significant reduction in personnel problems. Local managers were then free to supervise the quality of work being conducted by the maintenance contractors. As a side benefit, requests for maintenance workforce services by others decreased significantly when the budget was asked to fund the cost of paying the contractor for the work to be done for them.

The British Columbia MTH also appears to be satisfied with privatization. In 1988, the MTH converted to 100 percent of maintenance work being accomplished by contractors. It currently keeps a staff of approximately 20 employees in the field to ensure that a quality product is given. The following excerpts from the *Quality Assurance Program Manual* (British Columbia MTH 1991) generally indicate how the program is operated:

> *The concepts and procedures should be explained to the Contractor, so that there is a basic understanding of the program objectives. It should be emphasized that the program is aimed at identifying good work service as well as substandard work.*
>
> *The benefits of the program should be explained and the Contractor should be encouraged to participate actively through the implementation of their own Quality Control Program.*
>
> *The results of the monthly performance evaluations should be discussed with the Contractor and acknowledgment given for good performance. This is particularly important as the only other documentation formally received by the Contractor under the program are Defect Notices and Non-Conformance Reports which both emphasize the substandard aspect of the work.*
>
> *Inspection check sheets should not be handed to the Contractor, although copies of selected sheets can be given if specifically requested.*
>
> *The responsibility for control of the work and its ultimate quality rests entirely with the Contractor. Under the terms of the Contract, the Contractor is responsible for procurement of material, organization of labor, allocation of equipment, training, selection of staff, and supervision. He or she also has the choice of method, means, and procedures providing only that they conform to the standards specified in the Contract Documents, and are completed in a good, competent, and skillful manner.*
>
> *Inspection staff must not assume any of these responsibilities. This may be difficult for Area Managers who for their entire working life have been used to the direct control of maintenance work. Adherence to these principles may lead to certain frustrations, but must nevertheless be followed.*

UNIONS

Because the QA program presented in this manual requires a fundamental change in attitude and psychology, it is wise to anticipate resistance to change on the part of labor unions. These unions represent the welfare of employees who will be involved in the changes, and they may request assurances that little or no disruption to these employees will occur. Involving labor unions in the QA process is a necessity and, if done properly, should produce good results. Making them familiar with the issues up front and providing an opportunity for feedback should reduce resistance to the proposed changes.

CHAPTER 6

SUMMARY AND CONCLUSION

As in most business ventures, a product or service must be clearly demonstrated as having a value to the potential users of that product or service. The value must be tangible and should outweigh the cost associated with obtaining the product or service. Although the principles and processes behind the prototype QA program presented in this implementation manual are available at no cost to highway agencies (research and development costs aside), there are costs that interested agencies must recognize and then weigh against the purported benefits of the program. These costs include the up-front cost of implementing the program and the annual cost of operating the program. Estimates of the up-front and annual operational costs of QA programs at four agencies were provided in Table 1, and these estimates may be used as guidelines for agencies interested in establishing a maintenance QA program.

The value of having a QA program must be measured in terms of providing a uniform LOS that meets the expectations of highway users. Obtaining uniformity in the highway system reduces waste and inefficiency, the savings of which become apparent as an agency transitions from a baseline LOS (i.e., an LOS prior to establishment of the QA program) to a target LOS.

As evidence of this phenomenon, an agency can examine the quality trends experienced by the Florida DOT since the start of its program in 1985. Figure 21 shows the agencywide LOSs for the four individual facility types and all facility types combined for the years 1990–1991 through 1995–1996. Similarly, Figure 22 shows the agencywide LOSs for the five maintenance elements and all elements combined for the same time period. It is clear from these figures that a steady increase in LOS occurred over the 6 years listed. Although the overall LOS rating was established at 80 in 1985, a funding shortfall in 1989 caused the system to decrease to 72 by 1990–1991.

Of interest in Figure 21 is that in 1990–1991, the ratings for the urban arterial system were significantly below those of the other three systems and were approximately 11 points below the target level of 80. By the 1995–1996 period, however, ratings for all systems were above the target level of 80. It can also be seen that the variability from year-to-year decreased, resulting in more uniform maintenance across the four facility types. In 1990–1991, the standard deviation was 4.8 points, whereas in 1995–1996, the standard deviation decreased to 3.4.

Figure 22 shows a similar trend for the element ratings. In 1990–1991, all but the roadway element ratings were **below** the target LOS of 80. By 1995–1996, all but the roadside element were **above** 80. A more uniform level of maintenance across the five elements was achieved, with the standard deviation decreasing from 12.0 in 1990–1991 to 7.7 in 1995–1996.

The changes shown in these charts were brought about by redirecting resources from activities with high ratings and concentrating them on activities that did not rate as highly. Not only did this provide a more equitable balance of work being performed, it also resulted in unit costs and total costs being lower than the costs experienced before the Florida DOT implemented its LOS rating system. The reduced costs resulted from concentrating the work effort more on areas of deficient LOS and less on areas exceeding the target LOS.

Similar results have been experienced in Maryland, where the DOT has reported that a major benefit of its peer review process is the ability to see differences in the findings on a year-to-year basis. Figures 23 and 24 show the 3-year LOS trends for the highway systems and maintenance categories (i.e., elements), respectively. Following a pilot study in 1992, maintenance conditions increased substantially the next year, but dropped slightly in 1994, due to a severe winter season. As can be seen in Figure 23, the interstate highway system exceeded 90 in 1994, whereas the other two systems were slightly less than 90. As for maintenance categories (Figure 24), three (drainage, traffic control and safety, and roadside) of the five categories exceeded 90 in 1994, and the other two categories exceeded 80. Maryland's internal grading system assigns an "A" rating for LOS's above 90, a "B" rating for values between 80 and 89.9, and a "C" rating for values less than 80.

With a few basic management tools already in place and a general understanding of the philosophy of quality management, agencies having a highway maintenance operation should be able to implement many of the QA program components described in this manual. Some of the components are commonplace in maintenance agencies, whereas others exist in a select few agencies. No agencies, however, have established all of the components.

Perhaps the biggest change that will be necessary is the culture shift that encompasses the way an agency will act,

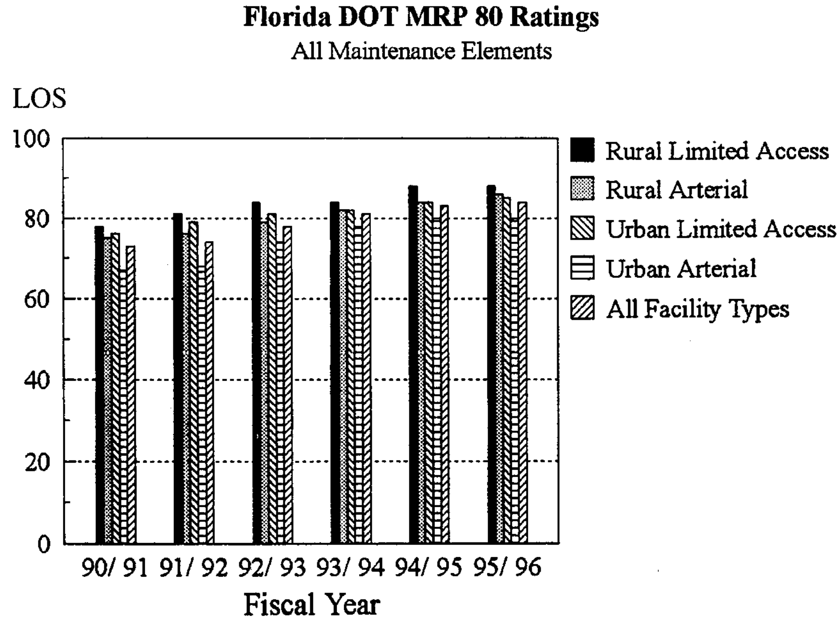

Figure 21. LOS ratings for various facility types in Florida between 1990 and 1996.

think, talk, and work to do things right the first time. Doing this will enable an agency to shift from a "fixing" mode to a "prevention" mode, including the benefits of cost avoidance associated with each repair that does not have to be repeated. Eventually, this culture shift will lead the way to greater levels of customer satisfaction with the LOS being received. Although initial success with customer satisfaction can be achieved, their needs and expectations will change; hence, continuous quality improvement will be necessary.

As stated in the first of Deming's 14 Points, *Create constancy of purpose toward improvement of product and service,* management must possess a long-term commitment to the principles of CQI. This implies a strategic plan that states this commitment and backs it up by channeling necessary resources toward quality improvement. Essential to the

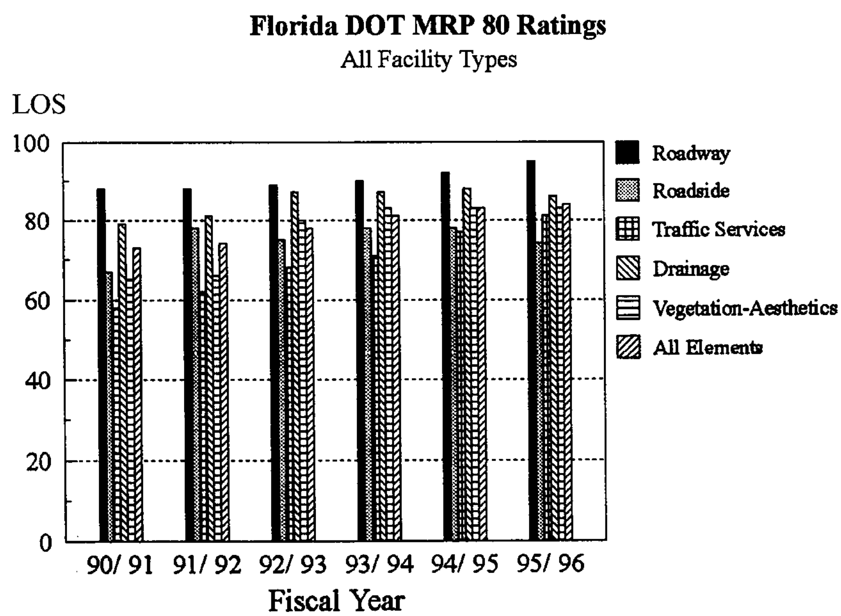

Figure 22. LOS ratings for various maintenance elements in Florida between 1990 and 1996.

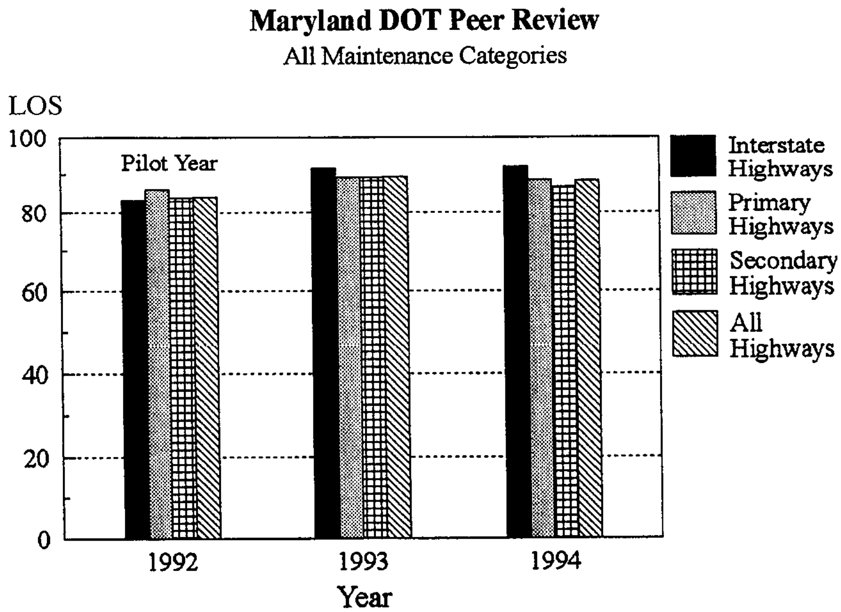

Figure 23. LOS ratings for various highway systems in Maryland between 1992 and 1994 (Maryland DOT 1994).

successful use of the concept of a quality management system is a commitment starting at the CEO level and working down the hierarchy.

In his writings, Deming maintained that management may be responsible for as much as 94 percent of quality problems. Another quality advocate, Joseph Juran, felt that management may be responsible for closer to 80 percent of quality problems. Regardless of who is more nearly correct, the implication is that management must change many of an agency's procedures and philosophies for quality to improve in a meaningful manner.

Assuming that the conclusions of these authors are correct, workers cannot produce better results if the same faulty materials, equipment, or procedures that were used in the past are to be used in the future. Management must be able to give its employees the tools necessary to perform properly, revise

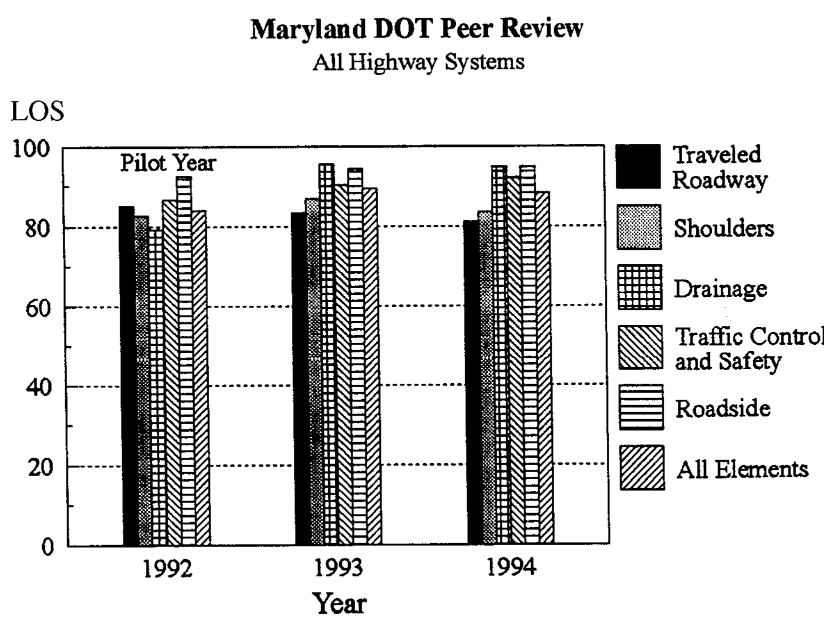

Figure 24. LOS ratings for various maintenance categories in Maryland between 1992 and 1994 (Maryland DOT 1994).

counterproductive rules and procedures, and remove serious impediments.

Agencies implementing a QA program for the maintenance of highways and bridges will soon recognize that the costs of providing desired LOSs for different activities will vary in comparison with past maintenance costs. For some activities, the costs will be higher, whereas with others, they will be lower. To obtain uniformity throughout the system, it will be necessary to shift resources and provide the appropriate training, materials, and equipment to use them. Knowing what LOS is being provided in each location enables a balancing act to occur with resources, correcting some of the inequities. These basic features, combined with the old-fashioned values of good work, hard work, and teamwork, can result in a significant improvement in customer satisfaction, which is what it's all about.

In closing, agencies must decide if they truly want to convert from the practice of business-as-usual to an approach that is quality oriented. The following approaches most likely describe the methods of operation used by many maintenance and operations personnel involved in governmental agencies:

1. *Business as usual*—Reactionary maintenance, based on complaints or work found by roving crews that specialize in performing certain activities and that perform on a scheduled route within certain geopolitical boundaries. Usually this type of organizational structure does not involve long-range agency maintenance strategies and it tends to exist from year to year based on the previous year's funding or work accomplishments. Uniformity in the service provided to its customers varies from location to location and from activity to activity, depending on the skill and dedication of field managers.
2. *Quality-based*—Measures the actual LOS, by activity, and compares it with a customer-based, agency-directed minimum level to be achieved. Agency managers establish targets to be achieved and assign field managers the task of ensuring that the target level is achieved in their area of responsibility. Work assignments are established to perform the right activity and apply the right treatment at the right time for the right reason. It involves providing employees with the appropriate tools (e.g., training, equipment) to accomplish workloads, the knowledge of knowing what LOS is required, and the ability to know when it has been achieved. Funding requests are based on needs to accomplish or maintain minimum LOS's with no regard to the previous year's funding level. It enables uniformity in the LOS that is provided to customers.

Most agencies will recognize the first approach as being representative of their method of funding and performing highway maintenance work activities. Although this style of management enables quality work to be done, it cannot identify needed work that should have been scheduled but was not. Similarly, it does not enable managers to balance deficiencies throughout the highway system and it precludes uniformity in the LOSs that are provided.

Although only a handful of agencies have established a quality management system similar to the second approach, each has had good results in improving LOSs, providing uniformity, and obtaining funding to continue maintenance operations on an as-needed basis. The quality-based management philosophy requires the development of agency-specified LOSs and a commitment to provide employees with the necessary resources to accomplish needed work. Agency managers also have the capability to measure results to ensure that customer needs are met, to establish priorities for conducting work, and to ensure that uniform conditions are achieved.

It is recommended that all highway agencies investigate the features described in this manual. Although not all of the features will be practical or desirable for each agency, many of them, as evidenced by the implementing agencies, have proven to be sound methods of improving LOSs in a cost-effective manner.

APPENDIX A

QA PROGRAM SUPPLEMENTS

SNOW AND ICE CONTROL

Most of the highway agencies in the northern portion of the geographical United States find winter snow and ice control to be a large part of their maintenance program. Because of its special demands, these agencies may expend between 10 and 50 percent of their total maintenance budget to provide an acceptable LOS for the traveling public. Much of this effort is expended during the period from January 1 to March 1, although isolated storms occur from November through the middle of April.

Because of the major impact on the daily operations of most citizens, businesses, schools, health care facilities, and churches during a winter storm event, the public demands that most highways be opened to traffic within a short period following the onset of such an event. The importance of traffic movement is underscored by many local and state legislative actions requiring motor vehicles to be prepared for travel during periods of snow and ice. Many individuals and public agencies begin preparing in the early fall for the coming winter season. Some of the items concentrated on include the following:

Individuals

- Install properly treaded tires.
- Acquire and carry chains for use as needed to ensure they will not block lanes of traffic during winter events.
- Ascertain media outlets to learn of emergency conditions.

