NCHRP
REPORT 511

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Guide for Customer-Driven Benchmarking of Maintenance Activities

TRANSPORTATION RESEARCH BOARD
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NCHRP REPORT 511

Guide for Customer-Driven Benchmarking of Maintenance Activities

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Booz Allen Hamilton
McLean, VA

SUBJECT AREAS
Planning and Administration • Maintenance

Research Sponsored by the American Association of State Highway and Transportation Officials
in Cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD

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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.

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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.

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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 Christopher J. Hedges
Staff Officer
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This report provides state and local roadway maintenance managers with guidance on how to evaluate and improve their agency's performance through a process called "customer-driven benchmarking." The objective of benchmarking is to identify, evaluate, and implement best practices by comparing your agency's performance with those of other agencies. Customer-driven benchmarking defines best practices as those practices that provide the highest levels of customer satisfaction, measured by customer surveys and other performance indicators. This guide leads the user through the benchmarking process, providing details on how to select partners, establish performance measures, use those measures to assess performance, and implement best practices. The guide is accompanied by a primer that promotes and encourages the use of customer-driven benchmarking. The primer, which is geared toward senior executives, summarizes the main concepts, success factors, and potential benefits that can be accrued by an agency willing to implement customer-driven benchmarking.

The use of performance measures for transportation agencies is currently receiving a great deal of attention from senior executives in the public sector. Of the performance measures currently in use or under consideration, customer satisfaction has become a major driver for strategic performance measurement in state departments of transportation (DOTs). The users of the transportation system are becoming more discerning and vocal in their expectations, and they increasingly demand better value and performance from the DOT.

Traditional maintenance management systems focus on efficiency and cost and measure performance in terms of resources used. This guide provides the means to evaluate roadway maintenance activities by the extent to which they meet customer needs. The nature and extent of roadway maintenance can have a significant impact on customer satisfaction through activities such as snow and ice control, pavement resurfacing, replacement of worn signs and pavement markings, and management of roadside vegetation and litter removal.

One effective means of measuring performance is benchmarking. Benchmarking can be used to improve any activity performed by an organization, including highway maintenance activities. A key component of any benchmarking effort is obtaining agreement among the participants regarding the performance measures that will be used to compare the effectiveness of the agency's current practice with those of other organizations. In this case, the performance measures are related to the requirements and expectations of the agency's customers.

Under NCHRP Project 14-13, a research team from Booz Allen Hamilton developed a step-by-step guide for the implementation of customer-driven benchmarking of maintenance activities. The guide begins by outlining the key concepts, success factors, use of performance measures, and selection of benchmarking partners. The rest of the guide provides the "how to" steps needed to implement customer-driven bench-

marking in a state or local highway agency. An appendix provides a very useful compendium of customer-oriented performance measures.

The guide is accompanied by a primer, which is intended to educate senior management on the principles and benefits of customer-driven benchmarking. Also available is the research team's final report, which contains detailed information about the research approach and findings and recommendations for the promotion and education necessary to optimize the benefits of customer-driven benchmarking and to make it an accepted and commonplace practice. The final report is available on the NCHRP website as *NCHRP Web Document 58*.

CONTENTS

INTRODUCTION TO THE GUIDE

Transportation agencies have recognized that continuous improvement is essential to managing a maintenance organization effectively in the face of growing demand, tight budgets, and limited staff. There is an imperative to improve the effectiveness and efficiency with which agencies deliver maintenance products and services to their customers. Effectiveness refers to the ability to deliver the attributes of maintenance products and services that customers want. Efficiency refers to the extent to which the use of resources is minimized in delivering those products and services.

In response to the need for continuous improvement, the National Cooperative Highway Research Program (NCHRP) funded Project 14-13 with the objective of developing a primer and a guide on customer-driven benchmarking. The purpose of the primer is to promote customer-driven benchmarking and to educate top management and other managers on the concept's main ideas and benefits. The purpose of the guide is to provide a "how to" manual. The project also involved preparing a final report—describing the research project, key findings, conclusions, and recommendations—which is published as *NCHRP Web Document 58.*

You have the guide in your hands. It was developed by preparing a draft and obtaining extensive review comments from various agencies including states, counties, and a toll authority. Preparation of the guide included field testing most of the procedures in the guide in three states (California, Minnesota, and Ohio) and then using the feedback from the field tests to revise the guide and to produce a document that is practical and easy to use.

Benchmarking is widely employed in both the public and private sectors to compare performances and to identify best practices. Benchmarking is a rigorous discipline that involves the use of accurate, agreed-upon measures. The basic steps of benchmarking are forming a partnership, reaching agreement on a set of common measures, taking measurements, identifying best performers and corresponding best practices, and following through with agency implementation and continuous improvement.

In customer-driven benchmarking, the measures used focus upon the results important to customers. In the past, maintenance organizations have used measures that tend to be internally focused—for example, the quantity of production and resource utilization (labor, equipment, and materials). Today, maintenance organizations are becoming increasingly focused on customer-oriented measures such as the smoothness of roads, the legibility of signs at night, sight distances at intersections, the attractiveness of roadsides, and the speed with which roads covered with ice and snow are returned to bare pavement.

Four types of measures are used in customer-driven benchmarking:

1. **Outcomes.** Outcomes are the results of performing maintenance activities that are important to customers. Examples of outcomes are smooth roads, edge markings that are easy to see in poor weather, and traffic signals that are reliable and work almost continuously.
2. **Outputs.** Outputs are measures of accomplishment or production. Examples of outputs are linear feet of ditches cleaned, the number of bags of litter collected, and acres of grass mowed.
3. **Resources.** Resources consist of labor, equipment, materials, and financial costs.
4. **Hardship factors.** These are factors outside the control of the maintenance organization that make it more difficult to satisfy customer desires and needs. Examples of hardship factors are weather, terrain, and population density.

Customer-driven benchmarking combines all four measures to give analysts and managers a broad perspective on how well various organizations are achieving outcomes that matter to customers in a manner that uses the fewest possible resources while taking into account the level of production and uncontrollable factors such as weather. Organizations that do this the best, as determined through measurement, are sources of practices that agencies should consider adopting.

This guide is divided into four chapters. Chapters 1 through 3 educate the reader regarding key concepts. Chapter 1 introduces the reader to the concepts of customer-driven benchmarking;

discusses important prerequisites that must be satisfied (such as obtaining strong leadership commitment to the effort); communicates the time required to benchmark for the first time (at least 2 years); dispels a number of benchmarking myths; and lists critical success factors. Chapter 2 examines key issues in forming a benchmarking partnership, including important elements of a benchmarking agreement. Chapter 3 discusses important issues of measurement, including various types of measures, key attributes of measures such as statistical validity, the need for each benchmarking unit to use the same measures, and sources of candidate measures—for example, the proceedings of the National Workshop on Commonly Recognized Measures for Maintenance.

Chapter 4 is the "how to" portion of the guide and is organized by the five main steps of customer-driven benchmarking:

1. Select partners,
2. Establish measures,
3. Measure performance,
4. Identify best performances and practices, and
5. Implement and continuously improve.

This guide contains six appendixes. Particularly useful are examples of survey questions and a compendium of customer-oriented measures.

The guide also employs icons to further direct the reader. Icons appear in the margin of the text to draw your attention to important points. The following is a list of icons used in the guide and their meanings.

MEASURE

TIP

IDEA

CAUTION

STEP

EASY METHOD

RIGOROUS METHOD

ADVANCED METHOD

QUALITY CONTROL/QUALITY ASSURANCE

QUESTION

ANSWER

CHAPTER 1: INTRODUCTION TO BENCHMARKING

WHAT IS BENCHMARKING?

Benchmarking is a concept that is at least as old as the athletic events of ancient Greece. Ancient athletes realized it was possible to learn and continuously improve by gauging the performance of others: first identifying the "best" performer in their event, then assessing the gap between their own performance and that of the "best," carefully observing how the "best" performance was achieved, and striving to exceed it. At the root of benchmarking is measurement. When the athletes in ancient Greece gauged the performance of others, they were measuring with a combination of their mind's eye and the measurements of judges.[1]

There is a large body of literature that describes the process of benchmarking. The main steps are shown in **Figure 1**.

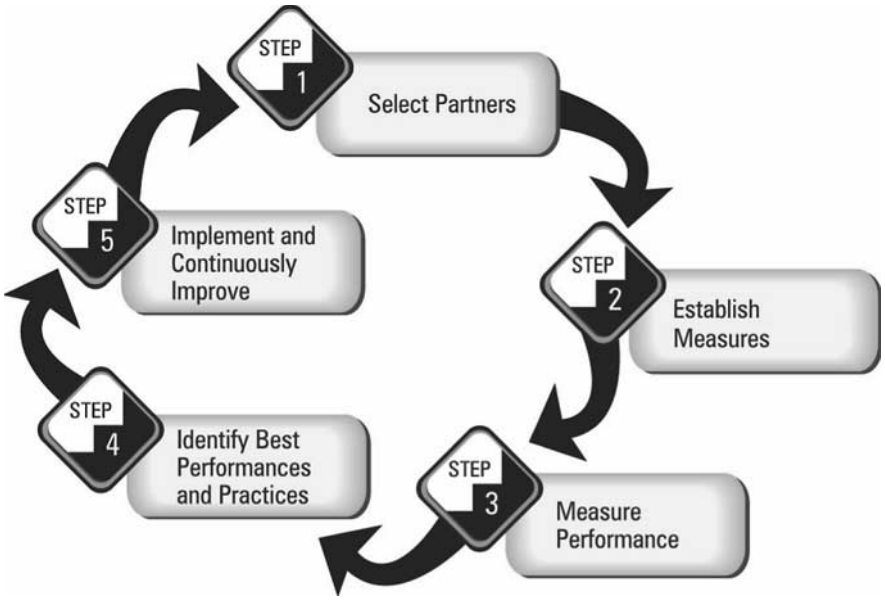


Figure 1. Steps in the Benchmarking Process

During the last 50 years, beginning with the arrival of modern methods of quality improvement, benchmarking has evolved through a number of stages. At first, benchmarking was focused

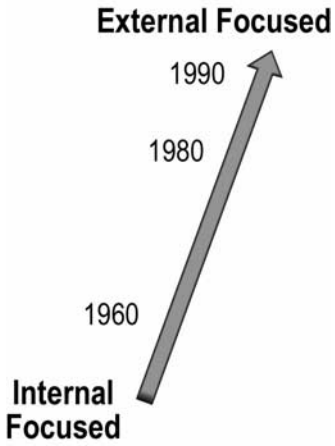
[1] www.upenn.edu/museum/olympics/olympicglossary.html

on internal business processes of an organization. Often, key aspects of industrial processes were measured and compared with those of other firms to speed up and improve the efficiency of production—for example, by increasing productivity of workers and reducing manufacturing defects.

By the early 1980s, benchmarking turned its focus outside of organizations. Firms such as Xerox, IBM, and Motorola were routinely benchmarking their performance against other firms in order to gain competitive and strategic advantage.

By 1990, it was recognized that benchmarking provides the greatest benefits when it focuses on the customers of an organization. Ultimately, the health—and often the survival—of an organization depends on the satisfaction and value customers receive from an organization's products and services.

Today, management of road maintenance is undergoing a similar transformation from being internally focused on production and resource usage to being externally focused and satisfying customers' needs and desires.



WHAT IS CUSTOMER-DRIVEN BENCHMARKING?

Customer-driven benchmarking is a management process to achieve continuous improvement that will eventually delight the customer. Customer-driven benchmarking involves assessing, adopting, and improving upon "best" practices that have been shown through measurement to lead to higher levels of performance—better products and services to customers. These better performances are achieved with the same or fewer resources and are applicable to a particular environmental setting.

The central ideas in customer-driven benchmarking are the following:

- It is a type of continuous quality improvement. You do not do customer-driven benchmarking once and then you are done.
- By improving continuously, you will not merely exceed your current levels of performance or the performance level of others—you will eventually exceed customer

expectations. As a result, your customers will be loyal supporters of your maintenance program and commend your accomplishments to other citizens and elected officials.

- Customer-driven benchmarking involves thinking more in terms of the attributes of products and services that customers of maintenance are buying, such as smooth and comfortable roads and attractive roadsides. The focus will not be on maintenance activities such as pothole patching, ditch cleaning, and sign repair, nor will it be on outputs or production rates such as number of potholes filled or linear feet of ditches cleaned.
- Central to customer-driven benchmarking is measuring the outcomes of maintenance that are important to customers. Outcomes include customer satisfaction and the conditions that result from providing maintenance products and services.
- Best performances reflect the best customer outcomes relative to the resources used, given a quantity of work performed and a set of environmental conditions such as weather, terrain, and traffic.
- Customer-driven benchmarking involves comparing performances of different organizational units—internal, external, or both—that operate under similar environmental conditions such as weather, terrain, and traffic.
- It entails identifying best practices associated with best performers and then implementing practices that lead to equal or better performances.

Figure 2 offers another way of thinking about customer-driven benchmarking by making the role of the customer more explicit. You determine customer preferences, expectations, and satisfaction by surveying them. You measure the attributes of the roads that customers care about—for example, smoothness of roads and legibility of signs. You identify practices that best serve customers based on the measured performance of a group of peers. Finally, you adopt improved practices and adjust your maintenance program accordingly. Implicitly, the customer drives the mix of activities that make up the maintenance program.

Periodic market research allows the agency to evaluate progress in satisfying or exceeding the customers' desires and expectations.

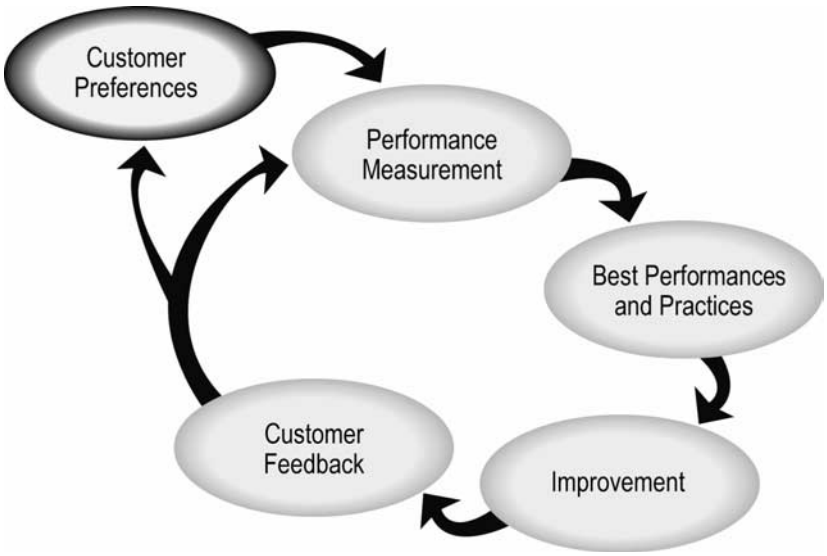


Figure 2. Customer Involvement in the Benchmarking Process

HOW DO YOU RECOGNIZE BEST PERFORMANCES AND PRACTICES?

One approach to identifying best performances has been to identify the frontier that represents the best performances that actually have been observed. **Figure 3** shows a plot of the results achieved by different organizational units versus the resources applied. Examples of results are customer satisfaction and conditions that are the outcomes of maintenance. Examples of resources are labor, equipment, materials, and costs.

Figure 3 shows a series of lines connecting the performances that form a frontier such that ***no performer is observed to achieve higher results using fewer resources.***

For any performance below or to the right of the frontier there is a gap between that performance and the frontier that represents the best performances. The gap represents the improvement opportunity. The practices of organizational units that achieve performances on the frontier are called "best practices."

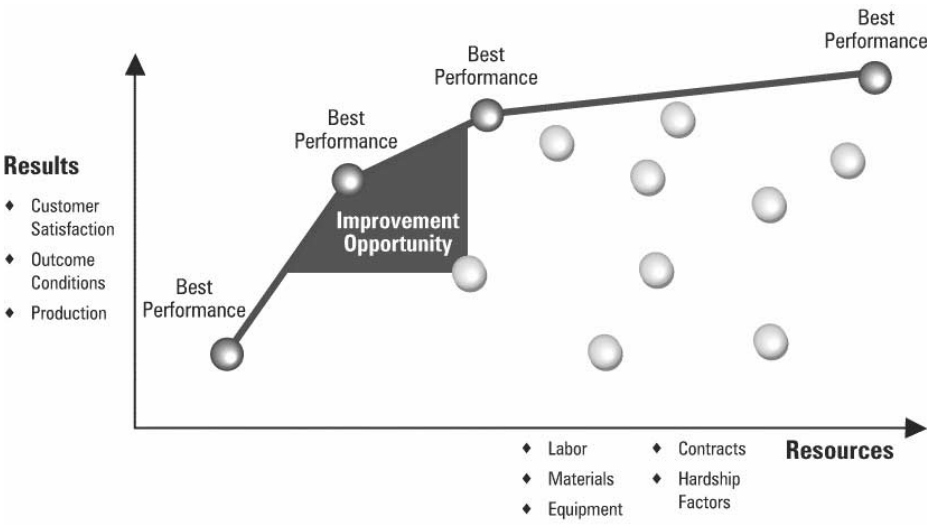


Figure 3. Frontier of Best Performances and Improvement Opportunity

Once best performances and the improvement opportunity have been identified, a key issue is to identify the practices associated with the best performances that can potentially close the performance gap. Careful investigation and analysis are required to understand the nature of best practices. Typically, these are accomplished via an agreement with benchmarking partners to document and share information about their practices. Documentation involves identifying the environmental conditions under which the best practices occurred; determining the resources that were used (labor, equipment, and material); examining work methods, including how the resources were combined and applied; and documenting each step of the business process.

Once an agency has identified best practices, it then must decide whether to adopt and implement them. Among the considerations are the following:

- The cost of the practice relative to the benefits that it will produce,
- Acceptance of the practice by those who will implement it,
- Ability to obtain management approval for implementation, and
- Whether to equal or improve upon the practice.

WHY BENCHMARK? WHAT ARE THE BENEFITS?

Benchmarking can transform your organization or workgroup in many positive ways. You will be more focused on the customer. Resources will be applied where they will do the most good. By systematically measuring your performance in terms of customer-driven outcomes relative to the resources used while controlling for factors outside your ability to influence, you will gain many insights regarding how to improve maintenance operations. The benefits of benchmarking are numerous:

- It is the most expedient way to discover and implement better practices that lead to better performance.
- You can learn from the observed successes and experiences you want to emulate or improve upon.
- You can minimize trial and error and avoid making the mistakes of others.
- It leads to continuous improvement.
- It stimulates creativity.
- Specific customer outcomes will improve:
  - The value customers receive will increase,
  - Customer satisfaction will increase,
  - Condition of assets will improve,
  - Life-cycle costs will decline,
  - Traffic delay will decline,
  - Safety of road users is likely to improve, and
  - The quality of the environment will be enhanced.
- One can deal more effectively with the groups that insist on accountability, such as the legislature.
- You will better understand how various factors—labor, equipment, materials, and external factors—affect performance and, therefore, you will be better able to allocate scarce resources.
- Job satisfaction of maintenance managers and field personnel increases as a result of serving the customer better and continually doing a better job.

There is a great deal of wisdom in the collective experience of the 50 states; 3,000 counties; 19,000 municipalities; and 75 bridge, tunnel, and turnpike authorities. Customer-driven benchmarking is a way to tap the combined experience of the road maintenance organizations within each of these organizations. There is additional wisdom to be found in other industries and in other countries.

- If you are striving to reach the frontier representing the best of possible performances, you can take pride in working toward being the best you can be.

Benchmarking has greatly benefited private industry. Firms have found that they cannot survive and thrive without being acutely conscious of how well their competitors perform in serving their customers. For the public sector to thrive in an increasingly competitive environment, it too must strive to understand how to best serve its customers. Customer-driven benchmarking is an important tool for accomplishing that goal.

PREREQUISITES FOR CUSTOMER-DRIVEN BENCHMARKING

There are three prerequisites for successful customer-driven benchmarking:

1. **Leadership.** Customer-driven benchmarking, in most cases, will require a complete reorientation of the maintenance organization from thinking about maintenance resources, production, and activities to thinking about the maintenance products and services that are important to customers and the efficiency and effectiveness with which those products and services are delivered. This reorientation requires the strongest support from the head of maintenance. Usually the full endorsement of the chief executive officer will also be required. Without the leadership to bring about this change, customer-driven benchmarking will not succeed.

   Another part of the leadership imperative is to commit the agency to benchmarking. The time, effort, staff resources, and attention to detail required of the organization cannot be underestimated. You need to use the same performance measures as your benchmarking partners, and most likely you will not have the same measures to start with. You will have to work hard to agree on what these measures will be. You need to collect data in accordance with a rigorous plan. You need to document the practices of subunits in your agency and share the practices with your benchmarking partners if they are different from those of your organizational subunits. You need to make a commitment to implement new ideas found elsewhere and to set improvement targets. You will also need to think about

whether measured performance and new practices ought to result in a reallocation of resources.

2. **Culture.** The culture must support the idea of continuous quality improvement. Customer-driven benchmarking requires a culture that is not satisfied with the status quo. Before customer-driven benchmarking begins, the maintenance organization must have made a substantial transformation toward continuous improvement and must be looking to others for better ways to serve its customers. This culture comes from leadership that continually seeks and studies success, is quick to admit failure, and rewards honest improvement and real effort to improve.

Culture and Management Responsibilities

. . . Changing the Focus from "What's Wrong" to "What's Right and Successful"

Many organizations have a culture that tends to focus on the lower-performing units in the organization and to fix what is wrong.

Benchmarking is different: it focuses on the best-performing units and seeks to understand why they are performing so well. In this new culture, management must want to understand the reasons for success and encourage everyone to recognize the possibility of change and improvement. Management also needs to challenge the organization to overcome the "not invented here" syndrome and to look elsewhere for ways to improve.

3. **Agreed-upon measures.** Participants in customer-driven benchmarking must agree on the measures they will use. It is much easier to reach agreement on measures if an agency plans to benchmark internally—across districts, areas, or garages—rather than externally—from one state or city to another. Even if an agency chooses to benchmark internally, many organizations do not have suitable customer-driven outcome measures. Many states lack customer survey information that is statistically valid at the county, sub-county, or area level of the organization, and they have few relevant technical measures of performance—for example, reflectivity of pavement markings. When benchmarking externally, it is much more challenging to identify relevant measures in each agency that are the same. Indeed, a major effort will be required by participating organizations to forge agreement on the measures to be used. Unless the measures are the same, there is no basis for reliable benchmarking. It is also critical that data be collected that fits the measures.

SCOPE OF CUSTOMER-DRIVEN BENCHMARKING

Customer-driven benchmarking has the following scope:

- **Products and services.** You will be focused on a certain number of products and services. In this guide, you will learn how to define maintenance products and services and to identify their attributes and corresponding customer-oriented outcome measures. It is desirable to concentrate on one or two products or services when doing customer-driven benchmarking for the first time.
- **Maintenance activities.** A specific set of maintenance activities results in an outcome associated with a product or service. One of the things you will have to do when benchmarking is gather labor, equipment, and material data for each relevant maintenance activity.
- **Internal or external organizational units.** If you are doing internal benchmarking, the scope will involve all the organizational units at a certain level within your agency—for example, all the districts or all the garages. Customer-driven benchmarking should occur at a level of the organizational structure where practices vary and the driving public will detect a difference in the service delivered. Types of practices that may vary include planning and scheduling of activities, configurations of labor and equipment, type of material used, training and excellence of execution, and management structure and processes of working with people.
- **External partners.** If you are doing external benchmarking, the scope will include each organization outside yours. Each partner will have to benchmark at a level of the organization that is mutually agreed upon.
- **Time frame.** Most maintenance activities tend to be seasonal, and customers only gain a perspective over time. An appropriate time period for comparing performance and practices is annually. But planning to undertake customer-driven benchmarking for the first time will likely take at least 2 years. The **Figure 4** provides a time line for customer-driven benchmarking for organizations that are beginning this activity for the first time.

Road maintenance managers and crews like to think for themselves, control their own destinies, figure out how to do a job in the best way that makes them comfortable, and take pride in their ability and their accomplishments. The challenge in government and business alike is to harness the best instincts and motivation of their employees in order to provide the best possible products and service to customers.

Activities	Range of Required Time Months	Months from Start of the Benchmarking Process 5 10 15 20 25 30 35 40
1. Form a Benchmarking Partnership	2	--2
2. Identify Possible Measures	3-6	5-----8
3. Get Partnership Agreement on Measures and Protocols for Assessing Performance	3-6	8--------14
4. Take Measurements	3-6	11----------20
5. Identify Performances of All Benchmarking Units and Identify the Better Performing Units	3	14----------23
6. Collect and Each Unit Compare the Practices of a Set of Better Performing Units	2	16----------25
7. Determine Adaptability of Best Performance Practices to Another Unit and Select Changes to Be Made for That Unit	3	19----------28
8. Implement New Practices	3-9	22----------37
9. Measure Performance Again	3-6	25----------43

Figure 4. Customer-Driven Benchmarking Time Line

WHO IS INVOLVED?

All Levels

Customer-driven benchmarking of maintenance activities requires the involvement of managers at all levels of the organization. Different levels of management in the maintenance organization have different roles in benchmarking:

- **Head of maintenance, chief engineer, chief executive officer:** Provide leadership, foster the necessary change in culture, facilitate communication among organizations or organizational units participating in benchmarking, approve new performance targets, and allocate resources for improvements.
- **District, area, and garage managers:** Take measurements by collecting data, help document existing practices and share practices with benchmarking partners, assist in implementing improved practices, and help make recommendations for reallocation of resources.
- **Superintendents and crew leaders:** Assist in documenting existing practices, implement improved practices, and provide data on accomplishments and resources used.
- **Contract managers and inspectors:** Work with contractors to identify existing practices, and provide data on accomplishments and expenditures on contractors.

Government personnel and contractors who perform road maintenance are on the frontlines in providing safe, efficient, pleasing, and environmentally sensitive highway transportation to the public. Also, road maintenance personnel must also make sure that a transportation agency is a good neighbor to all owners of property along highways and streets.

Each level of the maintenance organization will need to fully buy into the benchmarking effort. This includes key maintenance managers in headquarters and the districts, areas, and garages in the geographic areas where benchmarking is likely to occur. In addition, crew leaders who may participate in benchmarking need to be brought along. Any effort that seeks to build support should ask managers for suggestions and ideas about the potential merits of benchmarking, identify challenges and ways to overcome

them, get their best ideas on how to proceed, and obtain their commitment.

Champions

It has been demonstrated repeatedly in many areas that a champion can greatly accelerate the implementation of a new process. A champion serves as an advocate, helps decisions move through the organization, and facilitates implementation.

You should look around your organization for a person who has the natural attributes of a champion for benchmarking. The person should be an early advocate, an articulate spokesperson, someone with credibility, a doer, and a facilitator. It is likely that this person is comfortable learning from others, is keen to adopt or exceed best practices wherever they are found, and can motivate others to do likewise.

It is wise not to rely on a single champion, but to have several, or at least one backup. Frequently a champion gets promoted or takes a new job elsewhere. If the benchmarking effort depends on the presence of the champion in order to move forward or to succeed and that person leaves, then the undertaking is likely to suffer or fail. Therefore, there should always be at least one other person who also serves as a champion or who can step into the champion's role and show similar enthusiasm.

Unions

It is very important for maintenance organizations to involve their union organizations in the benchmarking processes. Benchmarking produces changes in the practices of those who perform maintenance work activities. Unions are very concerned about workers and any management actions that impact workers. Unions may take issue with various aspects of benchmarking, such as the agency enrolling in a benchmarking partnership that might expose the agency to new work methods.

Approached properly, unions will buy into benchmarking. They are likely to cooperate with the process once they realize that improved performance from benchmarking activities strengthens the workers' position and reduces the potential for replacement by private contracting.

GETTING STARTED

Two important actions are required to begin customer-driven benchmarking. The first is to establish the internal benchmarking team. The second is to explore related management processes within the agency that affect performance measurement.

Internal Team

To begin, establish the internal team that will be responsible for implementing customer-driven benchmarking. This team will do all that is necessary to establish the agreements, processes, and procedures for customer-driven benchmarking and to inform and support the line organization regarding what is going on. This team may be a task force that will operate under the direction and management of the senior maintenance leader or may consist of several people who already report to the senior maintenance leader. In either case, recognize that this team will be functioning as long as the agency is involved in customer-driven benchmarking.

This team must include the most senior maintenance leadership, other maintenance and systems staff, and, if necessary, consultants. Collectively this team requires background and experience in the following:

- Defining maintenance practices and managing maintenance work (i.e., the team requires an expert who has credibility with field managers);
- Designing, administering, and interpreting costumer surveys and related consumer research;
- Collecting and utilizing data for performance measurement;
- Inputting, manipulating, and extracting data from the maintenance and related asset management systems;
- Inputting, manipulating, and extracting data from the financial management system;
- Setting performance targets, budgeting, and allocating resources to field organizations; and

- Training superintendents, crew leaders, and equipment operators.

One person may provide several of these capabilities. This team will work across internal maintenance suborganizations such as districts, counties, areas, and garages. The team will also be the primary coordinating body with partner agencies.

Related Management Processes

A typical organization, whether public or private, has many related management processes and systems that seek to achieve some of the same goals as customer-driven benchmarking. It is important to be aware of these related management processes, to use relevant data and performance measures from these processes, and to coordinate with them.

The following management processes related to benchmarking are found in many organizations:

- Asset management,
- Outsourcing,
- Performance-based planning, and
- Public reporting in conformance with the Governmental Accounting Standards Board (GASB).

Asset Management

With the completion of the Interstate Highway System and the enactment of the Intermodal Surface Transportation Efficiency Act in the early 1990s, national policy regarding roads turned decisively in the direction of preserving the existing investment and making the best use of existing highway capacity. By the end of the 1990s, the thrust to preserve existing investment was folded into the idea of "asset management." Asset management is a systematic process of maintaining, upgrading, and operating physical assets cost-effectively, although in the broadest sense it can apply also to materials, equipment, and financial resources.[2] According to the proceedings of an executive seminar on asset management conducted in 1996, attributes, key components,

[2] Center for Infrastructure and Transportation Studies at Rensselaer Polytechnic Institute, *21st Century Asset Management, Executive Summary,* Proceedings of a workshop sponsored by the American Association of State Highway and Transportation Officials and the Federal Highway Administration, October 1997.

procedures, and outputs of an of asset management system include the following:

- A common understanding of performance measures and criteria;
- Understandable results in a user-friendly environment;
- Customer focus;
- A mission-driven orientation (i.e., asset management strives to help the organization achieve its mission);
- Accessibility at many levels within the organization;
- Linkages to technical analysis, decision making, and budgetary processes;
- Inventory information and condition databases;
- Life-cycle cost analysis; and
- Optimization (i.e., allocates limited funds in order to maximize net benefits or minimize total costs).[3]

These attributes are strikingly similar to key elements of a customer-driven benchmarking process. Because of the similarity, the likelihood of succeeding in a benchmarking effort can be substantially strengthened by properly coordinating with the asset management program of an agency and by thoroughly understanding the asset management systems that are in place, under development, or being planned.

Therefore, at the start of undertaking a benchmarking effort, it is desirable to take an inventory of your agency's asset management efforts. By doing so, you will be able to identify procedures, performance measures, sources of data and information, and other resources that can help in benchmarking.

You are also likely to find increased support for your benchmarking efforts. Those charged with asset management will usually recognize that customer-driven benchmarking can benefit asset management, and vice versa.

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[3] Asset Management, Advancing the State of the Art into the 21st Century Through Public-Private Dialogue, Proceedings of an executive seminar sponsored by the American Association of State Highway and Transportation Officials and the Federal Highway Administration, Washington, DC, October 1997.

There may also be shared recognition of the desirability of integrating benchmarking into the overall asset management program.

Outsourcing

Nearly all agencies outsource at least some of their maintenance operations. A critical issue in outsourcing is determining which activities to outsource, developing performance specifications for contracting these activities, and evaluating the performance of contractors. In addition, contractors themselves have a compelling need to evaluate their own performance in order to serve their clients effectively and to remain competitive.

Doing each of these tasks well depends on having appropriate performance measures. Many of these performance measures are similar to those that might be used for benchmarking.

When getting started on benchmarking, it is desirable to determine what type of performance measurement, if any, is being used in conjunction with outsourcing. You should coordinate with those responsible for performance-based outsourcing and, if possible, arrange to share data and results.

It is also desirable to contact contractors who must work under performance-based specifications. Contractors may have insights regarding how to establish an effective benchmarking process. Also, contractors may wish to become benchmarking partners.

Performance-Based Planning

The reinvention of government to make it more responsive to customer needs and more accountable has been going on for a long time and accelerated in the late 1980s. Gradually, and then with increasing speed, public officials and managers in government recognized that establishing customer-oriented performance measures and targets for accomplishments is one of the most effective ways to improve government efficiency and effectiveness.

With the enactment of the Government Performance and Results Act, all federal agencies were required to develop a performance-based strategic plan by identifying appropriate input, outcome, and output measures; setting targets; striving to meet the targets; and reporting on their progress. Many states have enacted similar

legislation, as have cities and counties. An excellent example of performance reporting is Oregon Benchmarks, which received national recognition.

The private sector has also been using performance-based planning. In order to avoid the dangers of relying upon an overly narrow set of performance measures, many private firms (and government agencies) have been developing "balanced scorecards." The balanced scorecard approach involves performance measurement, goal setting, reporting, and monitoring in four areas:

1. Customer perspective,
2. Internal perspective,
3. Innovative and learning perspective, and
4. Financial perspective.

When beginning a benchmarking process, you should determine what types of performance-based planning are occurring in your agency and identify opportunities to cooperate and share information and results.

Accountability and the GASB

The GASB has played a major role in fostering performance assessment, mainly to foster increased accountability of agencies to their customers and the people who finance and pay for government services. To this end, the GASB carried out a major research program entitled "Service Efforts and Accomplishments Reporting: Its Time Has Come," which produced a series of reports on performance measurement and reporting, including one on road maintenance.[4]

An outgrowth of this effort has been Ruling 34 of the GASB, with calls for government transportation agencies to depreciate their assets or report on the condition of assets by using data in an asset management system when they prepare their annual financial reports to the public. Virtually every government agency prepares its financial reports in conformity with GASB

[4] Hyman, W., R. M. Alfelor and J.A. Allen, *Service Efforts and Accomplishment Reporting: Its Time Has Come,* Road Maintenance, Governmental Accounting Standards Board, February 1993.

requirements and procedures. The reason the GASB has added the requirement to depreciate assets or report on their condition is to encourage transportation agencies to preserve existing investment and to avoid the unnecessary costs of deferred maintenance. The GASB believes that failure to maintain transportation assets properly wastes financial resources that otherwise could be expended for more productive purposes, including meeting debt payments.

Top managers of transportation agencies are developing strategies to comply with the GASB's public reporting requirements, including customer-driven performance measurement systems.

Before getting started on benchmarking, learn what your agency is doing to comply with GASB reporting requirements. Those efforts may produce measures, data, and other information useful for customer-driven benchmarking of maintenance activities.

REWARDS AND RECOGNITION

Rewards and recognition help an organization realize its potential to continually perform at the best possible level. Management needs to recognize and reward positive changes in performance that are achieved through benchmarking.

Recognition and rewards in benchmarking should focus on changes in performance of individual units and work groups rather than on the highest levels of performance achieved. Benchmarking is all about improvement, regardless of the starting point. Individual units and work groups with low levels of performance may have the greatest opportunity for improvement, whereas those units and work groups that have had consistently high levels of performance will likely have less opportunity for improvement. Regardless of the size of the opportunity, improvement is worthy of acknowledgment.

For organizational units that have lower levels of performance, it may take significant time for dramatic improvement. If rewards and recognition are based solely on the highest level of performance, then units with lower levels of performance might not be motivated to improve.

Conversely, high levels of performance should not be ignored. Those units and work groups that have had consistently high levels of performance are not likely to achieve great improvements through benchmarking. However, they need recognition for what they have achieved year in and year out. For these units, continued improvement, even if small, is worthy of recognition.

BENCHMARKING MYTHS

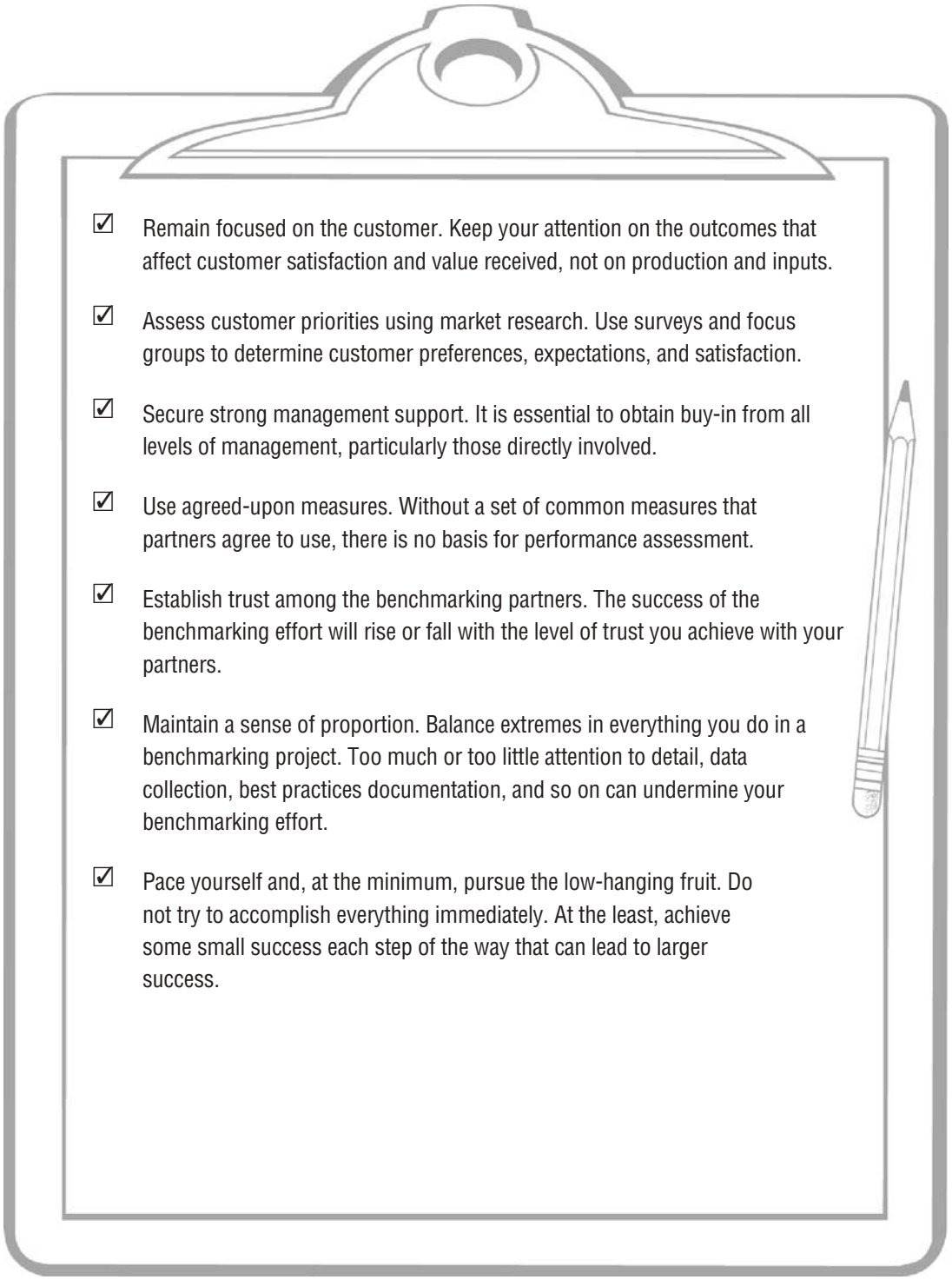
There are many misconceptions regarding benchmarking. Benchmarking is a positive and rewarding activity that can only benefit the individuals and the organizations involved if it is approached from the right perspective and with the right attitude. Here are some benchmarking myths that need to be dispelled:

- **Everybody and every organization is different, so you cannot compare performance.** Effective customer-driven benchmarking methods control for variations in weather, terrain, traffic, and other hardship factors outside the control of organizational units. Likes are compared with likes.
- **Benchmarking places too much emphasis on who is best.** This emphasis is misplaced. Identifying best performance is a means to an end. The end is to continuously improve the satisfaction and value that customers receive from road maintenance by illuminating and adopting best practices. Benchmarking is also about the personal and professional growth that results from sharing and learning from others.
- **By focusing on the "best" performer, you single out one organization.** In benchmarking, there usually are numerous "best" performers that vary depending on the set of measures used and the environmental factors at play. Also, once the best performer is identified, the attention should be focused on trying to understand the nature of the best performers' business practices and the feasibility of others easily adopting or improving upon them. Also, it should be noted that over time, the "best" performers will change.