Agencies

- Field check all snow- and ice-control equipment to ensure they are in proper working order.
- Identify snow removal priority routes and train equipment operators to perform their duties on those routes. An example of priority road criteria is as follows:
  - Priority 1. All lanes open at all times. At least two lanes in each direction should have bare pavement within 2 hr following a winter event.
  - Priority 2. At least one lane in each direction shall be opened at all times. All lanes should be opened within 24 hr following a winter event.
  - Priority 3. Apply abrasives to pavement areas in curves and hilly slopes. Assign resources to this priority after priorities 1 and 2 have been completed, if resources are available.
- Publish the snow- and ice-control policy and priority routes in the local newspapers and TV and radio stations. This provides the public with information concerning routes to be traveled during winter events thereby establishing two-way communications before an event actually occurs. The public will also know the LOS to expect during winter events, which will reduce phone calls from concerned citizens.

During these winter events, governmental agencies are called on to begin snow- and ice-control operations within a short time. These operations may be conducted by the agency itself, by contract forces, or by a combination of both. The specific activities generally include, but are not limited to, the following:

- Mobilization of workers and equipment,
- Spreading of abrasives (sand, cinders),
- Spreading of de-icing and anti-icing (and other) chemicals,
- Plowing of snow, usually with an accumulation of 2 in. (51 mm) or more,
- Blowing snow,
- Plowing back of shoulders,
- Cleaning of bridges and shoulders,
- Providing access to all emergency vehicles on all roads following a winter storm, and
- Ensuring that railroad crossings are free of heavy snow.

Immediately following the winter snow and ice season, each agency should begin preparing for the next season (while the lessons of the past season are still fresh). Some of the items that should be considered at this time are as follows:

- Determine areas of improvement involving policy changes, equipment needs, employee training, and environmental problems created by use of de-icing and anti-icing chemicals.
- Train each equipment operator for each assigned route. Because each route has unique characteristics, many agencies use this time to train operators in the proper use of equipment and safety requirements to ensure good snow and ice control.
- Make recommendations concerning resource needs (equipment, staff, contractors) to ensure compliance with snow and ice policy changes affecting the next winter season.
- Ensure that all pieces of equipment are properly calibrated for spreading de-icing and anti-icing chemicals.

- Arrange for the purchase and delivery of proper stockpiling/storage of de-icing and anti-icing chemicals to ensure availability during the next season for winter events. The amount of materials to be stockpiled should be adequate to handle an average winter season without requiring resupply. It should be anticipated, however, that unusual years will require additional materials and equipment. If possible, it is recommended that arrangements be made with suppliers during the spring and summer months to have additional materials available should the regular supply be depleted.
- Establish a list of snow- and ice-control priority routes, assign priorities and standards, notify the public of any changes through the use of public service announcements (PSAs) and newspaper maps showing the priority routes.
- Assign responsibility within the agency to provide the traveling public with information on road conditions during winter events.
- Install snow fences to minimize the probability of snow drifting across roadways and install snow poles in locations known to have heavy snowfall accumulations.

Application of Prototype QA Program

As can be seen, much of the work involved in preparing for a winter event must be accomplished in the off-season, when comparisons with LOS criteria have little meaning. Also, because of the immediate response required to a winter event, the normal schedule used in evaluating compliance with established LOS criteria does not provide the immediate feedback necessary to ensure proper compliance. These constraints can be overcome, however, by summarizing and including the daily snow and ice inspections with the periodic reports of other maintenance activity LOS compliance. These daily inspections can be conducted using a variety of inspection techniques, such as the one being used by the British Columbia MTH to evaluate the quality provided by maintenance contractors.

Figure A-1 shows the standard inspection form used by British Columbia MTH to assess the quality of snow- and ice-control operations. The top portion of the form pertains to winter maintenance of the highway surface (i.e., traveled roadway), whereas the bottom pertains to winter maintenance of the roadside (i.e., shoulders, intersections). In each case, in-process and end-product quality assessments can be made of a combined plowing–sanding or plowing–salting operation, by rating the adherence to snow removal standards (left side of the form) and the adherence to standards for abrasives and de-icing and anti-icing chemical application (right side of the form).

British Columbia's quality assessment approach allows for three possible ratings of winter maintenance. "Good" indicates clearing of winter events well in excess of the agency's requirements, "fair" indicates clearing that barely satisfies the requirements, and "not to standard" indicates unacceptable clearing actions. (A fourth rating, "N/A," or "not applicable," is used if the item to be inspected cannot be inspected, for whatever reason.) Table A-1 lists the bottom-line criteria associated with each aspect of winter maintenance evaluated in the British Columbia QA system. By combining the "good" and "fair" ratings of this program, the pass–fail methodology of quality assessment described earlier in this manual can be applied to snow- and ice-control operations.

The selection of locations for inspections must be fair and consistent, with an inspection plan already in place before the winter event begins. Generally, this should consist of predetermined inspection blocks of roads, each of which is to be assessed in its entirety. The size of the blocks will depend on the configuration of the area, with the maximum size being that which can be maintained by one crew or shift.

It is recommended that a separate form be completed for each selected block and applicable activity. Inspections should commence immediately after a major event has begun and should continue on a daily basis until all sections have been completed. Should a new winter event begin before all the clean-up for the previous event is completed, the response time for all activities should be restarted at the beginning of the new storm.

By summarizing these forms in a compatible time frame when the rest of the maintenance ratings are reported, an analysis of the LOS for snow and ice control can be performed. An example of such an analysis is provided in Table A-2. For each priority level, the number of passing inspections is divided by the total number of inspections made to obtain an LOS rating. As can be seen in this example, an agency can display its compliance with its snow- and ice-control policy in a manner consistent with the quality assessment methodology described previously in this manual. It should be noted, however, that many variations can be used depending on the desires of the implementing agency.

BRIDGES

The Bridge Inspector's Training Manual (FHWA 1991) states the following:

> *In 1971, the National Bridge Inspection Standards (NBIS) came into being. The NBIS set national policy regarding bridge inspection frequency, inspector qualifications, report formats, and inspection and rating formats. Because of the requirements that must be fulfilled for the NBIS, it is necessary to employ a uniform bridge inspection reporting system. A uniform reporting system is essential in evaluating correctly and efficiently the condition of a structure. Furthermore, it is a valuable aid in establishing maintenance priorities and replacement priorities, and in determining structure capacity and the cost of maintaining the nation's bridges. The information necessary to make these determinations must come largely from the bridge inspection reporting system. Consequently, the importance of the reporting system cannot be overemphasized. The success of any bridge inspection program is dependent upon its reporting system.*

British Columbia — Transportation and Highways

WINTER HIGHWAY INSPECTION

ITP7

Inspection Date (Y Y M M D D) | C A / M / S | Time | Highway Number | Start Landmark | Offset

Location: ______

Activity No. ______ (applies to 300, 315) — SURFACE - IN PROCESS - END PRODUCT

Activity No. 3 1 0 — SURFACE - IN PROCESS - END PRODUCT

N/A	Good	Fair	N.T.S.		N/A	Good	Fair	N.T.S.
				Snow removal as specified				
				Response to conditions				
				Safety & work procedures				
				Preventative actions taken				
				Specified Materials utilized				
				Surface traction as required				

N.C.R. Number

Defect Notice

N.C.R. Number | Defect Notice

Air temperature (C°) ______ Surface temperature ______

Comments: ______

Activity No. 3 0 0 — Shoulder Clear/Wing — ROADSIDE - IN PROCESS - END PRODUCT

ROADSIDE SNOW AND ICE CONTROL - IN PROCESS - END PRODUCT

N/A	Good	Fair	N.T.S.		N/A	Good	Fair	N.T.S.
				Shoulders clear				
				Rest Area/ intersections clear				
				Response times met				
				Sight distances plowed				
				Footpaths Clear				
				Snowdrift control				
				Glaciation control				

N.C.R. Number

Defect Notice

N.C.R. Number | Defect Notice

Comments: ______

H-807 (93/01)

Figure A-1. Winter highway inspection form (ITP7) used by the British Columbia MTH (British Columbia MTH 1991).

TABLE A-1 Guide to completion of winter highway inspection form ITP7 (British Columbia MTH 1991)

Item No.	Maintenance Item Evaluated	Condition Standard
In-Process Inspection		
1	Preventive Actions Taken.	Were de-icing chemicals applied to prevent black ice or applied pre-snowfalls?
2	Response to Conditions.	Was response to conditions in accordance with the specified periods?
3	Safety and Work Procedures.	Are the work procedures and safety requirements as specified (i.e., are warning signs in place)? Plowing in tandem to clear full lane-widths? Is appropriate equipment being used?
4	Specified Materials Utilized.	Is correct material being used? Chemicals or winter abrasives should be used at temperatures specified.
5	Snow Removal as Specified.	Is extent of snow removal correct? Are maximum accumulations below specified limits? Is snow being removed within the specified periods?
6	Surface Traction as Required.	Does contractor have sufficient chemical or abrasive on surface to provide good traction or de-icing?
End-Product Inspection		
1	Shoulders Clear.	Are shoulders being cleared within specified periods?
2	Rest Areas Clear.	Are designated rest areas and pullouts being plowed within specified period?
3	Footpaths Clear.	Are footpaths, walkways, etc. being cleared within specified periods?
4	Sight Distances Clear.	Are sight distances being cleared within specified periods?
5	Response Times Met.	Are post-storm clean-up response times being met (i.e., shoulders clear)?
6	Glaciation Control.	Is overhanging snow and ice being removed as specified?

The NBIS requires that the findings and results of a bridge inspection be recorded on standard forms. Although the Structure Inventory and Appraisal (SI&A) sheet shown in Figure A-2 is not a standard form, it represents a list of bridge data that each state must periodically report to the FHWA for public structures within its inventory. As a result, many states have developed their own standard forms using the SI&A sheet as a guide.

The FHWA makes available the information and knowledge necessary to accurately and thoroughly inspect and evaluate bridges. Through the manuals developed by the FHWA and training courses taught by the National Highway Institute (NHI), standardizing the complex issue of bridge inspection has been accomplished. The following subject matter is available upon request:

- Identification and function of bridge components and elements
  - — decks
  - — superstructures
  - — bearings
  - — substructures
  - — waterways
- Bridge inspection (routinely conducted on a 2-year interval)
  - — planning

TABLE A-2 Example LOS analysis for snow- and ice-control inspections

Priority Level	Total No. of Inspections Made	No. of Passing Inspections	LOS Rating
1	1,027	962	94
2	737	615	83
3	429	398	93

NATIONAL BRIDGE INVENTORY - - - - - - - STRUCTURE INVENTORY AND APPRAISAL MM/DD/YY

```
********** IDENTIFICATION **********************
(1) STATE NAME - ________________ CODE ___
(8) STRUCTURE NUMBER #_______________
(5) INVENTORY ROUTE (ON/UNDER) - ____ = _________
(2) STATE HIGHWAY DEPARTMENT DISTRICT __
(3) COUNTY CODE ___ (4) PLACE CODE _____
(6) FEATURES INTERSECTED - ______________________
(7) FACILITY CARRIED - ________________
(9) LOCATION - ______________________
(11) MILEPOINT ___.___
(16) LATITUDE __D __.__' (17) LONGITUDE ___D __.__'
(98) BORDER BRIDGE STATE CODE ___ % SHARE __%
(99) BORDER BRIDGE STRUCTURE NO. #_____________

********** STRUCTURE TYPE AND MATERIAL *********
(43) STRUCTURE TYPE MAIN: MATERIAL - ___________
       TYPE - __________________ CODE ___
(44) STRUCTURE TYPE APPR: MATERIAL - ___________
       TYPE - __________________ CODE ___
(45) NUMBER OF SPANS IN MAIN UNIT ___
(46) NUMBER OF APPROACH SPANS ___
(107) DECK STRUCTURE TYPE - ______________ CODE _
(108) WEARING SURFACE / PROTECTIVE SYSTEM:
   A) TYPE OF WEARING SURFACE - __________ CODE _
   B) TYPE OF MEMBRANE        - __________ CODE _
   C) TYPE OF DECK PROTECTION - __________ CODE _

********** AGE AND SERVICE *********************
(27) YEAR BUILT ____
(106) YEAR RECONSTRUCTED ____
(42) TYPE OF SERVICE: ON - ______________________
       UNDER - __________________ CODE __
(28) LANES: ON STRUCTURE __ UNDER STRUCTURE __
(29) AVERAGE DAILY TRAFFIC ______
(30) YEAR OF ADT 19__ (109) TRUCK ADT __%
(19) BYPASS, DETOUR LENGTH ___MI

********** GEOMETRIC DATA **********************
(48) LENGTH OF MAXIMUM SPAN ____ FT
(49) STRUCTURE LENGTH ______ FT
(50) CURB OR SIDEWALK: LEFT __.__ FT RIGHT __.__ FT
(51) BRIDGE ROADWAY WIDTH CURB TO CURB __.__ FT
(52) DECK WIDTH OUT TO OUT __.__ FT
(32) APPROACH ROADWAY WIDTH (W/SHOULDERS) ___ FT
(33) BRIDGE MEDIAN - __________________ CODE _
(34) SKEW ___ DEG (35) STRUCTURE FLARED __
(10) INVENTORY ROUTE MIN VERT CLEAR __ FT __ IN
(47) INVENTORY ROUTE TOTAL HORIZ CLEAR __.__ FT
(53) MIN VERT CLEAR OVER BRIDGE RDWY __ FT __ IN
(54) MIN VERT UNDERCLEAR REF - ______ __ FT __ IN
(55) MIN LAT UNDERCLEAR RT REF - ______ __.__ FT
(56) MIN LAT UNDERCLEAR LT __.__ FT

********** NAVIGATION DATA *********************
(38) NAVIGATION CONTROL - ______________ CODE _
(111) PIER PROTECTION - ________________ CODE _
(39) NAVIGATION VERTICAL CLEARANCE ___ FT
(116) VERT-LIFT BRIDGE NAV MIN VERT CLEAR ___ FT
(40) NAVIGATION HORIZONTAL CLEARANCE ____ FT

**************************************************
SUFFICIENCY RATING = ___.__
STATUS = _______________

********** CLASSIFICATION ***************** CODE
(112) NBIS BRIDGE LENGTH - ___
(104) HIGHWAY SYSTEM - ____________________ _
(26) FUNCTIONAL CLASS - ____________________ _
(100) DEFENSE HIGHWAY - ____________________ _
(101) PARALLEL STRUCTURE - __________________ _
(102) DIRECTION OF TRAFFIC - ________________ _
(103) TEMPORARY STRUCTURE - _________________ _
(110) DESIGNATED NATIONAL NETWORK - _________ _
(20) TOLL - ________________________ _
(21) MAINTAIN - ________________________ _
(22) OWNER - ________________________ _
(37) HISTORICAL SIGNIFICANCE - ______________ _

********** CONDITION ********************** CODE
(58) DECK _
(59) SUPERSTRUCTURE _
(60) SUBSTRUCTURE _
(61) CHANNEL & CHANNEL PROTECTION _
(62) CULVERTS _

********** LOAD RATING AND POSTING ******** CODE
(31) DESIGN LOAD - ________ _
(64) OPERATING RATING - ________ __
(66) INVENTORY RATING - ________ __
(70) BRIDGE POSTING - __________________ _
(41) STRUCTURE OPEN, POSTED OR CLOSED - _
       DESCRIPTION - ____________________

********** APPRAISAL ********************** CODE
(67) STRUCTURAL EVALUATION _
(68) DECK GEOMETRY _
(69) UNDERCLEARANCES, VERTICAL & HORIZONTAL _
(71) WATERWAY ADEQUACY _
(72) APPROACH ROADWAY ALIGNMENT _
(36) TRAFFIC SAFETY FEATURES ____
(113) SCOUR CRITICAL BRIDGES _

********** PROPOSED IMPROVEMENTS ***************
(75) TYPE OF WORK - __________________ CODE ___
(76) LENGTH OF STRUCTURE IMPROVEMENT ______ FT
(94) BRIDGE IMPROVEMENT COST $___,___,000
(95) ROADWAY IMPROVEMENT COST $___,___,000
(96) TOTAL PROJECT COST $___,___,000
(97) YEAR OF IMPROVEMENT COST ESTIMATE 19/20__
(114) FUTURE ADT ______
(115) YEAR OF FUTURE ADT 20__

********** INSPECTIONS ************************
(90) INSPECTION DATE __/__ (91) FREQUENCY __ MO
(92) CRITICAL FEATURE INSPECTION: (93) CFI DATE
   A) FRACTURE CRIT DETAIL - __ - __ MO A) __/__
   B) UNDERWATER INSP      - __ - __ MO B) __/__
   C) OTHER SPECIAL INSP   - __ - __ MO C) __/__
```

Figure A-2. 1988 FHWA Structure Inventory and Appraisal sheet (FHWA 1991).

— preparing
— performing

- Underwater inspections (routinely conducted on a 5-year interval)
  — diver training certifications
  — dive team requirements
  — OSHA safety requirements
- Inspection and evaluation of fractured critical bridge members
  — redundancy
  — fatigue cracks
- Moveable bridges
  — elements
  — mechanical, electrical, and hydraulic equipment

- Special bridges
  - — suspension
  - — cable stayed
  - — segmental
- Bridge reporting system
  - — standard forms
  - — report preparation
  - — load rating analysis
  - — repair and maintenance recommendations

Because the areas of emphasis in bridge inspection programs change as a result of newer types of design and construction techniques, the guidelines for inspection must also be modified to increase uniformity and consistency. A primary use of the inspection reports is to provide guidance for immediate follow-up inspections or corrective actions. These reports provide information that may lead to decisions to limit or deny the use of any bridge determined to be a safety hazard to the traveling public.

Deficient bridges are divided into two categories: structurally deficient and functionally obsolete. Generally speaking, structurally deficient bridges are weight-restricted because of condition, are in need of rehabilitation or, in rare instances, have been denied access by the public. Functionally obsolete bridges are normally structurally sound but do not meet current standards for deck geometry, clearances, or approach alignment.

At the close of the inspection, the bridge inspector must use his/her experience to document inspection deficiencies that have been observed. A thorough and well-documented inspection is essential for making informed and practical recommendations to correct bridge deficiencies. A well-prepared bridge inspection report not only provides information on existing bridge conditions, but it also serves as an excellent reference source for future inspections.

The accuracy and uniformity of information is vital to the management of an agency's bridge network. QC is the enforcement tool used on a daily basis to ensure the inspection conclusions and recommendations are based on correct information. Many states are assigning the final review and signing of inventory results to the chief inspector, who should be a professional engineer or have a minimum of 10 years' experience in bridge inspection. Quality assessment is usually accomplished by independent inspection teams conducting a reinspection, with the results being used to improve bridge inspector training in the future. Using these inspections will enable an agency to identify deficiencies within structures and keep the structures in safe operating condition.