- **Benchmarking is time-consuming and expensive.** Managed properly, benchmarking yields large improvements in customer-oriented outcomes and organizational cost savings. Nearly every major corporation does some type of benchmarking because the net benefits are so compelling. The profitability and even the survival of many firms and lines of business depend on informed benchmarking. The government can reap similar benefits.
- **You can't get started unless you have all the data and the measures.** You can begin a benchmarking process without an ideal set of data and measures. By making judicious choices about which attributes of the maintenance products, services, and activities you want to explore in benchmarking, you can start to reap the benefits; learn from an initial effort; and fill in missing steps, data, and measures as you go.
- **The rewards of benchmarking just go to the best performers.** Not just one organizational unit will improve its performance when it adopts a best practice: all organizational units can potentially adopt the best practice, and thus the service to customers of the entire organization will be enhanced.

CRITICAL SUCCESS FACTORS

As you apply the method of customer-driven benchmarking in this guide, bear in mind the following critical success factors:



- ☑ Remain focused on the customer. Keep your attention on the outcomes that affect customer satisfaction and value received, not on production and inputs.
- ☑ Assess customer priorities using market research. Use surveys and focus groups to determine customer preferences, expectations, and satisfaction.
- ☑ Secure strong management support. It is essential to obtain buy-in from all levels of management, particularly those directly involved.
- ☑ Use agreed-upon measures. Without a set of common measures that partners agree to use, there is no basis for performance assessment.
- ☑ Establish trust among the benchmarking partners. The success of the benchmarking effort will rise or fall with the level of trust you achieve with your partners.
- ☑ Maintain a sense of proportion. Balance extremes in everything you do in a benchmarking project. Too much or too little attention to detail, data collection, best practices documentation, and so on can undermine your benchmarking effort.
- ☑ Pace yourself and, at the minimum, pursue the low-hanging fruit. Do not try to accomplish everything immediately. At the least, achieve some small success each step of the way that can lead to larger success.

CHAPTER 2: SELECTING BENCHMARKING PARTNERS

Customer-driven benchmarking requires organizations that perform or are responsible for highway maintenance to make a commitment to work together for a considerable period of time—at least 2 years to obtain meaningful initial results and 3 to 5 years to make substantial progress toward continuous improvement. The commitment of the benchmarking participants involves using an agreed-upon set of measures focused on customer-driven outcomes, taking measurements for a set of benchmarking units, sharing the data regarding the benchmarking units, and sharing details of the maintenance practices of the benchmarking units.

This guide distinguishes between benchmarking partners and benchmarking units. Benchmarking partners are organizations that have the authority to do all of the following:

- Enter into an agreement with other organizations to perform customer-driven benchmarking;
- Define a set of maintenance products and, services, or both that are appropriate for their organization; and
- Establish or change the performance measures used by their organization.

Internal benchmarking may be the best place to begin a customer-driven benchmarking initiative.

The types of organizations that satisfy these three criteria are

- State agencies,
- Cities,
- Counties,
- Turnpike authorities,
- Private-sector firms,
- Organizations in different industries, and
- Organizations in other countries.

Benchmarking units are the units within a particular level of an organization that compare performances with one another to identify best practices and to continually improve. Customer-driven benchmarking is unlikely to be successful unless the benchmarking units have the following attributes:

- The managers of the units make decisions regarding the resources (labor, equipment, and material) used in their geographical area and the procedures for applying them.
- The managers of the units bear responsibility for the results of the maintenance program in their geographic area.
- The driving public can distinguish the results the units achieve over a specific time period from the results that neighboring units or other units achieve.
- The organization under which the unit resides finds it practical and economically feasible to collect statistically valid customer satisfaction data.

A benchmarking partner and a benchmarking unit are not necessarily the same—for example, a state maintenance organization could be a benchmarking partner with benchmarking units consisting of districts, counties, areas, or garages. Private companies could be benchmarking partners, and their benchmarking units could consist of districts. County government or municipalities could both be partners, while having subunits that are benchmarking units.

It is strongly recommended that a state maintenance organization not be a benchmarking unit. The state maintenance organization is represented by a headquarters that usually is too far removed from the actual performance of maintenance work and from the outcomes of maintenance perceived by road users. Also, it is unlikely that the state has just one set of practices for a maintenance product or service; it is likely there are many different practices for any maintenance product or service across a state.

In short, the benchmarking partners make an agreement to work together and to settle upon mutually agreed-upon performance measures. In contrast, the benchmarking units are the level at which performances are compared and descriptions of practices are prepared. New or different practices are implemented at the organizational level of the benchmarking unit.

CRITERIA FOR SELECTING PARTNERS

Finding maintenance practices that lead to better performance is an important objective of customer-driven benchmarking. The criteria that you use to select partners should be consistent with this objective.

Initial Agreement on What to Benchmark

As explained earlier, customer-driven benchmarking requires that a maintenance agency define its purpose and function in terms of a set of products and services that it provides to its customers (e.g., a smooth ride); the important attributes of each product or service (e.g., a smooth pavement surface); and customer-driven outcome measures (e.g., the International Roughness Index, Customer Satisfaction Rating) related to each attribute.

There are many demanding steps to go through, and it is likely that neither you nor most of your partners have been through this process. In the absence of a mutually agreeable set of products and services, each agency can agree to the general area that they want to benchmark, perhaps focusing upon the types of maintenance assets of mutual interest. The benchmarking partnership should not admit organizations that cannot agree on the same general focus as the other partners.

Suppose that the organizations of a benchmarking partnership are primarily interested in providing higher quality and more effective signage to customers. An agency that is only interested in benchmarking its performance in delivering a comfortable ride to customers would not be a good candidate for the partnership.

Cooperation and Willingness to Share Information

Partners need to demonstrate cooperation and a willingness to share information. The lead benchmarking organization needs to be assured that each participant will use agreed-upon measures, collect accurate data for each benchmarking unit, share the data with the partners, document existing practices, and share information on best practices with all the benchmarking partners. The more open and forthcoming potential partners are in

preliminary discussions about their degree of commitment and the quality of existing performance information, the more likely it is that they will cooperate and share information.

Willingness to Create Common Measures

A community of organizations that uses or has adopted common customer-driven performance measures represents a major target of opportunity to develop a set of benchmarking partners. However, in the early 2000s, it is unlikely that you will find organizations external to yours that use precisely the same measures that you use or would like to use.

Customer-driven benchmarking requires common types of data to create common measures of performance. For example, if one agency measures sign quality through rigorous retro-reflectivity measurements and customer surveys and a second agency measures sign quality through "windshield surveys," you cannot compare performance.

An essential criteria for selecting a partner is its willingness to work with others to define common measures of performance and to develop data collection procedures that will be used by everyone.

Some agencies have defined their own performance measures, data requirements, and data collection procedures and are not willing to consider changes that will be necessary for a particular benchmarking partnership. These agencies are not suitable members of the partnership.

Commitment to Data and Measurement Quality

Benchmarking does not require "audit quality data," but it will fail without continually paying adequate attention to data and measurement quality. Each benchmarking partner needs to be willing to submit to a benchmarking process that instills faith in all partners that measurements are accurate and reliable enough to serve as the basis for identifying best practices and improvement opportunities. If you think a partner's commitment to measurement quality is weak, you should seek partners elsewhere.

Commitment of Time, Effort, and Resources

Successful benchmarking requires a strong commitment of time, effort, and resources among all participants. Potential partners that signal a willingness to make this commitment should be among your top preferences. Keep looking for partners if discussions with a potential partner suggest it may have a problem making a serious commitment to benchmarking. Be alert to any unwillingness of potential partners to devote staff, equipment, materials, data collection, databases, or other resources that are essential to successful benchmarking.

Operating Environment

You may want to find a group of benchmarking partners that have benchmarking units that operate in similar environments (e.g., weather, terrain, population density). By doing so, you do not have to control for different environmental factors when taking measurements, and it is more likely that it is feasible to implement a best practice discovered by one of the benchmarking units.

Suppose that benchmarking partners are going to benchmark the service "roadways clear of snow." Assume further that the benchmarking units of those partners operate at totally different elevation levels (elevations above 5,000 feet and elevations of less than 600 feet above sea level). These benchmarking units are less likely to have practices relevant to one another than if they all operated at the same elevations.

More typically, you will benchmark with partners that function in a variety of operating conditions, including conditions that are very different from yours. Benchmarking units in different operating environments will have adapted to different factors (hardships) that affect their maintenance operations. Sometimes the practices that have evolved in sharply different settings are a source of new ideas that can help your agency improve its performance.

Public Sector or Private Sector

If you are a public agency, you may desire to limit your partners to those in the public sector. One reason to do so is to build a group of benchmarking partners through government and quasi-governmental associations such as the American Association of State Highway and Transportation Officials, the National Association of County Engineers, the National League of Cities, the Conference of Mayors, the American Public Works Association, and the International Bridge Tunnel and Turnpike Association. Public-sector partners are more likely to have similar cultures and outlook, which may make it easier to communicate and work together.

On the other hand, public agencies contract out various types of maintenance operations to private companies. Sometimes public agencies even contract out all types of maintenance activities along a route (i.e., an Interstate highway) or even within a certain jurisdiction.

Although there is no strict rule that the private sector is more effective or efficient in serving customers, in many cases the private sector can be more responsive to customer demands. There is a great deal to learn from the business practices of the private sector because the revenue, profitability, and survival of private firms depend on their being attuned to customers and remaining competitive.

You may also want to consider benchmarking with private firms that are not in road maintenance—for example, firms that do landscaping for campuses, buildings, and parks might be a source of innovative ideas and best practices that you would not discover without their involvement. As another example, many firms specializing in facilities maintenance might provide insight about how to improve the management of rest areas owned and operated by public agencies.

National or International

A number of states, including Minnesota and Michigan, have cultivated close relationships with other countries in order to learn from them. These states clearly perceive the benefits of learning what organizations in other parts of the world are doing.

Fewer barriers to trade and constantly improving communications have created a global economy that knows no borders. Multinational corporations find it imperative to stay abreast of best practices from around the world. When they engage in a benchmarking effort, they not only select organizations in their own country, but also search worldwide for the "best in breed," "best in class," or "world class." In the most competitive environments, firms that do benchmarking hope not only to identify best practices, but also to leapfrog past them.

You may not feel the competitive pressure to be the best on a global scale, but many road maintenance managers are interested in adopting best practices from anywhere in the world if doing so is a means of efficiently and effectively improving customer products and services and of fostering superior performance in their own agencies.

DETERMINING THE ORGANIZATIONAL LEVEL AT WHICH TO BENCHMARK

A decision you will need to make before finalizing a partnership agreement is to determine at what geographic or organizational level you plan to or can benchmark; this is the benchmarking unit. Key considerations are as follows:

1. **There should be well-defined administrative, geographic, or natural boundaries.** Districts, areas, garages, counties, and municipalities qualify as administrative units. Quadrants or sections within a county or city should have geographical features that make it easy for the driving public to distinguish boundaries. Rivers, lines of trees, changes in topography, railroad tracks, and major highways help to make such distinctions.
2. **You should benchmark at an organizational level as close to the delivery of maintenance to customers as possible,** but also where customers can discern differences in performance from one geographical area to another due to differences in maintenance practices. Managers should have a good deal of control over the outcomes of maintenance at this organizational level. Among the factors managers should be able to influence are whether

to contract out work, the number of crews to assign to various maintenance activities and different locations, the types and configurations of resources to apply, and when the work should be performed.

3. **As a rule of thumb, you should benchmark at the lowest level at which you can survey customers practically and economically to obtain statistically valid measures of their satisfaction with a product or service.** In a state agency, this is likely to be an area approximately the size of a county (however, today most state agencies do not have statistically valid customer satisfaction data below the district level, such as at the county or area level). The same practical and economic considerations apply to condition or level-of-service data obtained from a random sample of roadway sections used in a Maintenance Quality Assurance Process described under NCHRP Project 14-12 (published as *NCHRP Web Document 8*).
4. **Generally, a crew or a roadway section should not be the benchmarking unit; the benchmarking unit should encompass the activities of a number of crews.** There are exceptions. For example, it is reasonable to benchmark at the crew level if benchmarking is going to focus on the performance of specialized crews serving a broad area. Examples of specialized crews are sign or striping crews. Sometimes, it is also reasonable for a roadway section to be a benchmarking unit if it is part of a tollway or if it is a road that a contractor is maintaining.

NUMBER OF BENCHMARKING PARTNERS

How many benchmarking partners will you need? The number of partners is not the issue; the number of benchmarking units is the important number.

You want enough benchmarking units among the partners to be able to differentiate levels of performance and to identify best practices within different environments (i.e., rural and urban areas). If you apply mathematical or statistical procedures, the techniques may have properties that depend on the number of observations (i.e., benchmarking units) to achieve a desired resolution, accuracy, or statistical significance.

Rules of thumb from statistics and experience in applying rigorous methods of benchmarking suggest you will need at least 30 observations. This means you will need at least 30 benchmarking units among the partners. You can make do with less, but your ability to identify practices that are better for any one of the benchmarking units will decline accordingly.

Large agencies such as state transportation agencies can perform customer-driven benchmarking without forming partnerships: they can benchmark internally among subunits—areas, garages, counties, and regions—all under the state's jurisdiction.

For many states, internal benchmarking may be the best way to start customer-driven benchmarking, allowing you to proceed more quickly. Subunits within the organization usually share a common vision, a mission, overall political goals, measures, data, a management structure, and communications networks.

The principal disadvantage of benchmarking within your own organization is that the best practices that you can potentially identify are limited to the best practices of your organization. **By looking outside your organization, you are open to new possibilities. No matter how good your own practices are, the further you look beyond your organization, the greater your opportunity to learn from others and to improve how you serve your customers.**

NEGOTIATING A CUSTOMER-DRIVEN BENCHMARKING PARTNERS AGREEMENT

Once benchmarking partners have been identified, it will be necessary to negotiate a benchmarking agreement. There are many important issues to address, and some may be difficult to resolve.

If yours is the lead organization, while getting ready to benchmark you should identify a person in your agency who has excellent facilitation and negotiating skills. That person should be the primary point of contact with each benchmarking partner and should take the lead in forging a benchmarking agreement.

You should take advantage of any existing relationships among managers in each partner organization. Frequently the head of maintenance in your organization will know the head of

maintenance in many of the partner organizations and can help close the deal on the benchmarking agreement. Also, the chief executive officer (CEO) in your organization may know his or her counterparts in other organizations. Reaching agreement to benchmark sometimes requires considerable political sensitivity. The CEO is likely to have the sensitivity to get the commitments of time, effort, and resources from other organizations that are necessary to succeed.

Principles of Partnership Agreements

Many years of experience by large numbers of organizations have led to a benchmarking code of behavior that has two overriding principles:

1. The golden rule, "Do unto others as you would have others do unto you," and
2. Do not do anything illegal or unethical.

In the private sector, competitors have to be very careful to protect proprietary information and not run afoul of antitrust laws, which prohibit anti-competitive practices.

A set of principles, based on the Benchmarking Code of Conduct adopted by the International Benchmarking Clearing House and the Strategic Planning Council, is as follows:

1. **Principle of Legality:** Avoid discussions or actions that could be considered or are, in fact, illegal.
2. **Principle of Exchange:** Be willing to provide the same type and level of information that you are asking others to provide.
3. **Principle of Confidentiality:** Never breech an agreement to protect proprietary or confidential information. Do not share the results of benchmarking information without prior permission of partners.
4. **Principle of Use:** Restrict your use of benchmarking information to the improvement of partnership organizations. Do not extend the results of one benchmarking study to another without the consent of each organization that participated in the original study.

5. **Principle of First-Party Contact:** Each benchmarking partner should designate a "first point of contact." Exchange of information and interaction with others in the organization should begin with those contact points.
6. **Principle of Third-Party Contact:** Do not give out an individual's name without his or her permission in response to a contact request, particularly in private firms.
7. **Principle of Preparation:** Show your commitment to the efficiency and effectiveness of the benchmarking process by being thoroughly prepared, especially when you initiate a contact with a partner.
8. **Principle of Completion:** Follow through in your commitments to a benchmarking process by sharing information about processes, offering to arrange reciprocal visits, and completing meetings and visits on time. Consider sharing study results.

Benchmarking Agreements

These principles are most likely to be followed if there is a formal agreement among benchmarking partners. A formal agreement clarifies the objective of the partnership and sets out the essential responsibilities of the partners. Generally, an oral agreement is not recommended unless the partners have strong mutual trust, have done benchmarking together before, and understand fully what is involved in producing and sharing information on performances and best practices.

In general, each partner should sign a benchmarking agreement that addresses the points described here.

Objective and Goals

The agreement should set out the goals and objectives of customer-driven benchmarking. The objective should be to improve customer satisfaction and observable customer-oriented outcomes or to reduce the cost of delivering the product or service, or both.

Partners and Benchmarking Units

The partnership agreement should list the name and address of each participating organization and a first point of contact with name, phone, and e-mail information.

The agreement should also provide the number and unique identification of the benchmarking units that each partner offers for possible participation. This list can change if the level of the benchmarking unit changes or if a partner has reasons to drop or to add benchmarking units.

Lead Partner and Roles

The agreement should state which organization will serve as the lead organization and the name and contact information (address, phone, e-mail, and fax) for the individual who will coordinate the benchmarking activities of all the partners. The lead agency will be responsible for forging agreement with the partners on the following:

- Developing customer-oriented measures,
- Establishing procedures for data collection procedures,
- Ensuring measurement and data quality,
- Scheduling data collection,
- Formatting and sharing data, and
- Documenting and sharing practices of benchmarking units.

Target Products, Services, Activities, and Business Processes

The partnership agreement should identify products, services, activities, and business processes that are candidates for benchmarking. In general, the agreement should be flexible and should not specify precisely what will be benchmarked. However, in some situations, you will need to be specific in order to obtain agreement from your partners to participate.

Roles and Responsibilities of Partners

Above all, each partner has a responsibility to diligently build consensus on what performance measures to use, to collect

accurate data in accordance with agreed-upon performance measures, and to provide documentation on business processes. Each partner depends on the others in order to obtain meaningful results and to ensure that the benchmarking partnership succeeds. If too many partners shirk their responsibility, a large amount of time and effort for everyone involved will be wasted. In a small partnership, only one or two agencies failing to uphold their end is enough to undermine all the benefits of working together.

Time Period

The time period for the agreement must be defined. Recognize that if the partners are defining product or services, establishing measures, and collecting data for the first time, 1 year can easily pass before any measurements are taken and the performances of the benchmarking units are evaluated. A longer time period will be required if the partners want to go through more than one measurement cycle. Therefore, partners should be thinking in terms of agreements of 2 to 5 years.

Common Measures

There should be a clause in the agreement that says that parties to the agreement will use the same outcome, output, input, and external measures and will take the necessary steps to take the measurements, including collection of underlying data.

The agreement should specify the general types of measures that will be used. There should be flexibility to change the measures as the benchmarking partners work together and become clearer regarding what to do.

Data Quality

The agreement needs to say that partners will abide by mutually agreed-upon procedures to ensure data and measurement quality. The agreement could leave these procedures open to future determination or could specify them. Examples include the accuracy and the confidence level of data and measurements.

Sharing Information on Performance

The agreement should contain a clause stating that each participant agrees to sharing information on performance in terms of each of the following:

- Outcomes and outputs;
- Inputs (labor, equipment, material, and costs; financial information may be problematic for private firms);
- Levels of external factors; and
- Details of business processes associated with each performance.

This clause might specify that partners agree to store information in a database having a particular format to facilitate exchanging information. The agreement could also specify other forms of information sharing—for example, willingness to complete a questionnaire or permit videotaping of operations.

Confidentiality

It is quite likely that potential partners will not participate in benchmarking unless there is confidentiality regarding sharing of data. The confidentiality clause might require that all results and data be attributed to organizations only by code, not by name.

This is an important issue not only for private firms, but also for many public agencies that are reluctant to exchange information that could be used to compare performance unless they can be assured that the results of comparisons will not be made public. However, open record laws (e.g., freedom of information acts), may make it difficult to guarantee that public data gathered at taxpayer expense remains confidential.

The confidentiality clause could specify that any database have security features that restrict different users from accessing various types of data and results. Some database users would have rights to create, update, and delete data. Others might have "read only" rights, while still others could be restricted to viewing only certain subsets of information.

Documentation

There should be a provision in the agreement that requires benchmarking partners to document, for the consideration of others, any practices that are determined to be superior or best practices. The documentation might include the following:

- Sources of data on outputs, inputs, and external factors;
- Information on the reliability, accuracy, and repeatability of data and measurements;
- Raw and reduced data from systems that provide the data for benchmarking;
- Description of work methods that may exist;
- Existing procedural manuals;
- Business process flow charts prepared according to conventions agreed upon by the benchmarking partners;
- Training, education, and experience levels of labor;
- Vendor information regarding the materials and equipment used; and
- Costs (variable and overhead). (Note: some organizations may not be willing to provide cost data, and the benchmarking agreement should provide the flexibility to not do so. However, it may be impractical not to use cost data as a measure of the resources used. Furthermore, if products or services are sold, sharing of pricing or cost information could violate antitrust laws).

Adding Benchmarking Partners

The benchmarking agreement should allow additional partners to be added to the group, provided they agree to all the terms and conditions of the agreement.

Resigning from the Partnership

The agreement should set out the conditions under which a participant can resign from the benchmarking partnership**. It is desirable for the agreement to state that each partner will satisfy its obligations under the benchmarking agreement as**

long as it remains involved, but may leave the partnership at any time without cause. It is a mistake to include stringent exit procedures, because they will discourage potential partners from entering the agreement. Partners will remain involved as long as the partnership provides compelling benefits by showing organizations how they can improve performance as a result of adopting best practices.

Sample Benchmarking Agreement

Appendix A includes a sample agreement suitable for customer-driven benchmarking of road maintenance.

ENROLLING BENCHMARKING UNITS IN EACH ORGANIZATION

Once you have developed a benchmarking agreement with your partners, you need to recruit units within your agency to participate in benchmarking activities. Ideally, you will have taken this step before you signed the benchmarking agreement so that you have buy-in. Even so, you will have more to do to solidify the participation of the benchmarking units so that you can proceed to measure and analyze performance.

By the time you sign a benchmarking agreement with your partners, you will probably know at what level of the organization you plan to benchmark and will have a general agreement to participate from the managers responsible for those organizational units. This understanding is more likely to have been reached at the middle and higher levels (e.g., garage level or higher) than at the crew level. You will need to fully engage the lower levels of the organization that are directly responsible for performing maintenance work. This is important because you will need to rely on work units to provide an accurate description of work methods, including labor, equipment and material used, as well as their role in the overall business processes of providing a maintenance product or service. In addition, you may need the cooperation of the work units in order to gather information not normally recorded in daily work reports, although crews should not be expected to collect data on outcomes. If there are possible barriers to engaging crews because of collective bargaining agreements, you may need to work with union representatives.

CHAPTER 3: MEASUREMENT

TYPES OF MEASURES

Central to benchmarking is measurement. Measurement provides an objective way to gauge performance and to identify best performances. In the case of customer-driven benchmarking, you need to apply a set of measures in order to assess how well you address customer desires and satisfaction. If you are not measuring, then you cannot possibly be doing benchmarking, and if you are not applying measures oriented toward how well you are serving your customers, then you are not doing customer-driven benchmarking.

During the last several decades, a system of classifying measures has evolved that helps to focus on customers. In the 1960s and 1970s, most attempts to develop performance management systems, including traditional maintenance management systems, focused on two types of measures: outputs and inputs. These measures are defined as follows.

Outputs

Outputs are a measure of production or accomplishment. In highway maintenance, examples of output measures are lane miles of roadway surfaced, the number of bags of litter picked up, and the number of acres mowed.

Inputs

Inputs are the resources used to deliver a product or service, perform an activity, or undertake a business process. In highway maintenance, the inputs consist of labor, equipment, and materials. The funds needed to pay for these resources may also be considered an input. Under certain circumstances, other productive resources—such as land, water, or air—can be treated as an input.

As illustrated in **Figure 5**, maintenance agencies focused on measures of productivity use these measures by looking at the ratio of output to various types of inputs. One could measure output per labor hour, per equipment dollar, per quantity of material used, or per dollar of expenditure. One might also examine unit costs expressed as the cost per unit of output.

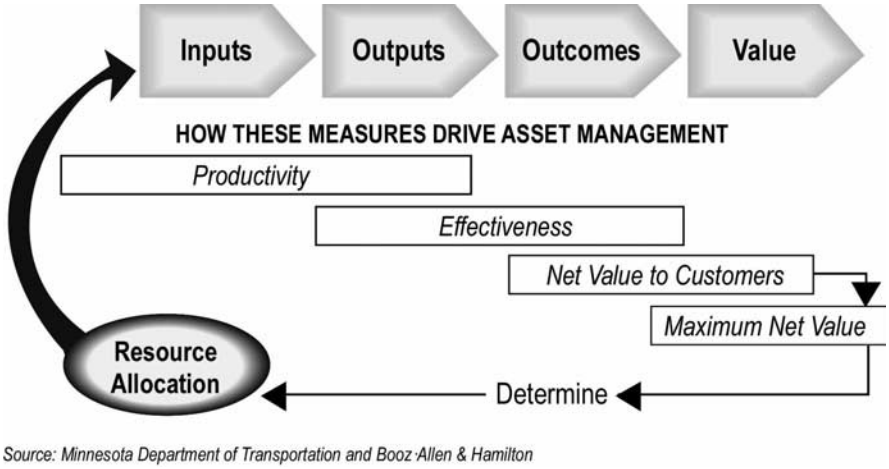


Figure 5. Product and Service Delivery Processes

The trouble with input and output measures is that they are internally focused on the work maintenance personnel do. They are not externally focused on customers.

More recently, especially since the enactment of the Government Performance and Results Act of 1993, the focus has been increasingly on outcomes.

Outcomes

Outcomes are the results, effects, or changes that occur due to delivering a product or service, conducting an activity, or carrying out a business process. For example, an outcome of pavement resurfacing might be smoother pavement. An outcome of litter pickup might be cleaner roadsides, and the outcomes of mowing might be increased sight distance at intersections and around curves and, consequently, reduced accidents.

Outcomes are more likely to be externally focused and frequently relate to customer preferences, expectations, and satisfaction. By looking at the ratio of outcomes relative to inputs, one can address the effectiveness of a program in addressing customer-oriented results. Typical measures might be an outcome per labor hour, per equipment hour, or per dollar of expenditure.

One might also examine cost effectiveness, which is the cost per unit of outcome achieved. Figure 4 illustrates that as one transitions from using output measures to outcome measures, the emphasis shifts from productivity to effectiveness.

Some agencies have gone one step further and identified another set of measures: value added.

Value Added

Value-added measures are customer-oriented outcome measures expressed in terms of the value received by the customer. Measures of value added include an increase in customer satisfaction or an increase in economic value from, for example, travel time saved or life-cycle costs avoided.

As one transitions from a focus on outcomes to value added, the perspective shifts from effectiveness to the net value added to the customer and provides the basis for resource allocation in economic terms.

Four Types of Measures for Customer-Driven Benchmarking

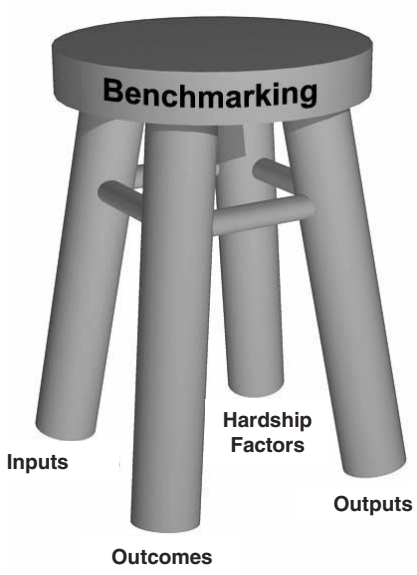
In customer-driven benchmarking, use measures similar in type to the ones described above. However, the project team suggests you think about four types of measures:

1. **Outcomes**—the customer-oriented outcome or value-added measures as defined above.
2. **Resources**—the same as the inputs defined above (e.g., labor, equipment, materials, and funding).
3. **Outputs—**measures of levels of production or accomplishment.
4. **Hardship Factors—**factors outside the control of the maintenance organization such as weather and terrain that influence the outcomes and level of resources used.

Relationship of Outcomes, Resources, and Hardship Factors

In the spirit of sound economic analysis, customer-driven benchmarking takes the approach that some overall picture of outcomes relative to some overall picture of the resources expended, while adjusting for factors outside the control of a maintenance organization, is the proper way to assess performance. There is no attempt to combine outcomes into a single measure of benefits, which would require converting all benefits into dollar terms or applying appropriate weights to each outcome in order to construct an overall performance index.

Customer-driven benchmarking is like a stool that rests on four types of measures



Instead, in customer-driven benchmarking, a variety of customer-driven outcome measures are treated as a group but remain separate. Similarly, a variety of resource measures are treated as a group but remain separate. Factors outside the control of the agency—weather, terrain, traffic volumes—are also treated as a group, but remain separate. Outputs have a bearing on the analysis because they help establish the level of effort for each benchmarking unit and the comparability of their performances.

The idea is to simultaneously preserve each of these measures while (1) continually bearing in mind the importance of looking at the outcomes achieved relative to the resources used and (2) taking into account hardship factors outside the control of each organizational unit and their level of production.

OUTCOMES

In customer-driven benchmarking, three important kinds outcomes can be measured:

1. Customer satisfaction,
2. Condition of assets and other attributes of roads, and
3. Value received by the customer.

Customer Satisfaction

Customer satisfaction is a topic addressed in countless books and articles on marketing and market research, as well as in specialized fields such as psychology. Benchmarking is ultimately about making continuous improvements through the identification and adoption of best practices in order to equal or exceed the satisfaction of the customer. Measuring changes in customer satisfaction over time provides the feedback regarding how well you are doing.

An important measurement tool for assessing customer satisfaction is statistically valid measures of customer satisfaction obtained from administering a survey using random sampling.

Types of Surveys

As you plan to get started with benchmarking, important questions you need to address are as follows:

- What role will surveys of customer satisfaction play as a measurement tool?
- What types of survey data are currently available?
- Should you develop your own survey?
- Should you rely on surveys developed by others?

You will also need to address the cost and timing of developing your surveys. If you decide to develop your own surveys, you will also want to address the issue of what related questions and answers you should be seeking in the survey—for example, do you want to merely learn about customer satisfaction regarding the department's maintenance products and services or do you also want to learn about customer preferences and expectations, the relative value of their preferences as they make tradeoffs, and perhaps even what they are willing to pay?

National Quality Initiative

As mentioned previously, FHWA, AASHTO, the American Public Works Association, and various industry associations are supporting the National Quality Initiative (NQI) in Transportation. The NQI develops and administers, with the assistance of the U.S. DOT, a national survey. In May 1996, the NQI released the results of a scientific random sample of 2,205 households that assessed customer satisfaction and preferences regarding the nation's highway system. Summary data from the survey's categorical questions are accurate within plus or minus 2 percent with, 95 percent confidence.[1]

The NQI survey included numerous questions that pertain to the outcomes of road maintenance. It is vitally important to recognize that the NQI survey, in attempting to determine customer satisfaction, focuses upon important *attributes* of highways. In the case of maintenance, the key issue is what the customer satisfaction is with regard to the attributes of maintenance products and services—for example, the NQI asks how satisfied survey respondents are regarding the smoothness of roads. It is not possible to solely associate the smoothness of roads with maintenance; nonetheless, certain types of road

[1] National Quality Initiative Steering Committee, *National Highway User Survey,* prepared by Coopers & Lybrand and the Opinion Research Corporation, May 1996.

maintenance, patching potholes, and resurfacing contribute significantly to the smoothness of roads.

Many administrators and managers in state DOTs have long believed that the driving public placed safety above smooth pavement in order of importance. An important result of the NQI survey is the revelation that road users' preferences are the reverse: they place more importance on road smoothness than safety. Results such as this have been highly influential to program managers in making resource allocation decisions. During the last several years, a number of states have increased the relative expenditures on actions that would improve pavement smoothness. **Figure 6** presents the NQI survey questions that are the most pertinent to road maintenance**.** **Figures 7a** through **7f** show the results that were obtained from the 1996 survey.

Thinking about the areas we just discussed, how satisfied are you with the following?

A. Traffic Flow

- **a.** Level of congestion
- **b.** Toll booth delays
- **c.** Construction delays
- **d.** Accident clean-up

B. Pavement Conditions

- **e.** Smooth ride
- **f.** Surface appearance
- **g.** Durability

C. Visual Appeal

- **h.** Appearance of sound barriers
- **i.** Landscaping
- **j.** Design of rest areas
- **k.** Compatibility with the natural environment

D. Maintenance Response Time

- **l.** Litter removal
- **m.** Snow removal
- **n.** Pavement repairs
- **o.** Guardrail and barrier repairs
- **p.** Rest area cleaning

E. Travel Amenities

- **q.** Number of rest areas or service plazas
- **r.** Variety of rest areas or plaza services
- **s.** Number of emergency call boxes and radio advisory stations
- **t.** Signs for motorist services and attractions
- **u.** Signs for mileage and destinations

Figure 6. Sample NQI Survey Questions

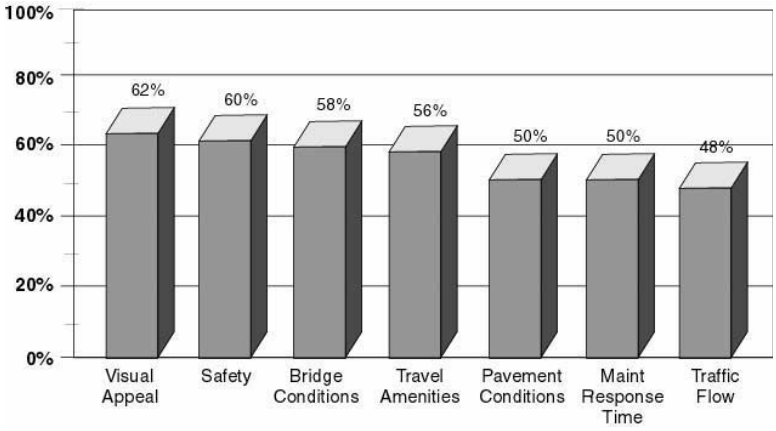


Figure 7a. Satisfaction with Attributes of Highway System

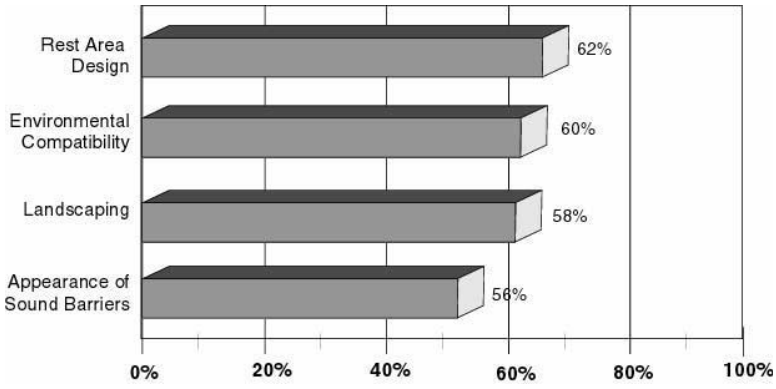


Figure 7b. Satisfaction with Visual Appeal

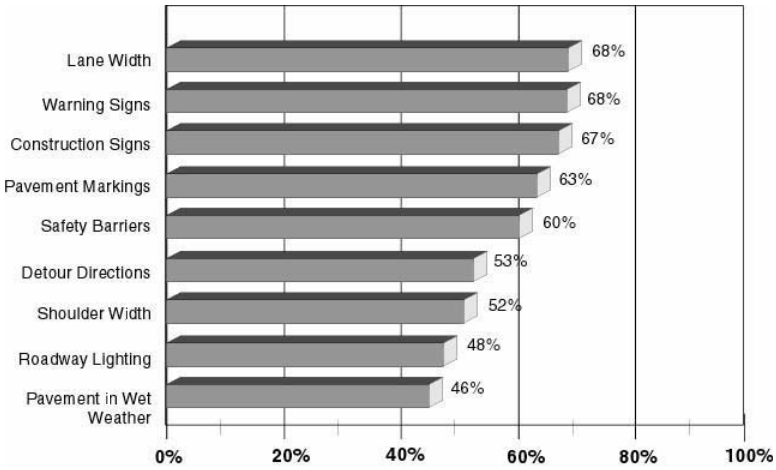


Figure 7c. Satisfaction with Safety Items

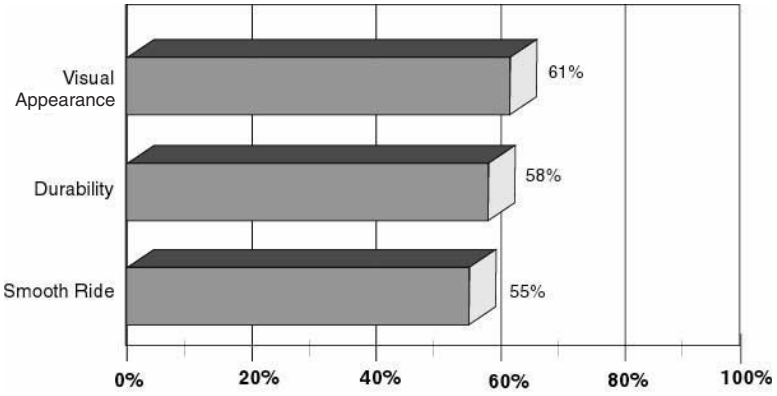


Figure 7d. Satisfaction with Bridge Conditions

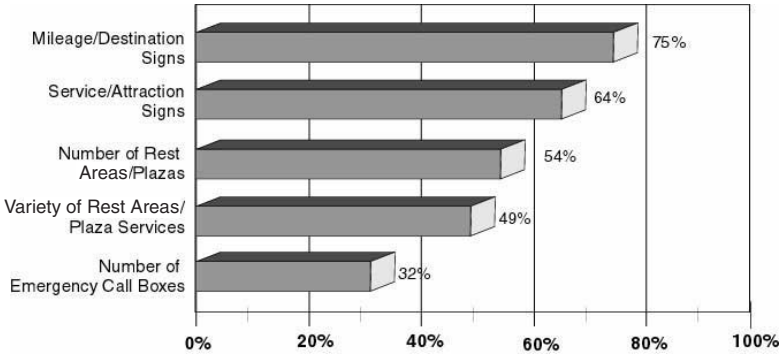


Figure 7e. Satisfaction with Travel Amenities

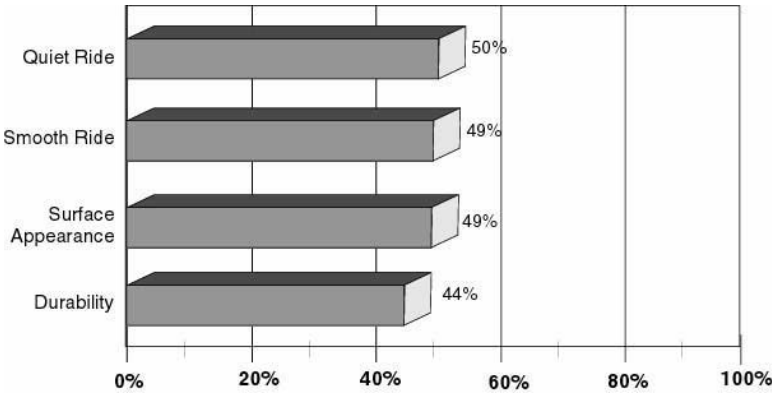


Figure 7f. Satisfaction with Pavement Conditions

Because the NQI survey provides a national baseline of data, many states have incorporated questions from the NQI survey into their own customer satisfaction surveys. This inclusion allows states to compare the results obtained from their own surveys with those obtained nationally. Kentucky, for example, compared the results of customer satisfaction surveys conducted in 1995 and 1996 with the national survey results.[2] Potentially, results could be compared with other states to do a simple form of customer-driven benchmarking.

The significance of the NQI survey is that the maintenance-related questions represent a set of widely or commonly recognized measures of customer satisfaction. Having an agreed-upon set of questions for assessing customer satisfaction makes it easier to do benchmarking.

Note that the NQI survey instrument was revised in 2000 but contains the same maintenance-related questions that were included in the early survey. Survey comparisons between the results of the 1995 and 2000 surveys can be found in "*Moving Ahead, The American Public Speaks on Roadways and Transportation in Communities*."

Agency Surveys

An alternative to using results from the NQI survey or to incorporating NQI survey questions into your own questionnaire is to develop a survey tailored to your own maintenance products and services and to the issues in your own state, city, or county or bridge, tunnel, and turnpike authority.

Many states are seeking more detailed insight about customer preferences and satisfaction than the NQI survey questions can provide, and thus have developed additional or more refined surveys and questions.

In constructing survey questions, you will need to first define products and services and identify their corresponding attributes—steps in the benchmarking process discussed in Part II. Then you will need to develop questions regarding customer preferences and satisfaction corresponding to each attribute. You will have to choose a suitable response scale.

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[2] Kentucky Transportation Cabinet, *The Path, Mid-Year 1999 Report,* p. 35.

Appendix B contains tables showing maintenance attributes and corresponding customer outcome measures found in surveys developed and administered by various states—for example, the State of California has a question to assess customer satisfaction regarding response time to emergency situations. This question pertains to the maintenance product category of "Maintenance Response to National Disasters." Respondents (i.e., customers) rate their satisfaction on scale of 0 to 10, where 10 represents "extremely satisfied" and 0 "extremely dissatisfied." This question is intended to provide the California DOT (Caltrans) with feedback regarding how the state does in responding to maintenance problems associated with mudslides, floods, earthquakes, and so on. Note that a random sample is unlikely to include very many people who have actually been in an emergency situation. The state was probably seeking information regarding public perceptions of the responsiveness of Caltrans to natural disasters, even though the respondent was unlikely to have experienced one directly.

The Caltrans survey also included a series of related questions intended to assess customer preferences regarding response time for time-sensitive maintenance activities such as sign repair, traffic delays due to maintenance, and pothole repairs. Respondents were asked to state whether the preferred response time should be within 15 minutes, 30 minutes, 60 minutes, 1 day, or 1 week.

Survey Design and Administration

If you decide to develop your own survey to be used as a benchmarking measurement tool, you should go through the standard steps for developing sound surveys:

1. Focus groups,
2. Survey design and pretesting,
3. Coding guide and database design,
4. Sample design,
5. Administration, and
6. Summarization and analysis.

Further guidance on developing and administering surveys is found in Appendix C.

Condition of Assets

The second category of outcome measures that are essential for customer-driven benchmarking consists of condition measures. Condition includes the condition of assets and other attributes of roads.

Condition is important to customers from three standpoints. First, the physical attributes of roads directly affect the experience of road users. Examples of these attributes are pavement smoothness and comfort, ruts and shoulder edge drop-offs, the narrowness of bridges, the brightness of signs at night, obstructions in the roadway, and whether ice is on the road.

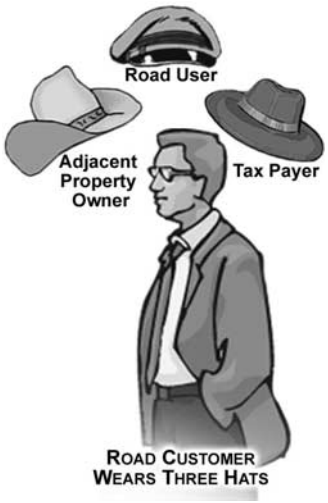
Second, virtually every customer of roads pays for the roads either directly or indirectly. The condition of roads is important to customers of roads, if for no other reason than they do not wish to pay higher gas and property taxes. Responsible stewardship of the roads through proper and timely maintenance preserves the investment in highways and streets and avoids wasting money that could be used for more productive purposes.

Third, not only does condition relate to the physical condition of roads, but also to the condition that results from maintenance services such as mowing; picking up litter; trimming brush and trees; cleaning ditches; removing drainage system blockages; controlling erosion; cleaning rest areas; and landscaping, including planting wildflowers.

Value Received by the Customer

The third category is value received by the customer. It is important to remember that customers of maintenance "wear three hats, "so to speak. One set of customers consists of those who use the roads. This set of customers is primarily concerned with avoiding road user costs such as travel time, vehicle-operating costs, and accident costs.

The second set of customers consists of those who pay for the roads and generally, but not necessarily, consists of those who use the roads. These customers do not like it if the taxes or fees they pay increase in order to pay for extra costs that could have been avoided if the roads were maintained by performing the right treatment at the right time in the right place. In other words, by not deferring needed maintenance one avoids increased maintenance, rehabilitation, and reconstruction costs in the future.



ROAD CUSTOMER WEARS THREE HATS

The third set of customers consists of those impacted by the operation of roads. Prominent among this group are adjacent property owners who can be impacted by what economists call externalities—costs or benefits experienced by others than the producers or consumers of a product. Pollution or changes in property value because of the use and activities occurring on the road or in the right-of-way are examples of externalities. Property owners adjacent to roads and who experience externalities are among those who pay for the roads, particularly in cities and counties where property taxes are a major source of road funding.

Economic value to maintenance customers can be conveniently grouped into the following types:

- Avoided user costs,
- Avoidable life-cycle costs, and
- Avoided external costs.

Customers are willing to pay to avoid user costs, life-cycle costs, and external costs; hence, the willingness to pay is also an important measure of economic value.

Appendix D includes a discussion of how to calculate life-cycle costs, user costs, and willingness to pay.

COMMONLY RECOGNIZED MEASURES

A prerequisite for benchmarking of any type, including customer-driven benchmarking, is that benchmarking participants agree on the measures that will be used. This is true regardless of whether all the benchmarking participants are within your organization or whether you benchmark with other organizations. Therefore, one of the early tasks in benchmarking is to begin to establish a foundation for agreed-upon measures.

There are several ways to tackle this prerequisite. First, if you are planning to do benchmarking only within your organization you can establish your own agreed-upon measures. Second, if you are benchmarking with other organizations, you can begin the process of identifying your partners, establishing what you plan to benchmark, and gaining agreement on the measures you will

use. Third, whether you are doing internal or external benchmarking, you can determine whether there is a pre-existing set of commonly recognized customer-driven measures for benchmarking maintenance activities.

Importance and Adopted Measures

The issue of widely agreed-upon measures for benchmarking and other purposes is of such importance that the AASHTO Subcommittee on Maintenance and FHWA sponsored the National Workshop on Commonly Recognized Measures for Maintenance in June 2000 in Scottsdale, Arizona.

At the workshop, states agreed to an initial set of "commonly recognized measures" that reflect the outcomes and satisfaction that customers experience from the delivery of maintenance products and services.

Table 1 summarizes the measures that were adopted by the states at the workshop. In only a few cases was a recommended measure fully defined. In most instances, the workshop participants adopted a type of measure with the expectation that the definition, units of measure, and other aspects of a measurement protocol would be established in the future. A view was expressed that it is not necessary to be overly specific in the workshop. It was sufficient for workshop participants to identify areas where there is general agreement that commonly recognized measures exist, particularly ones that relate directly or indirectly to the customer.

The adopted commonly recognized measures exist side-by-side with other performance measures that many states have already developed and generally use for maintenance management and asset management. However, over time it is anticipated that an increasing number of states, cities, counties, turnpike authorities, and contractors will apply commonly recognized measures for an increasing number of purposes.

The common measures are useful for customer-driven benchmarking, customer-driven asset management systems, performance-based contracting, and public reporting of maintenance performance. Commonly recognized measures create efficiencies in data collection, measurement systems, and management systems.

Table 1. Commonly Recognized Measures Adopted by Consensus

Maintenance Element	Recommended Commonly Recognized Measure	Adopted by Consensus?	Discussion/Issues
Pavement Surfaces	Roughness: International Roughness Index (IRI)	Roughness	The strongest measure in evaluating pavement conditions as seen by customers. However, because many states use a Ride Quality Index instead of IRI, the group could only agree that "roughness" is a commonly recognized measure. It was suggested that profile might be a more basic measure common to both IRI and a Ride Quality Index. It was also suggested there could be alternative commonly recognized measures for roughness.
	Rutting	Yes	
	Friction	Yes	Recommended as a measure to be applied on a localized basis. There are also issues concerning testing and its relevance to maintenance.
Signs	Retroreflectivity	Yes	Standard measurement procedures.
	Physical appearance Contrast Color fade Legibility Sign post condition	Yes	Attributes and measurement procedures not fully defined.
	Customer satisfaction	Yes	Survey questions need to be identified; possibly NQI survey.
Pavement Markings	Retroreflectivity	Yes	Standard measurement procedures.
	Physical appearance Contrast Presence	Yes	Not fully defined.
	Customer satisfaction	Yes	Survey questions need to be identified; possibly NQI survey
Shoulders and Roadside	Clear zone Horizontal from edge (distance) Vertical clearance (distance)	Yes	Vertical clearance applies to clearance over vehicles using roadway; needs to be defined.
	Obstruction (yes/no)	Yes	Vegetative obstruction of guardrail, signs, etc.
	Vegetation height (e.g., grass) – inches	Yes	
	Noxious weeds (yes/no)	Yes	Presence or absence of noxious weeds.
	Litter count (per segment)	Yes	Method of counting litter needs to be defined.
	Customer satisfaction (appearance/aesthetics) Phone calls Survey results	Yes	Survey questions need to be identified; possibly NQI survey.
	Edge variance Drop-off Build-up	Yes	Method needs to be defined.

(*continued on next page*)

Table 1. (Continued)

Maintenance Element	Recommended Commonly Recognized Measure	Adopted by Consensus?	Discussion/Issues
Safety Features and Appurtenances	Attenuators (functioning as intended)	Yes	Method needs to be defined.
	Guardrails (functioning as intended)	Yes	Method needs to be defined.
	Guardrail end treatment (functioning as intended)	Yes	Method needs to be defined.
Drainage	Culverts, cross drains (percent blocked/damaged)	Yes	
	Open ditches (percent blocked/damaged)	Yes	The total length of the ditch in feet should also be determined.
	Curb, gutters, and barrier wall (percent blocked/damaged)	Yes	The total length of the drainage system in feet should also be determined.
	Catch basins and inlets (percent blocked)	Yes	
	Subsurface drainage (percent blocked)	Yes	
Ice and Snow	Road closures	Yes	Method of measurement needs to be defined; could include duration, traffic volume impacted, and number of closures.
	Bare pavement indicator	Yes	Method of measurement needs to be defined; could be duration of loss of bare pavement; duration of time to recover from end of event.
	Customer satisfaction surveys Focus groups	Yes	Survey questions and interview protocols for focus groups need to be identified; survey questions could come from the NQI survey.
Customer Satisfaction Surveys	Survey questions	Yes	Customer satisfaction should always be included as a measure along with others; however, a problem is how to address some aspects of maintenance that are not visible to the public.

Key Issues in Adopting Agreed-Upon Measures

When adopting benchmarking measures, there are a number of key issues to consider:

- Desirable attributes of the measurement scale;
- Types of measures to avoid;
- Selection of appropriate units;
- Segment length;
- Repeatability, reliability, and accuracy; and
- Protocols.

Type of Measurement Scale

Just as you would select an appropriate tool to pound a nail into wood, it is critical to select measures for benchmarking that have the appropriate attributes**. The measures need to support objective, repeatable measurement—in some cases, with desirable precision and statistical confidence.** To do so, the measures generally need to have a continuous measurement scale, be expressed in units with appropriate resolution, apply to standard lengths or parts of roadway geometry, and be taken under a standard and rigorous protocol. There may also be a need for acceptance testing of data using random sampling.

Continuous Measures

It is strongly recommended that wherever possible you apply measures with a continuous scale. **A continuous scale extends indefinitely from a starting point, and the units of measurement can be divided into equal, arbitrarily small intervals.** Examples of continuous scales are as follows:

- Extent of bridge deck distress measured in terms of percentage of the deck area affected,
- Roughness measured according to the International Roughness Index (IRI),
- Shoulder edge drop-off measured in inches or centimeters and arbitrarily small fractions thereof,
- Retroreflectivity of signs measured as candelas per foot-meter square foot,
- Mean response time to fix a problem, and
- Mean time between failures.

The Virginia DOT contracted for the collection of roadway inventory feature and condition data. The contract specified that the data must be accurate within plus or minus 5 percent, with 95 percent accuracy. The contractor had to agree to acceptance testing to ensure that the data was of the accuracy and statistical confidence specified in the contract.

By using a continuous scale, you remove the subjectivity and difficulty of having to define the meaning of scale intervals other than the units of measurement. The results of a measurement can be of any magnitude from very small to very large. Measurement systems that use continuous, well-established scales are more likely to be repeatable, and there is a basis for establishing the statistical quality of measures to any degree of accuracy and statistical confidence.

Discrete or Continuous Interval Scale

If you cannot select a continuous scale, **the next best type of scale is a discrete scale with constant intervals between steps, otherwise known as a continuous interval scale.** Examples of such an interval scale are

- 1, 2, 3, 4, 5 and
- 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

A discrete interval scale has most of the desirable attributes of a continuous scale. However, one must define what each step in the scale means, and this can be fraught with subjectivity and technical challenges. The following customer rating scale attempts to maintain equal distances between each step of the scale:

- 1 = Very dissatisfied;
- 2 = Somewhat dissatisfied;
- 3 = Satisfied;
- 4 = Somewhat more than satisfied; and
- 5 = Very satisfied.

A similar type of scale might also be a letter grade—for example, "A, B, C, D, and E." This type of scale has the same strengths and weaknesses of the continuous interval scale if it is equivalent to "1, 2, 3, 4, 5" or some other similar equally spaced discrete scale. Occasionally, a letter scale has a leap in it—for example, A, B, C, D, and F. Usually this type of scale implies that measurement will occur in constant steps up to a point, and thereafter the only measurement of concern is failure.

You are likely to encounter a measurement system that involves probabilistic condition states. The measurement scale is likely to be a discrete scale such as 1, 2, 3, 4, and 5**. Probabilistic condition states are used to identify the probability that a maintainable element, such as bridge deck or pavement surface, will deteriorate from one condition state to another.** The distances between steps on the scale are not necessarily even, but are defined by alternative actions that may be considered for maintaining a maintenance element in a particular condition state.

Binary Measures

Binary measures take on just two values such as "0 or 1" or "yes or no." The project team recommends avoiding binary scales because they have much less resolution than do a continuous or continuous interval scale. Establishing the definition of each value is likely to be much more subjective.

In some cases, using a binary scale is the only logical choice. Examples are whether a traffic signal is working, a sign is up or knocked down, or a drainage structure is blocked.

Types of Measures to Avoid

Do not choose targets, objectives, or goals for benchmarking measures. Frequently people confuse these points on the measurement scale with the measurement scale itself. A target, goal, or objective may have such importance (for example, a performance target agreed upon by a Chief Administrative Officer and the legislature) that managers may think of little else besides whether the target or goal is being met.

The measurement process of benchmarking is not about targets, objectives, or goals; it is about measuring performance along some scale to discern best performers so that benchmarking partners can explore what work methods and business processes lie behind best performances and can adopt or improve upon best practices.

You should also avoid choosing measures that represent thresholds for actions, such as minimum tolerable conditions (e.g., a warrant to replace a traffic signal). An important exception is a probabilistic condition state that has alternative actions associated with it.

Selection of Appropriate Units

Not only can a measurement scale be too coarse to differentiate performance, but choosing inappropriate units can have the same effect. You may decide to measure litter count per unit of elapsed distance along the roadside. If you select as your measure litter count per mile, you will get one result; if you select litter count per tenth of mile, you will get another; and if you select litter count per foot or inch, the quantity of litter you

observe may always be close to zero, which is not very useful for benchmarking. **This example reveals how important it is to select units that will provide enough resolution to measure the performances of different organization units.**

Agreement on Road Segment Length and Geometric Measurements

In reaching an agreement with your benchmarking partners regarding what measures to use, you may find it necessary to define an agreed-upon segment length or other standard measurement procedures pertaining to roadway geometrics so that everyone takes the same measurement in the same manner.

Suppose you are measuring guardrail condition. Do you measure the percent of total guardrail damaged over a 1-mile distance, over a tenth of a mile, or over a kilometer? Suppose you are measuring the presence of a type of noxious weed. How will you define the area over which you will take measurements?

Perhaps you might agree with your partners that a measure of roadside vegetation management will be sight distance at intersections. How will you define the procedure for measuring sight distance? Do you determine, for example, how many feet from the corner along one side of the intersection you can see a car at an equal distance along the other side of the intersection?

In general, you will need to reach prior agreement on how to define segment length, area, and other geometric procedures for different types of measurements.

Repeatability, Reliability, and Accuracy of Measurement

Any measure selected for customer-driven benchmarking needs to be repeatable and reliable. Repeatable means that different people who apply the measure and take a measurement under the same circumstances obtain the same or nearly the same result. To obtain repeatability usually requires training. Each person who takes a measure requires instruction on how to do it. If equipment is involved such as a profilometer or a friction meter, it will need to be calibrated and recalibrated from time to time to ensure repeatability.

The measure needs to be reliable. The equipment used to take the measure should not break down easily. Excessive measurement deviations should not occur due to normal changes in weather, normal wear and tear, or a switch in the personnel who are taking the measurement.

The measure needs to be accurate, and it is desirable to specify its accuracy. In other words, if you or others take repeated measurements, you should get the same result within some range. This range is often referred to as the "accuracy" or "precision" of the measure and is expressed as "plus or minus" some percentage deviation from the mean score (e.g., plus or minus 5 percent). The accuracy or precision is a random variable; the measurements will occur within the accuracy with some statistical confidence level—for example, 95 percent of the time. Indeed you should specify what accuracy and statistical confidence you expect of your measurements.

Measurement Protocols

In general, it is a good idea to develop formal protocols for measurement. Protocols exist for taking many different kinds of measurement—for example, the IRI and rutting.

A good protocol should set the purpose, scope, measurement, data recording procedure, and quality assurance and should document references. An outline of a protocol for edge drop-off (taken from the proceedings of the National Workshop on Commonly Recognized Measures) might consist of the following:

1. **Purpose.** The edge drop-off protocol defines a standard method for estimating and summarizing edge drop-off. The purpose is to produce consistent estimates of edge drop-off.

2. **Scope.** Applies to estimating edge drop-off on any pavement surface, but does not provide specifications for equipment. Any equipment capable of taking the measurement is acceptable for the protocol. Safety issues in applying the protocol are the responsibility of the organization taking the measurement.

3. **Measurement.** Each agency should designate the lane(s), shoulders, and direction(s) of travel to be surveyed based on sound engineering principles and management needs. Edge drop-off is an elevation difference between the

paved travel lane and shoulder, between a paved shoulder and an unpaved shoulder, or both. Measurements are made longitudinally at maximum intervals of 15 meters (50 feet).

4. **Data Recording.** Data collection sections should be of a constant length within some prescribed range as determined by the agency. Sample intervals within each data collection section should be of uniform length. Minimum sample section lengths are 30 meters (100 feet). There are five edge drop-off condition levels defined as a function of the length of the edge drop-off and the elevation difference (for example, the edge drop-off condition levels used by the Texas DOT). The minimum data recorded should consist of section identification, the length of the data collection section, the date of collection, and the rating for the section.
5. **Quality Assurance.** Each agency should develop a quality assurance plan that addresses personnel certification training, accuracy of equipment (including calibration), daily quality control procedures, and periodic and ongoing quality control.
6. **Reference Documents.** A list should be provided of references associated with the measurement protocol.[3]

Data Availability, Quality, and Costs

Some types of measures depend on making a calculation—for example, a measure of response to customer demand for control of ice and snow is the ratio of the time it takes to restore pavement to bare condition from the onset of a snowstorm relative to the duration of the snowstorm. To calculate this ratio, you need to track how long it takes from the start of each storm to the point in time when snow removal crews have removed all the snow from the roadway. You also need to calculate how long the snowstorm is. Neither of these numbers is trivial to determine. You have to define when a storm starts. Does this mean the storm begins when precipitation starts, or when snow starts to stick to the roads? Do you measure where snow sticks to the road in one standard place or along every section of road and then take an average of the time the snow starts to stick? Similar

[3] *Proceedings, National Workshop on Commonly Recognized Measures.*

difficulty exists in trying to define when a storm ends and when pavement has been restored to a bare condition.

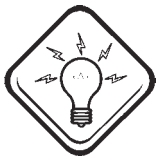
Once you settle on the definition of the measure, you need to compile or collect data to calculate it. If the data is unreliable or inaccurate and without an appropriate degree of statistical confidence, then the measure will be also unreliable or not accurate enough.

Before you finalize the measures you will be using for benchmarking, you need to do a careful assessment of data availability, reliability, and accuracy.

In addition, you need to estimate the costs of data collection. If the costs are excessive, you may have to choose another measure or accept a lower level of accuracy and confidence.

You may think that there is too much emphasis on data and measurement quality. Many important decisions will eventually depend on the accuracy of the measures you collect and the underlying data; however, **overemphasizing accuracy has its costs, too. Do not go overboard in trying to be too accurate. The right thing to do may be to start benchmarking and measuring as soon as possible and to gradually improve the quality of your measurements.**

A CATALOG OF MEASURES



Appendix B provides a catalog of measures you may want to use for benchmarking. Many of the measures presented are widely used, and include those identified as "commonly recognized measures" at the national workshop on the topic. Some types of measures discussed are not yet widely used but are important from the standpoint of their relationship to the customer.

As you get started with benchmarking, you will want to select among these and other possible measures. The catalog offers some guidance regarding the pertinence of each measure to the customer and its reliability, accuracy, and ease and cost of application.

Performance measures are presented for the following areas:

- Pavements;
- Shoulders;
- Bridges;
- Signs, striping, and markings;
- Safety features;
- Ice and snow control;
- Roadside vegetation;
- Drainage;
- Litter removal;
- Rest areas;
- Signals; and
- Other electronic devices.

As an example of the material in Appendix B; Table 2 (which is identical to Table B1) shows measures for pavements. Pavements experience different types of deterioration that affect their appearance, riding experience, and structural soundness. **Table 2** presents the following information:

- **Attributes important to the customer** that the measure addresses;
- **The name of the measure** (e.g., IRI);
- **Units of measurement** (e.g., inches per mile);
- **Commonly recognized** at the National Workshop on Commonly Recognized Measures for Maintenance;
- **Repeatable, reliable, and accurate—**in other words, an assessment of whether the measure has these attributes; and
- **Cost of using the measure** or other important issues.

Table 2. Condition Measures for Pavements

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, and Accurate?	Cost and Other Issues
Pavement Smoothness (roughness)	IRI	Inches/mile or m/km	Yes	Well-established procedures and equipment that result in repeatable, reliable, and reasonably accurate results	Low incremental cost for agencies already collecting IRI; moderate to high cost of new data collection effort
Pavement Smoothness (customer satisfaction)	NQI or other survey question asking customer satisfaction regarding pavement smoothness	1–5 response scale	Survey question on pavement smoothness	Standard NQI survey question; not accurate for jurisdictions lower than state, unless separate survey administered	Low cost to use NQI survey results; moderate to high cost to develop and administer your own survey that includes question on pavement smoothness
Pavement Smoothness (potholes)	Number of potholes of specified size per unit distance	Number per unit distance		Potholes are easily observed, but the number per unit distance can be difficult to count. The number of potholes can change rapidly as new ones appear and existing ones are repaired.	High cost to develop a comprehensive, accurate pothole count.
Pavement Smoothness, Accessibility (blowups)	Number of blowups per unit distance	Number per unit distance		Blowups are easily observed and easy to count. Blowups occur during the freeze-thaw transition, so new ones can suddenly emerge and affect the reliability of the count.	Seasonal problem that requires moderate measurement cost; motorist call-ins could reduce data collection costs.
Safety (danger of hydroplaning)	Rutting	Inches	Yes	Well-established, reliable, repeatable, and reasonably accurate measurements using a ruler	Low cost to do for sample sections or if data already exists; high cost to obtain comprehensive coverage if data doesn't exist

(*continued on next page*)

Table 2. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, and Accurate?	Cost and Other Issues
Safety (skid resistance)	Friction		Yes	Well established equipment and procedures for reliable, repeatable, and reasonably accurate measures	Low incremental cost if agency already routinely measures; high cost for new measurement program
Preservation Characteristic (protection against water damage to structure due to faults)	Faulting	Inches		Repeatable, reliable, and reasonably accurate measures obtained using ruler	Low cost to do for sample sections or if data already exists; high cost to obtain comprehensive coverage if data doesn't exist
Preservation Characteristic (appearance of deterioration, raveling, water infiltration)	Extent and severity of different types of cracking: –alligator –longitudinal –transverse	Percent of area covered or length of cracks and rating of severity on a scale		Challenge in maintaining consistency among raters; automated distress identification technology not highly accurate	Much lower cost to do for sample sections in comparison to comprehensive network coverage
Overall Pavement Condition	Health Index	Some type of index, e.g., from 0–100		Requires construction of index reflecting key pavement attributes; each characteristic can be measured with varying degrees of reliability	Low to high cost to develop and apply index, depending upon the availability of data to calculate index components
Overall Level of Service	Visual Level of Service Condition Rating	Rating scale of A, B, C, D, or E		Often visual rating scales combine more than one characteristic, and so it is difficult to portray and isolate condition of different attributes	Mainly useful for communicating to policy makers and general public

RESOURCE MEASURES

The next broad class of measures needed for benchmarking is resources composed of labor, equipment, and material, as well as financial costs.

Labor

Labor is an important input to the production of maintenance products and services. In benchmarking, you need an overall measure of the quantity of labor that is used to produce a maintenance product or service or undertake an activity. **The quantity of labor is measured in terms of person-hours of labor.** Person-hours equal regular hours plus overtime hours. Try to separate travel hours (i.e., time to go from the garage to and from the worksite). Some agencies require workers to report travel hours in addition to regular and overtime hours.

Eventually, as you become more deeply involved in benchmarking and desire to understand your practices in detail, you will want to distinguish between labor hours of different quality. Measures of quality pertain to training, education, and experience. The productivity of different people is not a measure of quality; productivity is the output of labor that is achieved as a result of labor hours expended and the quality of the labor.

As you assemble labor data to support initial benchmarking and for subsequent comparison of your own and "best" practices, you should break down your labor hours by categories that distinguish the levels of training, education, and experience of different personnel. You can do this by categorizing labor hours expended into one or more of the following:

- Wage class or other class of personnel (e.g., equipment operator or not);
- Number of years of experience; or
- Documented training or certification to perform certain types of activities or to use certain types of equipment (e.g., herbicide application).

Key sources of labor data are the agency's maintenance management system and the payroll system. Some agencies might also have a database containing information on the training of each employee.

Equipment

As with labor, you will need an overall measure of the equipment used. **Equipment quantity consists of the number of hours each type of equipment is used or some metered measurement of usage—for example, a truck odometer reading.**

Equipment quality is determined by the type of equipment, its condition; frequency of breakdown; and operator requirements, which relate to the ease of operation and number of operators required**. In preparation for analysis of best practices and comparison to your own, try to categorize your equipment along these different dimensions of quality and to measure equipment usage of each in hours, by odometers, or both.**

Information on equipment type and utilization usually can be obtained in a maintenance management system, an equipment management system, a financial management system, or in all three.

Material

You will also need a measure of material usage**. Material usage can be measured by the physical quantity of each type of material used to deliver a specific maintenance service or product or to undertake a specific activity.** Examples of material use are the number of signs and posts, linear feet of guardrail, tons of pothole material, and gallons of crack sealant.

Selection of the proper units to measure material usage requires some care. For example, it might be better to measure signs replaced not by the number of signs replaced, but by the area of the sign facing, which reflects the magnitude and difficulty of putting up or replacing a sign. Alternatively, one could count both the number of signs replaced and the number of signposts. The number of signposts required might be an indicator of the difficulty in replacing certain types of signs.

Various information on materials used can be found in the maintenance management system, material management system, financial management system, or in all three.

Costs

Another measure of resource utilization is the total dollar costs of using the labor, equipment, and material involved in delivering a maintenance product or service. Sometimes, however, it is better to employ measures of the raw labor, equipment, and material inputs instead because there can be local and regional differences in the unit cost of labor, equipment, and materials. If you use total resource costs or even costs of each input to maintenance production, you will not easily be able to distinguish to what degree the physical inputs or variation in price of inputs are contributing to the outcomes.

If physical measures of labor, equipment, and material resources are not available and only cost data is available, then cost data can be used as a measure of resource utilization. Indeed, one can argue that expressing all resources in financial terms results in convenience of analysis and, in some cases, in a better measure of resource utilization than does separate usage rates for labor, equipment, and materials.

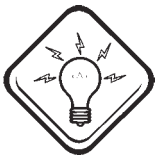
Note that if a maintenance cost index that varies by year and part of the country is available, you can use dollars as a measure of resource costs and can normalize the costs by geographical area for any past year covered by the index.

It is important to understand that even if you do not use resource costs when you measure performance, once you have identified best performers and improvement opportunities and begin to analyze the effect of adopting best practices, you will need cost information in order to estimate potential cost savings or the costs of improving certain outcomes.

Variable Costs

Wherever possible, you should distinguish between variable and fixed costs. **Variable costs vary with output and include labor, selected equipment costs such as fuel, and material costs.** Variable costs do not include overhead and other fixed costs. Therefore, fixed costs should be excluded from your measures of labor, equipment, and material input.

Fixed Costs and Activity-Based Costing



Fixed costs are those costs that do not vary with output, such as costs of administration and buildings. Ideally, your agency should have an accounting system that determines fixed and variable costs by maintenance activity and by product and service category. This is known as "activity-based costing." **If your agency does not have such an accounting system, eventually you may want to implement activity-based costing to identify your fixed and variable costs by activity, product, and service.**

HARDSHIP FACTORS

In addition to outcomes and resources**, the third major group of measures needed for customer-driven benchmarking is hardship factors. These are factors outside the influence of maintenance crews.** Examples of hardship factors are the following:

- Weather,
- Terrain,
- Traffic,
- Absence of shoulders along roads where work is performed,
- Average travel distance to work sites, and
- On-street parking.

You need to prepare to collect data on these kinds of hardship factors because these will be assessed alongside outcomes and resources used.

Weather

In most states, weather varies considerably from one part of the state to another. Some states have wide extremes in weather that are partly a function of geography. Mountains, plains, deserts, heat island effects of urban areas, and proximity to oceans and large lakes are just a few factors that influence weather. It is desirable to adjust outcomes based on differences in weather from one location to another. Ideally, one should store data on

weather conditions present at the time maintenance work is performed. To be more specific, standard daily work reporting should be augmented with weather data—at a minimum, the type and quantity of precipitation that occurred during the day and the high, low, and mean temperature.

The drawback to further data collection is that it requires additional effort on the part of crew leaders to record this information, which detracts from getting their jobs done.

An alternative approach to crew leaders recording weather data is to gather data from other sources and to combine it in a database with accomplishment and resource utilization information reported in daily work reports.

There is extensive weather-related information available from the National Weather Service and state meteorological agencies. Weather data includes temperature; precipitation (rain and snow); wind direction; wind speed; humidity; and other information. Weather information is collected at selected sites throughout a state, but not necessarily in every county. Therefore, if you want to benchmark at the county level or a at lower organizational level, you will probably have to interpolate weather data from information collected at existing weather stations, unless maintenance personnel record weather conditions at the time they work.

Another potential source of weather information is the Roadway Weather Information System (RWIS). Most states that experience snow and ice conditions have a RWIS. These systems consist of a set of pavement surface temperature sensors; subsurface sensors; and regular weather sensors (air temperature, wind direction, wind speed, humidity) at various locations along the roadway network. RWIS roadside units continually monitor weather-related pavement conditions and weather conditions. The data is collected and transmitted to a service bureau or to the transportation department that has responsibility for the roads. RWIS data can also be analyzed and extrapolated to counties, areas, and garages throughout a state.

Geographic Information

Another hardship factor that affects maintenance productivity and outcomes is terrain. Mountainous and hilly areas are likely to affect maintenance outputs and outcomes differently than will flat areas. Information on terrain is readily available from both government and private-sector data sets. Most state DOTs have access to a geographic information system (GIS) that has information on terrain.

However, information in a digital map often is not adequate for recording the type of terrain or other geographic information that affects maintenance outcomes in different locations. The reason is that a digital map is often a bit map, which is not in a form that allows manipulation of data concerning attributes of the roadway. **More useful is roadway attribute data, which describes the type of terrain and other geographic features present where a section of road is located.**

Most if not all state agencies have a highway database containing this information. Ideally, terrain data will be included in the attribute database of the GIS and linked to a roadway centerline. It should be possible to transfer terrain data to the database in which you will be keeping information for benchmarking. Then, when work is performed, you can associate terrain and other geographic data with the data used to measure outcomes and resource usage.

Roadway Attributes

Certain roadway attributes affect the productivity and outcomes of maintenance work—for example, the presence of shoulders makes it easier for crews to park their vehicles and work on roadside safety features such as guardrails and signs. In the absence of shoulders, work zones will probably need to be established, which requires blocking off a lane of traffic and takes time that could otherwise be spent performing maintenance work.

Data concerning roadway attributes such as shoulders will be found in the agency's roadway feature inventory database. Every state and most cities and counties will have data on the presence or absence of shoulders along various sections of road.

Frequently, this information will also be available within the agency's GIS. Like terrain data, roadway attribute data will need to be combined with information regarding outcomes and resource usage in order to support benchmarking.

OUTPUT MEASURES

The discussion so far has ignored output measures because they are not focused on what the customer gains from road maintenance. **Output measures, as stated above, are used to record maintenance production—for example, the miles of pavement resurfaced per day or the number of feet of guardrail repaired.** Even though output measures are not focused on the customer, you will want to add output measures to your set of outcome, resource usage, and hardship measures. There are a number of reasons to do so:

- **A way to establish comparability.** Output measures provide a means to access the scale of activity of a benchmarking unit and therefore provide a more informed basis for comparing performance. For example, one benchmarking unit may resurface only 10 miles of pavement per year, whereas another may resurface 100 miles. These benchmarking units are not really comparable.
- **Surrogates for outcome measures.** Reliable, repeatable, accurate, and reasonable-cost outcome measures may not be available in some instances. You may want to use an output variable as a proxy for an outcome variable. For example, you may not be able to estimate the degree to which damaged guardrail replacement along a stretch of highway saves lives. Instead, you may simply use the linear feet of damaged guardrail replaced as a proxy for fatalities avoided, in the rare event that a vehicle crashes into a previously damaged guardrail.
- **Utility for productivity measurement.** Even though you should remain focused on the customer, it will be important to analyze the productivity of crews and other work units. Output information is essential for analyzing productivity. You may also want to estimate production functions that predict output as a function of labor, equipment, material, and environmental factors.

- **Linkage to outcomes.** Some analysts find that the most logical way to establish a measure of certain types of outcomes is to establish a functional relationship between outputs and various types of outcomes. Under this approach, output data is essential to establishing outcomes.

In preparing to benchmark, you will need to assess the role that output information will play in customer-driven benchmarking and related analysis. You will need output data and measures—even if you are focused on outcomes.

CHAPTER 4: STEPS OF CUSTOMER-DRIVEN BENCHMARKING

AN OVERVIEW OF THE STEPS

Chapter 4 sets out a five-step process for customer-driven benchmarking for road maintenance. It provides a detailed description of each step and includes worksheets to help you develop measures, organize your measurement activities, record the results, analyze improvement opportunities and best practices, and implement improvements. The main steps are illustrated in **Figure 8**.