Depending on the volume of bridges in the agency's network, tracking the status of repairs can be overwhelming. Upon recognizing the difficulty for managers to properly monitor the more critical work orders being issued, the Florida DOT developed a bridge work order system that electronically transmits work orders to its maintenance units. This system requires the maintenance unit to post updates when work has been completed. To simplify the task of monitoring the status of each work order, a priority number is assigned by the bridge inspection team according to its importance to the structure. (It should be noted that these work orders do not include most damage caused by vehicular crashes, which usually result in significant damage that cannot wait until the routine bridge inspection cycle occurs.) The priorities assigned for work orders occurring as a result of routine inspections are as follows:

- Priority 1—Work orders are considered to be **emergency** in nature (significant structural deterioration or safety problems). All work should be completed within 60 days.
- Priority 2—Work orders are considered to be **urgent** in nature (e.g., spalls in concrete, need for cathodic protection). All work should be completed within 180 days.
- Priority 3—Work orders are considered to be **routine** in nature (e.g., flush bearing caps with water, inoperable deck lights, clean scuppers). All work should be completed within 365 days.
- Priority 4—Work orders are considered to be **informational** items only (e.g., sweep deck, remove vegetation or litter). No time limit is established.

Figure A-3 illustrates a typical bridge work order form completed by a Florida DOT maintenance unit.

Periodic reports are then produced for management review to ensure that work needs are being met and to determine if any priority 1, 2, or 3 work orders have been assigned but not completed (see Figure A-4). In Figure A-4, the Flag column with an "N" indicates work orders in which no work has been reported. The Days Left column indicates the time remaining until the work is delinquent. A negative (–) Days Left value indicates that the work has exceeded its due date. Depending on the reports chosen, information showing the days remaining before delinquency, or a listing of the total delinquencies within a work unit (see Figure A-5) are also available.

Monitoring work order status has become an integral part of Florida's QA system, because it provides managers with timely data concerning critical bridge repairs. Using the information ensures that a high degree of customer satisfaction is available and that tort liability claims are minimized. Quality assessment of the data is handled using random samples of work orders to spot check that work was complete as reported.

After a careful review of the requirements to inspect bridges and periodically report the results to the FHWA, it is difficult to envision a situation where the reporting of compliance with inspection deadlines has not already been conducted. However, the monitoring of work orders issued by an agency can be readily adapted to the format presented in this manual. By summarizing the forms in a time frame comparable to when the rest of the maintenance ratings are reported, an analysis similar to that carried out for snow- and ice-control inspections can be performed.

THE SAS SYSTEM 09:10 TUESDAY, MARCH 21, 1995 1

STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION
WORK ORDER

DATE OF ISSUE: 01/28/94	DATE COMPLETED: 11/28/94
BRIDGE NUMBER: 070612	SECTION: 201
COUNTY: 07	STATE ROAD: 953
BEG MILE POST: 4.609	ROAD SYSTEM: 901
ESTIMATED UNITS: 2.00	PRIORITY: 3
TYPE OF UNITS: MH	BRIDGE ACTIVITY: 000
TIME REQUIRED: 1	MMS ACTIVITY: 006
AREA: 690	SITE: 0066003
ACTUAL UNITS: 06.00	ACTION: NEW
LABOR SOURCE: IN-HOUSE	LABOR COST: $435.40
MATERIAL COST: $6,256.28	EQUIPMENT COST: $125.00
CONTRACT NUMBER:	COMPLETION CODE:

LOCATION: N.W. 42 ND AVE OVER TAMIAMI CANAL

DESCRIPTION/INSTRUCTIONS:
FILL IN LOW SECTION OF ROADWAY AT APPROACH SLAB #1

COMMENTS:

Figure A-3. Example of a bridge work order printout (Florida DOT 1995).

BRIDGE MANAGEMENT SYSTEM   14:51 MONDAY, MARCH 20, 1995   1

DISTRICT 7

JOBS THAT ARE ASSIGNED BUT HAVE NOT BEEN REPORTED

------------------------------ PRIORITY=3 ------------------------------

DATEX	ACT	AREA	STROAD	BRIDGENO	COUNTY SECTION	PRIORITY	BRDGACT	SITE	FLAG	DAYS LEFT	DELINQUENT WORK ORDERS
01/24/94	411	796	93	100120	10190	3	411	4116001	N	-55	***
05/12/94	411	799	688	150003	15120	3	880	4116003	N	53	
05/23/94	421	796	CR672	100365	0710	3	421	4216002	N	64	
02/13/95	421	796	CR672	100365	N/A	3	421	4216003	N	330	
02/18/94	423	799	93	150090	15190	3	882	4236003	N	-30	***
02/18/94	423	799	93	150091	15190	3	882	4236004	N	-30	***
10/11/93	432	796	43	100003	10010	3	432	4326005	N	-160	***
10/11/93	432	796	600	100097	10030	3	432	4326006	N	-160	***
03/31/94	432	796	93	100217	10320	3	861	4326009	N	11	
06/23/94	432	799	592	150128	15002	3	432	4326010	N	95	
10/11/93	437	796	45	100091	10060	3	437	4376002	N	-160	***
10/11/93	437	796	45	100279	10060	3	437	4376003	N	-160	***
05/23/94	437	796	60	100058	10110	3	437	4376007	N	64	
05/23/94	437	796	93	100060	10320	3	437	4376008	N	64	
05/23/94	437	796	43	100502	10010	3	437	4376010	N	64	
06/23/94	437	799	93	150185	15190	3	437	4376011	N	95	
02/13/95	437	796	43	100006	10010	3	437	4376012	N	330	
02/13/95	437	796	43	100006	10010	3	437	4376013	N	330	
02/13/95	437	796	43	100278	10010	3	437	4376014	N	330	
02/13/95	437	796	93	100384	10075	3	437	4376015	N	330	
02/13/95	437	796	43	100502	10010	3	437	4376016	N	330	
06/23/94	451	799	93	150122	15190	3	898	4516003	N	95	
06/23/94	451	799	93	150185	15190	3	451	4516004	N	95	

N = 23

Figure A-4. Example of a bridge report listing assigned but not completed work (Florida DOT 1995).

BRIDGE MANAGEMENT SYSTEM 13:34 THURSDAY, MARCH 14, 1996 1

DISTRICT 1

DELINQUENT JOBS

---------- PRIORITY=3 ----------

DATEX	AREA	BRIDGENO	PRIORITY	BRDGACT	SITE	LABRSOR	STATUS	TUNITS	TLABRCST	TEQPCST	THATCOST
02/16/94	190	160129	3	863	4576014	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
02/18/94	194	170068	3	457	4576019	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
08/22/94	192	010060	3	526	5266071		DELQ, WK BEG	53.00	214.19	124.50	0.00
02/16/94	192	120094	3	830	8056068	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
02/16/94	192	120094	3	830	8056069	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
02/18/94	194	170077	3	834	8056071	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
02/18/94	194	170135	3	834	8056079	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
02/18/94	194	170951	3	832	8056082	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
04/26/94	190	160007	3	832		C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
04/27/94	190	160123	3	830		C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
04/27/94	190	160166	3	832		C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
07/26/94	192	120106	3	830	8056083	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
07/26/94	192	120107	3	830	8056084	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
07/26/94	192	120123	3	834	8056085	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
08/22/94	192	010050	3	830	8056086		DELQ, WK BEG	1.00	6.05	0.00	0.00
08/22/94	192	010057	3	834	8056089	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
08/22/94	192	010058	3	834	8056093	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
08/22/94	192	010060	3	831	8056094	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
08/22/94	192	010071	3	834	8056095	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
08/22/94	192	010076	3	831	8056096	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
08/22/94	192	010082	3	830	8056097		DELQ, NOT BEG	0.00	0.00	0:00	0.00
08/30/94	194	130070	3	835	8056119	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
08/30/94	194	130072	3	834	8056121	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00
08/30/94	194	130073	3	834	8056122	C9999	DELQ, NOT BEG	0.00	0.00	0.00	0.00

Figure A-5. Example of a bridge report showing delinquent jobs by priority (Florida DOT 1995).

TABLE A-3 Example of QA of bridge work orders

Priority Level	Total No. of Work Orders Examined	No. of Work Orders in Compliance	LOS Rating
1	31	28	90
2	138	125	91
3	229	198	86

Table A-3 illustrates this process. For different work order priorities, the number of work orders in compliance with the bridge work order repair policy is divided by the total number of work orders examined to produce an LOS rating. This analysis process is consistent with the LOS rating process described in this manual. It should be noted, however, that many variations can be used depending on the requirements of the implementing agency.

APPENDIX B

INPUT FROM OTHER MANAGEMENT INFORMATION SYSTEMS

Although originally required by the Intermodal Surface Transportation Efficiency Act (ISTEA), passage of the 1995 NHS Designation Act removed the management systems certifications and sanction requirements for SHAs, thereby making the systems optional. At that time, many agencies had progressed to the point of fully implementing some systems, while continuing to develop others. Even after the NHS Designation Act, several agencies have made previously incomplete systems at least partly operational, though perhaps in a different form than required by ISTEA.

The six specific management systems mandated under the ISTEA are as follows:

1. Pavement Management System (PMS),
2. Bridge Management System (BMS),
3. Safety Management System (SMS),
4. Congestion Management System (CMS),
5. Public Transportation Facilities and Equipment Management System (PTMS), and
6. Intermodal Facilities and Systems Management Systems.

Although a vast amount of information is contained in these systems, only three—PMSs, BMSs, and SMSs—have potential linkage applications with the prototype QA program outlined in this manual. That is, some of the data elements that commonly reside in these systems may be useable in the LOS rating system. A brief discussion of each of these three systems, as well as infrastructure management systems (IMSs), and the data elements that may best lend themselves to use in the QA program is provided in the following sections.

PAVEMENT MANAGEMENT SYSTEMS

A PMS is defined as an established, documented procedure that treats all pavement management activities—planning, budgeting, design, construction, maintenance, monitoring, research, rehabilitation, and reconstruction—in a systematic and coordinated manner. PMSs usually include condition surveys, a database of pavement-related information, analysis schemes, decision criteria, and implementation procedures, all of which can be used to establish priorities for overlays, maintenance, and allocation of funds; budget preparation; development of rehabilitation strategies; and identification of problem areas. In essence, a PMS is a data bank for a network of pavement sections (Peterson 1987).

The element of a PMS having the most potential to serve as an input interface for the QA program is pavement survey condition information. Typically, four primary condition indicators are taken as part of a PMS. These are structural capacity, friction, roughness/ride quality, and distress. Though highway agencies use a variety of methods to collect condition indicator information and agencies key in on different condition measures, they all share an overall objective, that is, having a means to determine how well pavements are performing.

The structural capacity of a pavement is today most commonly measured using nondestructive deflection testing (NDT) techniques. A falling weight deflectometer (FWD) is used at selected locations throughout a pavement section to identify weak areas, to estimate the strength of the pavement system, and to predict the load-carrying capability of the pavement section given the amount of traffic it experiences. Because pavement maintenance actions provide very little structural improvement, deflection data are not considered suitable for use as indicators of maintenance quality. The prime determinants in structural capacity are design, construction, materials quality, and traffic.

Pavement friction is a safety-related condition measure that describes the slipperiness of a pavement surface. Most commonly expressed as a friction rating or skid number, the lower the value, the more potentially hazardous the pavement is to motorists. Application of skid numbers or friction ratings to the LOS rating system may or may not be appropriate, depending on the agency's policy for correcting slippery pavements. In some agencies, the prime responsibility for improving pavements with low friction may rest with maintenance, whereby maintenance is tasked with applying surface treatments or mechanized patches or performing some sort of surface milling or grinding. In other agencies, however, correction of slippery pavements is a rehabilitation action item and is privately contracted.

The ride quality or roughness of pavements is evaluated by many SHAs on an annual or biennial basis using either a response-type measuring instrument, such as the Mays Ride Meter and the PCA Roadmeter, or an inertial profiling vehicle, such as the South Dakota Profiler and the K. J. Law Profilometer.© Both system types generate a longitudinal roughness parameter, expressed as in./mi (m/km), for a specified length of pavement section, with the inertial profilers measuring the longitudinal profile of a pavement and then computing an international roughness index (IRI) based on the measured profile and standardized vehicle response characteristics.

Although maintenance is obligated to correct various surface defects (bumps, holes, dips, swells) that can collectively result in a rough ride, they are primarily concerned with localized rough spots from the standpoint of safety. Any bumps, holes, dips, or swells significant enough to cause a hazard to the traveling public are under the immediate domain of maintenance. As a pavement becomes more and more deteriorated, the amounts of these distresses become greater and greater. However, generally speaking, the severity levels of the distresses will be kept somewhat in check through proper maintenance, for reasons of safety.

The one data element of roughness/ride quality surveys that may have possible use in the QA program is the longitudinal profile measured by inertial profilometers. These computerized profiles are usually stored for a time after completion of a survey and may be available for visual examination. Though the profiles will usually be smoothed or filtered, vertical deviations identified in the computerized profile may indicate localized defects that have not been treated by maintenance.

The last type of pavement condition indicator data is distress. Evidence of distress is manifested through various characteristics, such as cracking, rutting, and potholes in asphalt pavement and spalling, cracking, and faulting in concrete pavement. Most highway agencies perform either a visual or automated distress survey in order to quantify the amount and severity of each distress type present in the pavement.

The correction or treatment of distresses is not the full responsibility of maintenance. Some distresses, such as fatigue cracking, rutting, or shattered slabs, are the result of structural deficiencies and, when they occur on a large scale, must be improved through appropriate rehabilitation strategies. Nevertheless, maintenance may provide temporary fixes until a long-term rehabilitation effort can be conducted.

Other distresses, such as bleeding, spalling, potholes, and bumps, require functional improvements to restore adequate safety and, to a lesser extent, riding comfort. Treatment of these types of distresses is usually provided by maintenance and, therefore, the condition data for these distresses may be suitable for use as indicators of maintenance quality.

Still other distresses, such as longitudinal and transverse cracking and joint seal damage, are also largely the responsibility of maintenance. These types of distresses are treated to preserve the pavement investment (i.e., extend the life of the pavement). Condition data for these types of distresses may also be applicable in the assessment of maintenance quality.

The suitability of PMS distress data for use in the LOS rating system depends on many factors, the foremost of which include the following:

- Frequency of pavement surveys—Most PMSs entail annual (100 percent of pavement sections sampled each year), biennial (100 percent of pavement sections sampled every 2 yr), or triennial (100 percent of pavement sections sampled every 3 yr) surveys of a given facility type. For instance, several SHAs perform annual condition surveys of their interstate pavements and biennial surveys of their non-interstate pavements. Because maintenance quality should be evaluated at least annually, PMS data based on biennial or triennial surveys would not be adequate.
- Timing of pavement surveys—Pavement management distress surveys are often performed in the spring and early summer, so as to avert the busy construction schedule. LOS inspections, on the other hand, may be done routinely with little regard to yearly seasons or construction/maintenance seasons, or may be done at selected times of the year. Any attempted linkages between the two systems must take into consideration the need for consistency in timing.
- Length of pavement survey segments—LOS sample segments will generally range between 0.1 and 1.0 mi (0.16 and 1.61 km). PMS survey segments may range from 100 ft (30.5 m) to the entire length of a pavement section (which could be several miles [kilometers]). If there is to be a linkage between the two systems, a common length must be established.
- Availability of desired data—Several highway agencies only collect key distress data, such as cracking, rutting, and patching. In such instances, the possibility of using PMS data for a more complete assessment of maintenance quality is substantially reduced.
- Accuracy of data and type of pavement surveys—PMS distress data are collected in a myriad of fashions, ranging from visual surveys of randomly selected samples to automated continuous surveys. For PMS data to be useful in the LOS ratings, the information must be collected from the same sample units as the LOS ratings, and the condition surveys must be objective, accurate, and repeatable.

Should an agency be able to overcome the above linkage obstacles, it still must consider the nature of the PMS distress data collected. The agency must first review each distress type and decide if maintenance has an obligation to correct it or whether, by policy, it is a distress that is "out of maintenance's hands."

If a particular distress is considered a major responsibility of maintenance, then the form in which the data are stored in the PMS database must be examined. Data from pavement conditon index (PCI) type surveys are generally in the form of severity and amount, and these types of data can be fairly conducive to translation into maintenance quality ratings. For example, in a PCI survey, rutting in asphalt pavement is recorded according to severity levels of low (mean rut depth of 0.25 to 0.5 in. [6 to 13 mm]), medium (mean rut depth > 0.5 to 1 in. [>13 to 25 mm]), or high (mean rut depth >1 in. [25 mm]), and the amount observed (in terms of ft^2 [m^2]). This information is considered sufficient for determining whether a sample segment passes a defined condition standard, thereby enabling an LOS rating to be made.

Tables B-1 and B-2 list several distresses that are commonly evaluated in condition surveys of asphalt and concrete

TABLE B-1 Flexible pavement distresses, nature of PMS data, and suitability for use in LOS rating system

Distress	PCI Survey		Suitable for Use Based on Maintenance Responsibility?	Suitable for Use Based on Nature of Data?
	Severity	Amount		
Alligator Cracking	L, M, H (based on crack width, deterioration, and interconnectivity)	ft^2	Partly, from standpoint of patching over cracks.	No.
Block Cracking	L, M, H (based on crack width, deterioration, and sealed or unsealed)	ft^2	Partly, from standpoints of sealing cracks or patching wide cracks.	No. Cracks may have been sealed by maintenance, but can be classified as L, M, or H based on surrounding deterioration. Also, amount is expressed in terms of area instead of linear ft.
Transverse Cracking	L, M, H (based on crack width, deterioration, and sealed or unsealed)	linear ft	Partly, from standpoints of sealing cracks or patching wide cracks.	No. Cracks may have been sealed by maintenance, but can be classified as L, M, or H based on surrounding deterioration.
Longitudinal Cracking	L,M, H (based on crack width, deterioration, and sealed or unsealed)	linear ft	Partly, from standpoints of sealing cracks or patching wide cracks.	No. Cracks may have been sealed by maintenance, but can be classified as L, M, or H based on surrounding deterioration.
Edge Cracking/Raveling	L, M, H (based on crack width and deterioration)	linear ft	Partly, from standpoints of sealing cracks or patching raveled areas.	Yes.
Potholes	L, M, H (based on diameter and depth)	number	Yes.	Yes.
Deteriorated Patches	L, M, H (based on deterioration level and subjective ride quality)	ft^2	Yes.	Yes.
Bleeding/Flushing	L, M, H (based on thickness)	ft^2	Yes.	Yes.
Raveling/Weathering	L, M, H (based on amount of material worn away)	ft^2	Possibly.	Yes.
Rutting	L, M, H (based on depth)	ft^2	Yes.	Yes.
Corrugations/Waves	L, M, H (based on subjective ride quality)	ft^2	Yes.	Possibly.
Bumps/Heaves	L, M, H (based on subjective ride quality)	linear ft	Yes.	Possibly.
Shoving/Pushing	L, M, H (based on subjective ride quality)	ft^2	Yes.	Possibly.
Lane–Shoulder Drop off	L, M, H (based on elevation difference)	linear ft	Yes.	Yes.
Depressions/ Settlements	L, M, H (based on depth)	ft^2	Yes.	Yes.