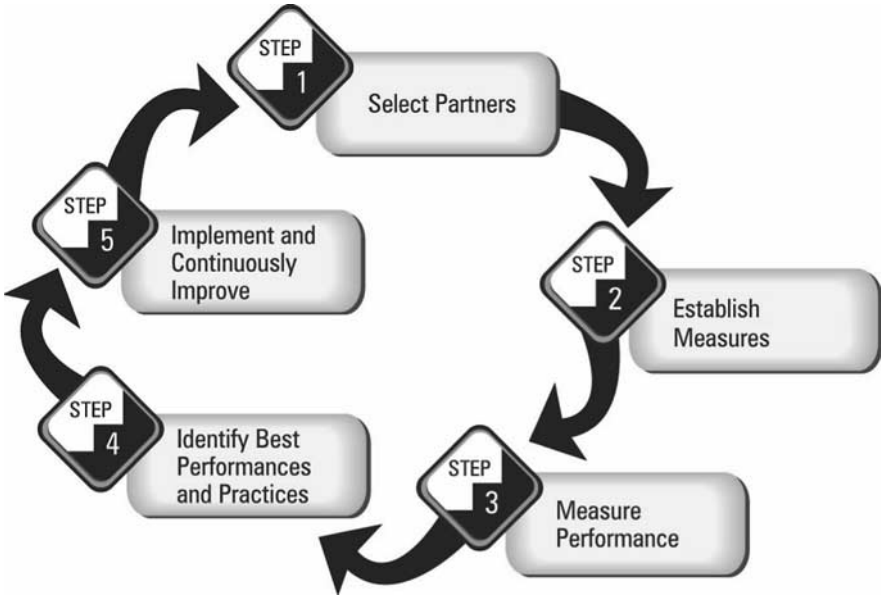


Figure 8. Steps in the Benchmarking Process

The five main steps are as follows.

1. **Select Partners.** The first step involves assembling a benchmarking partnership. Partners are agencies that also desire to improve performance through sharing information. They have the authority to allocate internal resources and make commitments to change internal practices to conform to decisions that are made by

partners and governed by a partnership agreement. The process of selecting partners consists of the following:

- Determine the partners you will commit to work with for at least 2 years,
- Determine the organizational level at which you will benchmark,
- Determine the number of benchmarking units you want, and
- Develop a benchmarking partnership agreement.

2. **Establish Measures.** The second involves identifying measures to use for benchmarking that directly relate to the attributes of the products and services that a maintenance organization provides its customers. Instead of thinking about maintenance activities, you will have to reorient your thinking to what the customer is "buying." This second step is composed of the following smaller steps:
   - Identify the role of the customer in the vision and the mission of the maintenance organization,
   - Identify products and services that the customer is buying and the corresponding attributes and maintenance activities,
   - Identify candidate customer-oriented outcome measures that correspond to each attribute,
   - Identify measures for resource usage,
   - Identify measures pertaining to hardship factors,
   - Identify output measures, and
   - Assess the value of using various customer-oriented measures and select the ones you will use.

3. **Measure Performance.** The third step involves measuring performance and reducing the measurements into summary results that will be used to assess best

performances. This third step is composed of these smaller steps:

- Plan and schedule measurement activities,
- Develop a database,
- Take measurements and record the results, and
- Share results.

4. **Identify Best Performances and Practices.** The fourth step involves analyzing best performers to unearth best practices and improvement opportunities. This step is composed of the following activities:
   - Determine best performers,
   - Identify improvement opportunities,
   - Identify best practices of best performers,
   - Document your own practices and best practices, and
   - Determine the value of adopting best practices.

5. **Implement and Continuously Improve.** The fifth step involves implementing best practices or making other improvements that exceed best practices and then continuing to improve by repeating the benchmarking cycle. This step consists of the following:
   - Identify improvement options,
   - Prepare the organization for improvements, and
   - Implement improvements.

Then start the benchmarking cycle again.

The remainder of this chapter takes you through each of these steps in detail.

STEP 1. SELECT PARTNERS

The first step of the benchmarking program is to select the group of benchmarking partners you will be working with. There are some preliminary activities you will have to go through to become internally organized. Indeed, one of your options is to perform customer-driven benchmarking on internal units. However, in this guide, benchmarking partners means external organizations.

You must **first assemble a team** that will guide the internal organization and coordinate with the benchmarking partners that you select. Review the material on selecting a team in Chapter 2, and establish your team.

Once assembled, your team should review the Primer document (included with this guide) and discuss what your organization hopes to gain from customer-driven benchmarking. Make the first assignment, which is to have each team member thoroughly study Chapters 1 through 3 of this guide and review Steps 1 and 2 of Chapter 4 before a second meeting.

At the second meeting, you will want to ensure that each team member is clear about what your agency needs to do to effectively lead or participate with other partners. All questions of team members need to be answered before continuing.

At this meeting, you should also establish the preliminary goals for customer-driven benchmarking in your agency. **You should discuss potential partners and, after reading about selecting partners, make assignments to contact targeted agencies as potential partners.**

At this point in time, your agency may not have previously defined maintenance work in terms of customer products or services and you may not be certain as to what organizational level you will want to benchmark. However, you should have a general idea of the primary maintenance elements or assets that you are interested in improving. The same will be true for agencies that you contact regarding forming a partnership.

Each agency will not necessarily know, at this time, at what organizational level they desire to or can benchmark; however, they should have a preliminary idea of the level and the number

of benchmarking units that they can offer for benchmarking to the partnership (see Worksheet 1).

Once you have established a group of potential partners and a prospective lead partner among the group, you should create a more formal agreement before proceeding. Review Appendix A and the content for a partnership agreement in Chapter 2 and then establish an agreement with the partners.

Each partner will need to complete Worksheet 1 and circulate it to the lead agency, which will share it with each of the partners. This worksheet is to identify the potential benchmarking units for each partner. This list may be altered later after the partners have determined what measures to use and what product or services they wish to benchmark first.

Each potential benchmarking partner should use **Worksheet 1** to identify its potential benchmarking units and their characteristics.

- At the top of the page enter the following:
  - The name of the organization that is a benchmarking partner,
  - An identification code for the benchmarking partner,
  - The number of benchmarking subunits,
  - The organizational level of the subunits that will be participating in the benchmarking activity,
  - Whether this partner has entered into an oral or written benchmarking agreement, and
  - The benchmarking agreement number.
- In the left two columns enter the number and the name of each subunit.
- In the remaining columns to the right, for each subunit provide the following information:
  - Lane miles;
  - Number of employees;
  - Budget (maintenance) in thousands of dollars;
  - Terrain (F = flat, H = hilly, M = mountainous); and
  - Weather/environmental region.

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 1.
BENCHMARKING UNITS OF EACH PARTNER

Name of Benchmarking Partner: Department of Transportation
Identifica tion Code: 00031
Number of Benchmarking Units: 13
Organizational Level of Benchmarking Units: County
Benchmarking Agreement #: B1234567

No.	Name of Benchmarking Unit	Lane Miles	No. of Employees	Budget ($000s)	Terrain (F,H,M)	Weather / Env. Region
1.	Jefferson	325	40	900	F	Wet
2.	Polk	567	62	1500	F	Wet
3.	Washington	1789	167	4500	F	Wet
4.	Hamilton	456	50	1200	F	Wet
5.	Adams	234	30	600	H	Snow
6.	Roosevelt	748	80	2100	F	Wet
7.	Truman	2788	201	6200	F	Wet
8.	Clinton	980	89	3100	H	Wet
9.	Jackson	654	56	1800	F	Wet
10.	Eisenhower	401	44	1200	F	Wet
11.	Lincoln	777	68	2100	M	Snow
12.	Nixon	903	88	2600	H	Wet
13.	Buchanan	1123	103	3300	F	Wet

STEP 2. ESTABLISH MEASURES

Once the benchmarking agreement is completed, you need to return to initial internal activities for customer-driven benchmarking. The next step is to be sure that your maintenance organization is focusing on providing customer-oriented products and services. A place to start is with the maintenance organization's or agency's vision and mission statements.

A vision statement describes what the agency wants to become in the future. The vision statement usually attempts to depict a desirable future end-state for the agency and therefore provides direction for the agency. The vision statement is also likely to address customers, attributes of key products and services, and quality.

Sometimes the vision statement addresses both external and internal customers. You should carefully distinguish between the two because the focus of customer-driven benchmarking is on external customers. The vision statement may also stress a commitment to quality, continuous improvement, or both.

Examining the vision statement of your maintenance organization and of the overall agency will help provide direction for benchmarking. Below is the vision statement for Caltrans.

> *California will have the safest, best-managed seamless transportation system in the world.*
>
> - *Every Caltrans employee contributes to improving mobility.*
> - *Our workforce will be a diverse, professional, and effective team whose members value each other's contributions.*
> - *We will be responsive and accountable.*
> - *We will be well managed and serve as a model for others.*
> - *We will work in partnership with other agencies and the public to ensure that our work is done in a way that is sensitive to the needs of the environment and communities.*
> - *We will use the latest research and technology to improve mobility for people, goods, and information.*
> - *We anticipate and plan for changes.*
> - *The public will appreciate the quality of our products and services and the participation that it has had in our decisionmaking.*

Use **Worksheet 2** to analyze the role of the customer in the vision of your agency:

- Write out your current vision statement,
- Identify key phrases in your vision statement,
- Identify how each phrase relates to the customer,
- Assess the degree to which your vision statement relates to the customer by checking off the appropriate answer to each question,
- Write a revised vision statement if you feel it will benefit your benchmarking activities, and
- Verify that key phrases of your revised vision statement have a relationship to the customer by completing the last part of the worksheet.

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 2.
ROLE OF CUSTOMER IN VISION

YOUR VISION STATEMENT

The department will meet the needs of its citizens, visitors, and commerce for mobility and accessibility in a manner that enables the people to prosper in a rapidly changing global economy and to enjoy a high quality of life in an environmentally sustainable manner.

KEY PHRASES	RELATIONSHIP TO CUSTOMER
1. Will meet needs of citizens, visitors, and commerce	1. Identifies three customer segments
2. For mobility and accessibility	2. Key transportation attributes important to customers
3. That enables the state to prosper in a rapidly changing global economy	3. Addresses economic prosperity of customers and need for continuous change
4. To enjoy high quality of life in an environmentally sustainable manner	4. Addresses environmentally sustainable quality of life of customers

ASSESSMENT OF VISION STATEMENT

- Customer(s) directly addressed? ☑ Yes ☐ No
- Key transportation attributes explicitly addressed? ☑ Yes ☐ No
- Addresses quality/continuous improvement? ☑ Yes ☐ No
- Others: _____

REVISED VISION STATEMENT (for Agency or Road Maintenance)

Vision statement is OK

1.	1.
2.	2.
3.	3.
4.	4.

Mission

While the vision statement of an organization describes what the agency wants to become in the future, its mission statement describes what the agency is supposed to do that justifies its existence.

In most cases, the customer is prominent in the mission of the overall agency and in the mission of the maintenance organization. A common mission statement says the agency is responsible for providing safe, efficient, aesthetically pleasing transport of people and goods in a manner that is sensitive to the environment.

Below is the mission statement of the Maryland State Highway Administration.

> *"To provide mobility for our customers on a safe, well-maintained and attractive highway system that supports Maryland's economy in an environmentally responsible manner"*

Note the following characteristics of this mission statement:

1. It addresses external customers, the people who use the highway system.
2. The mission identifies in broad terms the main product or service the agency provides, namely mobility.
3. The mission stresses the importance of certain attributes of the products and services and lists them in an order that may reflect the agency's priorities: safe, well maintained, attractive, supportive of Maryland's economy, and environmentally responsible.

This mission statement, like many others, provides strong clues regarding how to begin thinking about a benchmarking program from the standpoint of the customer.

Use **Worksheet 3** to analyze the role of the customer in the mission:

- Write out the current mission statement,
- Identify key phrases in your mission statement,
- Identify how each phrase relates to the customer,
- Assess the degree that your mission statement relates to the customer by checking off the appropriate answer to each question,
- Write a revised mission statement if you feel it will benefit your benchmarking activities, and
- Verify that each key phrase of your revised mission statement has a relationship to the customer by completing the last part of the worksheet.

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 3.
ROLE OF CUSTOMER IN MISSION

YOUR MISSION STATEMENT

The mission of the department is to provide safe, efficient, pleasing transportation that protects or enhances the environment.

KEY PHRASES	RELATIONSHIP TO CUSTOMER
1. Provide safe, efficient, pleasing transportation	1. These are three attributes important to the road user
2. That protects or enhances the environment	2. This is an attribute important to road users, general public, and adjacent property owners
3.	3.
4.	4.

ASSESSMENT OF MISSION STATEMENT

- Customer(s) directly addressed? ☐ Yes ☑ No
- Key transportation attributes explicitly addressed? ☑ Yes ☐ No
- Addresses quality / continuous improvement? ☐ Yes ☑ No
- Others: _____

REVISED MISSION STATEMENT (for Agency or Road Maintenance)

Our mission is to continually improve and exceed the customer's expectations by delivering safe, efficient, pleasing road transport in a manner that promotes economic growth and protects and enhances the environment.

KEY PHRASES	RELATIONSHIP TO CUSTOMER
1. Continually improve and exceed customer expectations	1. Customer can expect continuous quality improvement and expectations to be exceeded
2. In delivering safe, efficient, pleasing road transport	2. These are highway attributes important to customer
3. Promotes economic growth and protects and enhances the environment	3. Goals important to road users and those affected by highway activity
4.	4.

Attributes of Products or Services and Activities

In the past, maintenance management has been organized around various activities. Managers and crews thought of themselves as performing certain types of activities ranging from pothole repair to trimming vegetation to snow and ice control. However, these activities were not described in such a way that the relationship to the organization's customer was apparent. The connection between the activities and customer satisfaction, customer-oriented outcomes, or the value customers received was weak or not evident.

An increasing number of agencies have taken a step back from always thinking in terms of activities and have asked more fundamental questions:

- What business are we in?
- Who are our customers?
- What products and services do we deliver?
- What attributes of the products and services are customers buying?
- How do we increase or create value for our customers?

Customer-driven benchmarking begins by answering these questions.

Approach

Determining what your customers are buying will require fresh thinking. If people in your maintenance organization are accustomed to thinking in terms of maintenance activities rather than being in the business of delivering products and services to various groups of customers, you might have difficulty at first.

You will need to assemble a group of key maintenance managers and charge them with determining what customers are fundamentally buying. Your challenge will be to reach some consensus.

Suppose you begin with winter maintenance operations. What are customers buying?

- Snow and ice control?
- Anti-icing or deicing?

- The ability to drive the speed limit, unrestricted by snow and ice?
- Safe passage to destination on roads free of snow and ice—in other words, on roads whose pavements are returned to bare condition as quickly as possible after snow or ice begins to accumulate?

Market Research

To determine what customers are buying, your agency should conduct market research. You will need to enlist people with expertise in market research to help you. They can be found inside your organization or in market research and consulting firms. There are four types of market research inputs that can provide insight regarding what customers are buying:

1. **Market** research literature regarding road maintenance. See the References section.
2. **Surveys** that have been previously conducted by various agencies. See Appendix E. Both the questions and the responses can be revealing in terms of what customers are buying.
3. **Focus groups** should represent different segments of customers, so you may have to conduct a number of them. See Appendix C for further guidance regarding focus groups.
4. **Surveys** of your own customers. Design, administer, and summarize responses to surveys of your maintenance organization's customers. See Appendix C for guidance on developing and administering surveys.

Example

The Minnesota DOT (MnDOT) undertook a major effort to rethink its approach to maintenance in business terms and defined seven products and services:

1. **Clear roadways**
   - Clear of debris, and
   - Roadway clear of ice and snow.

2. **Smooth and reliable pavements**
   - Availability of roadway for year-round use,
   - Road ride comfort, and
   - Road reliability.

3. **Available bridges**

4. **Attractive roadsides**
   - Amount of roadside litter,
   - Noxious weed control, and
   - Vegetation height control.

5. **Safety features**
   - Guardrail and bridge rail condition,
   - Pavement markings,
   - Roadway lighting,
   - Signing, and
   - Traffic signals functioning as designed.

6. **Highway permit/regulations**
   - Encroachments on the right-of-way,
   - Accessibility of permit office,
   - Consistency of permit requirements, and
   - Time required to issue permits.

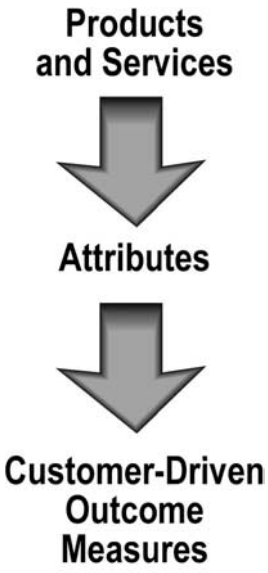
7. **Motorist services**
   - Motorist information on unplanned conditions, and
   - Attractive rest areas.

In the process of identifying products and services, MnDOT also identified the products' and services' important attributes. The list above shows the attributes the department initially associated with each product and service. Over time, MnDOT has become increasingly sophisticated in its understanding of the attributes of its products and services, partly as a result of carrying out an extensive program of market research. **Table 3** presents an expanded set of attributes that MnDOT has identified. These attributes become the basis for developing customer-oriented outcome measures.

Table 3. Attributes MnDOT Has Identified or Addressed in Market Research

Category	Attributes
Clear Roadways	Clear of unplanned obstructions
	Roadway clear of ice and snow
	Trucks plowing as soon as snow appears
	Plowing frequency during average snowfall
	Ability to see shoulder striping during snowfall
	Ability to see road edge during snowfall
	Ability to make turns at crossovers/intersections
	Driving speed during snowfall
	Day versus night snow removal expectations
	Weekend versus weekday snow removal expectations
	Radio channels listed for weather/road information
	Bare wheel paths
	Scattered slippery spots
	Only right lane plowed to bare pavement
	All driving lanes plowed to bare pavement
	All lanes plowed full width
	Fully cleared intersections/crossovers
Smooth and Reliable Pavements	Availability of roadway for year-round use
	Road ride comfort
	Road reliability
Available Bridges	Availability of bridges
Safety Features	Guardrail and bridge rail condition
	Pavement markings
	Roadway lighting
	Signing
	Traffic signals functioning as designed
	Attractive woods by road and lack of clear space to woods
	Vegetation on shoulders blocking site distance
	Vegetation blocking site distance at corners
	Vegetation blocking signs
Attractive Roadsides	Amount of roadside litter
	Noxious weed presence
	Vegetation height
	Neatness of vegetation
Highway Permits/ Regulations	Encroachments on right-of-way
	Accessibility of permit office
	Consistency of permit requirements
	Time to issue permits
Motorist Services	Motorist information on unplanned conditions
	Rest area attractiveness

Attributes of Products and Services Important to Your Customers



You will now use the inputs you have obtained from market research literature, surveys conducted by other organizations, focus groups, and additional customer surveys your organization has undertaken in order to begin to characterize what customers of maintenance are buying. If no research information is available, you can use your internal team for ideas on what customers want, desire, or are buying. These are the attributes of a product or service.

Brainstorm or extract from research a list of what your customers desire. These are the outcome attributes of maintenance work that are important to your customers. Reorganize the list of attributes into categories. Derive each category by grouping attributes based on a specific aspect of a driver's experiences. Finally, give the category a name that summarizes what the customer is receiving from the collection of attributes. The completed Worksheet 4 presents an example of how to proceed.

Use **Worksheet 4** to define your products and services.

- In the left column, list all of the attributes (what the customer is buying, wants, or desires) from the available research or your implementation team's ideas. This is an exercise to generate a list. Then edit the list: eliminate items that are redundant or not really important.
- In the center column, group the attributes into categories that relate to a similar aspect of driving experiences. There will likely be 5 to 10 categories.
- In the right column, establish a name for each category that captures the essence of what the driving customer desires, wants, or is buying, as represented by the group of attributes. These names then become the names of the maintenance products or services.

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 4.
FIGURING OUT YOUR PRODUCTS AND SERVICES

Attributes	Attributes by Category	Product/Services Name
1. Legibility of signs 2. Guardrail and bridge rail condition 3. Posted loads 4. Signpost condition 5. Plowing frequency during snowfall 6. Clear of unplanned obstructions 7. Nighttime visibility of signs and markings 8. Condition of bridge components 9. Traffic detoured × detour length 10. Bridge open and closed 11. Clear intersections and crossovers 12. Clear of ice and snow 13. Obstruction of safety features 14. Ride comfort	a. Clear of unplanned obstructions b. Clear of ice and snow c. Plowing frequency during snowfall d. Clear intersections and crossovers	Clear Roadways
	a. Ride comfort	Smooth Pavements
	a. Bridge open and closed b. Posted loads c. Traffic detoured × detour length Condition of bridge components	Available Bridges
	a. Guardrail and bridge rail condition b. Nighttime visibility of signs and markings c. Legibility of signs d. Signpost condition e. Obstruction of safety features	Safe Guidance

Mapping Maintenance Activities to the Products or Services

Maintenance management systems typically group work activities according to maintenance activities. It is critical to reorganize the maintenance activities to match the products and services that the maintenance department is delivering to its customers.

This is significant because performance means performance of a maintenance product or service. Performance can only be understood when the level of outcomes (results) from delivering these products or services, the level of output (production), and the level of resources expended are known.

Use **Worksheet 5** to map maintenance activities to the maintenance products or services.

- In the left column, list the products or services (probably 5–10).
- In the center column, list the maintenance activities that impact the attributes of the product or service.
- In the right column, write the maintenance code from your maintenance management system that accompanies the maintenance activity from the center column.

WORKSHEET 5.
MAPPING MAINTENANCE ACTIVITIES TO PRODUCTS AND SERVICES

Name & Code of Partner: Department of Transportation, 0031

Benchmarking Agreement #: 1234567

Organizational Level of Benchmarking Unit: County

Number of Benchmarking Units: 13

Product/Services	Maintenance Activity Description	Activity Code
1. Clear Roadway (Ice and Snow)	a. Deicing	101
	b. Anti-icing	102
	c. Plowing and sanding	103
	d. Removal of ice and snow	104
2. Smooth Pavements	a. Micro-surfacing	150
	b. Fog seal	151
	c. Chip and seal	152
	d. Pothole repair	153
	e. Deep patching	154
3. Available Bridges	a. Deck repair	45
	b. Deck replacement	46
	c. Strengthening	47
	d. Repair of bridge component	48
	e. Maintenance of bridge component	49
4. Safe Guidance	a. Guardrail repair	70
	b. Bridge rail repair	71
	c. Sign repair	72
	d. Sign replacement	73
	e. Signpost replacement	74

Thus far, you have determined the attributes important to the customer that are associated with different products and services and you have listed the combination of maintenance activities that produce the products and services.

The next step is to identify possible outcome measures that correspond to each product or service attribute important to the customer. You need to prioritize these candidate measures and identify the two to four most important measures from your agency's perspective. You should also determine whether your agency currently has the data for each candidate measure or whether the data exists.

Refer to the list of commonly recognized measures in Chapter 3, Table 1 and to Appendix E for ideas regarding outcome measures to consider.

For each product or service attribute, fill out **Worksheet 6** to identify customer-driven outcome measures corresponding to each product or service attribute. These should be measures that you are currently using or those that you think should be used for benchmarking this product or service.

- At the top of the worksheet, fill in the product or service name and the attribute(s) for which you are identifying candidate measures.
- In the top half of the worksheet labeled "Outcome, Condition Measures," list candidate measures that are for assessing the conditions of a product or service attribute resulting primarily from maintenance activities (e.g., "time to return to bare pavement" after a snowfall).
- In the bottom half of the worksheet labeled "Outcome, Customer Survey Questions," list customer survey questions that you use and that you believe give a good indication of the customers' satisfaction with the level of performance of the product or service attribute (e.g., "ride comfort" of pavement). Also, list potential customer survey questions that you believe would give a good indication of customers' satisfaction.
- In the second column, indicate (yes or no) whether the measure is available, meaning that the data exists, that the agency already uses this measure, or both.
- In the last column, place a check if you believe that this is a measure of high priority for the benchmarking partners to consider.

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 6.
IDENTIFYING MEASURES FOR ATTRIBUTES

Product/Service: Smooth Pavement

Attributes: Ride Comfort

OUTCOME, CONDITION MEASURES	AVAILABLE?	PRIORITY
1. International Roughness Index	☑ Yes ☐ No	✓
2. Maintenance Ride Quality Index	☑ Yes ☐ No	
3. Longitudinal Profile	☑ Yes ☐ No	
4. Number of potholes per lane mile	☑ Yes ☐ No	
5.	☐ Yes ☐ No	
6.	☐ Yes ☐ No	

OUTCOME, CUSTOMER SURVEY QUESTIONS	AVAILABLE?	PRIORITY
1. Satisfaction with pavement smoothness (1 = very unsatisfied; 5 = very satisfied)	☑ Yes ☐ No	✓
2. Satisfaction with ride comfort	☐ Yes ☑ No	
3.	☐ Yes ☐ No	
4.	☐ Yes ☐ No	
5.	☐ Yes ☐ No	
6.	☐ Yes ☐ No	

Calculation, Source, Network Coverage, and Quality of Outcome Measures

Before you decide what outcome measures to use, you will need to compile information on the data necessary for calculating the measure and on the availability of this data. If data is not available or does not exist for measures that you need for benchmarking, then you will need to document the data that does not currently exist.

Use **Worksheet 7** to identify the calculation, availability, source, network coverage, and quality of data for each outcome measure (i.e., condition or survey measure) for each product and service attribute.

- At the top of the page, write the name of the product or service.
- Enter the attribute(s) of the product or service.
- In the left column labeled "Name of Measure," list the name of each candidate benchmarking measure corresponding to the product or service attribute.
- In the column labeled "How Measure Calculated/Scale,"
  - Write the formula and/or description of how the measure is calculated, and
  - Write the scale for the measure.
- In the column labeled "Month Data Available," write the dates or months in each year that data is available, or needs to be available, to calculate the measure.
- In the column labeled "Where Data Stored," write the name of the system, database, or location where the data is or should be maintained.
- In the column labeled "Roadway Network Coverage,"
  - Describe the types or classes of roads for which data exists.
  - Indicate whether the data is 100% coverage or is a sample.
  - If the data is sample data, then indicate the lowest geographical or organizational level for which the data is statistically valid.
- In the column labeled "Data Quality H, M, L, N," write the letter for high (H), medium (M), or low (L) that best describes your team's assessment of the data quality; if the data does not exist, then write "N."

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 7.
OUTCOME MEASURES

Product/Service: Smooth Pavement
Attribute(s): Ride Smoothness

Name of Measure	How Measure Calculated/Scale	Month Data Available	Where Data Stored	Roadway Network Coverage	Data Quality H, M, L, N
IRI	Instrumentation: the number of inches of deviation in elevation from a fixed horizontal plane per mile	September	PMS	Nat. Highway Sys. 100% coverage	H
Survey Question	Semi-annual driver survey rating smoothness of pavement on a 1–5 scale	April & October	Customer Survey Database	County	M

Resources Associated with Maintenance Activities That Produce Outcomes

Historically, maintenance organizations may not have defined outcome measures for individual products or services; however, it is likely that they have data for measuring the amount of resources that are used in specific time periods to deliver a product or service.

In Worksheet 4, you identified the maintenance activities performed that deliver a desired product or service. In Worksheet 8, you want to identify the measures that will be used to indicate the amount of resources expended to deliver the product or service.

Resources are labor, material, and equipment used by the maintenance agency and other service providers with whom the agency contracts to perform maintenance activities for the product or service. It would be most useful if contracts were divided by labor, materials, and equipment usage; however, total dollars may be the only measure available for contracts.

Other measures will likely include hours for labor, pounds or gallons for material, and hours of usage or miles driven for equipment. In most cases, dollars spent for each of these resources can be a surrogate measure of the resource usage.

Also, some agencies use the quantity of a resource used (e.g., gallons of material) as a measure of the amount of work completed (output or production). For customer driven-benchmarking purposes, the quantity of a resource is a resources measure, not a production or output measure.

The purpose of **Worksheet 8** is to identify the measures of resource usage of the maintenance activities for a specific product or service.

At the top of the worksheet, enter the product or service that you plan to benchmark.

- In the first and second columns, enter the activity code and the name for each maintenance activity that will affect a measured outcome of this product or service.
- In the third column labeled "Labor (UOM)," enter the units of measure (other than $) for labor resources.
- In the column labeled "Equipment Type," enter each primary type of equipment that is typically used to carry out the maintenance activity, and enter the equipment units of measure in the fifth column labeled "Equipment (UOM)."
- In the sixth column, enter the type of material that is typically used to carry out the maintenance activity and enter the units of measure for the material in the seventh column.
- In the eighth column, provide your judgment of the average quality of the resource data (H = high, M = medium, L = low).
- In the ninth column labeled "Cost Data Available," indicate whether the dollar expenditures are available for these resources; write L = labor, E = equipment, or M = material for the respective resource for which dollar expenditures are available. Write T = total cost if only the total dollar amount is available for the activity (this may be the situation for contracted activities). Also, write OH if overhead cost data is available for the activity.
- In the tenth and last column, for each maintenance activity identify the lowest organization level for which resource data is maintained and enter the number of these organizational units that have complete resource data—labor, equipment, material, and related costs.

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 8.
RESOURCE MEASURES

Product/Service: Clear Roadways (Ice & Snow)

Activity Code	Name of Activity	Labor (UOM)	Equipment Type	Equip. (UOM)	Material Type	Material (UOM)	Quality of Data H,M,L	Cost Data Available (L,E,M,T,OH)	Lowest Org. level & #
102	Anti-icing	Hrs	Truck Spreader	Hrs	Brine CMA	Gallons Pounds	H	L, E, M, T, & OH	Areas 43
103	Plowing and Sanding	Hrs	Truck Plow	Hrs	Sand	Tons	H	L, E, M, T, & OH	Areas 43

Hardship Factors

Roadways exist in many different environmental settings that create varying degrees of hardship. Hardship in this context means that the greater the hardship, the greater the quantity of resources required for maintenance activities to deliver a level of a product or service.

A specific correlation may not exist or be known between hardships factors and the ease of delivering maintenance products or services. However, it is generally understood that the greater the hardship, the greater the difficulty in delivering a maintenance product or service. High population density, severe weather, and difficult terrain are examples of hardship factors. Data regarding several hardship factors should be collected and measures should be calculated before a judgment is made as to which hardship measures to use in evaluating performance.

Use **Worksheet 9** to identify the potential or candidate hardship measures for a product or service and the data required to calculate the measure.

At the top of the page, enter the name of the product or service being benchmarked.

- In column one, list the factors that are believed to affect the level of resources (e.g., weather, traffic, population density, etc.).
- In column two, list possible measures for each respective factor and a description of how the measure is calculated.
- In column three labeled “Specific & Data Source,” identify for each measure the source of the data.
- In column four, identify the lowest level of organization for which the data and the measure is/or could be available.
- In column five labeled “Time Period,” identify the time period covered by the measure (e.g., monthly, quarterly, or annually).
- In column six, the last column, rate the quality of the data: H = high, M = medium, L = low, or N = not available.

WORKSHEET 9.
HARDSHIP FACTORS

Product/Service: Clear Roadways (Ice & Snow)

Factor	Possible Measures & Description of How Each Is Calculated	Specific Data & Source	Lowest Org. Level	Time Period	Data Quality
Weather	Inches of freezing precipitation	National Weather Service	District	Nov-Apr	M
Weather	Number of storms that require crews to treat or clear roads	RWIS & Maintenance Management Information System (MMIS)	County	Nov-Apr	H
Traffic	Average daily traffic		County	Annual	M
Terrain	Elevation change per mile in feet	Topographical Map	Area	Continuous	H

Outputs

Good performance reflects both quality and quantity of work; therefore, for each product or service, you will need measures of the amount of work that was accomplished—that is, production (also called output). Each primary maintenance activity of a product or service will likely have its own measures of production; however, the ones to examine are measures for the entire product or service.

Use **Worksheet 10** to identify the candidate measures of production for each product or service.

- At the top of the worksheet, enter the product or service name.
- In column one, enter a list of potential measures for this product or service that would give an indication of how much total work was done in a time period.
- In column two, describe how each measure is or would be calculated.
- In column three, list the data required for the measure and the timing of the data's availability (monthly, annually, in September, etc.). If the data is not collected, indicate so by stating "NC."
- In column four, identify the lowest organizational level for which this data exists and the number of these organizations that have this data.
- In column five, rate the quality of the data for the measure: H = high, M = medium, or L = low.

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 10.
OUTPUT MEASURES

Product/Service: Clear Roadways (Ice & Snow)

Name Measure	How the Measure Is Calculated	Data Required & Timing of Availability	Organization Level & # of Orgs	Data Quality (H, M, L)
Total Miles of Anti-icing, Plowing & Sanding	Sum of miles traveled for all trucks for Activities 150, 151, & 152 for the season	Truck log miles from first event to last event of the season–data available daily and at end of the season (May 10)	Garage 57	M

Benefits and Costs of Measures

By completing the first 10 worksheets, you may well have determined that your agency should create additional measures, possibly for any of the four categories of measures: outcomes, outputs, resources, or hardship factors. As you work with benchmarking partners to determine common measures for the product or services that you wish to benchmark, some of the partners will likely need to develop new measures.

Your agency may need to collect data that has not previously been collected in order to calculate measures. Rather than indiscriminately launching activities to collect data, you and your partners should assess the cost of collecting the new data and of creating a measure and the benefits that would come from having the new data and measure.

This assessment could result from a thorough investigation with detailed calculations; however, a more general and subjective assessment is appropriate to ensure that there likely is a benefit to the agency and partnership for having a new measure. Also, if there are several candidate new measures for which data needs to be collected, then there should be a comparison of the cost-benefit relationship of the candidate measures.

This comparison will help to ensure that the agency and partnership collects data and creates the measures that are of the highest priority and do not spend unnecessary time and money collecting data that has little value.

Costs can be estimated by considering the equipment required for data collection; whether you need sample data or complete coverage (census) data for a benchmarking unit; the staff and training required for data collection; and the systems required for maintaining and/or manipulating the data to create a measure.

Benefits resulting from using the measure can be estimated by determining a feasible range of cost reduction in delivering the product or service or by determining the importance of improving the outcome of the product or service to customers.

The estimate can be subjective—for example, high, medium, or low—for both benefits and costs.

Use **Worksheet 11** to profile your estimates of the cost-benefit relationship of various candidate measures that will require new data collection and cannot currently be calculated.

- For each measure, rate the cost as high, medium, or low.
- Rate the benefit of the measure based on its usefulness of measuring the value to the customer of the production service; also, considering the feasible savings in delivering the product or service. The net benefit should be rated as high, medium, or low.
- Place the name of each measure in one of the nine cells that corresponds to the measure's rating on both the cost to collect and to calculate the measure and the benefit from using the measure.
- Choose which measures to create based on which will give the best combination of high benefit and low cost. These are measures that are closest to the upper right corner of the grid.

WORKSHEET 11.
BENEFITS VERSUS COST OF MEASURES

Product/Service: Smooth Pavement

BENEFITS	HIGH	MEDIUM	LOW
HIGH	Survey Question rating drivers satisfaction with pavement smoothness	IRI National Highway and all primary roads annually, all others every other year.	Contractor breakout of costs of labor equipment, material
MEDIUM		Condition rating, surface rating inspections	
LOW		Potholes per lane mile	

HIGH **MEDIUM** **LOW**

C O S T

Summary of Performance Measures for Each Product or Service That a Partner Would Like to Benchmark

Each partner will need to complete a description of the measures that they have available or believe are appropriate for the each product or service to be benchmarked. This set of measures will later need to be reviewed by each partner and a commitment will be reached on the common data and measures that each member of the partnership will use.

From their own Worksheets 6 through 10, each partner should aggregate the outcome, resource, hardship, and output measures and use it in Worksheet 12.

Use **Worksheet 12** to summarize the recommended measures that your organization uses or would like to use for benchmarking a desired product or service:

- At the top of the page, enter:
  - The product or service being benchmarked,
  - The name of the partner and Identification code,
  - The benchmarking agreement number,
  - The organizational level for the benchmarking units, and
  - The number of benchmarking units.
- In the left two columns, number and list the code and the name of each recommended measure. For coding, use "OC" to indicate it is an outcome measure; "OP" to indicate it is an output measure; "R" to indicate it is a resource measure; and "H" to indicate it is a hardship measure. Code each measure of each type consecutively (e.g., R1, R2, . . . RN).
- In the remaining columns to the right, for each outcome, output, resource, or hardship measure, provide the following information:
  - In column three, a description of the measure (e.g., mean of total segment samples of edge drop-off of more than 2″ extrapolated to the number of lane miles);
  - In column four, "UOM" is the unit of measure (e.g., the number of linear ft. of edge drop-off >2″ per 1/4-mile segment);
  - In column five, "Scale" is the measurement scale (e.g., linear feet/lane mile);
  - In column six, "Summary Statistic" is the summary statistic of the measure (total, mean, median, etc.); and
  - In column seven, "Protocol" is the measurement protocol that is the name or code of a document that defines the measure.

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 12.
SUMMARY OF RECOMMENDED MEASURES

Product/Service: Smooth Pavements

Name & Code of Partner: Department of Transportation, Code 00031
Benchmarking Agreement #: B1234567
Organizational Level of Benchmarking Unit: County
Number of Benchmarking Units: 13

Measure Code	Measure Name	Description of the Measure	UOM	Scale	Summary Statistic	Protocol
OC 1	IRI	Deviation in the elevation of a pavement from a fixed horizontal plane	Inch per Mile	50–210	Section Mean in County	FHWA
OC 2	Survey Q on Smoothness	Semi-annual drivers survey rating their satisfaction with the smoothness of the pavement	Rating	1–5	Mean County Response	Survey Design & Interview Instruct.
R 1	Labor	Total hours of labor for activities 150–165	Hrs		Total Hrs	Maint. Manual
R 2	Equipment	Total hours of equipment usage, activities 150–165	Hrs		Total Hrs	Maint. Manual
H 1	Degree Days	Number of degrees below freezing summed for the year	Degrees	0–50	Sum	Maint. Manual Section 4.2
OP 1	Lane Miles Treated	Numbers of lane miles treated with activities 150–165 for the season	Lane Miles	0–500	Sum	Maint. Manual Section 5.6

Availability of Performance Data and Measures

Benchmarking requires performance evaluations to be made and shared among the benchmarking units of all benchmarking partners. Performance is calculated for a specific time period—for example, monthly, semi-annually, or annually (for most customer driven-benchmarking, the time period will initially be annually).

Therefore, the time of the year that the measure is available for calculating performance is important to the partners. Suppose the product or service is "Clear Roadways"(clear of ice and snow). If "customer's satisfaction with this service" is an outcome measure that partners agree to use, then it is important to know when the data (in this case, the customer research data) and the corresponding measure are available to the agency and all of the benchmarking partners.

One agency might conduct a customer phone survey on a continuing basis throughout the winter season, and complete data may be available at the end of the season in May. Another partner might conduct a single survey in July and not have data available until October. Unless the latter partner is willing to change the timing, the type of survey, or both, the benchmarking could not take place until sometime after October.

Data availability will therefore significantly impact the time of year that the partnership can conduct benchmarking for a specific product or service. Knowing when data and corresponding measures are available is very important information to consider and share with partners.

Use **Worksheet 13** to document when each candidate measure from Worksheet 12 is available. At the top of this worksheet, repeat the information from the top of Worksheet 12.

- Repeat the code and name of the measure and the first two columns from Worksheet 12 (e.g., OC1, Customer Satisfaction with Sign Visibility).
- In the third column, write the specific data that is collected for the measure (e.g., Response to Semi-annual Customer Survey).
- In the columns representing the months of the year, place an "x" in the columns representing the months in which the data is collected or needs to be collected for the measure.
- Place an M (for measure) in the months that the measure is calculated and available or should be available. If in one month data is both collected and the measure is available, just place an M in that month.

WORKSHEET 13.
AVAILABILITY OF DATA AND MEASURE

Product/Service: Smooth Pavement

Name & Code of Partner: Department of Transportation, 00031
Benchmarking Agreement #: 1234567
Organizational Level of Benchmarking Unit: County
Number of Benchmarking Units: 13

Code	Measure Name	Descriptions of Data Being Collected	J	F	M	A	M	J	J	A	S	O	N	D
OC 1	IRI	Roughness ratings, mean for primary roads for each county						*x*	*x*	*x*		***M***		
OC 2	Survey Pavement Smoothness	Summary mean of responses to question rating smoothness or roads				*x*	*x*	*x*	*x*	*x*	*x*	***M***		
R 1	Labor Hours	All labor hours logged in MMIS for activities 150–159			*x*	*x*	*x*	*x*	*x*	*x*	*x*	***M***		
R 2	Equipment Hours	All equipment hours logged for activities 150–159			*x*	*x*	*x*	*x*	*x*	*x*	*x*	***M***		
H 1	Degree Days	Number of degrees below freezing each day of the year	*x*	*x*	*x*	***M***						*x*	*x*	*x*
H 2	Precipitation	Amount of rain, ice, and snow fallen in a year, annual data	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	***M***	*x*	*x*	*x*
OP 1	Lane Miles Treated	Total # of lane miles treated by activities 150–159			*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	***M***	

Now that you have determined what your organization uses or would like to use as measures of performance, the lead partner organization must coordinate with each of the partners to reach agreement among the partnership to ensure that each partner is committed to a common set of measures for each product or service to be benchmarked.

The lead partner will need to ensure that completed Worksheets 5, 12, and 13 from each partner are shared with all other partners for this purpose.

It is likely that individual partners will need to be flexible in three primary areas:

1. **The partnership will want each of the partners to aggregate a similar (as much as is possible) set of activities that define a product or service even though the product or service may have different names.** For example, one agency may call its winter services by the name "clear roadways," while another agency refers to the same service as "snow and ice control." The focus is not on the name, but rather on the activities that make up the product or service.
2. **Any partner may need to include activities that might be performed by another organization or organizational units.** For instance, in providing a smooth ride, a substantial portion of the activities that affect ride quality may be performed by construction or contractors. Therefore, the partnership will have to make a commitment regarding what activities of the maintenance organization and other organizations are included in the customer-oriented product or service that they want to benchmark.
3. **Data collection for measurements may need to change for any given partner.** For example, many maintenance organizations have instituted a "level of service" measure to determine the actual quality of highways or specific aspects of highways and other maintenance assets. If the measurements to determine level of service are different from one partner (and its benchmarking units) to the next, then partners cannot very well compare performance of benchmarking units. Another example is that some partners may need to institute customer satisfaction

measures for its benchmarking units. Such measures need to be the same for all benchmarking units of the partners.

Once the partners have reached agreement and have made a commitment to the activities to be included in a product or service to be benchmarked and the measures and their timing of availability, then a single set of Worksheets 5, 12, and 13 will be completed by the lead partner and circulated to all partners, thereby clarifying the commitment that each partner has made. The performance comparisons that will take place depend upon this commitment.

At this point, the lead partner will need to establish the time frame for the benchmarking activities and to receive a commitment from each partner for completing activities according to this timeframe. For each product or service to be benchmarked, this includes the following:

- The beginning time for performance measures data collection (this assumes that data is not already available and that you are not benchmarking from past performance).
- A time at which the completed measures will be available to all partners.
- A time when the partner who will perform the performance comparisons will provide the results to all partners.
- A time frame for each of the "best" or better-performing benchmarking units to document their practices and make them available to each of the other partners.
- A time frame for partners and their respective benchmarking units to assess the practices of better-performing benchmarking units and to make decisions regarding any practices that they wish to implement.

Likely, the partnership is planning to compare performances in the future (e.g., fall of next year); each partner will need to ensure that it has the capability and procedures for collecting the agreed-upon data for outcomes, outputs, resources, and hardship factors within the agreed-upon time periods.

This may mean that there is a time gap between the time that the partnership shares final information from Worksheets 5, 12, and

13 and the time when data is collected for the first benchmarking performance comparison. During this time period, each partner should begin documenting the business processes of each of its benchmarking units. If there is no gap in time, then each partner will need to document business processes during the period of data collection.

Documenting Existing Business Processes

Part of your preparations for benchmarking should involve documenting your existing business processes, particularly those you plan to benchmark. You will need this documentation as a basis for making comparisons to business processes associated with best practices.

Examining Existing Business Processes

You should take a preliminary look at the business processes you are most likely to benchmark and make sure you have a solid understanding of them. Many maintenance organizations have performance standards or maintenance handbooks that describe what complements of labor, equipment, and material are normally used to carry out each activity. Performance standards may also include steps of the business process in broad terms. If the steps are exceedingly broad, you may wish to prepare a more detailed set of steps.

Also, rapidly advancing technology may have affected how you do your work, and you should understand how current and evolving technology contributes to your business process.

Environmental and occupational and safety regulations may pertain to a certain type of activity, and you should understand how procedures for complying with them fit in your work flow.

How scheduling and daily work reporting fit into the business process can also affect productivity and outcomes. For example, organizations use different strategies to minimize the amount of time that crew leaders spend filling out daily work reports. Some methods are very effective in certain circumstances and completely free crews and their leaders to do maintenance work.

Business Process Diagramming

An effective way to help thoroughly understand the business process is to diagram it using standard business process flow diagrams. A few simple conventions should be observed when you prepare a business process flow diagram:

1. Make a list of each step of the overall business process. Each step should be described at roughly the same level of detail.
2. Identify the personnel who carry out each step.
3. Diagram the business process using the conventions shown in **Figure 9**.
4. Begin every step of the business process with a verb (e.g., set up work zone, remove litter, clean spreader).
5. Connect each box by arrows in the sequence in which the steps of the business process occur. There may be parallel processes.
6. Some business processes involve one or more decision points. Diagram each decision point and show the business processes that follow from each branch of the decision.
7. If the gathering, storage, retrieval, and transfer of information are part of the business process, use the convention in **Figure 9** to show databases that are sources or destinations of information.

Figure 10 shows an example of a business process flow diagram. Note that the actors involved in each step are identified at the top of the diagram. You could use a different convention for identifying the actors, but this is as good as any.

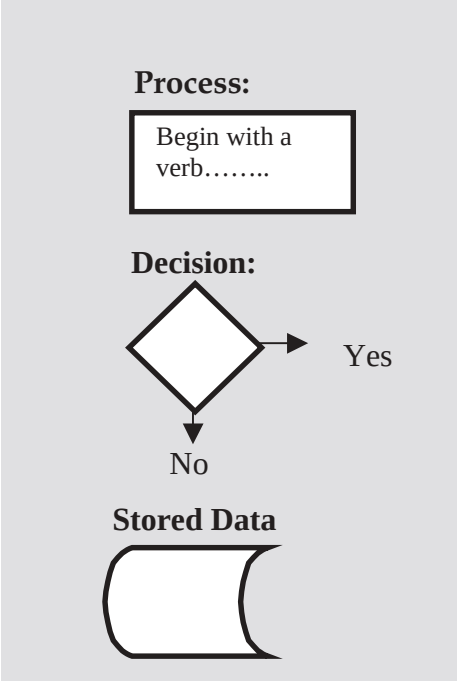


Figure 9. Business Process Diagramming Conventions

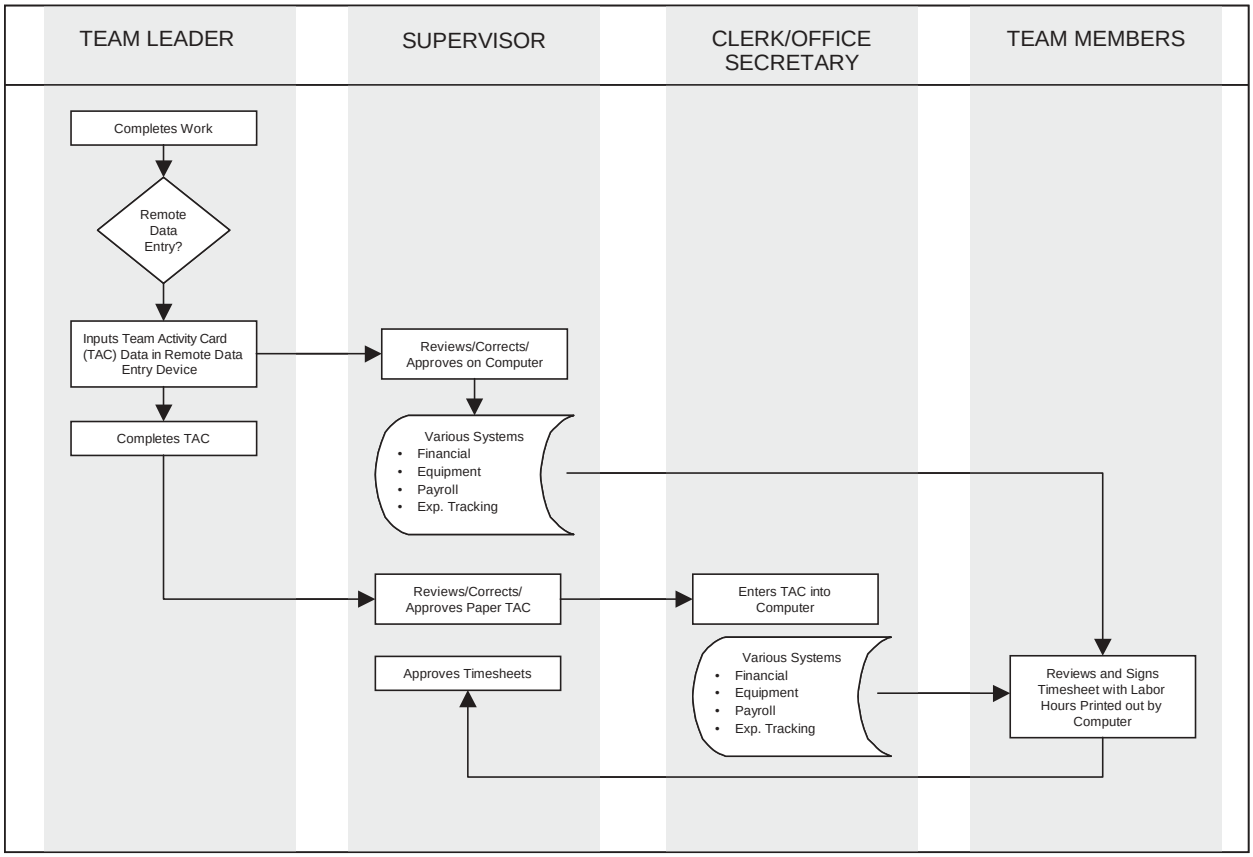


Figure 10. Example Business Process Flow Diagram

Once you have prepared the diagram, you should also write out the corresponding steps in the manner shown below in order to make the diagram fully understandable and to check its accuracy. Frequently, by writing out the steps you will see errors or ways to draw the diagram to more accurately reflect the business process it depicts.

The steps of the example business process shown in **Figure 9** are as follows:

1. The team leader (and rest of team) completes work.

2a. If remote data entry occurs, the team leader inputs the Team Activity Card (TAC, or daily work report) into a remote data-entry device.

2b. A supervisor reviews, corrects, and/or approves the daily work report on a computer, and the work report is uploaded to various systems (e.g., financial, equipment, payroll, or expenditure tracking).

2c. Each team member reviews and signs a timesheet with labor hours printed out by computer.

3a. If remote data entry does not occur, the team leader fills out a paper TAC.

3b. The supervisor reviews, corrects, and/or approves the paper TAC.

3c. The clerk or office secretary enters the information on the paper TAC into a computer and it is uploaded to various systems (e.g., financial, equipment, payroll, or expenditure tracking).

3d. Team members review and sign the timesheet, with the labor hours printed out by computer.

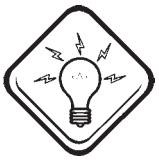
4. The supervisor approves the timesheets.

Developing a Repository

You should develop a repository of business process flow diagrams. You could place them in a file folder, but it is better to store them electronically in a computer: you can easily retrieve

them, place them in electronic documents, and exchange them with your benchmarking partners when you are analyzing best practices.

Usually the diagrams you will need for benchmarking are simple enough to draw, and there is no reason to use special software. You can prepare them using any standard drawing tool, including the one found in your computer office suite software. **However, there are a large number of Computer Assisted Software Engineering (CASE) tools that include software for business process flow diagramming. So you could use a CASE tool instead. CASE tools typically include an electronic repository for business process flow diagrams.**



Database Design

As soon as you take various outcome measurements and collect other relevant data, you will need to store it. Therefore, before you collect performance data, it is necessary to design a database. One of the benchmarking partners or a third party will need to develop the database.

It is recommended that you pay careful attention to the details of database design because you may have to store a considerable amount of data. Since benchmarking is a continuous activity, you will be collecting data year after year. You may be able to get by with the database that is part of the suite of software on your desktop or laptop computer. Nonetheless, consider getting the assistance of a person experienced in developing databases.

Database design includes selecting the database software you will use and establishing each of the fields, their location in the record, and their type and length. You should use standard database software that supports Standard Query Language (SQL) operations and Open Database Connectivity (ODBC). For certain applications, it may be important to store the data in a manner that easily permits standard database operations such as "joins" and "select." In such a case, formal database design procedures may be warranted (i.e., preparing an entity relationship diagram).

Other Software Design and Development

If data you require for benchmarking comes from a variety of sources and databases, you may wish to develop interfaces to transfer data into a benchmarking data repository. Among the interfaces you might need to develop are the following:

- Maintenance management system interface,
- Roadway feature inventory database,
- GIS database interface,
- RWIS data interface,
- Pavement management system interface, and
- Bridge management system interface.

Data Entry and Communications Technology

It is possible that with the rapid growth of wireless technology, you might want to support remote data entry into pen-based computers or laptops. Linkages between the database and remote data-entry devices will need to be established.

If you decide to use field data collection devices and software for data collection—pen-based computers, voice recognition, bar coding, global positioning system receivers, or digital maps—you will need to design and program the user interface, the data entry procedures, and the data transfer procedures accordingly.

STEP 3. MEASURE PERFORMANCE

The third step of customer-driven benchmarking involves measuring performance. This entails collecting data on outcomes, resources, hardship factors, and outputs.

Collecting and Recording Data

You will measure performance at the appropriate level of the organization in accordance with your data collection plan. Collecting and recording data entails the following:

- Transferring related data needed for benchmarking into the database,
- Taking various types of measurements and entering them into the benchmarking database,
- Calculating any measures that are a function of the related data, and
- Performing quality checks on the measurement and related data.

Data collection procedures may involve surveying customers, sampling roadway sections, conducting condition assessments, and retrieving data from management systems.

Regardless of whether the partnership is using electronic databases or sharing data electronically, the information needs to be verified, checked, and shared among partners.

Each of the benchmarking partners will need to complete Worksheets 14, 15, 16, and 17 and submit them to each of the other partners in the partnership within the agreed-upon time frame. These worksheets contain the measures for the outcomes, resources, hardship factors, and outputs. These measures will be used for the performance comparisons.

Outcomes

The purpose of **Worksheet 14** is to record, for each outcome measure, the observed outcomes for each subunit of the benchmarking partner.

- At the top of the page, enter
  - The name of the product or service being benchmarked,
  - The name of the benchmarking partner organization,
  - An identification code for the benchmarking partner,
  - The organizational level of the benchmarking units that participated in the benchmarking activity,
  - The number of benchmarking units,
  - The benchmarking agreement number, and
  - The time period over which performance is measured.
- In the left two columns, number and list the name of each benchmarking unit of the benchmarking partner.
- Place the code and name of each outcome measure in each of the column headings to the right. Code the outcome measures as OC1, OC2, OC3, etc.
- For each subunit, fill in the measurement that was taken for each outcome measure (e.g., for OC1, OC2, OC3, etc.).

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 14.
BENCHMARKING RESULTS—OUTCOME MEASURES

Product/Service: Smooth Pavement

Name of Partner: Department of Transportation

Identification Code: 00031

Organizational Level of Benchmarking Units: County **No. of Units:** 13

Benchmarking Agreement #: 1234567

Period of Performance: **From:** 11-01-01 **To:** 10-15-02

NO.	NAME OF BENCHMARKING UNIT	OUTCOME MEASURES				
		OC 1	OC 2	OC 3	OC 4	OC 5
		IRI	Customer Satisfact. Rating			
1.	Jefferson	75	4.1			
2.	Polk	83	4.0			
3.	Washington	160	2.9			
4.	Hamilton	139	3.1			
5.	Adams	129	3.2			
6.	Roosevelt	112	3.5			
7.	Truman	82	4.0			
8.	Clinton	98	3.8			
9.	Jackson	181	2.8			
10.	Eisenhower	70	4.2			
11.	Lincoln	126	3.3			
12.	Nixon	141	3.0			
13.	Buchanan	110	3.7			

Resources

The purpose of **Worksheet 15** is to record for each resource measure the observed resource usage of each subunit of the benchmarking partner.

- At the top of the page, enter
  - The name of the product or service being benchmarked,
  - The name of the organization that is a benchmarking partner,
  - The identification code for the benchmarking partner,
  - The organizational level of the subunits that participated in the benchmarking activity,
  - The number of benchmarking subunits,
  - The benchmarking agreement number, and
  - Time period over which performance is measured.
- In the left two columns, number and list the name of each subunit of the benchmarking partner.
- Put the code and name of each resource measure in each of the column headings to the right. Code the resource measures as follows: R1, R2, R3, etc.
- The benchmarking partner will need to fill out the remainder of the worksheet or provide the data.
- For each subunit, fill in the measurement that was taken for each resource measure (e.g., for R1, R2, R3, etc.). The measurement should be consistent with the relevant summary statistic (e.g., total cost for each county over the time period from January through December).

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 15.
BENCHMARKING RESULTS—RESOURCE MEASURES

Product/Service: Smooth Pavement
Name of Partner: Department of Transportation
Identification Code: 00031
Organizational Level of Benchmarking Units: County **No. of Units:** 13
Benchmarking Agreement #: 1234567
Period of Performance: **From:** 11-01-01 **To:** 10-15-02

NO.	NAME OF BENCHMARKING UNIT	RESOURCE MEASURES (Cost in Thousands of $)				
		R1	R2	R3	R4	R5
		Maint.	Contract	Total		
1.	Jefferson	456	33,700	34,156		
2.	Polk	691	25,350	26,041		
3.	Washington	1,210	28,740	29,950		
4.	Hamilton	631	24,796	25,427		
5.	Adams	1,100	22,330	23,430		
6.	Roosevelt	490	20,790	21,280		
7.	Truman	3,475	131,600	135,075		
8.	Clinton	675	12,260	12,935		
9.	Jackson	1,517	29,000	30,517		
10.	Eisenhower	897	13,100	13,997		
11.	Lincoln	1,400	9,473	10,873		
12.	Nixon	859	20,600	21,459		
13.	Buchanan	1,263	18,429	19,692		

Hardship Factors

The purpose of **Worksheet 16** is to record for each hardship measure the observed resource usage of each subunit of the benchmarking partner.

- At the top of the page, enter
  - The name of the organization that is a benchmarking partner,
  - The identification code for the benchmarking partner,
  - The organizational level of the subunits that participated in the benchmarking activity,
  - The number of benchmarking subunits,
  - The benchmarking agreement number, and
  - Time period over which performance is measured.
- In the left two columns, number and list the name of each subunit of the benchmarking partner.
- Put the code and name of each hardship measure in each of the column headings to the right. Code the hardship measures as follows: H1, H2, H3, etc.
- The benchmarking partner will need to fill out the remainder of the worksheet or provide the data.
- For each subunit, fill in the measurement that was taken for each hardship measure (e.g., for H1, H2, H3, etc.). The measurement should be consistent with the relevant summary statistic (e.g., mean daily high temperature for each county over the time period from January through December).

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 16.
BENCHMARKING RESULTS—HARDSHIP (UNCONTROLLABLE) FACTORS

Product/Service: Smooth Pavement

Name of Partner: Department of Transportation
Identification Code: 00031
Organizational Level of Benchmarking Units: County **No. of Units:** 13
Benchmarking Agreement #: 1234567
Period of Performance: **From:** 11-01-01 **To:** 10-15-02

NO.	NAME OF BENCHMARKING UNIT	HARDSHIP MEASURES				
		H 1	H 2	H 3	H 4	H 5
		ADT	Degree Days	Liquid Equiv Precip.		
1.	Jefferson	401	1,539	29.1		
2.	Polk	275	1,819	28.2		
3.	Washington	159	1,654	26.3		
4.	Hamilton	310	1,679	31.1		
5.	Adams	950	1,455	27.9		
6.	Roosevelt	600	1,500	23.5		
7.	Truman	1,817	1,009	26.7		
8.	Clinton	851	1,103	34.2		
9.	Jackson	1,310	731	36.7		
10.	Eisenhower	729	761	31.0		
11.	Lincoln	557	1,216	29.8		
12.	Nixon	392	1,310	24.0		
13.	Buchanan	992	712	21.1		

Outputs

The purpose of **Worksheet 17** is to record for each output measure the observed output of each subunit of the benchmarking partner.

- At the top of the page, enter
  - The name of the organization that is a benchmarking partner,
  - The identification code for the benchmarking partner,
  - The organizational level of the subunits that participated in the benchmarking activity,
  - The number of benchmarking subunits,
  - The benchmarking agreement number, and
  - Time period over which performance is measured.
- In the left two columns, number and list the name of each subunit of the benchmarking partner.
- Put the code and name of each output measure in each of the column headings to the right. Code the output measures as follows: OP1, OP2, OP3, etc.
- The benchmarking partner should complete the remainder of the worksheet.
- For each subunit, fill in the measurement that was taken for each resource measure (e.g., for OP1, OP2, OP3, etc.). The measurement should be consistent with the relevant summary statistic (e.g., total cost for each county over the time period from January through December).

USE MORE THAN ONE WORKSHEET IF NECESSARY.

WORKSHEET 17.
BENCHMARKING RESULTS—OUTPUT MEASURES

Product/Service: Smooth Pavement

Name of Partner: Department of Transportation
Identification Code: 00031
Organizational Level of Benchmarking Units: County **No. of Units:** 13
Benchmarking Agreement #: 1234567
Period of Performance: **From:** 11-01-01 **To:** 10-15-02

NO.	NAME OF BENCHMARKING UNIT	OUTPUT MEASURES				
		OP 1	OP 2	OP 3	OP 4	OP 5
		Maint. Lane Miles	Contract Miles	Total Miles		
1.	Jefferson	190	371	561		
2.	Polk	57	709	428		
3.	Washington	130	250	380		
4.	Hamilton	199	679	878		
5.	Adams	410	412	822		
6.	Roosevelt	165	810	975		
7.	Truman	1,400	390	1,790		
8.	Clinton	390	401	791		
9.	Jackson	195	318	513		
10.	Eisenhower	410	527	937		
11.	Lincoln	851	755	1,606		
12.	Nixon	417	498	915		
13.	Buchanan	537	611	1,148		

STEP 4. IDENTIFY BEST PERFORMANCES AND PRACTICES

All the preparation described above leads to the heart of the matter—evaluating the outcomes and resources used by each benchmarking partner to identify best performers and improvement opportunities for each organizational unit. There are many possible approaches to evaluating performance, and this guide describes a few that are useful to maintenance organizations. The guide describes a simple approach to assessing performance and then presents a rigorous procedure capable of simultaneously handing outcomes, inputs, and external factors for large numbers of benchmarking units. But first, some important definitions are given:

- **Best performance:** a performance such that there is no other performance that could produce higher customer-oriented outcomes in one or more dimensions of measurement with the same resources and under similar conditions or, equivalently, a performance such that there is no other performance that could produce the same customer-oriented outcomes with fewer resources or under worse conditions. There is no single best performance because it depends on the outcomes, inputs, and levels of hardship factors being examined.
- **Best performer:** a performer that produces a best performance.
- **Frontier of best performances:** the boundary represented by the lines through the points connecting the best performances (see Figure 11).
- **Improvement opportunity:** the gap in one or more measurement dimensions between the frontier connecting best performance and a performance inside (i.e., below) the frontier.
- **Best practice:** a business practice associated with those of a best performance.

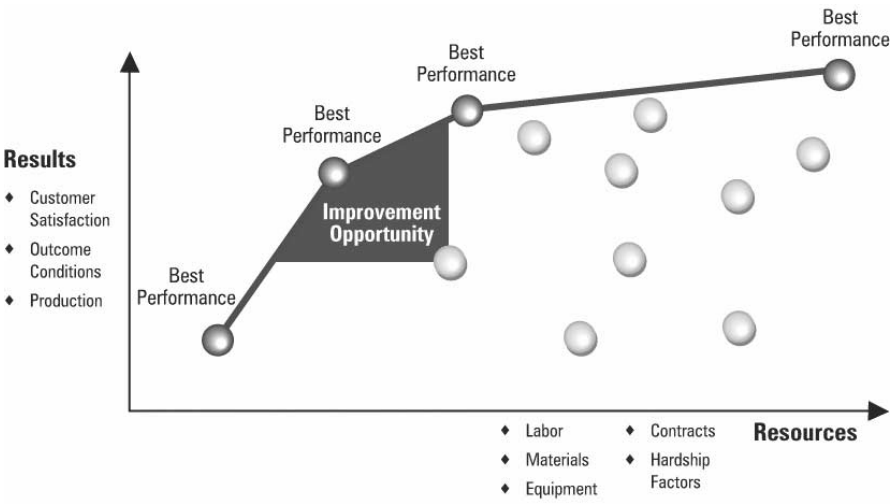


Figure 11. Best Performance

Simplified Benchmarking Procedure

The overriding philosophy of customer-driven benchmarking is that best performers have the highest customer-driven outcomes relative to the resources used while taking into account significant differences in production requirements (outputs) and hardship factors (i.e., factors outside their control).

If you are working with just a few benchmarking units—between 7 and 20—it is possible to use a process of visual inspection to obtain enough insight to identify benchmarking units that are best performers and, therefore, sources of best practices. If you have more than 20 units, visual inspection becomes difficult; if you have benchmarking units numbering higher than 30—for example, in the hundreds—you will need to use mathematical and statistical analysis tools such as the data envelopment analysis discussed below.

Assuming you have just a small number of benchmarking units, you can analyze their benchmarking data by going through the following steps:

1. **Prepare spreadsheet:** present the data in a spreadsheet for each outcome, resource, output, and hardship measure for each benchmarking unit.

2. **Determine value:** examine each measure and establish whether increasing or decreasing values of the measure are better or worse from the standpoint of performance. For example, higher customer satisfaction ratings are better, but higher resource usage is worse.

3. **Plot bar graphs:** plot a bar graph for each measure so that you can see which are the three or four best-performing benchmarking units when judged according to that measure of performance. The best performers will vary depending upon the selection of the measure. You can obtain this information from the spreadsheet, but the bar graphs help you see more clearly which are the best performers for each measure.

4. **Consolidate measures:** attempt to consolidate the measures in the spreadsheet you developed under the first step so there are as few as possible—for example, five. Do not exceed seven because it is well established in psychological research that individuals have difficulty simultaneously weighing more than seven factors at once. When you consolidate measures, try to do it in such a way that the reduced set of measures provides more insight into the performance of the each of the benchmarking units. Also, establish for each new measure whether increasing or decreasing values represent better performance.

5. **Prepare a new spreadsheet:** build a new spreadsheet that shows for the reduced set of measures the outcomes, resource usage, outputs, and hardship factors combined in new ways for each benchmarking unit. Now you can determine the best performers by visual inspection.

6. **Identify best performers:** for each measure, highlight the three or four best performers. You can do this highlighting using the "cell color fill" feature of the spreadsheet software. Now go down the list of benchmarking units and see which ones have the most important cells highlighted or the most cells highlighted. Since you are concerned with customer-driven benchmarking, you want to identify units that do well in serving their customers as reflected by customer survey information, by a technical measure of performance related to the attributes of roads

that customers care about, or both. Furthermore, in the best of all worlds, it is desirable that the organizations with the highest customer-oriented outcomes also have the lowest resource usage, have the highest production, and achieve this regardless of the level of hardship. Usually you will find that no benchmarking unit satisfies all these criteria simultaneously and that several could be identified as best performers and therefore are potential sources of best-practices information.

Let's go through an example using the data that was obtained from the field test used to validate the procedures in this guide.

Prepare Spreadsheet

The first step is to put all the measurement data for each benchmarking unit in a spreadsheet. **Table 4** shows a spreadsheet with groups of outcome, resource, output, and hardship measures.

Table 4. Performance Measures for 12 Districts

	Outcomes		Resources			Output	Hardship		
District ID	Customer Satisfaction Rating	Regain Time	Labor Cost	Equipment Cost	Material Cost	Total Miles Covered for Season	Actual Lane Miles	Number of Snow and Ice Events	Average Daily VMT
A	8.1	12.2	$536,568	$661,478	$899,520	242,060	1,960	95	4,262,352
B	8.1	34.7	$420,765	$437,788	$666,665	214,819	1,809	95	2,315,384
C	7.9	6.4	$422,308	$847,359	$254,430	490,051	3,933	89	3,280,673
D	7.5	6.2	$238,392	$551,179	$669,172	139,991	1,984	72	3,445,186
E	7.5	4.9	$686,286	$862,725	$527,519	141,725	2,072	72	7,908,242
F	7.5	1.09	$580,406	$1,278,141	$632,392	277,679	3,673	63	4,850,026
G	8.2	3.4	$3,426,774	$6,108,419	$3,107,224	398,279	3,751	56	41,892,999
H	7.7	5.6	$519,652	$487,406	$775,949	164,425	1,931	65	4,049,412
I	7.7	5.4	$645,410	$786,760	$477,106	109,395	1,700	65	4,964,813
J	7.7	8.2	$514,695	$851,307	$480,502	251,281	1,931	91	2,914,743
K	7.7	5.7	$457,553	$449,117	$389,594	193,980	1,579	91	2,173,749
L	7.5	43.8	$261,447	$386,734	$203,525	267,262	3,035	74	3,601,587

Determine Value

The second step in the example is to determine whether increasing or decreasing values of each measure is better.

- **Outcomes**
  - Customer satisfaction rating—higher values are better.
  - Regain time (time required to restore bare pavement after a snow storm)—lower values are better.
- **Resources**
  - Labor—lower values are better.
  - Equipment—lower values are better.
  - Material—lower values are better.
- **Output**
  - Total miles covered per season—higher values are better, given a certain amount of snow and ice.
- **Hardship factors**
  - Lane miles—fewer are better.
  - Number of snow and ice events—fewer are better.
  - Average daily vehicle-miles traveled (VMT)—more is better because more customers are being served.

Plot Bar Graphs

By graphing how each benchmarking unit performs with regards to each measure, one can obtain a clear picture of which benchmarking units are the best performers when examined from the standpoint of a single dimension of performance.

The following are a series of bar graphs providing different views of the performance of the benchmarking units depending on the measure of interest.

Figure 12a. Outcome: Customer Satisfaction

Figure 12a shows that District G achieved the highest level of customer satisfaction. Districts A, B, and C also did well in this regard.

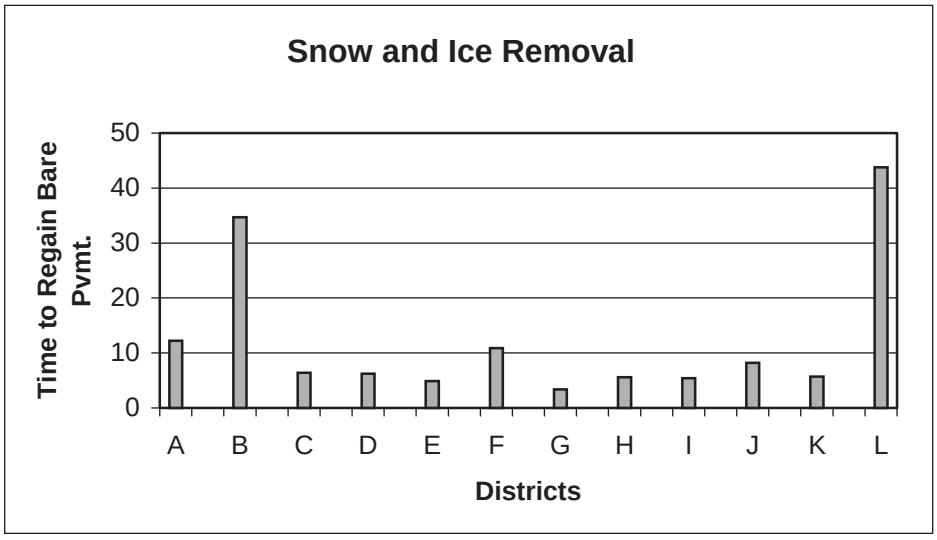


Figure 12b. Outcome: Regain Time

Figure 12b shows that Districts E, G, H, I, and K regained bare pavement in the shortest average time.

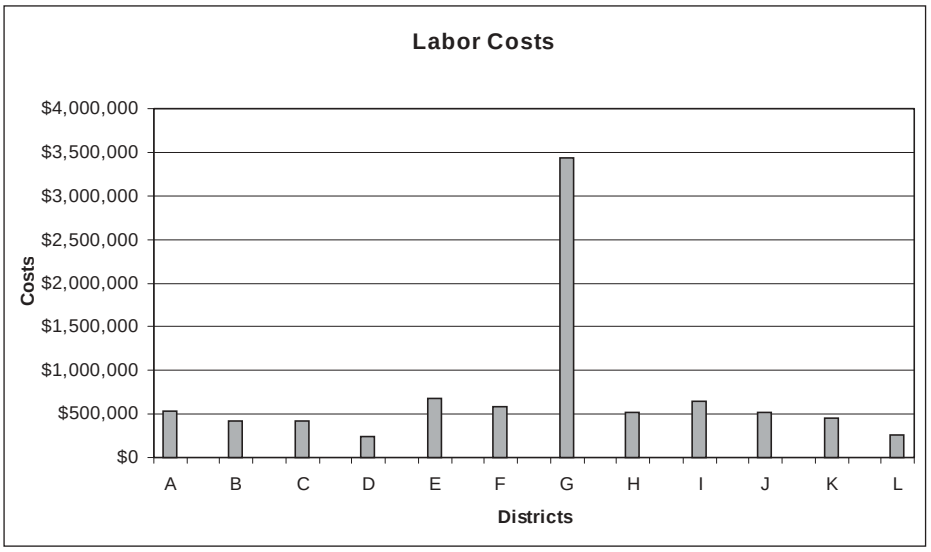


Figure 12c. Resource: Labor

Figure 12c shows each district's labor costs. Districts with the lowest costs were D, L, B, and C. District G is an aberration—its labor costs are many times the costs of the other districts.

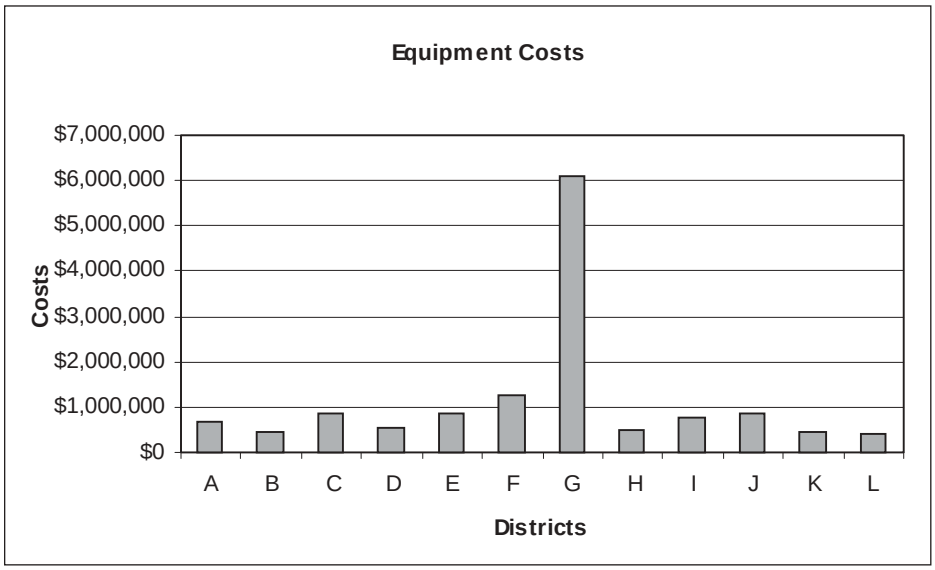


Figure 12d. Resource: Equipment

Figure 12d shows the equipment costs for each district. Districts with the lowest equipment costs were B, K, L, H, and D. Again District G is an aberration—its equipment costs are many times the costs of the other districts.

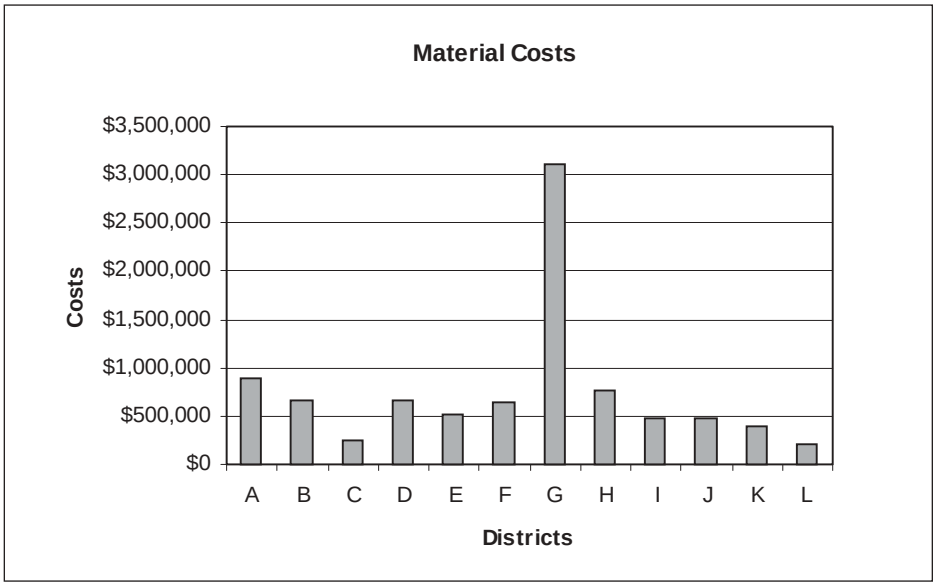


Figure 12e. Resource: Material Costs

Figure 12e shows that districts C, L, and K have the lowest material costs.