1 ft = 0.305 m

TABLE B-2 Rigid pavement distresses, nature of PMS data, and suitability for use in LOS rating system

Distress	PCI Survey		Suitable for Use Based on Maintenance Responsibility?	Suitable for Use Based on Nature of Data?
	Severity	Amount		
Transverse Cracking	L, M, H (based on crack width, faulting, and sealed or unsealed)	No. slabs	Partly, from standpoints of sealing cracks or patching wide cracks.	No. Cracks may have been sealed by maintenance, but can be classified as L, M, or H based on crack width and/or faulting.
Longitudinal Cracking	L, M, H (based on crack width, faulting, and sealed or unsealed)	No. slabs	Partly, from standpoints of sealing cracks or patching wide cracks.	No. Cracks may have been sealed by maintenance, but can be classified as L, M, or H based on crack width and/or faulting.
D-Cracking	L, M, H (based on area of distress and extent of pieces "popped out")	No. slabs	Partly, from standpoint of patching severely deteriorated areas.	No.
Corner Breaks	L, M, H (based on crack width and deterioration, and degree of breakup)	No. slabs	Partly, from standpoint of sealing cracks.	No. Cracks may have been sealed by maintenance, but can be classified as L, M, or H based on crack width and deterioration.
Faulting	L, M, H (based on difference in elevation)	No. slabs	Possibly, if maintenance does grinding on a routine basis.	Yes.
Joint Seal Damage	L, M, H (based on deterioration level of seals within entire sample unit)	—	Yes.	Yes.
Punchouts (CRC)	L, M, H (based on number of punched out pieces along majority of cracks)	No. slabs	Yes.	Possibly.
Spalling	L, M, H (based on depth and dimensions)	No. slabs	Yes.	Yes.
Patch Deterioration	L, M, H (based on level of deterioration)	No. slabs	Yes.	Yes.
Pumping	— (No severity levels given, either exists or doesn't exist)	No. slabs	Possibly, if maintenance performs slabjacking on a routine basis.	Yes.
Blow-ups/Buckling	L, M, H (based on subjective ride quality)	No. slabs	Yes.	Possibly.
Lane–Shoulder Drop off	L, M, H (based on elevation difference)	No. slabs	Yes.	Yes.
Polished Aggregate	—(No severity levels defined, either exists or doesn't exist)	No. slabs	Possibly, if maintenance does grinding or thin overlay work.	Possibly.

pavements. How the severities and amounts of these distresses are recorded as part of a PCI survey are also listed. Given the nature of maintenance condition standards that make up the prototype QA program (Tables 6 and 7 in Chapter 3), suggestions are offered in Tables B-1 and B-2 concerning the suitability of PMS distress data for use in the QA program (i.e., LOS rating system). These suggestions are made with the assumption that all other aspects of QA program–PMS linkages (e.g., frequency and timing of surveys, availability and accuracy of data) are consistent.

As seen in these tables, several of the distress types appear to be fairly suited for application to the QA program. The occurrence of such distresses is generally a reflection of whether maintenance has been applied effectively, and the formats in which the data for these distresses are recorded are fairly suitable for generating LOS ratings. A few of the distress types in these tables are not considered suitable for use. For example, longitudinal and transverse cracking in asphalt may be adequately treated (i.e., sealed or filled) by maintenance forces, but a PCI survey will not necessarily account for that work, because surrounding deterioration can be cause for a medium- or high-severity rating.

It is recognized that most highway agencies have unique ways to record distress data. Some agencies record the actual quantities of each severity level of a particular distress, whereas others record a rating for each distress, based on a qualification of the severity and extent observed. Agencies interested in trying to use their pavement distress survey data in the LOS rating system as a means of eliminating duplication must examine the compatibility of the two systems; carefully review the availability, accuracy, and appropriateness of the PMS data; and make sure that the distresses of interest are clearly a responsibility of the agency maintenance organization.

BRIDGE MANAGEMENT SYSTEMS

As stated in the Bridge Inspector's Training Manual (FHWA 1991), "Because for the requirements that must be fulfilled for the National Bridge Inspection Standards (NBIS), it is necessary to employ a uniform bridge inspection reporting system." Because of this level of standardization, a linkage between BMS and the maintenance QA program may be easier to create than with a PMS. Although many varieties of BMSs exist, most of them contain at least some of the items shown in Figure A-2 in Appendix A.

Because of the requirements for periodic reporting of bridge inspection results to the FHWA, most agencies will have access to excellent bridge inspection data. These data are the results of routine inspections conducted on all public structures on a 2-yr basis. Using these data as a basis deficiencies within the structure should be identified and repairs to keep the structures in safe operating condition can be made.

As with PMSs, careful consideration should be given to BMSs to ensure that the inspection periods and procedures coincide (i.e., one review may done three times a year, whereas the other is performed annually or biennially), and that the BMS data are available, accurate, and in a format appropriate for converting to a maintenance LOS rating.

SAFETY MANAGEMENT SYSTEMS

In the initial *Rules and Regulations* (Federal Register 1993) concerning the development of an SMS, the following was proposed:

> *Formalized and interactive communication, coordination, and cooperation shall be established among the organizations responsible for these major safety elements including: enforcement, emergency medical services, emergency response, motor carrier safety, motor vehicle administration, State highway safety agencies, the public health community, State and local transportation/highway agencies, and State and local railroad and or/trucking regulatory agencies.*

The goal of the SMS is to reduce the number and severity of traffic crashes by ensuring that all phases of highway planning, design, construction, maintenance, and operation are involved. Given this challenge, one can only imagine the size and complexity of the SMS and the amount of data it typically contains.

In recent discussions with several SHAs that are in various stages of implementing an SMS, most have indicated they will not be collecting field information for the development of new data files. Instead, they plan on reading available information from the data files of those organizations quoted in the *Rules and Regulations* (Federal Register 1993). Since maintenance data are dynamic and are updated periodically, it appears that most SMS administrators plan to use maintenance data as the input for the SMS. A concern was also expressed by some of the agencies dealing with the quality of the data (not necessarily maintenance) contained in the files they were planning to access. Should an agency desire to perform a linkage between the maintenance QA program and their SMS, care should be given to ensure the data collected and provided by others are accurate and repeatable.

INFRASTRUCTURE MANAGEMENT SYSTEMS

An IMS is an overall management system that integrates all the infrastructure components and individual management systems of an agency. It is a tool that provides highway and public works managers with the information necessary to make important decisions about total infrastructure maintenance, renovation, and replacement.

IMS usage is not very common among state and local governmental agencies. However, it is anticipated that IMS usage will increase dramatically in the next several years because of the growing demand to provide high-quality service within very limited budgets. Many agencies collect all or several components of an IMS, but most do not coordinate the data collection activity or consolidate the information into one overall system.

IMSs are perhaps most commonplace in a large local government agency with centralized management responsibility of the entire infrastructure system. Out of necessity, these agencies have been required to "do more with less," and an IMS assists them in this task.

For an IMS to operate effectively, a well-coordinated data collection plan, database update schedule, and universal location referencing method are required. These items ensure that data collection duplication or redundancy does not occur, that the database is maintained and has current and accurate data, and that data can be exchanged between the various IMS subsystems.

Because of this well planned and organized data collection effort and referencing method, it may be possible that some IMS data are suitable for use in the QA program. Listed in Table B-3 are the drainage, traffic control and safety (signs and barriers), and vegetation and aesthetics maintenance elements and the corresponding types of information typically stored in an IMS for these elements. An IMS can contain hundreds of different data items; in no way is this table meant to serve as a complete comparison of all items.

As with PMS and BMS data, the suitability of IMS data for use in the QA program depends on several factors, including the following:

- Frequency of surveys—Many IMS items are collected only once and serve as inventory items. These items do not change as long as the facility is in use and could be used to help populate the inventory portion of the QA program database. Other IMS data that relay condition information are collected on a biannual (2 times per year) or more frequent schedule. These data are not suitable for use in most LOS ratings.
- Timing of surveys—IMS data collection cycles are based on the data collection cycles established for the individual management subsystems in an IMS. Most surveys are performed during the time of nonpeak construction and maintenance activity. These cycles often do not fit the timing of surveys being recommended as part of the prototype QA program. If information from an IMS is to be used in the QA program, the survey timing of the IMS would require modification to allow data collection at different times.
- Accuracy of data and type of surveys—IMS data are collected using several different methods within the same

TABLE B-3 Summary of highway features/characteristics condition-evaluated as part of IMSs

Element	QA Feature/Characteristic	IMS Information
Drainage	Ditches	Type, width, slope, inslope, backslope erosion control and condition.
	Culverts/Pipes	Location, type, size, age, direction of flow, slope, condition, maintenance schedule, complaints.
	Catch Basins/Drop Inlets	Same as culverts/pipes.
	Under/Cross Drains	Same as culverts/pipes.
	Curb and Gutter	Type, age, condition.
Traffic Control and Safety (signs)	Signs	Location, size, type, age, message, colors, reflectivity, condition, and mounting type.
	Pavement Markers/Symbols	Location, type, age, condition.
	Striping/Markers	Same as pavement markers/symbols.
	Signal	Location, age, style, arm size and type, color, paint condition, structural defects, base type, and luminance.
	Luminaries	Same as signals.
Traffic Control and Safety (barriers)	Barrier Wall	Location, type, size, age, condition, meets standards, and accident history.
	Guardrail	Same as barrier wall.
	Impact Attenuators	Same as barrier wall.
Vegetation and Aesthetics	Mowing	Acreage.
	Litter/Debris	None.
	Bush & Tree Control	Location, size and type.
	Graffiti	None.
	Fence	Location, type, size, age, condition.
	Slopes/sidewalks	Location construction history, width, and condition.
	Landscaping	None.
	Debris	None.
	Turf	None.

agency. This can result in a combination of visual, automated, continuous, partial, random, and other survey methods. For IMS data to be useful in the LOS ratings, the information must be collected from the same sample units, and the condition surveys must be objective, accurate, and repeatable.

- Availability of desired data—As a result of an IMS's integrated database and universal referencing system, the actual physical exchange of data should not be a problem. The problem will arise when the data required by the QA program are not collected, or are collected in a different form. In all IMSs, some modifications will have to be made by the agency to obtain condition data that can be directly downloaded to the QA database.

Even though IMSs have a well-planned data collection process, the information is not exactly what the QA program needs. Information from the IMS is suited to help establish the inventory items in the QA database, but beyond the initial survey, it is generally not suited for use in updating the condition elements or performing LOS ratings. In an IMS, just as in other management systems, most condition surveys are not performed with the frequency recommended for a QA program, at the same locations as the LOS sample sections, and may not contain the exact items needed to perform the LOS ratings.

APPENDIX C

LONG-TERM PERFORMANCE OF HIGHWAY FACILITIES

INTRODUCTION

Once the prototype QA program is in place, the implementing agency is faced with a very challenging question—How can the program's effectiveness be judged? Most agencies are interested in minimizing the costs of achieving and maintaining the target LOS. This sounds simple, but the truth is that nearly all agencies are faced with the same dilemma every year—there is not enough money in the maintenance budget to complete all of the desired maintenance activities. Agencies are forced to make choices when distributing maintenance funds in order to simultaneously accomplish two objectives:

1. Keep the customers happy by coming as close as possible to achieving or surpassing the public's expected LOS.
2. Optimize the overall highway facility's performance.

This is the tradeoff that must be investigated to judge the QA program's effectiveness. As the overall highway facility's long-term performance is improved, it becomes much easier to achieve desired LOS with the same maintenance budget. Because of these agency goals, it appears that one of the best methods to judge the QA program's effectiveness involves tracking the relationships between the QA program outputs (i.e., LOSs associated with various maintenance features) and the measured long-term performance of highway facilities, such as pavements, bridges, drainage features, and safety appurtenances.

The long-term performance of highway facilities must be evaluated in terms of the following four aspects, which are the main considerations of maintenance:

- Safety,
- Preservation of investment (service life),
- Comfort and convenience, and
- Aesthetics.

Once again, agencies must make sure that customers are happy with the delivered LOSs related to safety, comfort and convenience, and aesthetics; however, at the same time, they must optimize their preservation of investment (i.e., maximum service life for the money available). The QA program provides an indirect evaluation of facility performance, as it assesses feature compliance with customer-based quality standards. For many highway features, what is measured as part of the QA program is also the true measure of performance (e.g., pavement striping is performing as expected if the striping is adhered to the pavement and a certain reflectivity can be measured). Other highway features, such as pavements and bridges, are more complicated and require additional condition measurements to truly assess performance.

In the quest for developing an appropriate methodology for tracking facility long-term performance and QA program outputs, the decision was made to focus on pavement facilities. This decision was made based on the following factors:

- Pavement performance is more difficult to assess (i.e., the effects of pavement maintenance on pavement performance are not as easy to assess as the effects of maintenance on the performance on some of the other highway elements, such as pavement striping, signs, or guardrails).
- A large amount of the maintenance budget goes into maintaining pavements.
- Highway users are greatly affected by the maintenance applied to pavements.
- PMSs are an excellent external data source.
- PMS and LOS rating system data are much more available.

Even though the methods presented herein relate specifically to pavement facilities, it is believed that the concepts can be applied to other maintenance components (e.g., bridges, safety structures/devices) without much difficulty.

Several different approaches were investigated in the attempt to identify connections between long-term highway performance and QA program outputs. Some of the key considerations in the development of tracking methods include the following:

- Minimize the effects of compounding factors (i.e., traffic, climate, design) on performance.
- Make use of readily available performance data contained in agency management information systems.
- Identify at least two tracking methods that an agency could select from based on management philosophy, organizational size and structure, and available resources.

Two relatively suitable methods were identified and developed for presentation in this manual. These methods are the *Backlog Analysis* method and the *Change in Condition Indicator* method. Each method is described in detail below, with listings of advantages and disadvantages given, recommendations for agency usage offered, and the adaptation of the concepts to other maintenance components discussed.

METHOD 1—BACKLOG ANALYSIS

Many agencies define a critical pavement condition level in their PMS, which is used to signal the need for rehabilitation. The group of pavements with deteriorated conditions worse than the chosen critical condition level are commonly referred to as the pavement backlog. It is a continuing goal of any agency to minimize (or, if possible, eliminate) its backlog. To assist in this goal, the maintenance division is generally given two objectives:

1. Provide the most appropriate maintenance to keep pavement conditions above the critical level for the longest period of time.
2. Once pavement conditions have deteriorated to (or past) the critical level, provide adequate maintenance until rehabilitation can be administered.

The *Backlog Analysis* method will help track not only the percentage of pavements in the backlog, but also the rate that pavements deteriorate from one condition to the next (otherwise referred to as the accrual rate). Because higher LOS ratings signify more effective and efficient maintenance, it is logical that an increase in LOS should be accompanied by a reduction in the pavement deterioration rate (i.e., increased pavement performance). The *Backlog Analysis* method has been designed to track this relationship.

Procedure

The following steps describe the details of the *Backlog Analysis* method.

Step 1. Determine the Analysis Group.

The analysis group refers to the chosen set of pavement projects to be included in the analysis. To determine the analysis group, the agency must answer the following questions:

- What geographical location is to be investigated?
  The agency must first decide on the geographical scope of the analysis. Different geographical location choices may include an entire state, a district, a county, a specific maintenance unit, or some other identifiable division.
- What facility types are to be included?
  The agency must next decide on the facility types to be included in the analysis. Highways categorized under the same facility type generally have similar functional types, pavement designs, and traffic, and contain similar types of features (signing, safety, structures). Sample facility types include rural limited access, urban limited access, rural arterial, and urban arterial.
- What pavement types are to be included?
  The final step in determining the analysis group is deciding on the pavement types to be included in the analysis. Some sample pavement type selections include all pavement types, all flexible pavements, all rigid pavements, JPC pavements, JPC with an AC overlay, and AC pavement.

By answering the above three questions, the agency can establish a definition of the required analysis group.

Step 2. Select Appropriate Condition Indicators.

Highway agencies use various indicators to assess pavement condition over time. Among the more commonly used indicators are the IRI, PCI, present serviceability index (PSI), rut rating, and crack rating. Many highway agencies have also developed their own composite rating indices that combine various individual condition indicators (ride quality, cracking amount, faulting) into one overall condition index. For those agencies, the composite index may be the most appropriate choice for this method. For other agencies, any reasonable condition indicator will be appropriate.

Step 3. Establish Performance Categories over the Scale of the Chosen Condition Indicators (optional).

Because condition indicators are typically measured with a continuous scale (e.g., 0–5, 0–10 or 0–100), it is suggested that an agency divide the scale into 5 or 6 performance categories, such as *Very Good, Good, Fair, Poor,* and *Very Poor.* The category or two representing the lowest performance ranges should correspond with the point at which a pavement is considered to have reached the backlog. Although the performance categories will increase the understanding by managers, elected officials, and the public, it is not a requirement in this method. For consistency, the performance categories *Very Good, Good, Fair, Poor,* and *Very Poor* will be used in the description of the remaining steps.

Step 4. Develop a Pavement Condition Range Matrix for All of the Pavements in the Chosen Analysis Group.

For each year, a pavement condition range matrix is developed for the chosen analysis group. The matrix allows an agency to track the conditions of all pavements in the analysis group from one year to the next. Table C-1 shows an example of such a matrix for an analysis group containing 100 pavements.

The columns labeled as Previous Year show the 100 pavements and their rated conditions as interpreted during the last year. The columns labeled as Current Year show how each pavement has changed condition from the previous year to the current year. For example, 30 pavements were interpreted as being in *Good* condition during the previous year. However, from the previous year to the current year, those 30 pavements have changed condition in the following manner:

TABLE C-1 Example of a pavement condition range matrix

Previous Year Distribution		Current Year Distribution					
Condition	No. of Pavements	*Very Good*	*Good*	*Fair*	*Poor*	*Very Poor*	Rehabilitated
Very Good	20	18	2	0	0	0	0
Good	30	0	19	8	3	0	0
Fair	20	0	0	15	4	1	0
Poor	20	0	0	0	15	5	0
Very Poor	10	0	0	0	0	4	6
Total	100	18	21	23	22	10	6

- Nineteen pavements have stayed at the *Good* condition.
- Eight pavements have deteriorated from *Good* to *Fair* condition.
- Three pavements have deteriorated from *Good* to *Poor* condition.

To complete this matrix, an agency must keep track of each pavement's condition from one year to the next. Once the matrix has been completed for the current year, say 1996, the values included in the Total row at the bottom are used as starting values for the next year (1997 Previous Year values). It is recommended that the six pavements receiving rehabilitation be removed from the analysis group if the rehabilitation has caused the pavement type to change. For example, if the analysis group contains only non-overlaid JPC pavements and the six pavements are rehabilitated with an AC overlay, then those six pavements should now be included under a new analysis group that consists of AC-overlaid JPC pavements. Because the deterioration of an AC-overlaid pavement is much different than that of a JPC pavement.

Step 5. Develop Pavement Condition Range Probability Matrix for the Chosen Analysis Group.

Once the pavement condition range matrix is developed for the chosen analysis group, the probabilities of moving from one condition to the next can be determined. This is done by taking the number of pavements observed in a Previous Year condition category and dividing it into the number of pavements observed in the corresponding Current Year category. For example, in Table C-2, a pavement labeled as *Good* for the Previous Year has the following Current Year condition probabilities:

- *Good* condition ⇒ *Very Good* condition: 0 percent ($0/30 \times 100\% = 0\%$).
- *Good* condition ⇒ *Good* condition: 63 percent ($19/30 \times 100\% = 63\%$).
- *Good* condition ⇒ *Fair* condition: 27 percent ($8/30 \times 100\% = 27\%$).
- *Good* condition ⇒ *Poor* condition: 10 percent ($3/30 \times 100\% = 10\%$).
- *Good* condition ⇒ *Very Poor* condition: 0 percent ($0/30 \times 100\% = 0\%$).

A table of probabilities, like the one shown in Table C-2, can be monitored from year to year in order to estimate the deterioration rates of pavements at different conditions.

Step 6. Summarize LOS Rating Data Representing the Chosen Analysis Group.

The yearly LOS program rating data for the roadway maintenance elements are summarized for all of the highway sections included in the analysis group. An average LOS rating is calculated and chosen to represent the analysis group for the particular year in question.

Step 7. Plot Probabilities of Pavement Condition by Year.

The probabilities of moving to a new pavement condition can be plotted for each year using the data from the probabil-

TABLE C-2 Example of a pavement condition range probability matrix

Previous Year Distribution		Current Year Probabilities					
Condition	No. of Pavements	*Very Good*	*Good*	*Fair*	*Poor*	*Very Poor*	Rehabilitated
Very Good	20	0.90	0.10	0.00	0.00	0.00	0.00
Good	30	0.00	0.63	0.27	0.10	0.00	0.00
Fair	20	0.00	0.00	0.75	0.20	0.05	0.00
Poor	20	0.00	0.00	0.00	0.75	0.25	0.00
Very Poor	10	0.00	0.00	0.00	0.00	0.40	0.60
Total	100	0.18	0.21	0.23	0.22	0.10	0.06

ity matrix constructed in step 5. An agency can use the yearly plots to identify trends in probabilities. At the same time, an agency can determine the respective LOS rating from step 6 and track these data simultaneously. Intuitively, yearly increases in LOS rating should result in higher probabilities of a pavement keeping the same condition—or possibly achieving a better condition. Figures C-1 and C-2 illustrate this concept, whereby the LOS rating has increased from a 65 to an 80 from 1990 to 1996. The figures represent an example of the effects of the application of more effective and uniform maintenance. They also illustrate the expected trend in which the probabilities of maintaining the previous year's condition are higher at a higher LOS rating (80 in 1996) than those probabilities calculated in a year with a lower LOS rating (65 in 1990).

Probabilities within each individual condition category can also be plotted and compared year to year. For instance, Figure C-3 shows the comparable probabilities of the *Very Good* category for the two hypothetical years 1990 and 1996 used in the examples above.

Advantages and Disadvantages

The advantages of the *Backlog Analysis* method include the following:

- This method is relatively easy to use if pavement condition history and LOS data are available.
- Most agencies understand and use the backlog concept.

The disadvantages of the *Backlog Analysis* method include the following:

- Backlog measurements are heavily dependent on the respective maintenance and rehabilitation budgets.
- Interpretation of the overall results is somewhat subjective and should be done very carefully.
- The method does not include cost information.
- Results are very sensitive to the type and timing of the rehabilitation applied.
- This method should only be used on pavements in the *Good, Fair,* and *Poor* categories.
- Condition ratings in a PMS are not updated with enough frequency to always make reliable comparisons.

Recommended Agency Usage

Agencies that routinely collect condition indicator data for pavements can use this method. As a minimum, this method supplies an agency with an assessment of the overall yearly rates of deterioration for pavements and another way to estimate backlog and its accrual rate.

Other Maintenance Components

This method may easily be applied to any maintenance component as long as a specific LOS rating and condition (performance) indicator can be determined.

METHOD 2—CHANGE IN CONDITION INDICATOR

The *Change in Condition Indicator* method compares the annual LOS rating to an annual change in a chosen condition indicator for a given analysis group. This method allows an

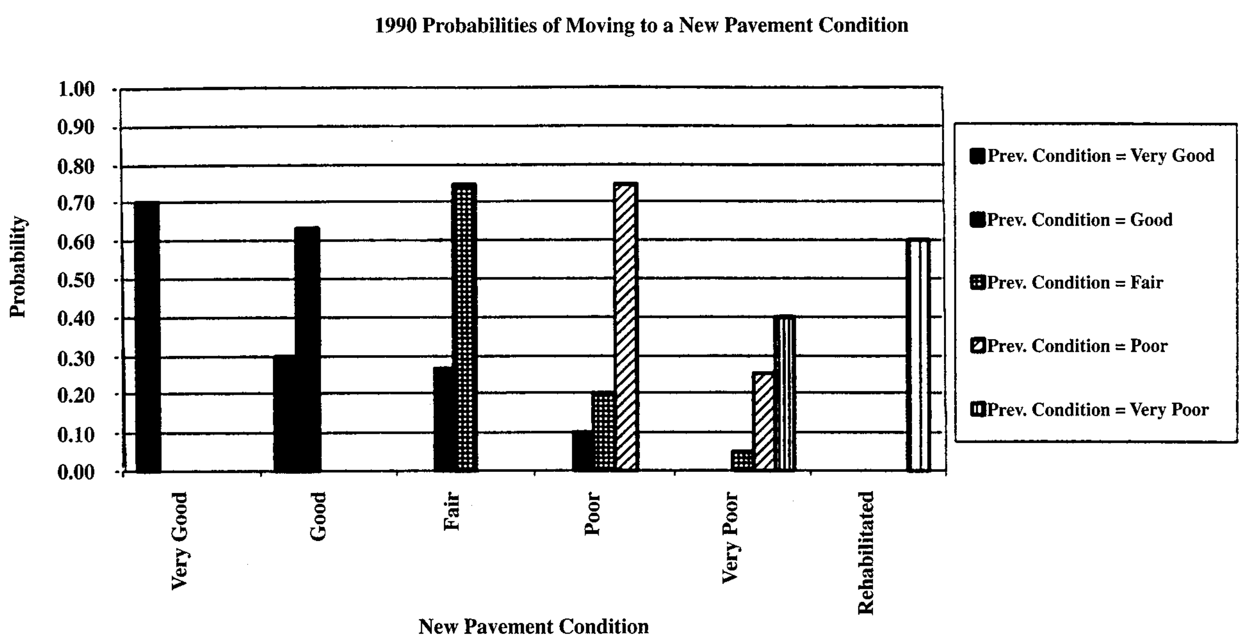

Figure C-1. Example of a probability plot for a year at a lower LOS rating (e.g., year = 1990 and LOS rating = 65).

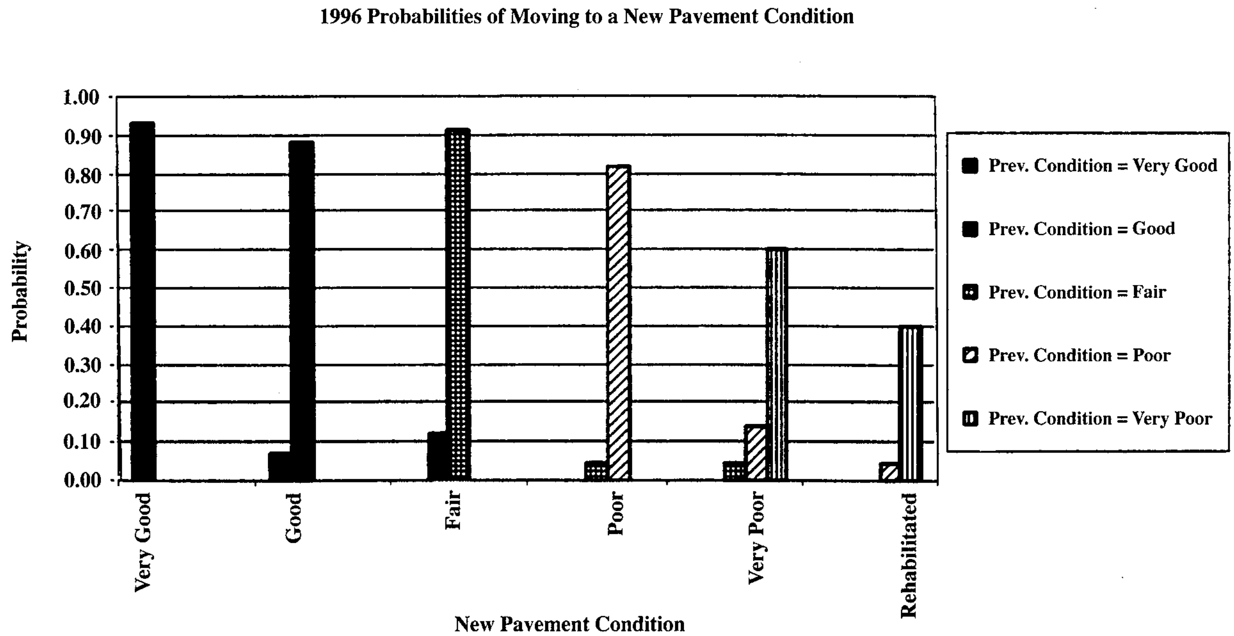

Figure C-2. Example of a probability plot for a year at a higher LOS rating (e.g., year = 1996 and LOS rating = 80).

agency to examine the relationship between the level of pavement maintenance and the corresponding effect on pavement performance, in terms of the rate of deterioration over time. These condition indicators are the same indicators described under step 2 of the *Backlog Analysis* method. Some appropriate choices would include IRI, PCI, PSI, rut rating, and crack rating.

As mentioned before, many highway agencies have developed their own composite rating indices that combine many condition indicators (e.g., ride quality, cracking amount, faulting) into one overall condition index. For those agencies, the composite index may be the most appropriate choice for use with this method. For other agencies, any reasonable condition indicator may be used for this method.

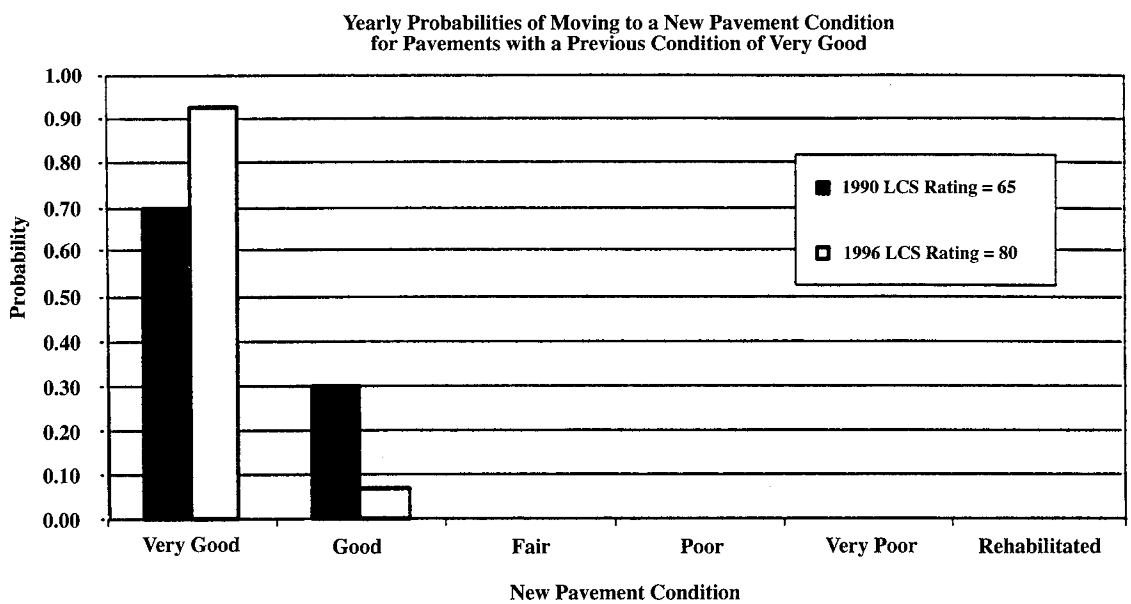

Figure C-3. Example of a year-to-year probability plot for those pavements with a previous condition of Very Good.

The *Change in Condition Indicator* method involves first determining the average yearly change in the chosen condition indicator for the pavement sections in the analysis group. This average yearly change is referred to as the deduct value for the given year, and the linear trend represented by this deduct value becomes the respective deduct curve. With deduct curves established for multiple years, the annual LOS ratings for those years can be linked together, and the resulting trend between maintenance quality and pavement performance can be examined. The deduct curve portion of this method is based on performance modeling work done for the Illinois DOT (ERES 1995).

Figure C-4 depicts the theoretical relationship between the deduct curve and LOS rating. In this figure, the deduct curves associated with two levels of routine maintenance—Good and Poor—are shown. Each level can be equated with an LOS rating: a higher rating, say 82, for well-maintained pavements and a lower rating, say 55, for poorly maintained pavements. The deduct curve associated with the well-maintained pavements is expected to have a flatter slope than the curve representative of poorly maintained pavements. The flatter slope reflects the higher maintenance level, and given a specific threshold (e.g., $(PSI)_{1,t}$) for rehabilitating pavements, the flatter slope would result in a longer pavement service life. The following sections describe the details of the *Change in Condition Indicator* method.

Procedure

Step 1. Determine the Analysis Group.

The analysis group refers to the chosen set of pavement projects that are to be included in the analysis. To determine the analysis group, the agency must answer the following questions:

- What geographical location is to be investigated?
  The agency must first decide on the geographical scope of the analysis. Different geographical location choices may include an entire state, a district, a county, a specific maintenance unit, or some other identifiable division.
- What facility types are to be included?
  The agency must next decide on the facility types to be included in the analysis. Highways categorized under the same facility type generally have similar functional types, pavement designs, and traffic, and contain similar types of features (e.g., signing, safety structures). Sample facility types include rural limited access, urban limited access, rural arterial, and urban arterial.
- What pavement types are to be included?
  The final step in determining the analysis group is deciding on the pavement types to be included in the analysis. Some sample pavement type selections include all pavement types, all flexible pavements, all rigid pavements, JPC pavements, JPC with an AC overlay, AC pavements, and so on.

By answering the above three questions, the agency can establish a definition of the required analysis group.

Step 2. Compile Table of Yearly Condition Indicator Data Representing the Chosen Analysis Group.

All of the yearly condition indicator data are compiled for all of the highway sections included in the analysis group. All of the sample units representing a particular highway section

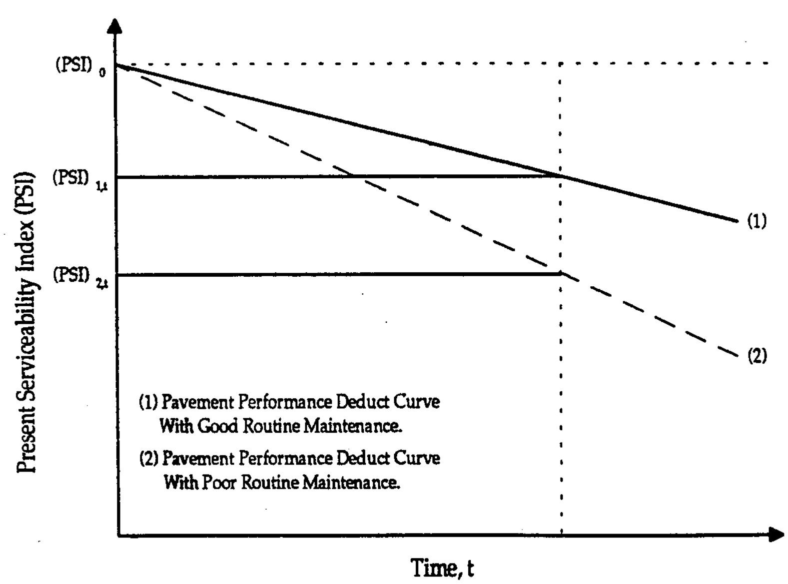

Figure C-4. Relationship between pavement performance and routine maintenance (Fwa and Sinha 1986).

TABLE C-3 Example table of PCI-type condition indicator data

Section ID	Construction Year	Yearly PCI Data 1992	1993	1994	1995	1996
1	1980	85	87	84	80	78
2	1972	72	71	68	60	58
3	1984	89	88	85	82	81
4	1993	—	100	98	97	93
5	1975	82	81	80	75	72

are averaged to obtain a representative yearly condition indicator value for each respective highway section.