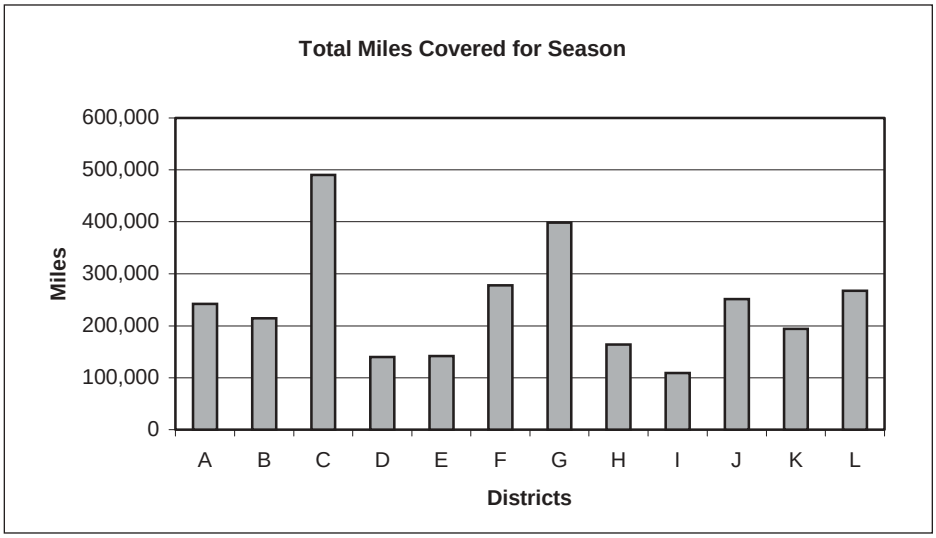


Figure 12f. Output: Total Miles Covered for Season

Figure 12f shows that Districts C, G, and F accomplished the most snow and ice control during the year measured in terms of miles. "Total Miles Covered for the Season" equals the total lane miles times the average percent of lane miles covered per storm event, which is then multiplied times the number of events or

storms for the season. Some storms may require going over all the roads numerous times.

Figure 12g. Hardship: Actual Lane Miles

Figure 12g presents the number of lane miles in each district that require attention when ice or snow accumulates. Districts C, G, and F have the most lane miles to address.

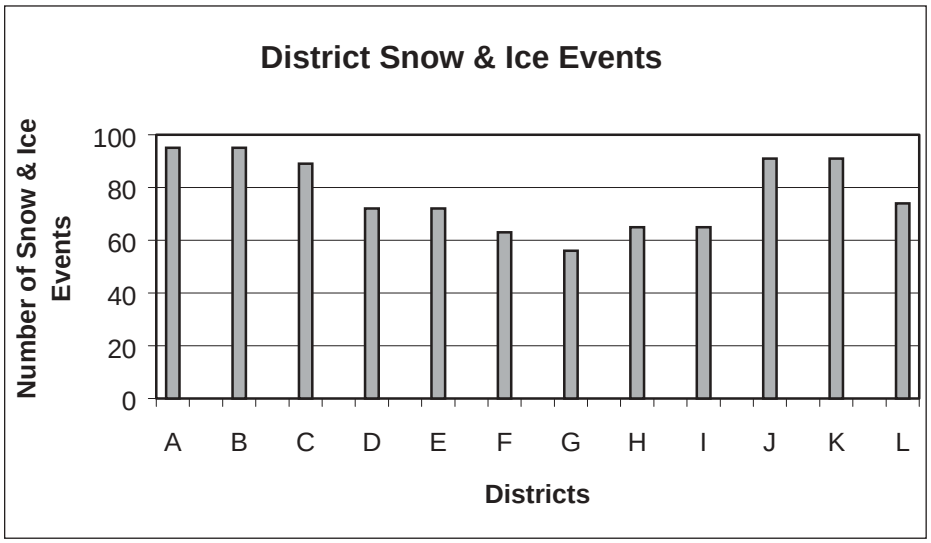


Figure 12h. Hardship Factor: Number of Snow and Ice Events

Figure 12h shows the number of snow and ice events that occurred in each district. The more events, the greater the challenge, everything else being equal. Districts A, B, C, J, and K experienced the most snow and ice events.

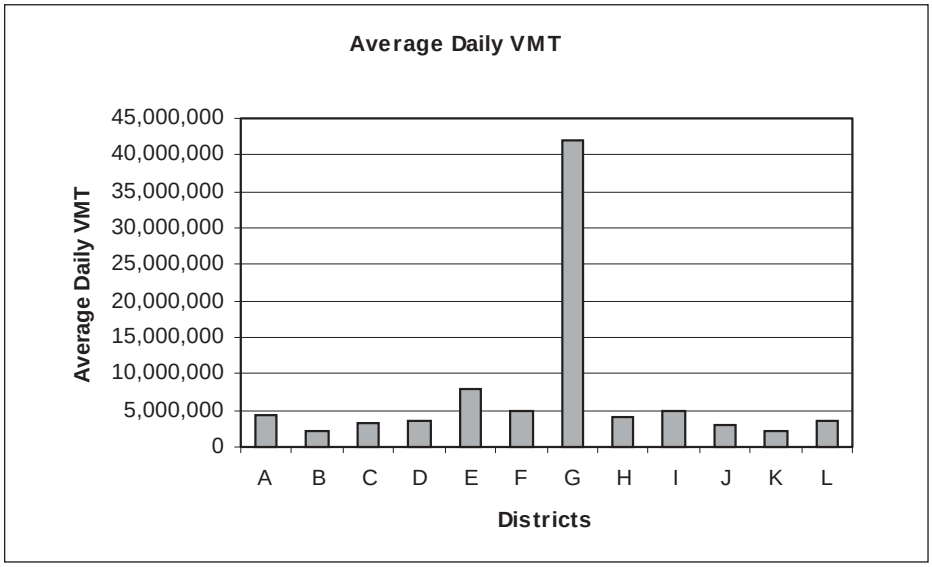


Figure 12i. Hardship Factor: Average Daily VMT

Figure 12i presents the level of traffic in each district expressed in terms of average daily VMT. District G has a far greater challenge in serving traffic and operating in traffic than does any other district. District E, A, and I are faced with more daily VMT than are the remaining districts.

These bar graphs provide some clarity regarding how well each district performs with regard to each variable and the hardships each faces in delivering winter services to its customers.

Consolidate Measures

The original table (**Table 5**) presents nine measures, which are too many to absorb and to use to identify best performers. By judiciously combining these measures, it is possible to obtain a clear picture regarding how well each district is able to serve its customers while managing its resources effectively and contending with hardship factors.

The original set of measures can be reduced to five that are useful for identifying best performers and searching for best practices:

1. **Customer satisfaction rating** (outcome measure);
2. **Regain time** (outcome measure);

3. **Daily VMT per total dollar expended** (combination of hardship and resource measures with emphasis on customers served per dollar of expenditure);
4. **Cost per lane mile** (combination of resource and hardship measure that address the cost efficiency in serving a lane mile of highway); and
5. **Number of snow and ice events** (hardship factor).

How was the reduced set of measures determined? A straightforward step is to combine the three cost measures (labor, equipment, and material) into "total resource cost." Furthermore, by dividing the total resource cost in a district by the number of lane miles in the district, a new measure is obtained—cost/lane mile—that simplifies the cost comparison between districts. One more step can be taken to reduce the number of measures: divide the average daily VMT by the total resource cost. This allows you to see how many miles are driven for each dollar spent in this area of maintenance; the more miles driven per dollar spent the better. This new measure eliminates the need for the single measure of average daily VMT.

As a result of these actions, four measures were eliminated and the total number of measures to view was reduced from nine to five, thereby simplifying the task of identifying those that perform the best.

Figures 13 and **14** are the bar graphs for the two new performance measures.

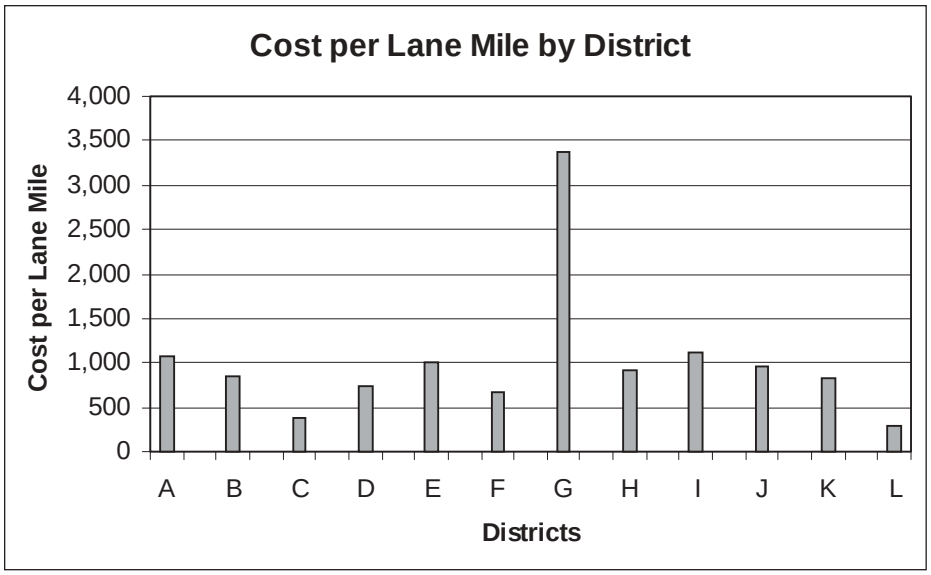


Figure 13. Cost per Lane Mile by District

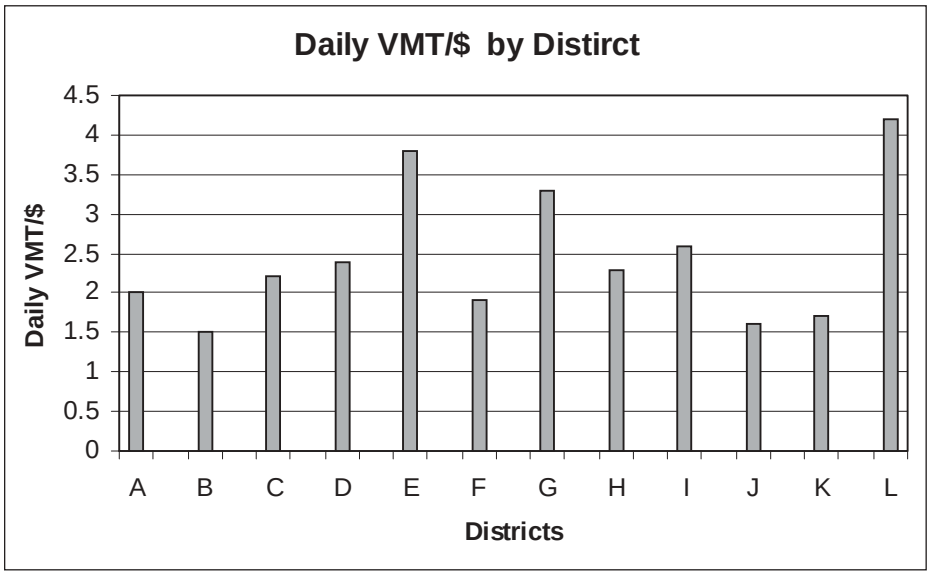


Figure 14. Daily VMT/$ by District

Table 5 presents a summary table of the new set of five performance measures and the values for each district. Note that visual inspection of the data can begin to provide some insight regarding which districts are the better performers, but this is difficult to do.

Table 5. Comparison of District Performance*

District	Customer Satisfaction Rating	Regain Time All Service Levels (in hours)	Daily VMT/$	Cost/Lane Mile in $	Number of Snow & Ice Events
A	**8.1**	12.2	2	1,070	**95**
B	**8.1**	34.7	1.5	843	**95**
C	**7.9**	6.4	2.2	**388**	**89**
D	7.5	6.2	2.4	**735**	72
E	7.5	**4.9**	**3.8**	1,002	72
F	7.5	10.9	1.9	**678**	63
G	**8.2**	**3.4**	**3.3**	3,370	56
H	7.7	**5.6**	2.3	923	65
I	7.7	**5.4**	**2.6**	1,123	65
J	7.7	8.2	1.6	956	**91**
K	7.7	5.7	1.7	821	**91**
L	7.5	43.8	**4.2**	**281**	74

***Tables 5 and 6** do not carry forward the number of digits after the calculations were performed. Numbers had to be expressed in different orders of magnitude to simplify calculations and facilitate interpretation. It is sufficient to provide the results of calculations for purposes of ranking.

Much more clarity can be achieved by highlighting the districts that are the best performers along each dimension of performance (see **Figures 13** and **14**). The next table shows the best-performing districts for each measure screened in gray.

It is a relatively trivial exercise to use visual inspection to see whether there are any districts that stand out clearly as best performers across all or most of the performance measures. In this example, it can be argued that District C is the best performer. It is able to achieve a high customer satisfaction score (7.9) at the second lowest cost ($388) per lane mile and while facing a relatively high number of snow and ice events (89).

District G does quite well also. It does the best job of any district in producing high customer-oriented outcomes. It has the highest customer satisfaction rating (8.2) and the lowest regain time (3.4 hours). While District G has the highest cost per lane mile ($3,370) and thus spends more on labor, equipment, and material per lane mile than any other district, the number of customers

served daily (VMT) per dollar expended is the third highest of any district (3.3).

Depending upon your perspective, you could argue that Districts A and B do fairly well. They both have the highest customer satisfaction score (8.1) and contend with the most snow and ice events (95). The reason for the high regain times might be attributed to various factors, including low customer expectations for restoration of bare pavement.

Further insight into the relative performance of the districts can be achieved by dividing the districts into various groups and by then selecting the best performers from each group (see **Table 6**). For example, one could break the districts into two groups, one facing more than a certain number of snow and ice events and the other facing fewer.

Table 6. Comparison of District Performance with Better Performances Highlighted*

District	Customer Satisfaction Rating	Regain Time All Service Levels (in hours)	Daily VMT/$	Cost/Lane Mile (in $)	Number of Snow & Ice Events
A	**8.1**	12.2	2	1,070	**95**
B	**8.1**	34.7	1.5	843	**95**
C	**7.9**	6.4	2.2	**388**	**89**
D	7.5	6.2	2.4	**735**	72
E	7.5	**4.9**	**3.8**	1,002	72
F	7.5	10.9	1.9	**678**	63
G	**8.2**	**3.4**	**3.3**	3,370	56
H	7.7	**5.6**	2.3	923	65
I	7.7	**5.4**	**2.6**	1,123	65
J	7.7	8.2	1.6	956	**91**
K	7.7	5.7	1.7	821	**91**
L	7.5	43.8	**4.2**	**281**	74

***Tables 5 and 6** do not carry forward the number of digits after the calculations were performed. Numbers had to be expressed in different orders of magnitude to simplify calculations and facilitate interpretation. It is sufficient to provide the results of calculations for purposes of ranking.

Note that by using visual inspection, you avoid developing weights for each factor and an overall index of performance. In this guide the project team has encouraged the use of analytic techniques that do not involve the development of a composite performance measure. There are several reasons why. First, a composite index disguises the factors contributing to performance, so analysts and maintenance managers lose substantial insight in working with the numbers. Second, which benchmarking unit is the best performer depends upon the combination of measures under consideration and the emphasis given to each measure. In the visual inspection process described, it is sufficient for the analyst to peruse the data and weigh in his or her mind which are the best performers under various assumptions.

This task becomes exceeding complex if more than a few benchmarking units are involved. Data envelopment analysis is a mathematical technique for performing similar analysis—without giving weights to the measures—that can be used to identify best performers when there is a large number of benchmarking units.

Data Envelopment Analysis

Introduction to Production Analysis

Production is a process whereby inputs (labor, buildings, plants, equipment, and raw materials) are converted into outputs (goods and services), given the existing technology.

Consider highway maintenance. The production process is characterized by decision-making units that employ labor, equipment, and material to provide maintenance activities (e.g., sign repair and snow and ice control) to achieve desirable outcomes (e.g., customer satisfaction, high-quality infrastructure, low accident rates, and minimal travel or delay time).

Business firms and other decision-making units must make important decisions that are either directly or indirectly related to the production. For example,

- How should resources be allocated to specific units?
- Should key processes be outsourced?

- Are decisions-making units providing services with the fewest resources necessary, or are they spending above minimum costs?

These and other key issues can be analyzed by understanding concepts of production economics. First, define technical efficiency similar to Koopmans (1951): a decision-making unit (DMU) is technically efficient if it is technologically impossible to increase any outcome, reduce any input, or both without simultaneously reducing another outcome, increasing one other input, or both. Second, define the production frontier as the maximum possible outcomes that are obtainable for all input levels. As a result, note that a technically efficient DMU is operating along the production frontier. Furthermore, performance of individual DMUs is evaluated relative to the production frontier. **Figure 15** provides an example production frontier. For simplicity, assume that there is only one outcome (customer satisfaction) and one input (labor). This assumption is made for simplicity only: it allows the illustration of the concepts introduced previously.

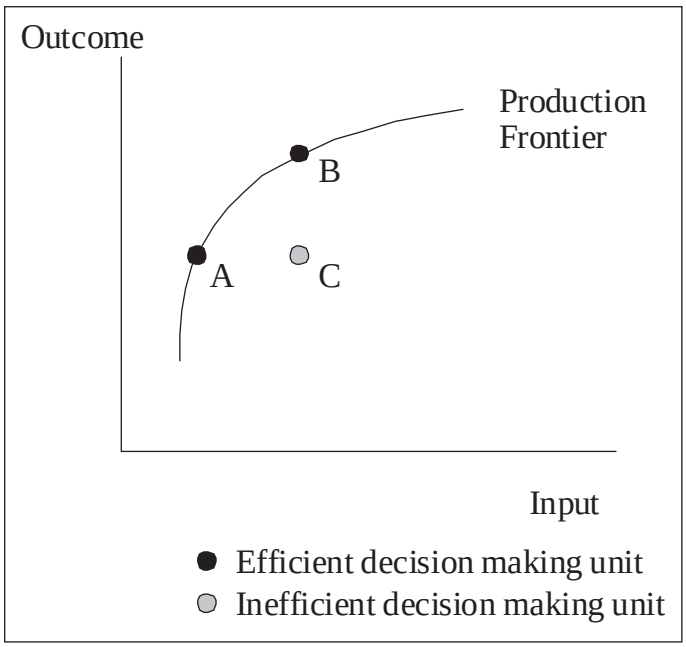


Figure 15. Example Production Frontier

A number of important points are illustrated in **Figure 15.** First, the production frontier allows a distinction between attainable and unattainable production combinations defined by the available technology. The production possibilities A through C

are on or below the production frontier, which is consistent with the "maximum outcomes" that are possible. Points above the frontier are not feasible. Second, DMUs A and B are providing the maximum outcomes possible given their resources and are, therefore, technically efficient. These firms would be ideal candidates to serve as benchmarks for DMUs looking to improve performance. Third, the intuitive notion that increased inputs will lead to increased outcomes along a frontier can be observed by comparing DMUs A and B. While both DMU A and B are efficient, B achieves a higher outcome level because it employs more inputs. Hence, the frontier provides a conceptual understanding of scale economies. Finally, DMU C is not efficient because it is not on the frontier. DMU C could decrease its input and still provide the same outcome by operating like DMU A. Alternatively, DMU C can increase its outcome without any additional input by operating like DMU B.

One common measure of performance, technical efficiency, can be measured as

$$TE = (\text{efficient input level})/(\text{observed input level}).$$

Efficiency is measured by comparing minimum resources consistent with observed production with observed input usage. This is highlighted in **Figure 16,** which shows the input and output levels of the DMUs from **Figure 15.** DMU A—represented by the point (4, 10)—uses 4 units of input to produce an outcome of 10. DMU B (9, 15) uses 9 units of input to provide an outcome of 15. Finally, DMU C (9, 10) uses 9 units of input to provide an outcome of 10.

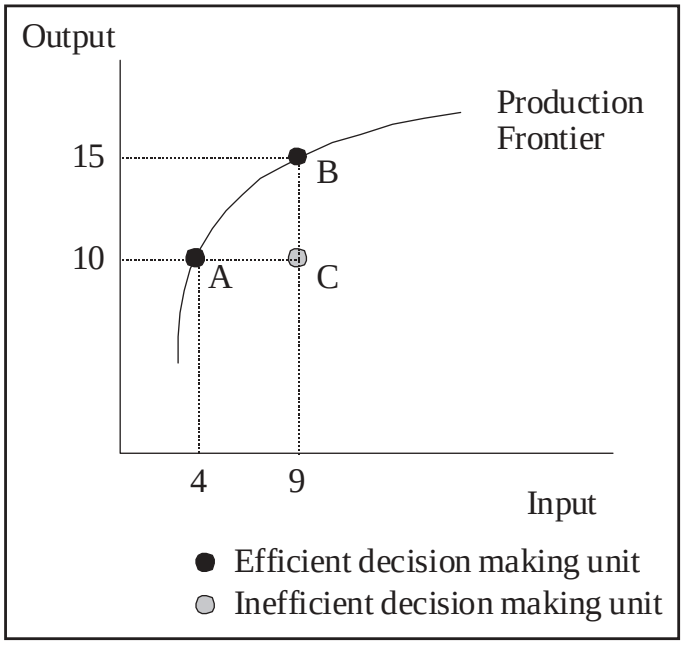


Figure 16. DMU Efficiency

Note that the minimum level of resources consistent with providing an outcome of 10 units is 4 units of input (i.e., DMU A). Also the minimum level of resources that is sufficient to produce an outcome of 15 is 9 units (i.e., DMU B). DMUs A and B are on the frontier and are efficient according to the definition provided previously. Now consider DMU C, which is not on the frontier. The measure of technical efficiency for DMU C is

$$TE_C = 4/9 = 0.4444.$$

In words, DMU C, which provides an outcome of 10, uses 9 units of the input. However, DMU C could have provided the same outcome with only 4 units of input, which implies that DMU C is only 44.44 percent efficient.

Technical efficiency can also be defined according to an output orientation:

$$TE = \text{(observed output level)}/\text{(efficient output level)}.$$

In this case, efficiency measures the degree to which a DMU's observed outcome level falls below the frontier output level given the resources used. Referring back to **Figure 16,** by comparing DMU C with DMU B, it can be seen that DMU C could have provided an outcome level of 15 given the resource

usage. Since DMU C only provided an outcome of 10, the output-oriented measure of technical efficiency for DMU C is

$$TE_C = 10/15 = 0.6667.$$

The output-oriented measure implies that DMU C is 66.67 percent efficient. Note that the input-oriented and output-oriented measures are not equal. Also note that DMU C is benchmarked against DMU A in the input-oriented model and against DMU B in the output-oriented model. This suggests that benchmarking capabilities for performance evaluation are arbitrary and depend on the model orientation.

Example 1 provides an algebraic analysis of production and efficiency.

Example 1: Production and Efficiency

For convenience, the project team chose a highway maintenance example where one outcome, customer satisfaction (CS), is provided. Labor (L) is assumed to be the only input. Further assume that the production frontier can be represented algebraically by

$$CS = 10L.$$

A DMU using 25 units of labor (i.e., $L = 25$) should be able to provide an outcome $CS = 10(25) = 250$. Likewise, a DMU using 20 units of labor should be able to provide an outcome of 200.

Now consider a DMU that uses 25 units of labor and only provides $CS = 200$. This DMU is technically inefficient: it should have provided a higher outcome given the labor usage; alternatively, it could have provided the same level of customer satisfaction with less labor. Using technical efficiency as the measure to evaluate performance, we find that the technical efficiency of this DMU is

$$(20/25)(100) = 80 \text{ percent (input orientation) or}$$

$$(200/250)(100) = 80 \text{ percent (output orientation).}$$

This DMU is only 80 percent efficient and, hence, could be targeted for performance gains. This DMU could reduce expenditures by eliminating excess labor usage.

This example serves as a conceptual basis for the definition and measurement of efficiency. Measurement is based on prior

knowledge of the production function $Y = 10X$, which is, in general, problematic for real-world applications. Recent advances in economics and operations research, however, do not require this knowledge. In particular, the technique of DEA measures relative performance based solely on the observed inputs and outcomes of DMU.

Uncontrollable Inputs

Production analysis in the public sector often ignores hardship factors. These factors are the uncontrollable factors that transform inputs into desirable outcomes. The relationship is shown in **Figure 17,** where the provision of outcome Y is determined by the levels of input X (i.e., resource X) and the uncontrollable input Z. Here, three technically efficient DMUs—A, B, and C—are shown. It is assumed that DMUs A and C face the same environment because they both have the same level of the uncontrollable input: $Z = Z_0$. Given the same level of hardship factors, note that DMUs A and C are on the same frontier. DMU C produces more output than DMU A because it uses more of input X.

Now consider DMU B, which faces a more favorable external environment than DMUs A and C. Here, DMU B faces $Z = Z_1$. To see the impact that the uncontrollable factors have on production, note that DMU B is able to provide a higher outcome than DMU A even though they both use the same amount of input X (i.e., resource X). Also note that the impact that the environment has on production can be gauged by comparing Y_C with Y_A. Also, DMUs B and C provide the same level of outcome even though both are efficient and DMU C uses more of the resource. Now directly gauge the harshness of the environment by determining the extra resources required to provide an equivalent outcome in a harsher environment. Note that this could be used to measure costs of functioning within different levels of hardship factors.

The discussion about uncontrollable inputs is especially important for highway maintenance. In particular, weather, terrain, road structure, traffic volumes, and even the average distance from the garage to the job site will have an impact on the conversion of discretionary inputs into outcomes. Typically, uncontrollable inputs can be identified as cost factors that are not explicitly paid for.

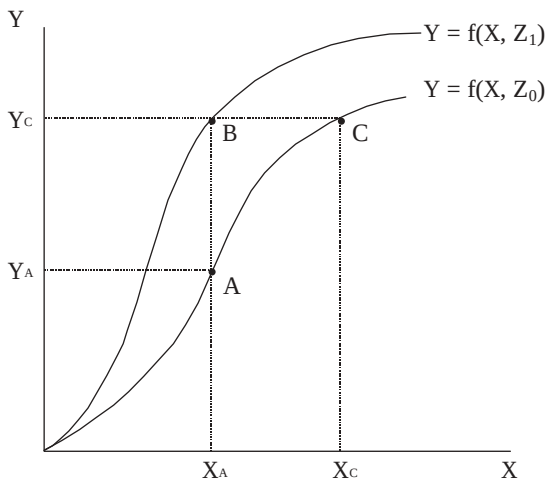


Figure 17. Uncontrollable Inputs and Production

This guide presents some basic principles of production and analysis. In the next section, the method known as Data Envelopment Analysis (DEA) is described. DEA is an applied approach to production analysis that provides the useful information described previously.

Key Concepts of Data Envelopment Analysis

DEA is a mathematical programming approach for evaluating the performance of DMU. This applied approach, developed in the late 1970s, builds on the economic theory of production by measuring performance relative to an empirically identified frontier. The frontier is constructed as the outer envelope of data points (i.e., the observed producers that are achieving the most output or highest outcomes for a given level of resources). Recent advances in the technique allow measurement of scale economies useful for resource reallocation, cost efficiency (by comparing expenditures relative to the outputs that are produced), and environmental harshness. In order to develop an understanding at an introductory level, DEA will be presented using an example. Information that can be obtained from DEA—including performance evaluation, benchmarking, economies of scale, cost efficiency, and environmental harshness—can be found in the literature on DEA listed in the references at the end of this guide.

The DEA approach has become popular in evaluating the technical efficiency of local governmental authorities in the public sector because it easily handles the multiple outcome characteristic of public-sector production; is non-parametric (i.e., does not require the estimation of parameters); and does not require input price data, which is often difficult to measure accurately in the public sector. Each DMU is evaluated relative to the frontier. Unlike Example 1, DEA does not require knowledge about the production function. Rather, information about the production process is inferred from the observed data.

In addition to the performance measure of each DMU, DEA provides DMUs with useful benchmarks that can serve as guides to better performance. In particular, the frontier producers can serve as role models for continuous improvement. Further, identification of efficient and inefficient DMUs allows further qualitative and statistical analysis that can help identify sources of poor performance. In addition, proper identification of scale economies (i.e., a disproportionate increase or decrease in outcomes relative to change in inputs) would allow reallocation of resources to improve overall outcomes collectively. Finally, recent advances in DEA allow construction of an environmental harshness index that would prove useful for overcoming adverse conditions due to noncontrollable inputs faced by the DMUs. Example 2 illustrates DEA in the context of highway maintenance.

Example 2: DEA

This example problem provides a relatively nontechnical discussion of the development of production frontiers using DEA, which handles multiple outputs and inputs. For this example, a basic understanding of algebra and geometry is assumed. Note that DEA models using linear programming can be solved using various software packages. It is also assumed that seven DMUs (A through G) provide one outcome—customer service—using one variable input—labor. (The observed production data are shown in **Table 7.**)

Table 7. Observed Production Data

Example 2 Data		
DMU	*L*	*CS*
A	4	2
B	6	8
C	10.5	14
D	15	16
E	18	16
F	10.5	8
G	8	5
This data will be used throughout the example.		

The technique of DEA and the measurement of efficiency will be discussed in three steps. Note that the steps cannot be applied to all problems, particularly because graphs will be used. This is the only reason that a simple production framework of one input and one outcome is assumed.

Extension to multiple outcomes and inputs is straight forward, but requires an understanding of more complex economics and mathematics.

Step One: Plotting the Data for Visual Representation

In the first step, the data are plotted. This will help visualize efficiency measurement and frontier construction. Following standard economics, labor (*L*) is represented on the horizontal axis and the outcome (*CS Y*) will be measured on the vertical axis.

Each DMU can be represented by the ordered pair (*x, y*), which shows the input usage and outcome provision of each DMU. For example, DMU A is represented by (4, 2), implying that 4 units of labor are used to provide a customer satisfaction level of 2 units.

The data plot is shown in **Figure 18.**

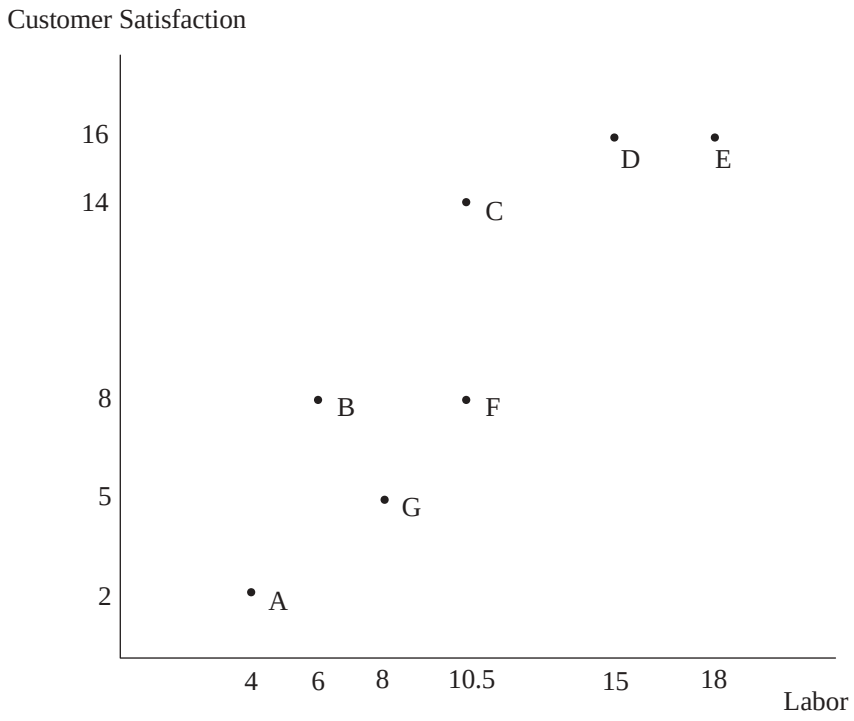


Figure 18. Data Plot

Step Two: Construction of the Frontier

In DEA, the production frontier is constructed with piecewise linear segments connecting the outermost data points subject to two conditions:

1. All DMUs are on or below the frontier; and
2. Along the frontier, an increase in inputs cannot lead to a decrease in the provision of outcomes.

The production frontier is shown in **Figure 19.**

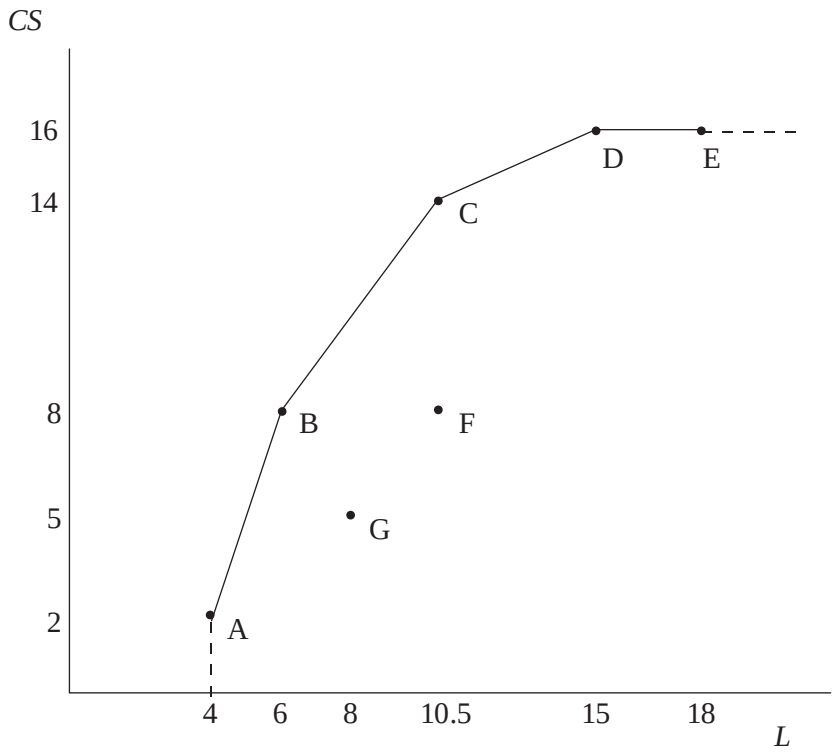


Figure 19. Example 2 Production Frontier

In this case, the frontier consists of line segments AB, BC, CD, and DE. DMUs A through E are on the frontier. Given construction of the frontier, one can evaluate the performance of the DMUs.

Step Three: Measuring Input-Oriented Technical Efficiency

For this example, the graph of the production frontier can serve as the basis for performance measurement. Recall that input-oriented models seek to find the minimum level of inputs necessary to provide the observed level of outcome. The minimum level of inputs necessary can be inferred from the production frontier. The graph of the production frontier is reproduced in **Figure 20.** The graph is modified, however, to show the projection to the frontier via the input-oriented DEA model.

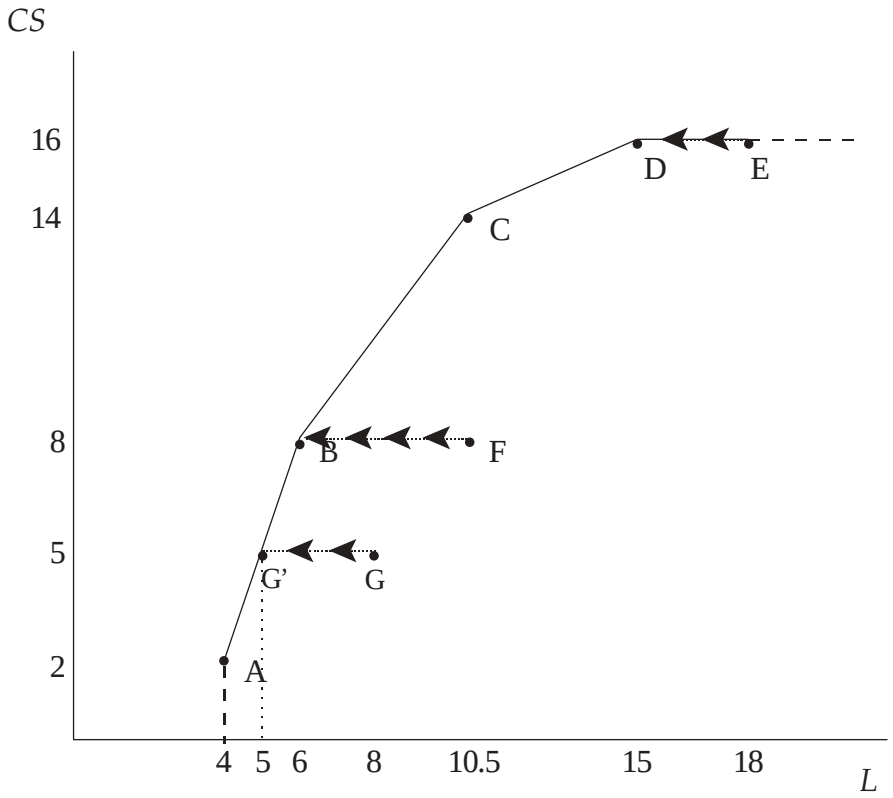


Figure 20. DEA Input-Oriented Projection

Each DMU is projected to the frontier by holding its level of customer satisfaction constant and contracting the level of the labor as far as possible. DMUs A, B, C, and D are efficient because it is not possible to contract their inputs without realizing a loss in customer satisfaction. DMUs E, F, and G, however, are technically inefficient because they could reduce their labor usage and still provide the same level of customer satisfaction. Consider DMU F. It is currently using 10.5 units of

labor to provide a customer satisfaction rating of 8. This is clearly inefficient because DMU B also provides a customer satisfaction rating of 8 while using only 6 units of labor. Consequently, the input-oriented measure of efficiency (TE_F) for DMU F is

$$TE_F = 6/10.5 = 0.5714.$$

Note that the numerator is the minimum required labor consistent with the observed customer satisfaction. It is also the observed level of input for DMU B (which is on the frontier). For this reason, DEA has useful benchmarking capabilities. Also, one could try to find reasons for the inefficiency of DMU F by comparing F with B in a secondary analysis. This would lead to causes of inefficiency.

DMU E is also inefficient because it is provides a satisfaction rating of 16 using 18 units of labor. It would be possible, however, to produce this level of output using 15 units of labor. In other words, DMU E could replicate DMU D. Therefore, the input-oriented efficiency measure (TE_E) for DMU E is

$$TE_E = 15/18 = 0.8333.$$

Finally, consider DMU G, which is using 8 units of labor while achieving a customer satisfaction of 5. As shown in the figure, DMU G is not on the frontier; it could provide the same outcome level using less labor. This case, however, is not as straightforward as the previous two. After projecting DMU G onto the frontier, note that the referent frontier point G′ is not an actual DMU. Instead, it is a convex combination of DMUs A and B. Since the outcome of this referent point is known ($CS = 5$ is the same level that G produces), solve for the associated labor for this referent point. Note that the slope of AB is

$$\Delta CS/\Delta L = (8–2)/(6–4) = 3.$$

Since the referent point G′ is on this line, line AG′ must have the same slope; therefore,

$$3 = (5–2)/(x–4).$$

Solving for x results in $x = 5$. Thus G′ ≡ (5, 5). Note that the convex combination G′ is obtained from an equal weighting of A and B (because it is the midpoint of line AB). The technical efficiency of DMU G is

$$TE_G = (5/8)\ 100 = 62.50\%.$$

Using DEA in Customer-Driven Benchmarking of Maintenance

To apply DEA to customer-driven benchmarking of road maintenance, you will need specialized software. Commercially available software packages and proprietary benchmarking services, including software, provide suitable analytical tools.

Applying DEA requires both technical expertise and practical experience in order to identify best performances, evaluate improvement opportunities, and uncover performers likely to have practices most pertinent to a specific situation. Among the specific reasons you will require expertise in applying DEA are the following:

- **To address situations where there is ambiguity as to whether a factor is an input or an output.** For example, regarding lead paint removal of steel structures, it is not clear whether pollution concentrations inside and outside a containment structure should be treated as an outcome or an input. Impact on health and safety, as reflected in airborne lead concentrations, is clearly an outcome—are as lead concentrations in soil and water. However, air and water can also be considered inputs to the lead paint–removal process.

- **To take into account the presence of economies or diseconomies of scale.** For some production processes, a proportionate increase in inputs results in a greater-than-proportionate increase in outcomes. Sometimes the reverse is true: a proportionate increase in inputs results in a less-than-proportionate increase in outcomes. Special analytic techniques are required to take into account economies and diseconomies of scale in DEA.

- **To take outputs into account properly.** Although customer-oriented outcomes are the focus of the benchmarking method discussed herein, the ability to identify best performers relevant to a particular organization or unit is enhanced by properly taking outputs into account.

Prototype Decision Support System of the Minnesota DOT

There are additional methods for customer-oriented benchmarking of maintenance activities that focus on the value added to customers, measured in monetary terms. The project team does not recommend that agencies just beginning to benchmark pursue such a process. However, as customer-oriented benchmarking evolves, it is likely to move in the direction pioneered by MnDOT. Appendix D contains a brief overview of MnDOT's prototype decision support system that was developed for purposes of customer-driven benchmarking of maintenance activities. The ultimate goal of this prototype was to allocate resources in accordance with the increase in value to customers (measured in monetary terms) due to an increase in input levels (also measured in monetary terms).

Identifying Best Performances and Best Practices

This section addresses the primary reason for benchmarking: to identify practices that will help to improve performance. The process of benchmarking is based on the premise that organizational units with the best performances have business practices that are different from those of most other organizational units. Practices may include the types of resources, the mix of resources, the procedures for implementing resources, the timing or sequencing of applying the resources, and/or the quality of the execution.

Identifying Peers Who Are Best Performers

To compare maintenance performance of specific products, services, or maintenance activities, numerous organizational units will be cooperating and sharing performance information. Actually, the more organizational units that are cooperating and sharing, the greater the opportunity for any one organizational unit to find practices of other units that will help improve its own performance.

The evaluation of the performances of all the units will indicate that many units have, relatively speaking, best performances. This generally means that given their conditions, level of resources, or both, the units are producing the highest customer-oriented outcomes.

When using DEA to evaluate and compare performances, many units may be on the "frontier" of best performances. The frontier may include 10 to 40 percent of the total number of units. If there are 50 organizational units comparing performances, then as many as 20 units could be determined to be best performers. Practically, 20 is too many units with which to compare processes or business procedures. To start comparing practices, it is best to select a small number of organizations, approximately 2 to 5 of the best performing units. The issue is then for each organizational unit to determine which of the best performing units are best for comparing practices.

A simple method usually works well to begin selecting peers with whom to compare practices. For maintenance organizations, this means selecting the peers with best performances who also meet one of the following criteria:

- Represent the largest improvement opportunities,
- Operate in environments that are most similar,
- Have a similar amount or type of roadway feature inventory, or
- Have a similar total resource budget.

The initial selection is not necessarily a final decision. Additional units or alternative units may be selected at any time.

Begin peer comparisons with those products, services, or maintenance areas that are most important to your customers and that have the greatest opportunity to impact customer-oriented outcomes.

Select one product, service, or maintenance area at a time to begin to develop a set of peers whose "best" practices you may investigate. Note that the peer set will vary as the product, service, or maintenance area changes.

For each outcome or resource measure, given a particular environmental setting, there will be a gap between the best performer and the others. If you are not a best performer, this gap is your improvement opportunity. The gap will represent the potential increase in the outcome you can achieve relative to a best performer.

After you have investigated all outcome measures, turn your attention to the resources and compare performances for labor, equipment materials, costs, and so forth. If you are looking at a type of resource usage, the improvement opportunity and corresponding gap will represent the potential savings in the resource you can achieve relative to the best performer.

To obtain your initial set of peers for purposes of investigating best practices, select the organizational units with the greatest improvement opportunities based on the performance evaluations of all of the products, services, or maintenance areas that you and your partners have evaluated. You can refine your initial set of peers by screening based on other criteria listed above—for example, by identifying which of the peer set have inventory quantity and budget levels similar to yours.

Geographical proximity and the same political structure are not the best reasons for picking peers. Maintenance organizations typically already know the most about others that are geographically close and that operate under the same type of political jurisdiction or administrative unit. Benchmarking is an opportunity to reach out beyond the typical regional or state relationships and to learn what others do. However, the project team is not suggesting that just because a unit is in geographical proximity, it should be eliminated from the peer group.

Also, the intent should not be to eliminate from the comparison peer group all organizational units that are different from yours in size and operating characteristics. Human nature too easily allows one to justify why an organizational unit cannot be compared with your own. Instead, you want to establish why units that have better performance can be a basis for comparison.

Identifying Best Practices

Once you have settled on a peer set for each product, service, or maintenance area, then you are ready to investigate best practices of the best performers.

Investigation of best practices is a critical part of benchmarking. A number of different approaches have been found to be effective; frequently, benchmarking involves all of them. Examples are as follows:

1. **Background research:** often there is published information available that illuminates the practices of the best

performers. This published information includes research reports, journal articles, conference proceedings, procedural manuals, specifications, regulations, Internet sources, and information from equipment and material vendors. Specific practices of organizations that are known to be top performers, both in the public and private sectors, often have been published and can be found among these sources.

2. **Questionnaires:** many benchmarking efforts involve the development of a questionnaire that is used to explore in detail the partners' practices. To some extent, the worksheets for recording measurements of outcomes, resources, hardship factors, outputs, and other information serve the function of a questionnaire. However, **you should also develop a detailed set of supplementary questions whose answers will shed light on the nature of the best practices of the best performers you wish to investigate. As soon as you know what business processes will be the focus of the best practice investigation, you should prepare the questionnaire and share it with the partners with whom you plan to exchange information.** The questionnaire should address the following types of issues:

   - **Work methods—**including the type of labor (skills and training levels); equipment (type, age, reliability); and materials (type, methods of application) and how these are combined in productive activity.
   - **Nature and impact of related processes on outcomes and resource usage—**for example, setting up and removing work zones, material and equipment requisition, scheduling, daily work reporting, timesheet reporting, budgeting, and resource allocation.
   - **Policies, procedures, or operating constraints—**including regulatory requirements, specifications, or other policies and procedures that affect work methods and results. Are there operating circumstances that require or limit the practices?
   - **Roles and responsibilities of different levels of management—**how do they affect outcomes and resource usage?

- **Hardship factors**—including weather, terrain, and population density—that are favorable or unfavorable for the practices.
- **Cost structures**—the costs associated with each resource needed for the practice(s).
- **Difficulties in transferring the practice**—including major investments in equipment, material, and skill training.
- **Critical success factors**—that is, the most important procedures or requirements to achieve successful implementation of the practices, including customer requirements.

Figure 21 is an example of part of a questionnaire completed by one of the participants in the field test used to validate the procedures of this guide.

Pavement Smoothness Survey

This survey is intended to elicit the design, planning, and construction/maintenance practices of agencies that lead to the pavement smoothness conditions of both fixed and flexible pavements. The environment is considered a major contributing factor to the smoothness or roughness of pavement, although it is out of the control of the agencies.

Please answer each of the following questions regarding your (or each) benchmarking unit in order to aid others in understanding differences in a unit's practices from their own practices.

Environment

1. What is the freeze/thaw index for your benchmarking unit? Don't have info
2. What is the annual amount of precipitation in inches? 24.6"
3. What is the annual amount of snow fall in inches? 11.8" liquid equiv
4. What is the average daily truck traffic on roads in the benchmark unit? 898
5. What is the general sub grade material? Plastic sandy loam

Policies & Planning

6. What is the method of assessing the surface conditions (i.e. drive-by, indexing of conditions)? IRI and surface rating (counting deficients)
7. What are the most relevant policies, general philosophies or guidelines that characterize pavement preservation (concrete and/or bituminous) for the benchmarking unit?
   We use the pavement management system as a tool to prioritize projects for preservation and also preventive maintenance
8. Which functional unit of the agency is accountable to the public for pavement smoothness? Maintenance and the District Materials Engineer

Concrete Pavement

From the Design & Specification Function

9. Identify the following on average, or for most of the concrete roads (a-e for inventory, f-n recent or current specs) of the benchmarking unit:
   a. The general age (range) of most of the concrete roadway 3-44 ave 11
   b. The base type, thickness & quality? 3" aggregate base
   c. The vertical alignment Used design standards in place at the time
   d. The horizontal alignment " " "
   e. The grade " " "
   f. The concrete mix specified 3A21 3900 psi Comp Strength
   g. The water-cement ratio & air content .46 before 1995 ; .40 after 1995
   h. The unit weight 143.5 5% ; 6.5%
   i. The slump 1½"
   j. Concrete strength 4500 psi before 1995 5300 psi after 1995
   k. Slab thickness 9"
   l. Initial smoothness level obtained 3.28 PSR
   m. Describe the typical contract incentives and/or disincentives used Work Cement, agg quality after 1995 Rate incentives and disincentives for 20 yrs
   n. Are the contractor's paving workers' qualifications certified? No

Figure 21. Sample Questionnaire

Business Process Flow Documentation

If you have followed the sequence of steps in this guide, you will have already documented the business processes associated with your practices. Once you have identified best performers whose "best" practices you wish to evaluate, however, you will need to obtain similar documentation from them. Documentation of practices of best performers should include results from background research, business process flow charts, answers to questionnaires, and results of site visits.

It is critically important to understand how each level of each organization that is a best performer contributes to the outcomes and resource usage. Management actions at different levels of the organization will have varying effects on customer-driven outcomes and resource usage and costs.

Conference Calls, Electronic Information Exchanges, and Video Conferences

It is possible that the background research, initial documentation, and answers to questionnaires are adequate for deciding to adopt a different practice; however, more frequently, additional data and understanding of peer practices will be necessary. The best-performing peers you have selected need to be contacted to gain a more complete understanding of their practices. Communication can occur using conference calls; electronic information exchanges such as e-mail, groupware, and chat rooms; and video conferences. The investigation should include the details of the practices, the circumstances under which the peer uses the practices, how long or how much experience the peer has had with the practices under investigation, the key requirements for implementation success, and any recommendations for other organizations considering the practices.

Before such communications begin, the initiating organization should establish objectives for the interchange and describe the questions to be answered.

Site Visits

Many organizations that do benchmarking find that site visits are valuable for understanding a practice of a best performer. **Avoid industrial tourism—making site visits simply for the sake of visiting other organizations. Site visits should only occur if there is strong reason to believe that they will add value and both parties are well prepared.** Generally, a pair of visitors is desirable to conduct the site visit because two pairs of eyes and ears help capture accurately what is observed. More visitors are usually unnecessary. Here are some guidelines for conducting site visits:

- Work through a specific point of contact to schedule the meeting and line up participants.
- Develop an interview protocol and agenda in advance and share it with the host. Presumably, a questionnaire will have been distributed earlier.
- Have the authority to share information and make sure your host does, too.
- Be courteous and professional.
- Offer a reciprocal visit.
- Keep to your meeting schedule and finish on time.
- Be sure to thank your host.
- Write up the practices you encountered during or immediately after your visit.

Example of Site Visit in Maintenance Benchmarking

The Kansas City Department of Public Works participated in a municipal public works department–benchmarking program with several other cities in North America in order to achieve the following three goals:

1. Improve the quality of service,
2. Reduce the cost of operations, and
3. Improve the satisfaction of customers.

In a structured program facilitated by a consultant, the group of public works departments chose benchmarking partners based upon performance comparisons and documented work processes. Then the benchmarking partners arranged on-site visits to compare practices and seek ideas for improvement opportunities.

The visits were a commitment of time consisting of 2 days of on-site visits and documentation of work flow and work processes. Individuals participating in visits to other departments were trained in benchmarking concepts. Priorities were set for the processes each participant wished to pursue.

The total benchmarking activity uncovered 32 specific work process improvements to be included in the Kansas City Department of Public Works operating plan. Some of the changes were implemented immediately, such as instituting quick service bays in all fleet maintenance facilities, while other changes were implemented over a much longer period.

Analyzing the Causes of Superior Performance

Before adopting a best practice, you may wish to understand in more detail the causes of superior performance. You can use a variety of techniques. The following three are explained in turn:

1. Root cause analysis;
2. Correlation, regression, analysis of variance, and other statistical methods; and
3. Design of experiments.

Root Cause Analysis

A straightforward and often helpful method of understanding the underlying reasons for performance, root cause analysis employs a diagram such as **Figure 22** to identify the main and deeper root causes contributing to an outcome.

To apply root cause analysis, a group of people knowledgeable about the business process identifies main categories of potential causes leading to an outcome and then dissects the causes further. The fishbone diagram is well suited for organizing the discussion and displaying the results.

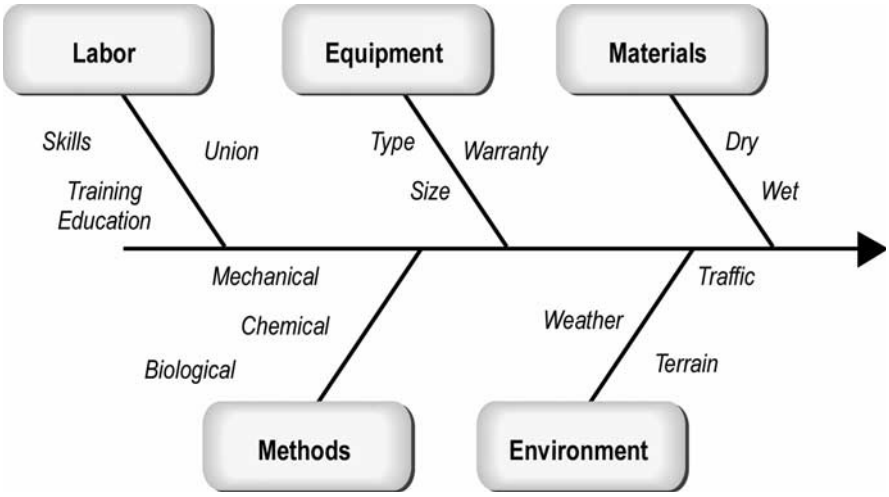


Figure 22. Root Cause Analysis Using Fishbone Diagram

Correlation, Regression, Analysis of Variance, and Other Statistical Methods

There are a wide variety of statistical techniques one can apply to identify statistically significant factors associated with an outcome. By using correlation, regression, analysis of variance, and other statistical methods, often you can identify factors that correlate or explain the variation in outcomes and resource usage. You can then make important strides in determining the likelihood that an attribute of a practice will contribute positively to an outcome or to a reduction in resource costs. Commonly applied statistical techniques include the following:

- **Correlation coefficients** provide measures of the degree that various variables or factors are correlated.
- **Regression** involves estimating an equation that involves many variables and that best fits a set of data points.
- **Analysis of variance** determines the degree that different variables contribute to the variance of another variable.

Analysis of variance allows you to analyze the variance within and among groups.

- **Factor analysis** helps to reduce a set of possible causal factors to a smaller set that explains most of the variation caused by the original set.

To perform various types of statistical analysis, you will need to assemble a data set for all the variables or factors of interest. Depending upon the properties of the data set, different types of statistical analysis will be appropriate. For example, you could make a list of factors contributing to pavement smoothness. If the factor is at play in a particular organization or unit, you would give it a value of 1; otherwise, you would give it a value of 0. Thus if there were 40 organizational units constituting a benchmarking partnership and 20 different factors potentially contributing to pavement roughness, then the data set would be a matrix of 40×20 composed of 1s and 0s. Pavement roughness could then be regressed against each of the 20 factors to determine the significance of each factor.

Before doing such an analysis, you should develop a hypothesis regarding which variables are most likely to be significant. The statistical analysis will allow you to accept or reject your hypothesis. Such analysis provides a great deal of objectivity and helps overcome the use of hunches and educated guesses regarding what attributes of a process are contributing to an outcome. You will end up with more insight and have a stronger foundation for deciding whether to implement a practice.

You will require a person knowledgeable about statistical methods to apply these techniques. Most larger agencies have individuals who can perform correlation analysis and do regression, and many also have people with advanced degrees in statistics or related fields. Individual consultants and firms that specialize in statistical analysis are additional sources of expertise.

Design of Experiments

The types of statistical analysis described above use historical data—that is, data concerning results that have already occurred from applying resources in various settings. However, additional

insights regarding variables that contribute to outcomes can be achieved by designing experiments and by carefully controlling for different factors of interest, whether they are main effects or interactions among factors. There is a large body of literature on the design of experiments to achieve quality improvements. Design of experiments plays an important role in diagnosing the causes of complex manufacturing problems and other processes.[4] You will need expert help to design experiments in an efficient manner in order to root out the factors contributing to outcomes.

The MnDOT used an experimental design in constructing a survey instrument to assess the strength of different factors contributing to the value motorists receive from different attributes of roadside vegetation. These attributes are affected by maintenance activities associated with the delivery of MnDOT's "Attractive Roadside" product. Appendix D briefly describes how the experimental design was used to better understand the underlying factors affecting customer preferences for roadside aesthetic features.

Considerations for Changing Practices

Matching best practices to the goals of the initiating organization is critical because some best practices may be excellent, but they may not be consistent with an organization's priorities.

The first determination is whether the identified best practices of peer organizations are aimed at reducing resource usage and costs or whether they are designed to increase customer outcomes. If the practices are aimed at reducing resource costs and if your organization is primarily concerned with increasing the level of customer outcomes, then this might not be the first practice to spend time implementing. Also, if you are satisfied with the level of outcomes that are being produced, then you will likely be seeking to implement practices that will lower resources and costs.

Estimating the Near Term-Impact of Changes

For a selected practice or set of practices, the originating organization needs to calculate the estimated costs of

[4] Keki R. Bhote and Adi K. Bhote, *World Class Quality: Using Design of Experiments to Make It Happen,* Second Edition, American Management Association, New York, 2000.

implementation. This will require estimating the amount of this practice to be performed in the next cycle of maintenance activity for the particular product or service that was benchmarked. The resource costs can be estimated based upon local conditions for the initiating organization. Estimating the change in outcome levels will be more difficult because the functional relationship between resource levels and outcome levels is unknown and is not easily estimated. This is especially true for customer satisfaction levels and may be true for some outcome measures of technical quality such as IRI, the number of inches of shoulder edge drop off, and the reflectivity of signs.

STEP 5. IMPLEMENT AND CONTINUOUSLY IMPROVE

Setting Targets for Improvements

Experiences of the peer organizations will be helpful in estimating a rate of change in the outcome measures. Targets can be set for improved performance. They could be set at the level of the best performances or in accordance with an estimate of the improvement potential for a unit, which may even be at a higher level than the best-performing unit. **It is usually best to set a reasonable target—a level that management believes can be accomplished in the next maintenance cycle.**

Making Improvement Plans

After investigating best practices of peers and setting targets for improved performance, an implementation plan for carrying out the improvement must be established. The implementation plan should address the questions of what, how, who, and when.

What?

What business processes will be changed and what outcomes and resources will be affected?

How?

How will the business processes be changed—through improved scheduling, training, new technology and equipment, better

materials, improved management and information systems, more efficient work reporting, or a combination of the above?

Who?

What managers and staff need to be involved? What levels of the organization need to participate? How broadly the changes will be implemented is an important part of the plan. Will implementation include all possible work units or will the changes in practices be implemented as a pilot project that affects just one unit?

When?

What is the schedule for improvements? Which improvements will occur first? Do some improvements depend upon the implementation of others?

Implementing New Practices

It is easy to maintain the status quo. Some organizations hesitate to embrace change, especially changes in practices that were developed elsewhere. Management must support the planned improvements and emphasize and reward improved performance.

Managers at appropriate levels should be given the responsibility to manage the changes and to give visibility to changed performance. Moreover, management will want to prepare the organization for the next cycle of continuous improvement. This should include gauging how the next round of improvements will affect customer-driven outcomes and resource usage.

Starting Again

Customer-driven benchmarking is a continuous five-step cycle:

1. Select partners,
2. Establish measures,
3. Measure performance,
4. Identify best performances and practices, and

5. Implement and continuously improve.

In fact, benchmarking is generally regarded as a continuous improvement process. Once the last step is completed, you start over again with the first step, as shown in **Figure 23.**

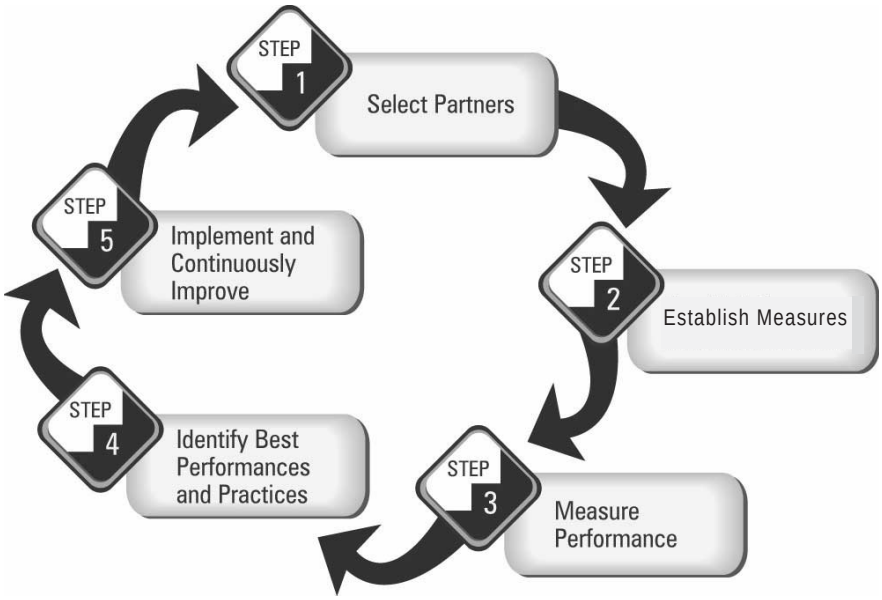


Figure 23. Steps in the Benchmarking Process

In organizations committed to benchmarking, there is an attitude of continually striving to produce the best possible results. Starting again is routine for organizations committed to benchmarking. There is an atmosphere of creativity, an enthusiasm for trying new work practices, and a genuine desire to better serve the customer.

Each cycle of the benchmarking process will result in a different set of best performers. There will continually be changes in the peer group with which an organization can compare practices. Each organization or unit that embraces customer-driven benchmarking can be confident that from time to time and perhaps frequently, they will be among the best performers. And even if they are not, they will be able to identify practices that will allow them to improve, year in and year out.

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APPENDIX A: DRAFT BENCHMARKING AGREEMENT

Agreement Number: _____

Lead/Initiating Organization: _____

Agreement between:

List names of benchmarking partners.

I. Objective and Goals

The objective of this benchmarking partnership is to continuously improve through periodic measurement customer satisfaction, observable customer-oriented outcomes, and the value customers of highway maintenance receive by measuring performance of organizations in this benchmarking partnership, by identifying best performances, by identifying improvement opportunities, and by assessing and adopting best practices.

II. Target Products, Services, Activities, and Business Processes

The partnership will benchmark highway maintenance products, services, activities, and/or business processes that the benchmarking partners will agree upon in the future. A tentative list of maintenance products, services, activities, and/or business processes is as follows:

List.

III. Common Measures

Partners will use the same outcome, resource, and hardship measures and will take the necessary steps to take the measurements, including collection of underlying data.

A tentative list of common measures is as follows:

List.

IV. Data Quality

Partners will abide by mutually agreed-upon procedures to ensure data and measurement quality. At the minimum these procedures will include the following:

List.

V. Sharing Information on Performance

Each participant agrees to share performance information regarding the following:

- Outcomes;
- Resources (labor, equipment, material and, possibly, financial);
- Levels of hardship factors such as weather and terrain; and
- Details of business processes associated with each performance.

Partners agree to store information in a database having a particular format to be determined in the future in order to facilitate exchanging information. Partners agree to the following additional forms of information sharing:

- Responding to a questionnaire regarding information regarding their practices,
- Hosting site visits regarding best practices, and
- Other.

VI. Documentation

Partners will document for the consideration of other partners practices that are determined to be superior or best practices. The documentation will include, but not be limited to, the following:

- Sources of data on outputs, inputs, and external factors;
- Information on the reliability, accuracy, and repeatability of data and measurements;
- Raw and reduced data from systems that provide the data for benchmarking;
- Description of work methods that may exist;
- Existing procedural manuals;
- Business process flow charts prepared according to conventions agreed upon by the benchmarking partners;
- Training, education, and experience levels of labor;
- Vendor information regarding materials and equipment used; and
- Costs (variable and overhead) (Note: some organizations may not be willing to provide cost data, and the benchmarking agreement should provide the flexibility not to do so).

VII. Confidentiality

Partners agree to keep the following confidential:

List.

No partner will release results to the public regarding the performance of other partners unless the partners to which the information pertains agree in writing.

Partners agree to the following in order to ensure the security of information developed:

List.

VIII. Adding Benchmarking Partners

Additional partners may be added to the partnership, provided they agree to all the terms and conditions of this agreement.

IX. Resigning from the Partnership

Each partner will satisfy its obligations under the benchmarking agreement as long as it remains involved, but may leave the partnership at any time without cause. Partners are assumed to be motivated to remain in the partnership as long as it provides compelling benefits by showing organizations how they can improve performance as a result of adopting best practices.

APPENDIX B: CATALOG OF BENCHMARKING MEASURES

This appendix provides a catalog of outcome and output measures that can be used for benchmarking. The measures presented focus on those that are important from the standpoint of the customer, but other useful measures are also offered.

Measures are organized by type of maintenance element (e.g., pavements, bridges) and then by attribute (e.g., smoothness, safety, and aesthetics). In addition, for each measure information is provided on the unit of measure, whether the measure is commonly recognized (based on the consensus reached at the National Workshop on Commonly Recognized Measures for Maintenance), repeatability, the cost of collecting the measure, and other issues that may be important.

The catalog of benchmarking measures covers the following maintenance elements:

- Pavements;
- Shoulders;
- Bridges;
- Signs, striping, and markings;
- Safety features;
- Ice and snow control;
- Roadside vegetation;
- Drainage;
- Litter removal;
- Rest areas;
- Signals; and
- Other electronic devices.

Note that many states have developed rating systems for Levels of Service (LOS). In many cases, rating scales are not the LOS the customer experiences, but instead are condition ratings. The table below attempts to make this clear by referring to "Levels of Service" as "Level of Service Condition Ratings" unless otherwise explicitly stated.

PAVEMENTS

Pavements experience a wide variety of different deterioration that affects their appearance, riding experience, and structural soundness. Table B-1 presents pavement condition measures that have an important direct or indirect relationship to the customer.

Table B-1. Condition Measures for Pavements

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Pavement smoothness (roughness)	International Roughness Index (IRI)	Inches/mile or m/km	Yes	Well-established procedures and equipment that result in repeatable, reliable, and reasonably accurate results	Low incremental cost for agencies already collecting IRI; moderate to high cost of new data collection effort
	National Quality Initiative (NQI) or other survey question asking customer satisfaction regarding pavement smoothness	1–5 response scale	Survey question on pavement smoothness	Standard NQI survey question; not accurate for jurisdictions lower than state level, unless separate survey administered	Low cost to use NQI survey results; moderate to high cost to develop and administer your own survey including question on pavement smoothness
Pavement smoothness (potholes)	Number of potholes of specified size per unit distance	Number per unit distance		Potholes are easily observed, but the number per unit distance can be difficult to count. The number of potholes can change rapidly as new ones appear and existing ones are repaired.	High cost to develop a comprehensive, accurate pothole count.
Pavement smoothness, accessibility (blowups)	Number of blowups per unit distance	Number per unit distance		Blowups are easily observed and easy to count. Blowups occur during the freeze-thaw transition, so new ones can suddenly emerge and affect the reliability of the count.	Seasonal problem that requires moderate measurement cost. Motorist call-ins could reduce data collection costs.
Safety (danger of hydroplaning)	Rutting	Inches	Yes	Well-established, reliable, repeatable, and reasonably accurate measurements using a ruler	Low cost to do for sample sections or if data already exists; high cost to obtain comprehensive coverage if data doesn't exist

(*continued on next page*)

Table B-1. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Safety (skid resistance)	Friction		Yes	Well-established equipment and procedures for reliable, repeatable, and reasonably accurate measures	Low incremental cost if agency already routinely measures; high cost for new measurement program
Preservation attributes (protection against water damage to structure due to faults)	Faulting	Inches		Repeatable, reliable, and reasonably accurate measures obtained using a ruler	Low cost to do for sample sections or if data already exists; high cost to obtain comprehensive coverage if data doesn't exist
Preservation attributes (appearance of deterioration, raveling, water infiltration)	Extent and severity of different types of cracking: –alligator –longitudinal –transverse	Percent of area covered or length of cracks and rating of severity on a scale		Challenge in maintaining consistency among raters; automated distress identification technology not highly accurate	Much lower cost to do for sample sections in comparison to comprehensive network coverage
Overall pavement condition	Health Index	Some type of index, say from 0–100		Requires construction of index reflecting key pavement attributes; each attribute can be measured with varying degrees of reliability	Low to high cost to develop and apply index, depending upon the availability of data to calculate index components
Overall level of service	Visual level of service condition rating	Rating scale of A, B, C, D, or E		Often visual rating scales combine more than one attribute and so it is difficult to portray and to isolate condition of different attributes	Mainly useful for communicating to policy makers and general public.

SHOULDERS

Shoulders can deteriorate in a number of ways. The shoulder and pavement edge can separate, letting in moisture that can lead to premature deterioration of the pavement and even structural failure. Shoulder drop-off or a significant rise in the edge can emerge over time and create safety hazards. Gravel shoulders lose their shape and require reshaping. Table B-2 presents measures of shoulder condition.

Table B-2. Potential Condition Measures for Shoulders

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Preservation attributes (shoulder separation)	Distance between edge and shoulder	Inches		Well-established, reliable, repeatable, and reasonably accurate measurements using a ruler	Low cost to obtain data if in a Pavement Management System or similar database
Safety feature	Edge drop off	Inches	Yes, edge variance	Protocol for commonly recognized measure needs to be established. However, well-established, reliable, repeatable, and reasonably accurate measurements using a ruler are available.	Low cost to obtain data if in a Pavement Management System or similar database
Safety feature	Edge rise	Inches	Yes, edge variance	Protocol for commonly recognized measure needs to be established. However, well-established, reliable, repeatable, and reasonably accurate measurements using a ruler are available.	Low cost to obtain data if in a Pavement Management System or similar database
Safety and preservation attributes (support for vehicles on shoulder and preservation of shoulder shape)	Gravel bunched or spread disbursed			Lack of agreed-upon, repeatable, reliable, accurate measure	Low cost to obtain data if in a Pavement Management System or similar database
Preservation, safety, and aesthetics	Survey question asking customer satisfaction regarding shoulder condition	1–5 response scale		Repeatable, and reliable, if rigorous sampling and administration procedures used; precision and statistical confidence depends on sample size and stratification	Moderate to high cost to develop and administer new survey; less costly to add this question to existing survey instrument
	Visual level of service condition rating	Scale of A, B, C, D, and E		Often visual rating scales combine more than one attribute and so it is difficult to portray and to isolate condition of different attributes	

BRIDGES

There have long been standardized measures of bridge condition based on the condition ratings in the National Bridge Investment Analysis System (NBIAS).[1] The condition ratings in the National Bridge Inventory (NBI) consist of ratings for substructure; deck; superstructure; and channel under the bridge, if one exists. There are also inventory and operating ratings. Certain ratings together signify that a bridge is structurally deficient, and other ratings signify a bridge is functionally obsolete. For years, FHWA has supported a bridge inspection training program that enables inspectors to fairly consistently and accurately rate the condition of bridges and, therefore, to rate the extent to which they are structurally deficient or obsolete. These condition ratings and determinations of structural deficiency and functional obsolescence are potentially useful for benchmarking.

More recently, states have established a more detailed, widely used, and widely recognized set of bridge condition measures known as condition states corresponding to "commonly recognized (CoRe) structural elements" of bridges. There are commonly recognized measures of bridge condition for nearly 100 elements that pertain to different parts of structures made of virtually every important type of bridge configuration and material found throughout the United States. Under the CoRe system, condition ratings have been carefully defined to be consistent with alternative actions appropriate to each condition state. In addition, eight smart flags that address such factors as settlement and fatigue have been defined under the CoRe definitions. [2]

Condition states have been carefully defined by bridge managers, structural engineers, and inspection experts so that the condition states are consistent with a set of alternative actions that are reasonable options for addressing a particular condition state. The actual actions an agency takes depend upon many factors, including the costs of each action.

Condition states were originally defined to facilitate the development of probabilistic deterioration models for use in the Pontis, BRIDGIT, and other bridge management systems. A large number of states have participated in the development of the commonly recognized elements. Also, software has been developed that automatically maps bridge CoRe condition states to condition ratings used in the NBI. Consequently, not only do the vast majority of state bridge programs use the CoRe condition states, but also FHWA fully supports their use and has funded the development of the bridge inspection training program that teaches inspectors how to rate bridges using the CoRe system.

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[1] *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges,* FHWA, U.S. DOT, December 1988 (update of 1979 Guide).

[2] *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements,* AASHTO, Washington DC, 1998.

Table B-3 provides bridge condition measures potentially useful for customer-driven benchmarking.

Table B-3. Bridge Condition Ratings

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Preservation attributes (condition)	Condition ratings of channel, approach, substructure, deck, and superstructure; also inventory and operating rating as measures of load capacity	Discrete scale of 0–9 for condition ratings		Long-established bridge inspection and rating procedures have been developed that are reliable, repeatable, and fairly accurate	Condition data easily obtained from NBI database; low cost
Preservation attributes (condition) and functionality	Classification of bridges according to whether they are structurally deficient or functionally obsolete	Binary measure of whether structurally deficient and whether functionally obsolete		Derived from NBI condition ratings and therefore well established, repeatable, and reliable	Determination of structural deficiency and functional obsolescence easily obtained from NBI database; low cost
Preservation attributes (condition)	CoRe condition ratings for nearly 100 bridge elements (e.g., deck, piers, railings, truss, and girders)	Discrete scale of 1 to 3, 4, or 5, depending upon the element	Adopted by the AASHTO Bridge Subcommittee in 1995	Well-established, reliable, repeatable, and reasonably accurate measurements based on well-defined bridge inspection procedures	Low cost to use bridge condition ratings in bridge inventory and condition databases
Preservation (condition)	Customer satisfaction	1–5 scale		Standard NQI survey question; not accurate for jurisdictions lower than the state level, unless separate survey administered	Low cost to use NQI survey results; moderate to high cost to develop and administer your own survey that includes NQI or similar type of question
Preservation (condition)	Visual rating level of service	Scale of A, B, C, D, and E		Often visual rating scales combine more than one attribute, and so it is difficult to portray and to isolate condition of different attributes	

SIGNS, STRIPING, AND MARKINGS

An important attribute of signs, markers, and striping that is critically important to drivers is nighttime visibility. During the daytime, signs still need to be legible. If a sign is knocked down, missing, or blocked by vegetation, it can pose a serious safety hazard. Pavement markers or striping that wears out completely, comes loose, or is not visible in rain is also a problem. Table B-4 presents customer-driven condition measures for signs, striping, and markers.