To make easy year-to-year comparisons of the data, it is useful to compile more than one year of condition indicator data into a single table. Table C-3 shows an example of such a table (using PCI as the condition indicator) with each row being specific to a particular pavement section and each column representing a year of collected condition indicator data. It is also useful to include the construction year so that the pavement age, at the time the condition data were collected, may be easily computed if required (see step 4).

Step 3. Determine the Yearly Deduct Value.

As described previously, the average yearly change in the chosen condition indicator is referred to as the deduct value for the given year. This deduct value allows an agency to examine more easily the impact of maintenance LOS on pavement performance. The agency's ability to obtain meaningful deduct values depends heavily on the availability of time-series pavement condition data and pavement construction data. As a minimum, an agency must have available pavement section data that fall into one of the two following categories:

- Reliable pavement age data and condition indicator data for 1 year, or
- Condition indicator data for 2 or more consecutive (or closely spaced) years.

It is recommended that an agency collect at least 2 years of consecutive (or closely spaced) condition indictor data before the *Change in Condition Indicator* method be applied. However, as a means of getting started, one set of condition indicator data and reliable pavement age information may be used to calculate deduct values for the first year. The different methods of calculating deduct values are described in the following sections.

- Scenario 1—Multiple year condition data, two-point analysis. Using a two-point analysis requires that deduct values be calculated for each pavement section using 2 consecutive (or closely spaced) years of data. The year for which the deduct values are to be calculated is the more recent of the 2 years of data (i.e., 1992 and 1993 data are used to calculate deduct values for 1993; 1993 and 1994 data are used to calculate deduct values for 1994, and so on). Individual deduct values are calculated by using the time and condition of a specified year and a previous year in the following equation:

$$\text{Deduct}_{(SY)} = \Delta PCI_{(SY-PY)}/\Delta \text{Time}_{(SY-PY)} \qquad \text{(C-1)}$$

where:

$\Delta PCI_{(SY-PY)}$ = PCI for specified year – PCI for previous year.

$\Delta time_{(SY-PY)}$ = specified year – previous year.

Table C-4 contains the 1994 individual deduct values calculated using the 1993 and 1994 PCI data presented in Table C-3. It also shows the 1994 mean deduct value for the five pavement sections considered. These condition data may be plotted on a chart of PCI versus age to help the agency visualize the impact of the calculated deduct values. A plot of the data used in the two-point analysis example is presented in Figure C-5. The respective section ages were calculated using the construction year data presented in Table C-3.

An agency having only 1 year of complete PCI data on file can use this two-point analysis approach if the respective construction years of the pavement sections are known. If only one data set and the pavement age are

TABLE C-4 Example deduct value calculations using the two-point analysis when 2 consecutive (or closely spaced) years of condition data are available

Section ID	Yearly PCI Data 1993	1994	1994 Deduct Values, $Deduct_{(94)}$
1	87	84	-3.00
2	71	68	-3.00
3	88	85	-3.00
4	100	98	-2.00
5	81	80	-1.00
		Mean Deduct Value ➡	-2.40

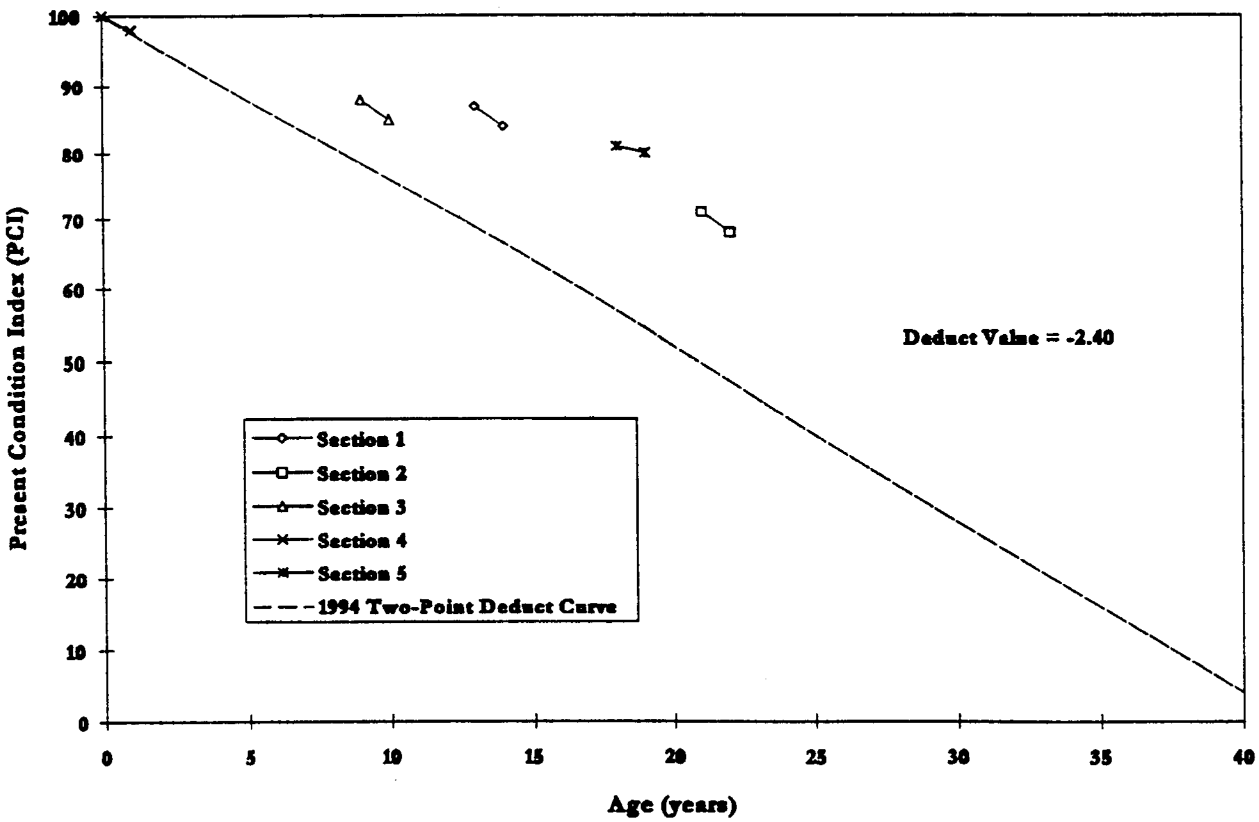

Figure C-5. Example plot of PCI versus age for data used in the two-point analysis with consecutive (or closely spaced) years of data.

available, the following equation can be used to produce individual deduct values:

$$\text{Deduct}_{(SY)} = \left(100 - \text{PCI}_{(SY)}\right)/\Delta\text{Time}_{(SY-CY)} \qquad \text{(C-2)}$$

where:

$\text{PCI}_{(SY)}$ = PCI for the specified year.
$\Delta\text{Time}_{(SY-CY)}$ = specified year − construction year (this is the pavement age at the time of the specified year).

In this equation, the initial PCI is assumed to be 100. This value may need to be adjusted somewhat based on an agency's experience regarding the ability of contractors to build pavements with a PCI of 100. Table C-5 contains the 1994 individual deduct values calculated using the 1994 PCI data and corresponding construction year data presented in Table C-3. It also lists the 1994 mean deduct value for the five pavement sections considered.

These condition data may also be plotted on a chart of PCI versus age to help the agency visualize the impact of the calculated deduct values. An example plot of the

TABLE C-5 Example deduct value calculations using the two-point analysis when only 1 year of condition data and age information are available

Section ID	Construction Year	PCI $\text{Data}_{(94)}$	Section Age in 1994, $\Delta\text{Time}_{(94-CY)}$	Total PCI Change by 1994, 100 - $\text{PCI}_{(94)}$	1994 Deduct Values, $\text{Deduct}_{(94)}$
1	1980	84	14	-16	-1.14
2	1972	68	22	-32	-1.45
3	1984	85	10	-15	-1.5
4	1993	98	1	-2	-2.00
5	1975	80	19	-20	-1.05
				Mean Deduct Value ➡	-1.43

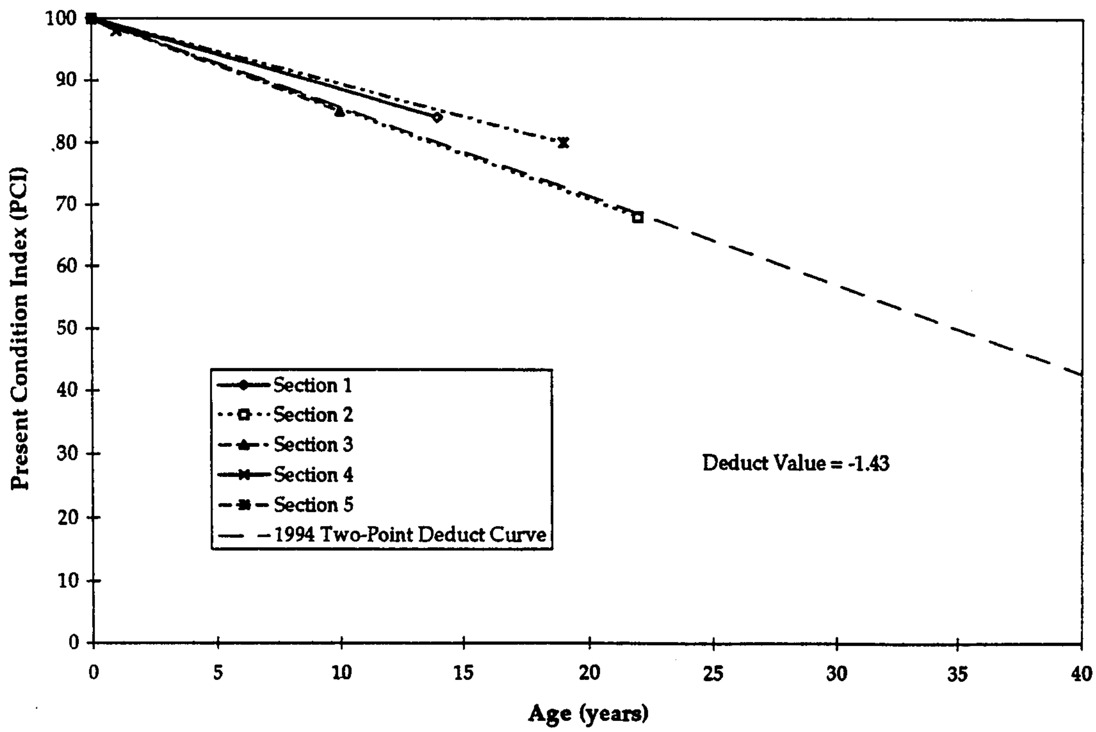

Figure C-6. Example plot of PCI versus age for the data used in the two-point analysis where only 1 year of data and age information are available.

data used in this application of the two-point analysis (when only one year of condition data and the pavement age is known) is presented in Figure C-6.

- Scenario 2—Multiple year condition data, three-point analysis. Once an agency has accumulated at least 3 years of consecutive (or closely spaced) condition data, it becomes more beneficial to include 3 years of data when determining the yearly deduct values. In this way, the resulting deduct values are made more stable over time, and the past actions of maintenance are more accurately considered.

Using the three-point analysis requires that deduct values be calculated for each pavement section using 3 consecutive (or closely spaced) years of data. The year for which the deduct values are being calculated is the most recent of the 3 years of data (i.e., 1992, 1993, and 1994 data are used to calculate a representative deduct value for 1994; 1993, 1994, and 1995 data are used to calculate a representative deduct value for 1995, and so on).

The three-point analysis essentially consists of applying the two-point analysis method to two sets of consecutive (or closely spaced) data. Equation C-1 is first used to compute the deduct value for the first set of data (e.g., 1992–1993), and then is used to compute the deduct value for the second set of data (e.g., 1993–1994). The two resulting deduct values are then averaged to obtain one deduct value that is representative of the entire time span for the analysis group. This process is illustrated below for the first pavement section listed in Table C-3 and using the data for 1992, 1993, and 1994.

$Deduct_{(94)} = (84 - 87)/(1994 - 1993)$
$Deduct_{(94)} = -3.00/1$
$Deduct_{(94)} = -3.00$

$Deduct_{(93)} = (87 - 85)/(1993 - 1992)$
$Deduct_{(93)} = 2.00/1$
$Deduct_{(93)} = 2.00$

$\text{Average Section Deduct}_{(94)} = (-3.00 + 2.00)/2$
$\text{Average Section Deduct}_{(94)} = -1.00/2$
$\text{Average Section Deduct}_{(94)} = -0.50$

Table C-6 summarizes the results for all five pavement sections and lists the mean 1994 deduct value based on the three-point method. It should be noted that only nine values are used because section 4 was constructed in 1993 and, therefore, had no 1992 condition data.

Once again, these condition data may be plotted on a chart of PCI versus age to help the agency visualize the impact of the calculated deduct values. An example plot of the data used in the three-point analysis example is presented in Figure C-7.

Step 4. Plot of Condition Indicator Data Versus Age (Optional).

The current year's condition data (from step 2) may be converted into a plot of condition indicator data versus age if

TABLE C-6 **Example deduct value calculations using the three-point analysis**

Section ID	Yearly PCI Data			Two-Point Analysis Deduct Values		Average Section Deduct$_{(94)}$
	1992	1993	1994	1993	1994	
1	85	87	84	2.00	-3.00	-0.50
2	72	71	68	-1.00	-3.00	-2.00
3	89	88	85	-1.00	-3.00	-2.00
4	—	100	98	—	-2.00	-2.00
5	82	81	80	-1.00	-1.00	-1.00
					Mean Deduct Value ➡	-1.44

the age information is available. It is not required that this plot be constructed in order to obtain a deduct value; however, it does supply an agency with a "snapshot" of what pavement conditions can be expected at certain ages for a particular analysis group.

Step 5. Summarize LOS Rating Data Representing the Chosen Analysis Group.

The yearly LOS rating data for all of the highway sections included in the analysis group are summarized, and an average LOS rating is calculated which will represent the analysis group for the particular year in question. Because the feature of interest in these examples is pavements, only the LOS rating for the **roadway** element is used. If the relationships for a different feature (e.g., guardrail, signs, striping) were to be evaluated, only the LOS for that feature would be used.

Step 6. Plots of Yearly Deduct Curves for Different Average LOS Ratings (Optional).

The yearly deduct curves for multiple years are next plotted on one graph to observe the effects of various LOS levels.

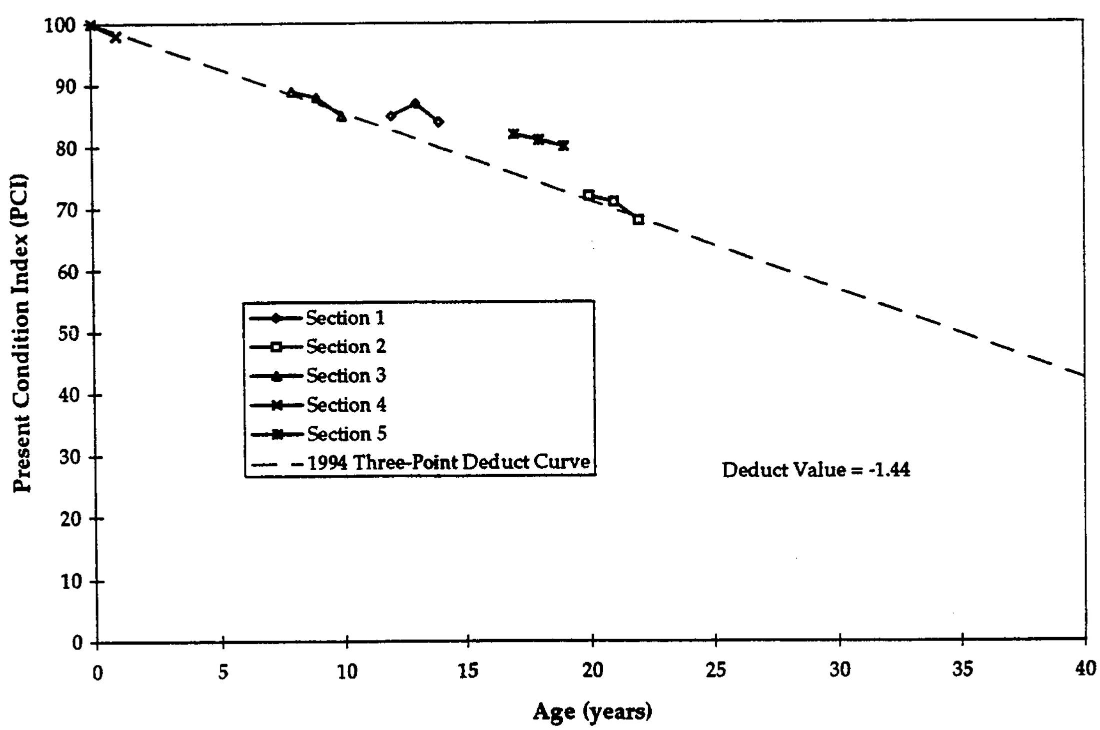

Figure C-7. Example plot of PCI versus age for the data used in the three-point analysis with consecutive (or closely spaced) years of data.

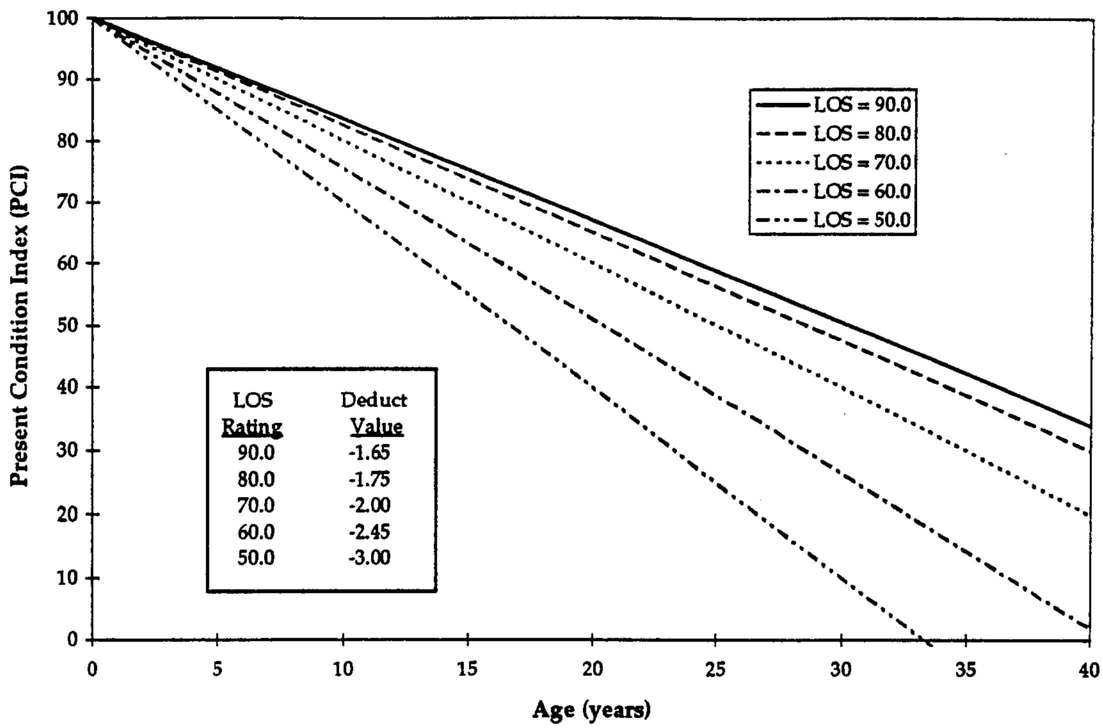

Figure C-8. Conceptual illustration of various combinations of deduct value and LOS rating.

A conceptual illustration of this is provided in Figure C-8. This figure shows a number of deduct curves associated with different LOS ratings. It is believed that this type of plot would be beneficial to agencies attempting to find the most cost-effective LOS. In this particular example, it can be seen that at higher levels of maintenance (say, LOS of 70 or 80) there are diminishing returns. That is, for a fixed increase in LOS, the added service life associated with the LOS increase decreases at higher maintenance levels.

Step 7. Plots of LOS Rating and Yearly Deduct Values Versus Time.

By plotting on the same chart the LOS ratings and yearly deduct values versus time, an agency can examine the correlation between LOS rating and the rate of change in condition. As illustrated in Figure C-9, two different y-axis scales must be used; one for the LOS rating and one for the condition deduct value.

Advantages and Disadvantages

The advantages of the *Change in Condition Indicator* method include the following:

- The method addresses both of the key functions of maintenance (i.e., to provide an adequate LOS and to preserve the agency's investment) and allows an agency to evaluate the relationship between maintenance LOS and facility performance.
- It is relatively easy to use if LOS and facility condition data are available.
- Indices provide good "rules of thumb" to follow and will provide benchmarks for future maintenance activities.
- Most highway agencies collect pavement condition data.
- The condition indicator versus LOS relationships that are developed can be used by other groups within an agency to project pavement performance based on a prescribed level of maintenance.
- The condition indicator versus LOS data could allow an agency to conduct "what if" scenarios and evaluate the performance and cost implications of various maintenance levels.

The disadvantages of the *Change in Condition Indicator* method include the following:

- The condition indicator versus LOS relationship is affected by rehabilitation activities that are not part of maintenance operations.
- Pavement condition data are typically not collected by maintenance departments, and accessing or obtaining the data may be difficult.

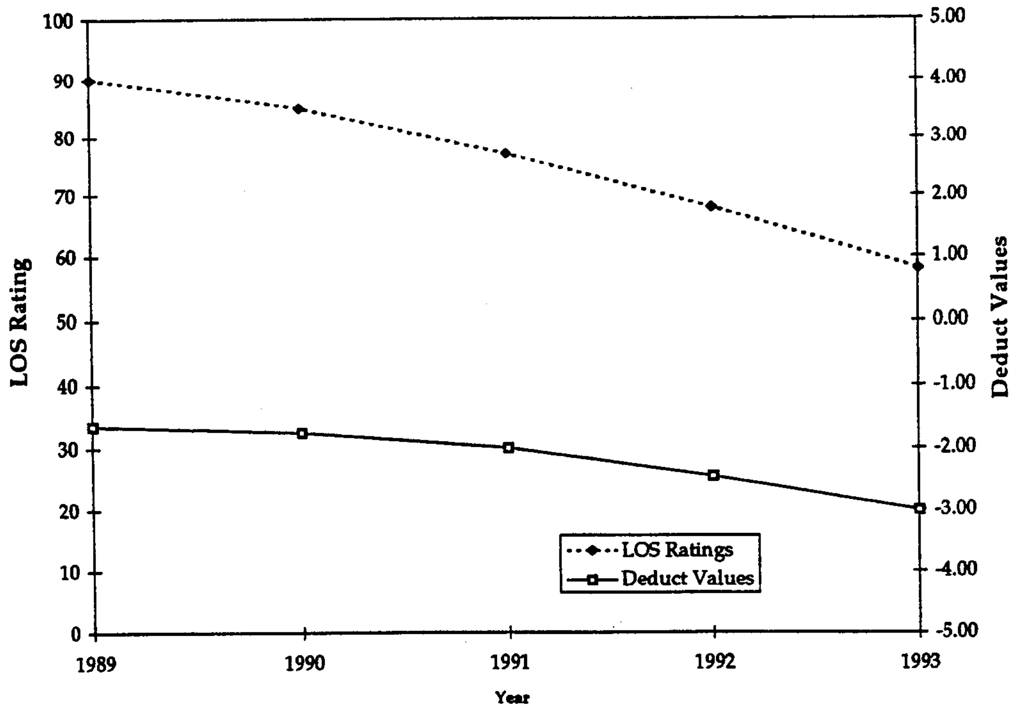

Figure C-9. Conceptual plot of LOS ratings and condition deduct values versus time.

- Obtaining LOS and condition indicator data that correspond to a specific pavement section may be difficult. Because these data typically are not collected within the same group, the spatial referencing and sectioning systems for each group of data may vary.

Recommended Agency Usage

All agencies that collect pavement condition data could use and benefit from this approach to maintenance management. However, this approach is probably more applicable to larger highway agencies, such as states and large metropolitan areas.

Application to Other Maintenance Components

This method is most applicable to those items that are routinely assessed for condition and that are routinely maintained (e.g., pavements, shoulders, and bridges). This method is not applicable for items where maintenance actually consists of replacement (e.g., signs, pavement markings, lights) and those items that are not routinely inspected for condition.

APPENDIX D

OVERVIEW OF WASHINGTON STATE DOT MAINTENANCE ACCOUNTABILITY PROCESS

INTRODUCTION

In 1995, the Washington State DOT hired a consulting team to evaluate its maintenance program in terms of performance measurement, program efficiency, program management, and communications. This evaluation was conducted primarily to serve the needs of two distinct groups. First, the results of this study would assist legislators in understanding management and operation of the maintenance program. Second, it would help DOT staff provide effective responses to requests concerning the impacts on the statewide program of numerous budget scenarios (Washington DOT 1998a).

One of the major recommendations that came out of the study was that the DOT should implement a maintenance accountability process (MAP). The MAP is a comprehensive planning, managing, measuring, and communication process for management of the state highway maintenance program. It provides a clear link between maintenance objectives, maintenance activities, maintenance service levels, the budget, and actual performance, and is consistent with departmentwide quality initiatives. The program consists of a seven-step continuous improvement cycle, as illustrated in Figure D-1 (Washington DOT 1998a).

MAINTENANCE PRIORITIES

As with the NCHRP Project 14-12 prototype QA program, a key concept in the Washington State MAP program is the prioritization of maintenance activities. As shown in Table D-1, a maintenance activity can be performed for a variety of reasons—to improve user safety, to preserve the taxpayers' investment in the roadway, to improve aesthetics, and so on. Each activity must be analyzed to determine which objectives it serves, and to what extent. For example, activity 1A1, pavement patching and repair, has a critical impact on safety and protecting the investment, but it contributes only slightly toward achieving pleasant aesthetics.

Using the matrix shown in Table D-1, DOT maintenance staff can observe the relative importance of each maintenance activity and create a framework for making budgeting decisions.

MAINTENANCE SERVICE LEVELS AND PERFORMANCE MEASURES

The LOS rating system described earlier in this manual is somewhat similar to the rating process established under the Washington State MAP program. In the MAP, the conditions associated with individual features/characteristics located within randomly selected, 0.10-mi (0.16-km) sample segments are measured (e.g., linear feet of cracking, number of pavement markings worn or missing) and recorded by trained personnel. Overall averages of the condition measurements (i.e., performance measures) for each feature/characteristic are then computed and the averages are translated into one of five service levels (A, B, C, D, and F) having progressively lower thresholds. Features/characteristics are linked to various work activities, which in turn are grouped into one of the following seven maintenance groups:

- Group 1—Roadway Maintenance and Operations,
- Group 2—Drainage Maintenance and Slope Repair,
- Group 3—Roadside and Landscape Maintenance,
- Group 4—Bridge and Tunnel Maintenance,
- Group 5—Snow and Ice Control,
- Group 6—Traffic Services, and
- Group 7—Rest Area Maintenance.

Table D-2 illustrates the performance measures and service-level thresholds for activities categorized under the Roadway Maintenance and Operations group. This table also includes the average condition measurements from January 1996 and October 1996 inspection rounds. Provided below are general descriptions of the five service levels established in the MAP program.

Service Level A (Best)

This is a very high service level in which the roadway and associated features are in excellent condition. At this maintenance service level, very few deficiencies are present and the overall appearance is pleasing. Preventive maintenance is a high priority in all maintenance activities, resulting in overall low life-cycle costs. Corrective maintenance activities are minimal. All systems are operational, and users experience no delays (Washington DOT 1997).

Service Level B

This is a high service level in which the roadway and associated features are in good condition. At this maintenance service level, very few deficiencies are present in safety and investment protection activities, but moderate deficiencies exist in all other areas. Preventive maintenance is a high priority for safety-related work but is deferred in other areas,

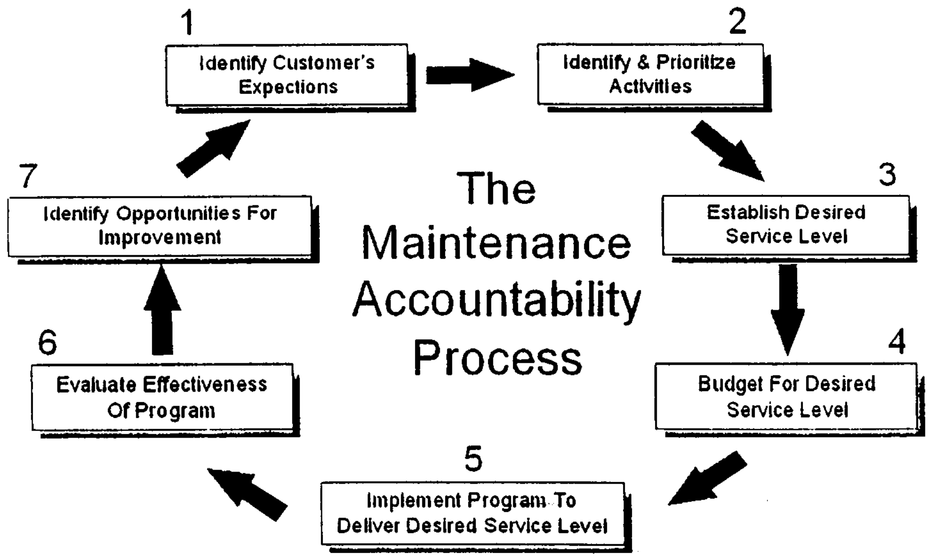

Figure D-1. MAP seven-step continuous improvement cycle (Washington DOT 1998a).

resulting in additional corrective maintenance activities. Corrective maintenance of all elements is given a high priority. Life-cycle costs for maintenance activities are generally low. All systems are operational, but users may experience occasional delays (Washington DOT 1997).

Service Level C

This is a medium maintenance service level in which the roadway and associated features are in fair condition. At this maintenance service level, very few deficiencies are present in safety-related activities, but moderate deficiencies exist for investment protection activities and significant aesthetic-related deficiencies. Preventive maintenance is deferred for many activities but not for safety-related work. Corrective maintenance is routinely practiced for all maintenance activities. A backlog of deficiencies begins to build up that will have to be dealt with eventually, at a higher cost. Some roadway structural problems begin to appear because of the long-term deterioration of the system. There is a noticeable decrease in appearance. Systems may occasionally be inoperable and not available to users. Short-term delays may be experienced when repairs are being made but would not be excessive (normally less than one day) (Washington DOT 1997).

Service Level D

This is a low maintenance service level in which the roadway and associated features are kept in generally poor condition. At this maintenance service level, moderate deficiencies are present in safety-related activities, and significant deficiencies exist for all other activities. Very little preventive maintenance is accomplished. Maintenance has become very reactionary, placing emphasis on correcting problems as they occur. A significant backlog of deficiencies will begin to build up and will have to be dealt with eventually, at a much higher cost. Safety problems begin to appear that increase risk and liability, and significant roadway structural deficiencies exist that accelerate the long-term deterioration of the system. The overall appearance is very poor. Systems failures occur regularly because it is impossible to react in a timely manner to all problems. Some delays may last longer than a day (Washington DOT 1997).

Service Level F (Worst)

This is a very low service level in which the roadway and associated features are kept in poor and failing condition. At this maintenance service level, significant deficiencies are present in all maintenance activities. The overall appearance is not aesthetically pleasing. Preventive maintenance is not practiced for any maintenance activities. Maintenance is a totally reactive operation, placing emphasis on correcting problems after they occur. Significant backlogs of maintenance deficiencies exist. Excessive safety problems occur, and road conditions are such that maintenance treatments are not enough to correct the deficiencies that exist, necessitating additional high-cost remedial construction preservation projects in the future. Overall maintenance operations are at their highest life-cycle costs. A backlog of systems failures would occur because it is impossible to react in a timely manner to all problems. Delays may regularly last longer than one day (Washington DOT 1997).

TABLE D-1 Priority matrix of maintenance activities (Washington DOT 1998a)

Activity Number	Program Activity	Policy Objectives: Improve Safety (10)	Operate Systems Reliably (9)	Protect Investment (7)	Support Economy (6)	Other Special Considerations (5)	Meet Environmental Responsibilities (3)	Contribute to Comfort & Aesthetics (2)	Total Priority
1A1	Pavement patching & repair	●	●	●	●	●	◉	○	314
5A1	Snow & ice control	●	●		●	●		◉	276
4B1	Operation of movable bridges	●	●		●	●			270
9B1	Disaster maintenance	●	●	●	◉	◉	○		270
2B1	Slope repairs	●	●	●	○	◉	◉	○	266
6A8	Traffic signal system maintenance	●	●	○	○	●		◉	249
4B2	Operation of Keller Ferry	●	●		●	●			240
4C1	Urban tunnel maintenance	●	●	○	◉	◉	◉		220
2A2	Maintain culverts	◉	●	●	○	○	◉	○	214
3A2	Noxious weed control	○	○	●	●	●	●	◉	214
6A10	SC & DI system maintenance	●	●	○	○	◉		○	201
1B1	Safety patrol	●	●	○		◉	○	○	198
4A2	Structural bridge repair	◉	◉	●	◉	●		◉	189
6A1	Pavement striping	●	◉			●		●	180
6A2	Raised pavement markers	●	◉			●		●	180
6A4	Repair/replace regulatory signs	●	◉	○	○	●	○	○	180
7A1	Rest area maintenance	◉	●	◉	◉	○	○	●	176
1A2	Crack sealing & chip seals	○	●	●	○	○	○	○	170
2A3	Maintain storm drainage systems	◉	◉	●	○	◉	◉	○	170
6A3	Pavement marking	●	◉			●		◉	168
6A7	Guardrail maintenance	●	◉	◉	○	◉	○	◉	168
4A1	Bridge deck repair	◉	◉	●	◉	○		●	161
2A1	Grade and clean ditches	◉	◉	●	○	○	◉	◉	146
6B1	Issuing oversized/overweight permits	◉	◉	◉	○	●	◉	○	140
3A4	Control of vegetation obstructions	◉	●	◉	◉	◉	◉	●	138
1A4	Sweeping and cleaning	◉	◉	○		◉	●	◉	112
1A3	Shoulder maintenance	◉	◉	◉	○	○	○	●	110
6A5	Repair/replace advisory signs	◉	◉	○	○	◉	○	◉	94
6A9	Highway lighting maintenance	◉	◉	○	○	○		●	93
3A3	Nuisance vegetation control	○	○	◉	◉	◉	◉	◉	88
3B1	Landscape maintenance	○	○	◉	◉	○	○	●	84
2A4	Maintain silt drainage systems	○	○	○	○	◉	◉	○	76
6A6	Repair/replace guideposts	◉	○		○	◉		◉	66
3A1	Litter pickup	○	○		○	○	○	●	57
1A5	Misc. roadway maintenance	○	○	○	○	○	○	○	42
2A5	Misc. drainage maintenance	○	○	○	○	○	○	○	42
3A5	Misc. roadside maintenance	○	○	○	○	○	○	○	42
4A4	Misc. bridge maintenance	○	○	○	○	○	○	○	42
4A3	Bridge cleaning			◉			○	◉	30
Nonprioritized Support Activities									
8A1	Field supervision								
8B1	Training and meetings								
8C1	Support maintenance								
9A1	Third-party damages & repair								

Contribution to Policy Objectives
● Critical impact.
◉ Significant impact.
○ Contributing impact.
Blank No impact.