Table B-4. Condition Measures for Signs, Striping, and Markers

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Nighttime visibility	Retroreflectivity	Candelas per lux per square meter, or candelas per foot-candle per square foot	Yes	Protocol for commonly recognized measure needs to be established. However, well-established, reliable, and repeatable procedures for measuring reflectivity of signs, striping, and markers exist for static measurements using a handheld retroreflectometer; measures taken from a van at highway speeds have not yet proven to be reliable, repeatable, and accurate	Measurements of retroreflectivity of signs, striping, or markers, either standing still or while in motion, are moderate to high cost. The labor costs for static measurements for a large portion of the network are high, and so are initial vehicle and equipment costs.
	Visual rating scale of nighttime visibility			This measure is fairly reliable, repeatable, and accurate, provided there is rigorous training and retraining of raters	Cost is a function of the number of signs to be rated and the miles covered. Generally low to moderate cost using windshield survey

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Table B-4. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Legibility of signs	Visual rating scale of daytime legibility		Yes	Protocol for commonly recognized measure needs to be established. Measurements are expected to be fairly reliable, repeatable, and accurate, provided there is rigorous training and retraining of raters.	Cost is a function of the number of signs to be rated and the miles covered. Generally low to moderate cost using windshield survey
Sign blocked	Percent of signs blocked by vegetation or other obstructions			This measure is fairly reliable, repeatable, and accurate, provided there is rigorous training and retraining of raters.	Cost is a function of the number of signs to be rated and the miles covered. Generally low to moderate cost using windshield survey
Downed or missing sign	Visual determination of whether sign is downed or missing			Downed or missing signs are likely to be detected quickly by motorists or maintenance supervisors or crews. Systematic inspections of downed and missing signs would also be reliable, accurate, and repeatable, provided inspectors know whether signs are supposed to be at each location.	Low cost
Day condition	Composite rating reflecting legibility, color fade, contrast, graffiti, and damage	Rating scale or index		Requires training and retraining to achieve reasonably reliable, accurate, repeatable ratings	Low cost if data already available in sign inventory and condition data base; otherwise, potentially high cost
Physical appearance	Sign condition ratings for contrast, color fade, legibility, and post condition; Pavement marking condition rating for contrast and presence	Individual ratings or composite rating scale	Yes	Protocol for commonly recognized measure needs to be established. Requires training and retraining to achieve reasonably reliable, accurate, repeatable ratings	Low cost if data already available in sign inventory and condition data base; otherwise, potentially high cost

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Table B-4. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Deterioration	Age of sign	Years		Reliable, accurate, and repeatable if age of each sign is accurately entered into sign inventory database; however, age is not necessarily a good proxy for deterioration. Many old signs can remain in good condition.	Low cost if database already exists. May be infeasible to determine age if age is not known.
Response time	Mean time to replace or repair in response to report of damaged, downed, or missing sign	Minutes and fraction thereof		Time from initial report to repair or replacement is almost always recorded in a log book and is quite accurate	Low cost to extract time to fix problem from log books
Missing striping and markers	Visual inspection of percent of markers or percent of striping missing	Percent	Yes	Protocol for commonly recognized measure needs to be established. This measure is expected to be fairly reliable, repeatable, and accurate, provided there is rigorous training and retraining of raters.	Low to moderate cost to estimate using windshield survey
Visibility of signs, striping, and markers	Customer satisfaction	1–5 scale	Yes	Standard NQI survey question; not accurate for jurisdictions lower than state level, unless separate survey administered	Low cost to use NQI survey results; moderate to high cost to develop and administer your own survey that includes NQI or similar question

SAFETY FEATURES

Many different types of appurtenances have been installed in roadways to protect motorists from accidents and to reduce the seriousness of crashes. These features include guardrails, medians, crash attenuators, and truck escape ramps. Table B-5 presents condition measures for safety features.

Table B-5. Condition Measures for Safety Features

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Guardrail functionality	Percent functioning as intended	Percent of components functioning as intended	Yes	Protocol for commonly recognized measure needs to be established. This measure is expected to be fairly reliable, repeatable, and accurate, provided there is rigorous training and retraining of rater.	Requires inspectors to determine whether guardrail components are functioning according to specifications. Low to moderate cost if part of other inspection activities
Guardrail end-treatment functionality	Percent functioning as intended	Percent of components functioning as intended	Yes	Protocol for commonly recognized measure needs to be established. This measure is expected to be fairly reliable, repeatable, and accurate, provided there is rigorous training and retraining of rater.	Requires inspectors to determine whether components of end-treatments are functioning according to specifications. Low to moderate cost if part of other inspection activities
Guardrail condition	Percent damaged so as to require repair, percent requiring replacement, and percent requiring no action	Percent of guardrail length in each condition state		This measure is fairly reliable, repeatable, and accurate provided there is rigorous training and retraining of raters	Low to moderate cost if part of other inspection activities
Guardrail appearance	Percent of guardrail having different visual appearance ratings of 1, 2, 3, 4 or 5	Percent of guardrail length in each condition state		This measure is fairly reliable, repeatable, and accurate provided there is rigorous training and retraining of raters.	Low to moderate cost if part of other inspection activities
Guardrail obsolescence	Percent of guardrail that is functionally obsolete and requires replacement	Percent of guardrail length that is functionally obsolete		This measure is fairly reliable, repeatable, and accurate provided there is rigorous training and retraining of raters.	Low to moderate cost if part of other inspection activities

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Table B-5. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Median (Jersey barrier) condition (crash protection)	Percent damaged so as to require repair, percent requiring replacement, and percent requiring no action	Percent of guardrail length in each condition state		This measure is fairly reliable, repeatable, and accurate provided there is rigorous training and retraining of raters.	Low to moderate cost if part of other inspection activities
Attenuator functionality	Percent functioning as Intended	Percent of components functioning as intended	Yes	Protocol for commonly recognized measure needs to be established. This measure is expected to be fairly reliable, repeatable, and accurate provided there is rigorous training and retraining of raters.	Moderate to high cost; requires inspectors to determine whether each component is functioning according to specifications
Crash attenuator condition (crash protection)	Damaged or undamaged	Yes or no		This measure is fairly reliable, repeatable, and accurate provided there is rigorous training and retraining of raters.	Low to moderate cost if part of other inspection activities
Safety (crash protection)	Customer satisfaction regarding safety features (crash barriers and attenuators)	1–5 Scale	Yes	Standard NQI survey question; not accurate for jurisdictions lower than state level, unless separate survey administered	Low cost to use NQI survey results; moderate to high cost to develop and administer your own survey that includes NQI or similar question

ICE AND SNOW CONTROL

In the northern-tier states and Canada, as well as in the mountains of the southern-tier states, freezing and subfreezing conditions are common during the winter months and, in many places, during the spring and fall. A major challenge of government jurisdictions in these areas is to prevent the build-up of ice and snow and, if there is significant snowfall, to remove the snow as quickly as possible to keep roads safe and open to traffic. In addition, there is the need to conduct clean-up operations such as the sweeping up of abrasives (e.g., sand). A key part of snow and ice control is the prevention of both (1) water pollution due to salt and other anti-icing chemicals and (2) air pollution due to dust caused by abrasives.

Table B-6 presents condition measures for ice and snow control.

Table B-6. Condition Measures for Ice and Snow Control

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Mobility, accessibility, and safety	Bare Pavement Indicator (such as response time to loss of bare pavement or duration of loss of pavement with respect to the duration of an ice or snow event)	Ratio or percent	Yes	Defining when a snowstorm starts and ends and when bare pavement is restored can be problematic. Protocol for commonly recognized measure needs to be established. This measure is expected to be fairly reliable, repeatable, and accurate, provided there is rigorous training and retraining of raters.	Low to moderate cost
Mobility, accessibility, and safety	Friction			Reasonably reliable, repeatable, and accurate friction measurements can be obtained using appropriate friction measuring equipment.	Friction measuring equipment for ice and snow control is currently prohibitively expensive except for limited applications. This is an area of active research.
Mobility, accessibility, and safety	Percent of time during cold season a road has a particular road and weather condition rating such as "good, fair, or poor" or "open, passable, closed."	Percent		A number of Roadway Weather Information Systems (RWIS) displayed on road condition ratings websites and kiosks. These are defined and applied in a consistent manner and can be adapted as maintenance performance measure.	Initial medium to high cost to write software to tap information on road and weather condition ratings in an Advanced Traveler Information System/RWIS. High cost to install RWIS sensors. Low to moderate cost to obtain information thereafter.

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Table B-6. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Mobility, accessibility, and safety	Closures	Number and/or duration of closures	Yes	Protocol for commonly recognized measure needs to be established; information on closures is expected to be accurate because it comes from public safety officials or a road maintenance organization.	Low cost
Mobility, accessibility, and safety	Elapsed time from the requirement that chains be put on vehicle tires to the removal of the requirement.			Measure has applicability only in areas where chains are used. Crews and managers involved in winter operations keep careful records of duration of time chains are required.	Low cost to obtain data from logs
Mobility, accessibility, and safety	Percent of miles in each functional class where roads have been treated for snow and ice in accordance with ice and snow control plan	Percent		Data obtain during snowstorms and debriefs after storms may provide reasonably reliable and accurate information	Requires careful recordkeeping during freezing conditions and snowfall to compile data. May require the use of Automated Vehicle Location Systems involving global positioning systems (GPS) and data storage in a geographic information systems (GIS). Initial cost to establish automated vehicle identification (AVI) and GIS/database is high.
Mobility, accessibility, and safety	Percent of population (or households and businesses) where roads have been treated for snow and ice in accordance with ice and snow control plan	Percent		Data obtained during snowstorms and from debriefs may provide reasonably reliable and accurate information.	Requires careful recordkeeping during freezing conditions and snowfall to compile data. May require the use of Automated Vehicle Location Systems involving GPS and data storage in a GIS. Initial cost to establish AVI and GIS/database is high.

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Table B-6. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Mobility, accessibility, and safety	Customer satisfaction regarding ice and snow control	1–5 scale	Yes	Accuracy and statistical confidence depends on sampling plan. Measure needs to be incorporated into reliable, accurate, and repeatable survey instrument.	Moderate to high cost to develop and administer your own survey that includes question on customer satisfaction regarding ice and snow control
Mobility, accessibility, and safety	Clear of unplanned obstructions	1–5 customer rating scale or percent of time road is in this condition		Needs to be incorporated into reliable, accurate, and repeatable survey instrument; the percent of time a road is in a certain condition is difficult to measure.	Low to medium cost to incorporate into existing survey instrument; medium to high cost to include in new instrument
Mobility, accessibility, and safety	Roadway clear of ice and snow	1–5 customer rating scale or the percent of time a road is in this condition		Needs to be incorporated into reliable, accurate, and repeatable survey instrument; percent of time a road is in a certain condition is difficult to measure.	Low to medium cost to incorporate into existing survey instrument; medium to high cost to include in new instrument
Mobility, accessibility, and safety	Trucks plowing as soon as snow appears	1–5 customer rating scale		Needs to be incorporated into a reliable, accurate, and repeatable survey instrument	Low to medium cost to incorporate into existing survey instrument; medium to high cost to include in new instrument
Mobility, accessibility, and safety	Plowing frequency during average snowfall	1–5 customer rating scale or frequency		Needs to be incorporated into a reliable, accurate, and repeatable survey instrument	Low to medium cost to incorporate into existing survey instrument; medium to high cost to include in new instrument
Driver comfort, safety	Ability to see shoulder striping during snowfall	1–5 customer rating scale		Needs to be incorporated into a reliable, accurate, and repeatable survey instrument	Low to medium cost to incorporate into existing survey instrument; medium to high cost to include in new instrument

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Table B-6. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Driver comfort, safety	Ability to see road edge during snow fall	1–5 customer rating scale		Needs to be incorporated into a reliable, accurate, and repeatable survey instrument	Low to medium cost to incorporate into existing survey instrument; medium to high cost to include in new instrument
Mobility, accessibility, and safety	Ability to make turns at crossovers and intersections	1–5 customer rating scale		Needs to be incorporated into a reliable, accurate, and repeatable survey instrument	Low to medium cost to incorporate into existing survey instrument; medium to high cost to include in new instrument
Mobility and safety	Driving speed during snowfall	1–5 customer rating scale or miles per hour by functional class		Needs to be incorporated into a reliable, accurate, and repeatable survey instrument	Low to medium cost to incorporate into existing survey instrument; medium to high cost to include in new instrument
Mobility, accessibility, and safety	Bare wheel paths	1–5 customer rating scale or percent of time there are bare wheel paths, by functional class		Needs to be incorporated into a reliable, accurate, and repeatable survey instrument	Low to medium cost to incorporate into existing survey instrument; medium to high cost to include in new instrument
Safety	Slippery spots	1–5 customer rating scale or percent of centerline miles with slippery spots, by functional class		Needs to be incorporated into a reliable, accurate, and repeatable survey instrument. Very difficult to obtain reliable, repeatable, and accurate objective, physical measurement	Low to medium cost to incorporate into existing survey instrument; medium to high cost to include in new instrument. Physical measurements of slippery costs would be very high cost.

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Table B-6. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Mobility, safety, and driver comfort	Only right lane plowed to bare pavement	Percent of centerline miles by functional class		Plow truck operators or patrol supervisors may be able to report this information reliably and accurately.	Low to medium cost to incorporate into existing survey instrument; Medium to high cost to include in new instrument. Measurements using image processing would be very high cost.
Mobility, safety, driver comfort	All driving lanes plowed to bare pavement	Percent of centerline miles by functional class		Plow operators or patrol supervisors may be able to report this information reliably and accurately.	Low to medium cost to incorporate into existing survey instrument; medium to high cost to include in new instrument. Measurements using image processing would be very high cost.
Mobility, safety, and driver comfort	All lanes plowed full width	Percent of centerline miles by functional class		Plow operators or patrol supervisors may be able to report this information reliably and accurately.	Low to medium cost to incorporate into existing survey instrument; medium to high cost to include in new instrument. Measurements using image processing would be very high cost.
Safety	Number of accidents	Fatalities, reported personal injury accidents		Fatalities are quite accurate; reported personal injury accidents do not include all personal injury accidents	Low cost; fatalities and reported personal injury accidents would normally be included in accident database.

ROADSIDE VEGETATION

Vegetation management is one of the most important functions of road maintenance. If vegetation is allowed to grow unchecked, it blocks signs, reduces sight distance at intersections, creates hazards for vehicles leaving the roadway, allows water to infiltrate the base and sub-base, causes pavement damage from roots of plants growing through shoulder edges and pavement surfaces, results in noxious weeds spreading to neighboring property, increases the likelihood of deer darting in front of vehicles, and

becomes unsightly. Proper vegetation maintenance provides cover for the nesting, feeding, and migration of wildlife and helps preserve habitat. In addition, vegetation management is critical for preventing erosion and facilitating drainage. Other purposes of vegetation management are for beautification and to serve as natural snow fences that prevent snow from drifting onto highways.

The customers of maintenance benefit from roadside vegetation management in many different ways, which are reflected in the outcome measures that appear in Table B-7.

Table B-7. Condition Measures for Roadside Vegetation

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Safety	Sight distance at intersections	Feet		Necessary to establish convention for measurement; requires training for reliable, repeatable, and accurate measurements. Periodic measurements may be required because of continual growth and trimming requirements.	Low cost to measure at selected intersections; high cost to cover road network
Safety and appearance	Grass height	Inches	Yes	Protocol for commonly recognized measure needs to be established. Easy measurement to take for reliable, repeatable, measurements; requires little training; periodic measurements may be required because of continual growth and cutting requirements.	Low cost to measure for sample sections; high cost to cover road network

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Table B-7. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Safety	Number of signs blocked by vegetation	Number	Yes	Protocol for commonly recognized measure needs to be established. Requires training for reliable, repeatable, and accurate measurements. Periodic measurements may be required because of continual growth and trimming requirements.	Low cost to count number of signs blocked by vegetation
Externalities (adverse effects on property owners adjacent to roads)	Presence or absence, area infested, or percent of right-of-way (ROW) infested with a type of noxious weed	Presence or absence, square feet or meters, percent	Yes (present or absence)	Protocol for commonly recognized measure needs to be established. Requires training for reliable, repeatable, and accurate measurements. Periodic measurements may be required because of seasonal changes and continual growth and control requirements.	Moderate to high cost to conduct accurate field inspections
Aesthetics	Aesthetic rating scale	1–5 customer rating scale		Requires training for reliable, repeatable, and accurate measurements	Low cost to measure for selected roadway sections; high cost to cover road network
Aesthetics	Neatness of vegetation	1–5 customer rating scale		Requires training for reliable, repeatable, and accurate measurements	Low cost to measure at selected roadway sections; high cost to cover road network
Environmental protection	Percent of ROW acreage managed to enhance wildlife habitat	Percent		Requires training for reliable, repeatable, and accurate measurements	Medium to high cost to establish GIS database and collect inventory and condition data
Safety	Clear zone distance: –Vertical clearance, –Horizontal clearance from edge	Feet	Yes	Protocol for commonly recognized measure needs to be established. Requires training for reliable, repeatable, and accurate measurements	Medium to high cost to establish GIS database and collect inventory and condition data; Low cost to measure for selected road sections; high cost to cover road network
Safety	Percent of centerline miles with thick trees too close to road to provide safe, clear area for cars running off road	Percent		Requires training for reliable, repeatable, and accurate measurements	Medium to high cost to establish GIS database and collect inventory and condition data; low cost to measure at selected road sections; high cost to cover road network

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Table B-7. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Safety	Percent of centerline miles with trees overhanging travel way in unsafe manner	Percent		Requires training for reliable, repeatable, and accurate measurements. Periodic measurements may be required because of continual growth and control requirements.	Medium to high cost to establish GIS database and collect inventory and condition data; Low cost to measure for selected road sections; high cost to cover road network
Aesthetics and environment	Percent of median, interchanges and ROW acreage planted with wildflowers	Percent		Requires training for reliable, repeatable, and accurate measurements.	Medium to high cost to establish GIS database and collect inventory and condition data

DRAINAGE

Maintaining proper drainage is critical to protect pavement structures and maximize their service life. Drainage is also important to prevent water accumulating from on roads and bridges and creating a hazardous situation. Other important functions of drainage control are to help prevent erosion, keep storm water from running off onto adjacent properties, and prevent contaminants on roads and bridges from entering surface and ground water.

Table B-8 shows drainage condition measures that are of direct and indirect importance to customers.

Table B-8. Drainage Condition Measures

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Safety	Number of spots on roads that flood during normal rainfall events and during 10-year storms	Spots of flooding		Difficult to measure reliably and accurately; may have to depend in part on motorist reports of flooding	Measurement would be facilitated by having a GIS; cost of data collection is relatively low
Safety and mobility	Customer satisfaction rating of drainage during storms	1–5 scale		Reasonably reliable, repeatable, and accurate if included in a well-designed survey administered using scientific sampling	Moderate to low cost if added to questions in existing survey; moderate to high cost if part of a new survey effort

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Table B-8. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Preservation	Percent of ditchline not maintained	Percent		Requires some training for reasonably accurate, reliable, and repeatable measurements	Low to moderate cost to do for sample road sections; high cost to cover entire network
Preservation	Linear feet of ditchline obstructed and unobstructed	Linear feet		Requires some training for reasonably accurate, reliable, and repeatable measurements	Low to moderate cost to do for sample road sections; high cost to cover entire network
Preservation	Level of service condition rating of ditches	Rating scale		Requires some training for reasonably accurate, reliable, and repeatable measurements	Low to moderate cost to do for sample road sections; high cost to cover entire network
Preservation, safety, mobility	Blockage of culverts, cross drains, ditches, curb, gutters, barrier walls, catch basins, and inlets	Percent of each drainage structure	Yes	Protocol for commonly recognized measure needs to be established; requires training for reliable, repeatable, and accurate measurements	Low to moderate cost to do for sample road sections; high cost to cover entire network
Preservation, safety, mobility	Damage of culverts, cross drains, ditches, curb, gutters, barrier walls, catch basins, and inlets	Percent of each drainage structure	Yes	Protocol for commonly recognized measure needs to be established; requires training for reliable, repeatable, and accurate measurements	Low to moderate cost to do for sample road sections; high cost to cover entire network
Preservation	Blockage for subsurface drainage	Percent of each drainage structure	Yes	Protocol for commonly recognized measure needs to be established; requires training for reliable, repeatable, and accurate measurements	Moderate cost for sample road sections; high cost to cover entire network
Preservation	Roadway settlement around and over culverts, cross drains, and storm drains	Pass/fail		Requires some training for reasonably accurate, reliable, and repeatable measurements	Low to moderate cost to do for sample road sections; high cost to cover entire network

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Table B-8. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Preservation, mobility, and safety	Flow area inhibited by debris or damage of culverts, cross drains, and storm drains –In the invert –Outside or near the inlet –Due to deflection or structural damage	Percent		Requires some training for reasonably accurate, reliable, and repeatable measurements	Low to moderate cost to do for sample road sections; high cost to cover entire network
Preservation, environment	Erosion around culverts, cross drains, and storm drains	Visual rating scale of none, moderate, or severe		Requires some training for reasonably accurate, reliable, and repeatable measurements	Low cost to do for sample road sections; high cost to entire cover network
Preservation	Structure distress of culverts, cross drains and storm drains	Pass/ fail		Requires use of closed circuit television cameras; training needed for reliable, repeatable, and accurate measurement	Moderate equipment costs; low cost to do for sample road sections; high cost to cover entire network
Safety, mobility	Obstructed and unobstructed barrier walls, curb, and gutter and slotted drains	Linear feet		Requires some training for reasonably accurate, reliable, and repeatable measurements	Low cost to do for sample road sections; high cost to entire cover network
	Paved and rock lined drainage ditches needing repair versus total length	Linear feet		Requires some training for reasonably accurate, reliable, and repeatable measurements	Low to moderate cost for sample road sections; high cost to cover entire network

LITTER REMOVAL

Lots of litter along the road creates an unpleasant experience for both drivers and passengers alike. Every state, locality, and turnpike authority has a significant program of litter pickup, often an adopt-a-highway program. Widely used customer-oriented outcome measures pertaining to litter removal appear in Table B-9.

Table B-9. Roadside Litter Condition

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Litter	Number of pieces of litter within 6 feet of shoulder edge per 0.1 mile	Pieces of litter per 0.1 mile		Fairly easy to measure reliably and accurately; requires training to obtain reliable, repeatable, and accurate measurement	Low cost to do for sample sections; high cost to do for all roads
	Litter count	Needs definition	Yes	Commonly recognized measure requires definition and protocol needs to be developed.	Low cost to do for sample sections; high cost to do for all roads
	Customer satisfaction rating of roadside litter	1–5 scale		Reasonably reliable, repeatable, and accurate if included in well-designed survey administered using scientific sampling	Moderate to low cost if added to questions in existing survey; moderate to high cost if part of a new survey effort

REST AREAS

Rest areas are one of the main places other than roads where customers encounter transportation facilities. Customers have expectations regarding parking availability; types of services offered; time to wait in line for food, restrooms, and gas; and neatness, cleanliness, odor, and absence of dog feces. Customers can be surveyed to obtain information regarding their level of satisfaction regarding each of these attributes of rest areas. Table B-10 shows potential customer-oriented outcome measures concerning rest areas.

Table B-10. Potential Customer-Oriented Outcome Measures—Rest Areas

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Functionality	All toilets in working order?	Yes or no		Observations would generally be repeatable, reliable, and accurate	
	Toilet paper available in all stalls?	Yes or no		Observations would generally be repeatable, reliable, and accurate	

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Table B-10. (Continued)

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Odor	Restrooms free of unpleasant odor?	Yes or no		Somewhat subjective responses; objectivity can be increased through training	
	Outdoor areas free of unpleasant odor?	Yes or no		Somewhat subjective responses; objectivity can be increased through training	
Delay	Average wait time to use restrooms	Minutes		Reliable and accurate, provided sufficient resources devoted to observe wait time	Moderate costs to make occasional observations; high cost to make frequent observations
Cleanliness	Customer satisfaction rating of cleanliness of rest rooms	1–5 scale		Reasonably reliable, repeatable, and accurate if included in well-designed survey administered using scientific sampling	Moderate to low cost if added to questions in existing survey; moderate to high cost if part of a new survey effort
Cleanliness	Customer satisfaction rating of cleanliness of outside eating areas	1–5 scale		Reasonably reliable, repeatable, and accurate if included in well-designed survey administered using scientific sampling	Moderate to low cost if added to questions in existing survey; moderate to high cost if part of a new survey effort
Neatness	Customer satisfaction rating of neatness of outside eating areas	1–5 scale		Reasonably reliable, repeatable, and accurate if included in well-designed survey administered using scientific sampling	Moderate to low cost if added to questions in existing survey; moderate to high cost if part of a new survey effort
Maintenance condition	Customer rating of overall maintenance condition	1–5 scale		Reasonably reliable, repeatable, and accurate if included in well-designed survey administered using scientific sampling	Moderate to low cost if added to questions in existing survey; moderate to high cost if part of a new survey effort
	Customer satisfaction rating of animal sanitation	1–5 scale		Reasonably reliable, repeatable, and accurate if included in well-designed survey administered using scientific sampling	Moderate to low cost if added to questions in existing survey; moderate to high cost if part of a new survey effort

SIGNALS

Traffic signals are essential to regulating traffic flow at intersections. Intersection safety depends on traffic signals functioning reliability and continually operating. However, occasionally there are traffic signal failures due to age, motor vehicle accidents, electrical outages and other reasons. From the standpoint of the customer, the average time between these failures should be as long as possible. Once a failure has been reported, road users expect signals to be repaired or replaced as quickly as possible. Table B-11 presents customer oriented performance measures for traffic signals.

Table B-11. Performance Measures for Traffic Signals

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Failure rate	Mean time to failure	Years and days		Nearly all agencies keep accurate logs of signal failure and potentially are able to assess mean time to failure accurately.	Requires establishment of electronic database; low to moderate cost
Response Time	Mean time to repair or replace once failure reported	Minutes		Nearly all agencies keep accurate logs of the time it takes to repair or replace a signal once signal failure is reported.	Requires establishment of electronic database; low to moderate cost

OTHER ELECTRONIC DEVICES

Other electronic devices are also expected to function reliably. Performance measures similar to those for traffic signals also apply to other electronic devices, as shown in Table B-12.

Table B-12. Condition Measures for Electronic Equipment

Attribute	Measure	Units	Commonly Recognized by AASHTO?	Repeatable, Reliable, & Accurate?	Cost and Other Issues
Functionality	Mean time to failure	Days		Most agencies keep accurate logs of electronic equipment failure and potentially are able to assess mean time to failure accurately.	Requires establishment of electronic database; low to moderate cost
Response time	Mean time to repair once reported	Minutes		Most agencies keep accurate logs of the time it takes to repair electronic equipment once a problem has been identified	Requires establishment of electronic database; low to moderate cost
Legibility of message signs	All lights in signs working	Yes or no		Easy to assess in a reliable, repeatable, and accurate manner	Low cost

APPENDIX C: GUIDANCE ON DESIGNING AND ADMINISTERING SURVEYS

If you decide to develop your own survey to be used as a benchmarking measurement tool, you should go through the standard steps of developing sound surveys:

- Focus groups,
- Survey design and pretesting,
- Coding guide and database design,
- Sample design,
- Administration, and
- Analysis and summarization.

FOCUS GROUPS

In order to understand what issues are important to your customers, you should begin any survey process with a series of focus groups. The main reasons to use a focus group are to identify what types of questions to include in your survey and to develop insight regarding how to provide a maintenance program that is more sensitive to the needs and desires of your customers.

Focus groups should be conducted in different parts of your jurisdiction to gain insight into how geography, urbanization, traffic congestion, and other factors outside the control of maintenance organizations affect customer satisfaction regarding the delivery of maintenance products and services. As much as is possible, focus group participants should be representative of all customers—including motorists, truckers, and adjacent property owners—as well as of different important categories such as gender, age, income, and ethnicity. The focus groups should be limited in size. Seven participants is a good size, but focus groups that are larger or smaller will work, too. Questions posed to focus group participants should be nondirective—do not steer respondents in any direction. Ask questions in a way that prompts focus group participants to freely discuss the issues, expectations, preferences, and satisfaction they experience as customers of road maintenance. Questions you might ask are

- What products and services do you perceive the maintenance organization delivers?
- What attributes of these products and services do you perceive?
- Which attributes are the most important?

- What is your expectation regarding different types of maintenance—for example, snow and ice control, mowing, and pavement resurfacing?
- Are you aware of other maintenance products and services that the DOT provides but that you cannot easily perceive (e.g., pavement durability, tree maintenance)?
- In your opinion, what factors affect the service quality of roads?
- In making travel decisions, what highway attributes have the most influence on your choices? Do you perceive that any of these attributes are related to maintenance operations?

From your notes from the focus groups, you should be able to make a list of questions that are prime candidates for incorporation into a survey.

SURVEY DESIGN AND PRETESTING

Next you will need to design the survey. You should have someone experienced in survey design draft it. You will have to decide how it will be administered, whether by mail, phone, or some other means. The administration process will influence the survey design. If the respondent will see the questions—for example, via a mail survey—a simple, pleasing design and clear layout is essential. Regardless of the format, the questions need to be easily understood and unambiguous.

Once you have drafted the survey, it should be pretested with a group of representative respondents and then revised. It may require additional pretesting and revision.

CODING GUIDE AND DATABASE DESIGN

When you have finalized your survey design, you will need to develop a coding guide to assist recording the results. You will also need to design the database in which you will enter the survey responses. You will have to specify a record layout for all data fields, including the order of each field, the type, and the length. This layout is usually sufficient to specify the database in a typical statistical analysis package.

SAMPLE DESIGN

You will need a statistician or a person with a strong statistical background to design a scientific sample for the survey. The survey should have scientific validity: you should establish target levels of statistical accuracy and confidence for the survey as a whole and for various customer groups or classes. In either case, you will want to take a random sample of customers; if you want to achieve specified levels of accuracy and confidence for subgroups, you will need to take some type of stratified random sample. For help, you should consult a statistician experienced in developing a sampling plan.

ADMINISTRATION

When you have completed your survey design, sampling plan, coding guide, and database design, you are ready to administer the survey. While you are proceeding through these steps, you should have been making plans regarding how you will administer the survey. There are many possibilities, but the most important are the following:

- Mail,
- Phone,
- Personal interviews, and
- Internet.

Your choice will depend upon the response rates you expect, the biases, and the costs.

You may wish to enlist a market research firm or service bureau that specializes in conducting surveys. They will have all the tools necessary to administer the survey efficiently, including procedures for selecting a random sample and conducting computer-assisted interviews. Survey administration over the Internet requires an altogether different skill set.

When your planning is complete, you will administer your survey. When the survey is completed, you will need to go through a number of additional steps before you can analyze the results:

- Check the survey responses and clean the data by removing nonsensical or extreme answers or respondents.
- If the survey results are not already in a database, you will need to put them in a database.

ANALYSIS AND SUMMARIZATION

Finally, you need to analyze and summarize the results. You should apply a standard statistical package to obtain total counts, means, standard deviations, and other standard statistics. You should use the graphical tools with the statistical package to summarize the results.

USE OF DIGITAL IMAGERY

Recently, Minnesota DOT (MnDOT) administered a number of innovative surveys that involve using digital imagery to help elicit information about customer preferences, satisfaction, and willingness to pay regarding different attributes of road maintenance.

MnDOT has used two survey techniques, one involving standard survey questions combined with video and the other involving the use of stated preference techniques and digital photographs. Both methods allowed survey respondents to better understand attributes of the maintenance products and services being explored. Also, in both cases, the surveys were administered to groups in a setting reminiscent of a focus group.

APPENDIX D: ASSESSING VALUE ADDED TO CUSTOMERS

This appendix describes in economic terms procedures for calculating value added to customers of maintenance attributes. For the most part, economic value to maintenance customers can be conveniently grouped into the following types:

- Avoided user costs,
- Avoided life-cycle costs, and
- Avoided external costs.

Customers are willing to pay to avoid user costs, life-cycle costs, and external costs. Hence, the willingness to pay is also an important measure of economic value.

AVOIDED USER COSTS

There is a well-established convention among transport economists that road user costs should be calculated by the following formula:

User Costs = Travel Time Costs + Vehicle Operating Costs + Accident Costs.

In customer-driven benchmarking, it may be desirable to employ avoided user costs or some component of user costs as a customer-driven outcome measure.

Avoided Travel Time Costs

In a project to develop a prototype decision support system for customer-driven benchmarking, Minnesota DOT (MnDOT) examined how its maintenance activity of removing obstructions in the roadway (e.g., spilled boxes, fallen branches) related to avoided travel time and accident costs. Consultants to MnDOT applied standard techniques of highway capacity analysis to calculate average travel time delay per vehicle experienced by a motorist as a function of the following:

- Capacity of the road in vehicles per lane per hour;
- The duration of the obstruction, which is equivalent to the time it takes maintenance personnel to remove the obstruction from the road; or
- The degree to which an obstruction reduces the highway capacity.

Figure D-1 shows the relationship between average delay per vehicle as a function of the capacity, q = 1,200 vehicles per lane per hour, and the percentage reduction in capacity of the road, R.

Once the average delay per vehicle is obtained, the mix of cars and trucks is estimated, and the average occupancy rate is determined, then it is possible to apply an estimate of the value of travel time to each driver and passenger in order to estimate the total avoidable road user costs in economic terms.

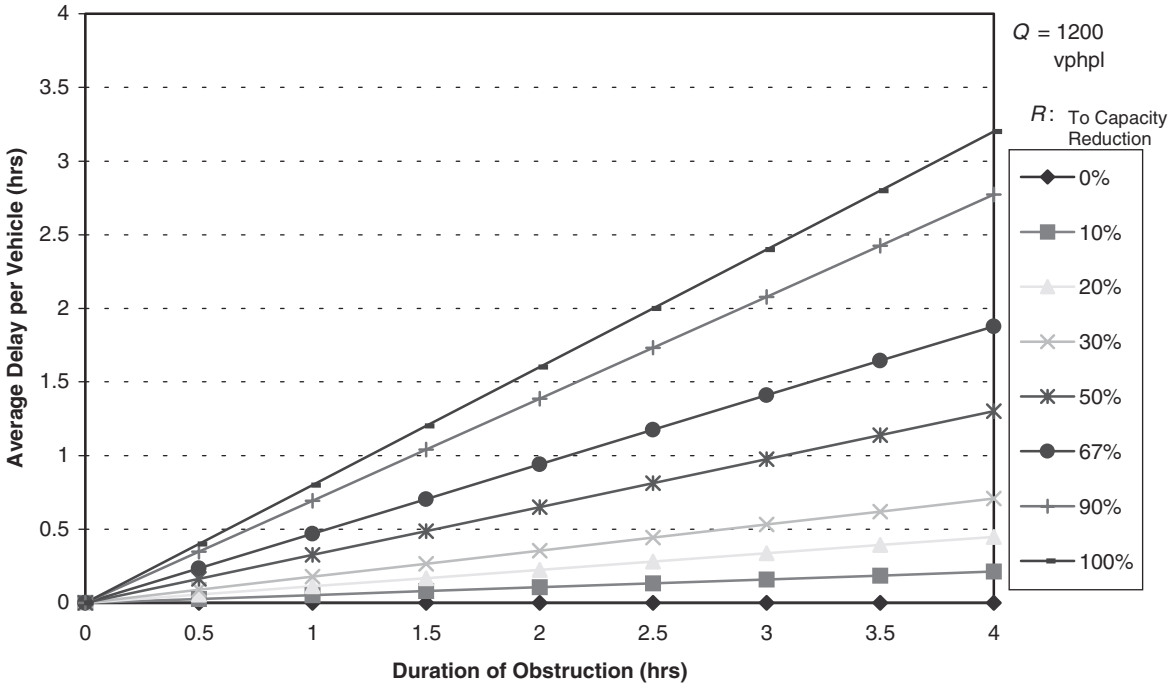

Figure D-1. Average Delay per Vehicle versus Duration of Obstruction for Traffic Volume = 1,200 Vehicles per Hour per Lane[1]

Equations such as these can be used to calculate avoidable road user costs. Indeed, many management and decision-support systems include estimation of road user costs, and the algorithms in those systems potentially can be used to develop performance measures for benchmarking. The Pontis Bridge Management System calculates travel time costs, vehicle operating costs, and accident costs as a function of deficiencies in clear deck width, vertical clearance, and load capacity of bridges. Pontis calculates the

[1] Alfelor, R. M., W.A. Hyman, and G.R. Niemi (1990). "Customer-Oriented Maintenance Decision Support System: Developing a Prototype," *Transportation Research Record 1672,* Transportation Research Board of the National Academies, Washington, DC, pp. 1–10.

reduction in these costs resulting from various improvement options, such as strengthening and widening bridges.

Similarly, the Highway Economic Requirements System (HERS), which the federal government uses to estimate national highway needs for the U.S. Congress, calculates all three types of user costs as a part of a benefit-cost calculation.

AVOIDED LIFE-CYCLE COSTS

Customers who are conscious of the taxes and fees they pay to maintain and improve roads would prefer not to pay more taxes and fees if they can avoid it. Therefore, an important performance measure is avoided life-cycle costs of assets. Life-cycle costs are defined as the stream of future costs an agency incurs over the life of an asset:

- Initial or startup costs,
- Recurring or periodic costs,
- Sporadic or infrequent costs, and
- Salvage and disposal costs.

For long-lived assets, under certain circumstances you can assume they will remain in service in perpetuity and you can ignore salvage and disposal costs. However, if you have reason to pay close attention to environmental ramifications of disposal and reuse, you may wish to account explicitly for these end-of-life costs.

Life-cycle costs can be derived from a life-cycle activity profile in which you identify for each year into the future each maintenance, rehabilitation, replacement, or reconstruction activity that will occur. From this life-cycle activity profile, you can identify a future stream of life-cycle costs by determining the cost of each activity. If the life of a particular asset will end during the calculation horizon, you will have to determine the nature of the replacement asset, identify its life-cycle activity profile, and append it to the first one.

AVOIDED EXTERNAL COSTS

A good example of external costs that can be avoided by road maintenance is the infestation by noxious weeds of farmland adjacent to a highway. Certain types of noxious weeds are destructive to crop yields and can significantly reduce the income of farmers. In fact, there is literature one can draw upon to estimate the reduction in crop yield of different types of crops as a function of the infestation of different types of noxious weeds.

Noxious weed control helps avoid infestation of property on neighboring roads. To calculate the avoided costs of noxious weeds caused by noxious weed control, you need to make the following calculation:

- Determine what type of noxious weeds are currently in the right-of-way;
- Assess the extent and severity of the weed in the right-of-way;
- Assess the extent and severity of infestation of noxious weeds in adjacent farmland;
- Assess, based on the literature, the reduction in crop yield caused by the infestation, assuming no control of the noxious weed;
- Calculate the reduction of income caused by the predicted infestation of the noxious weed, assuming no control of the noxious weed;
- Determine what percentage of the reduction of income to farmers can be avoided by controlling the noxious weed in the right-of-way; and
- Apply the percentage to the estimated reduction in income to farmers to calculate the avoided loss in farm income.

One could potentially make similar calculations regarding other external side effects—for example, the effect of salt damage to vegetation outside the right-of-way. One can also, in theory, make estimates using well-known statistical methods (e.g., regression) for estimating how changes in certain types of maintenance affect property values. For example, failure to remove graffiti from noise barriers is likely to reduce property values of adjacent property.

DISCOUNTING

Three different types of economic costs have just been discussed: avoidable user costs, avoidable life-cycle costs, and avoidable external costs. Estimated avoidable costs do not all occur at the same time, but rather at different times in the future. Economists have a way to put benefits and costs that occur in the present and at different times in the future on an equal footing. The method is called "discounting." Discounting is based on the idea that $1 in your hand today is worth more than a $1 you receive a year from now. An important reason is that there is some amount less than $1 that you could put in a bank or in some other investment at the prevailing interest rate or rate of return and earn $1 dollar in the future. The prevailing rate of return you can earn on your money is called the discount rate, r. It is useful to think of the discount rate as the opportunity cost of investment—that is, the rate of return you can earn on your next best use of funds.

To determine the present worth of an amount of a cost or of a benefit that will be incurred n years in the future, you multiply that amount by the following discount factor:

$$1/(1+r)^n .$$

The following is an example of how to calculate the present worth—discounted costs—of a future stream of benefits involving a future avoidable cost of $1,000 per year by using a discount factor of $r = 0.07$. The example reveals that a stream of avoidable future costs of $1,000 per year totaling $10,000 over 10 years has a present worth or discounted present value of $7,023.58

Year	Undiscounted Costs ($)	Discount Factor	Discounted Costs ($