FIELD RATING PROCESS

An important part of the Washington State MAP program is routine field condition surveys of the highway system to determine the maintenance service levels that exist at a given point in time. The surveys are performed by trained rating personnel on a biannual basis throughout each of the state's six regions. Statistical sampling methods are used to select approximately 400, 0.10-mi (1.61-km) survey sections throughout the state, and these sections are located in the field using mileposts and a DMI. The start and end points of the section are marked in paint at the edge

TABLE D-2 Maintenance performance measures for roadway maintenance and operations (Washington DOT 1997)

Category				Service Level						
Roadway Maintenance				A	B	C	D	F	Condition Rating	
No.	Activities	Condition Indicators	Performance Measures	Threshold	Threshold	Threshold	Threshold	Threshold	Jan-96	Oct-96
1A1	Pavement patching & repair	Potholes (6 x 6 x 1 in or larger)	Number of unfilled potholes per lane, per mile	0.50	2.00	4.00	6.00	>6.00	3.45	1.2
1A2	Crack sealing & chip seals	Cracking	Linear ft of pavement with unfilled cracks/joints per lane, per mile (incl. shoulders)	250	1000	2000	4000	>4000	969	655
1A3	Gravel/sod shoulder maintenance	Shoulder edge drop-off or erosion >2 in	% of shoulder with drop-off or erosion greater than 2 in deep	0	5	10	20	>20	4.8	3.8
1A4	Sweeping & cleaning	Sand, rocks, and debris on paved shoulder	% of shoulder area with sand & debris	5	10	20	40	>40	(13)[a]	6
1A5	Misc. roadway maintenance	None	N/A							
Roadway Operations				A	B	C	D	F	Condition Rating	
1B1	Safety Patrol	Rocks, large debris, and other hazards on roadway & shoulder	Objects on roadway & shoulder (see condition description matrix-1B1)	see condition description matrix - 1B1					Service level C	Service level C

[a] Condition estimated.
1 in = 25.4 mm
1 ft = 0.305 m
1 mi = 1.61 km

of the shoulder for future reference. If any portion of the sample falls on a structure, the section is moved forward or backward to avoid the structure, and if any portion of the sample falls in a construction zone, the section is relocated as close as possible to the original site (Washington DOT 1998b).

The MAP data collection procedures also emphasize the importance of safety in the field. Surveyors are advised to activate the flashing lights on the vehicle and use traffic cones to mark off the work area. They are also advised to wear safety gear (hat, reflective vest, and appropriate footwear) and walk facing traffic while conducting surveys (Washington DOT 1998b).

An example of one of the data collection sheets used by MAP field rating personnel is shown in Figure D-2. This sheet allows for the documentation of conditions for features/characteristics categorized into five elements: Pavement, Paved Shoulder, Drainage, Roadside, and Traffic. Note how the data recorded in this sheet are measurements and not Pass–Fail (Yes–No) ratings, as suggested earlier in this manual. Field data collection sheets for Bridges and Snow and Ice Control also exist.

SERVICE LEVEL REPORTING

The condition measurements recorded in the field are mathematically processed and reported in various ways. At the highest level of maintenance, a listing of the statewide average service levels for key work activities within each of the seven maintenance groups is developed, as illustrated in Table D-3. In this table, the average service level for each activity is designated by a square (■) and the range in observed service levels throughout the state for each activity is defined by dashes (-). Similar reporting forms are developed that show the average service levels for key activities by region.

SERVICE LEVEL INVESTMENT

An important aspect of the maintenance QA process is how to link LOS with the maintenance budget, or, in other words, how to predict LOSs for various budget scenarios. One such process, developed and used by the Florida DOT, was described in Chapter 4 of this manual. The Washington State MAP program includes a detailed procedure for estimating on an activity-by-activity basis the investment required to achieve each of the five service levels. Past investment-LOS trends are used to develop the investment predictions and the results are provided (along with a display of current service levels) in a Service-Level Investment Worksheet, which is then presented to the State Legislature. Table D-4 contains a sample one such worksheet, pertaining to activities categorized under the Roadway Maintenance and Operations element.

Site Number: ______ SR:: ______ SRMP:: ______ Region:: ______ Area: ______

Taken By: ______

Date:: ______ Number of Lanes:. ______

PAVEMENT - Traveled Lane

Potholes
Number of Potholes: ______
Square Feet of Potholes: ______

Rutting
Total Width of Rutting >3/4": ______

Alligator Cracking
Severity: ▣ Low ▣ Medium ▣ High
Sq. Ft. of Alligator Cracking: ______

Cracking
Lin. Ft. of Longitudinal Cracking: ______
Lin. Ft. of Transverse Cracking: ______

PAVED SHOULDER

Total Width of Paved Shoulder: ______
Number of Shoulders: ______

Shoulder Potholes
Number of Shoulder Potholes: ______
Sq. Ft. of Shoulder Potholes: ______

Shoulder Alligator Cracking
Severity: ▣ Low ▣ Medium ▣ High
Sq. Ft. ofAlligator Cracking: ______

Shoulder Cracking
Lin. Ft. of Longitudinal Cracking: ______
Lin. Ft. of Transverse Cracking: ______

Shoulder Edge Raveling
Lin. Ft. of Edge Raveling: ______
Avg. Width of Edge Raveling: ______

Shoulder Edge Drop-Off
Lin. Ft. of Edge Drop-Off >2" : ______

Shoulder Sweeping/Cleaning
Lin. Ft. of Shldr. Debris Build-Up: ______
Width of Shldr. Debris Build-Up: ______

DRAINAGE

Ditches
Linear Feet of Ditch: ______
Linear Feet of Ditch >25% Full: ______

Culverts
Number of Culverts: ______
Number of Culverts >25% Full: ______

Catch Basins
Number of Catch Basins: ______
Num. of CBs with <16" Storage: ______

Slope Failures
Num. of Minor Slope Failures: ______
Num. of Moderate Slope Failures: ______
Num. of Major Slope Failures: ______

ROADSIDE

Total Width of Roadside: ______

Noxious Weeds
Lin. Ft. of Noxious Weeds: ______
Avg. Width of Noxious Weeds: ______
Density: ▣ Low ▣ Medium ▣ High

Nuisance Vegetation
Lin. Ft. of Nuisance Vegetation: ______
Avg. Width of Nuisance Vegetation: ______
Density: ▣ Low ▣ Medium ▣ High

Vegetation Obstructions
Lin. Ft. of Potential Veg. Obstr.: ______
Lin. Ft. of Moderate Veg. Obstr.: ______
Lin. Ft. of Major Veg. Obstr.: ______

Litter
Number of Pieces of Litter: ______

TRAFFIC

Pavement Stripes
Lin. Ft. of Pavement Stripes: ______
Lin. Ft. of Stripes Worn/Missing: ______

Raised Pavement Markers
Num. of Raised Pvmt. Markers: ______
Num. of Markers Worn/Missing: ______

Pavement Markings
Num. of Pavement Markings: ______
Num. of Markings Worn/Missing: ______

Regulatory Signs
Num. of Regulatory Signs: ______
Num. of Reg. Signs Deficient: ______

Advisory Signs
Num. of Advisory Signs: ______
Num. of Adv. Signs Deficient: ______

Guideposts
Number of Guideposts: ______
Num. of GPs Broken/Missing: ______

Guardrail
Lin. Ft. of Guardrail: ______
Lin. Ft. of Guardrail Damaged: ______

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

Figure D-2. MAP field data collection form (Washington DOT 1998b).

TABLE D-3 Statewide program service levels in FY 1997 (Washington DOT 1998a)

No.	Activity	Service Level: 1.0 + A - 1.9	2.0 + B - 2.9	3.0 + C - 3.9	4.0 + D - 4.9	5.0 + E - 5.9
Group 1 - Roadway maintenance and operations						
1A1	Pavement patching & repair		—■—			
1A2	Crack sealing & chip seals		-■-			
1A3	Shoulder maintenance		-■—			
1A4	Sweeping and cleaning		——■—	–		
1A5	Misc. roadway maintenance					
1B1	Safety patrol			-■-		
Group 2 - Drainage maintenance and slope repair						
2A1	Grade and clean ditches		—■—			
2A2	Maintain culverts					—■—
2A3	Maintain storm drainage system				——■-	—
2A4	Maintain silt drainage system			-■-		
2A5	Misc. drainage maintenance					
2B1	Slope repairs			—■—		
Group 3 - Roadside and landscape maintenance						
3A1	Litter pickup				—■—	
3A2	Noxious weed control			——■——	—	
3A3	Nuisance vegetation control		——	—■——	—	
3A4	Control of vegetation obstructions			——■—	——	
3A5	Misc. roadside maintenance					
3B1	Landscape maintenance				-■—	
Group 4 - Bridge and tunnel maintenance						
4A1	Bridge deck repair				—■—	—
4A2	Structural bridge repair				—	-■—
4A3	Bridge cleaning			-■-		
4A4	Misc. bridge maintenance					
4B1	Operation of movable bridges			-■-		
4B2	Operation of Keller Ferry		-■-			
4C1	Urban tunnel maintenance			-■-		
Group 5 - Snow and ice control						
5A1	Snow and ice control			-■-		
Group 6 - Traffic services						
6A1	Pavement striping	—	—■—			
6A2	Raised pavement markers				—■-	—
6A3	Pavement marking				——■—	——
6A4	Repair/replace regulatory signs	–	——	—■——	——	
6A5	Repair/replace advisory signs		——	—■——	——	——
6A6	Repair/replace guideposts			——■	——	
6A7	Guardrail maintenance	——	-■——			
6A8	Traffic signal system maintenance			-■-		
6A9	Highway lighting maintenance		—■—			
6A10	SC & DI system maintenance			-■-		—
6B1	Issuing oversized/overweight		-■-			
Group 7 - Rest area maintenance						
7A1	Rest area maintenance		—■—			

■ FY '97 average service level. Note: Dashes are service level range for 10/96 and 4/97 surveys.

TABLE D-4 Sample service-level investment worksheet (Washington DOT 1998a)

No.	Activity	Current Law Budget (CLB), FY97 dollars				Service Level								
		CAL + Inflation	System Addition	Service Delivery Cost Increase	Total CLB	+ A -	Investment Threshold	+ B -	Investment Threshold	+ C -	Investment Threshold	+ D -	Investment Threshold	+ E
1A1	Pavement patching & repair	21,814,309	99,649	127,156	22,041,114		32,100,000	———	23,400,000	-●——	18,100,000		15,800,000	
		100.96	1.04	1.08	103.08		150.12		109.44		84.65		73.89	
1A2	Crack sealing & chip seals	6,444,561	27,907	39,550	6,512,018		8,500,000	—●--	5,600,000		4,400,000		3,900,000	
		28.59	0.29	0.34	29.22		38.14		25.13		19.74		17.50	
1A3	Shoulder maintenance	4,006,920	15,438	22,670	4,045,028		5,400,000	-●-	4,000,000		2,800,000		1,600,000	
		11.76	0.16	0.19	12.11		16.17		11.98		8.38		4.79	
1A4	Sweeping & cleaning	4,754,933	24,146	135,296	4,914,375		6,100,000	———	5,000,000	-●——	3,400,000		2,200,000	
		26.47	0.25	1.15	27.87		34.59		28.36		19.28		12.48	
1B1	Safety patrol	4,425,074	-	-	4,425,074		6,700,000		5,200,000	-●-	3,700,000		2,500,000	
		38.25	-	-	38.25		57.91		44.95		31.98		21.61	
1A5	Misc. roadway maintenance	261,551	1,383	1,780	264,714		900,000		600,000		400,000		200,000	
		1.57	0.01	0.02	1.60		5.44		3.63		2.42		1.21	
Group 1 total		41,707,348	168,523	326,452	42,202,323			——		-●—				
		207.60	1.75	2.78	212.13									

GLOSSARY

Activity-Level Maintenance — A discrete class of maintenance work (e.g., machine mowing, pavement patching) (Miller 1989).

Confidence Level — The degree of certainty placed on a statistic being within a range of values.

Continuous Quality Improvement (CQI) — A client-focused, strategic, and systematic approach to continuous performance improvement (Greenhorne & O'Mara 1993).

Corrective Maintenance — Type of maintenance used to take care of day-to-day emergencies and repair deficiencies as they develop. May include both temporary and permanent repairs; sometimes referred to as remedial maintenance (Peterson 1987).

Distress — Deterioration in the pavement that results in a loss of structural or functional adequacy.

Geographic Information System (GIS) — A computerized database management system for capture, storage, retrieval, analysis, and display of spatial data or information defined by its location (Markow et al. 1994). A GIS has three main parts: (1) data, (2) software, and (3) a location referencing system.

Level of Service (LOS) — A desired/required level of quality for a given maintenance activity. LOS may be represented by one of four methods (Miller 1989):

1. A specific threshold value that triggers the requirement of a maintenance activity;
2. A written description that states the maintenance effort authorized for a specific activity;
3. A defined frequency of a maintenance effort or a predetermined number of inspections in a specified time; or
4. A policy of replacement of the missing, repair of the damaged, or elimination of the undesirable.

Maintenance Attribute (Natural and Constructed) — A numerical scale for measuring the effect on a given consideration (e.g., frequency of accidents — for safety; roughness — for riding comfort) (Kulkarni et al. 1980). Natural attributes are attributes whose levels are physically measurable. Constructed attributes are attributes for which a physical measurement is impractical or inappropriate, thereby requiring that a subjective scale or index be constructed to define various degrees of impact.

Maintenance Characteristic — A specific quality/defect in a maintenance feature that is condition-evaluated (e.g., AC pavement is composed of rutting, cracking, patching, potholes, bumps, and other characteristics/deficiencies).

Maintenance Condition — That condition of a maintenance characteristic that requires routine maintenance to prevent deficiencies or that needs to be repaired or corrected (e.g., roadway cracking or rutting).

Maintenance Considerations — The factors used in evaluating the performance of maintenance elements (e.g., safety, riding comfort, economics, aesthetics) (Kulkarni et al. 1980).

Maintenance Element (or Maintenance Category) — A part of the highway system (e.g., traveled-way, roadside, drainage, traffic services) that requires maintenance (Kulkarni et al. 1980). A group of maintenance features (e.g., signs, pavement striping, pavement marking, lighting) that serve a similar purpose (e.g., traffic control and safety).

Maintenance Feature (or Maintenance Component) — A part of a maintenance element that, combined with other features/components, compose the maintenance element (e.g., the roadside element is composed of front slope, back slope, turnout, sidewalk, and other features/components).

Maintenance Features Inventory — A data bank containing types, quantities, and locations of maintainable items.

Network-Level Maintenance — Maintenance of an entire highway system maintained by an agency or a separately identifiable major portion thereof (e.g., the interstate system) (Miller 1989).

Pavement Performance — A measure of the accumulated service provided by a facility and the adequacy with which the pavement fulfills its mission based on all of the various indicators or measurements (Peterson 1987).

Performance — The measured change of condition and/or serviceability over increments of time (Peterson 1987).

Precision — The closeness of agreement between randomly selected individual measurements or test results.

Preventive Maintenance — A program strategy intended to arrest light deterioration, retard progressive failures, and reduce the need for routine maintenance and service activities (O'Brien 1989).

Project-Level Maintenance — Maintenance of a discrete portion of a highway system (e.g., a bridge or a relatively short section of pavement) (Miller 1989).

Quality (definition #1) — The degree of excellence which a thing possesses. A physical or nonphysical characteristic that constitutes the basic nature of a thing or is one of its distinguishing features.

Quality (definition #2) — Providing the product and/or service that consistently meets the expectations and needs of the customer (Miller and Krum 1992). Quality in a highway program was best described by Maslin et al. (1983) as:

That characteristic of a product (road or street) that provides a level of performance in terms of service or life. "Quality" doesn't mean "perfect." If the objective of a surface treatment is to carry anticipated traffic safely (service) for 8 years (life), then "quality" refers to those characteristics of the surface treatment that are necessary to achieve that objective.

Quality Assurance (QA) (definition #1) — The product and process sampling and ongoing feedback loop that provides management with information concerning the adherence of operational units with expectations. (This allows management to take corrective action, improve the product/process, and ensure that rules, standards, procedures, and so forth are being followed).

Quality Assurance (QA) (definition #2) — All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service. Quality assurance addresses the overall problem of obtaining the quality of a service, product, or facility in the most efficient, economical, and satisfactory manner possible. Within this broad context, quality assurance involves the continued evaluation of the activities of planning, design, development of plans and specifications, advertising and awarding of contracts, construction, and maintenance, and the interactions of these activities (TRB 1996).

Quality Control (QC) (definition #1) — At the activity level, it is an assessment practice performed by operational personnel that ensures that work products meet requirements (i.e., specifications, procedures, guidelines) and that contains a corrective-action mechanism to allow for changes in the process (e.g., verifies that mowing is at the proper height and that no skips or misses occur; ensures that joint sealing material is being placed at the proper depth, that the proper temperature is being used, and that the material type is suitable for the expected results). At the project or network level, it is an evaluation of completed or continuing work activities that provide feedback to maintenance managers about the overall quality achieved on a project, in a district, or over the entire network. This feedback is used in the maintenance management procedures to aid in the planning, organizing, and directing of maintenance work activities.

Quality Control (QC) (definition #2) — Also called Process Control. Those quality assurance actions and considerations necessary to assess production and construction processes so as to control the level of quality being produced in the end product. This concept of quality control includes sampling and testing to monitor the process but usually does not include acceptance sampling and testing (TRB 1996).

Quality Assessment (or Quality Evaluation) — At the activity level, it is an assessment practice performed by independent personnel (usually from the central office or members of a trained quality assessment/evaluation team) that ensures that field crews are adhering to procedural requirements (i.e., specifications, procedures, guidelines) as well as providing work products that meet a predetermined quality level. At the project or network level, it is an assessment practice performed by independent personnel (usually from the central office or members of a trained quality assessment/evaluation team), that measures the present condition (LOS) of each maintenance work activity required on a particular section of road. Sample sections are determined randomly by statistical processes. The assessment of these sample sections provide feedback to maintenance managers about the overall quality achieved on a project, in a district, or over the entire network.

Quality Improvement (QI) — The set of techniques that is associated with the management of quality and that provides for continuous performance improvement. (These techniques can span all operations of an organization, from human resource development, to accounting, to technical design, to construction operations).

Quality Standards — Descriptions of the results to be achieved (Miller 1989). Quality standards define the physical conditions that indicate a need for maintenance and repair activities and prescribe the character of workmanship and the properties of the completed product (AASHTO 1987).

Quantity Standards — Definitions of the amount of work and resources necessary to meet the quality standard or a predetermined level of service (Miller 1989).

Routine Maintenance — A program to keep pavements, structures, drainage, safety facilities, and traffic control devices in good condition by repairing defects as they occur (O'Brien 1989).

Sampling Frame — A comprehensive list of people, businesses, or organizations from which one intends to select a sample (Heister 1996).

Statistical Control Process — A production process in which the mean and variability of a series of tests on the product remain stable, with the variability due to chance alone (TRB 1996).

Survey Population — All of the persons or organizations making up a market of interest (Heister 1996).

Total Quality Management (TQM) — A top-down management philosophy focused on monitoring process variation, employee involvement, and continuous quality improvement in order to meet customer needs (Knouse 1995).

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Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation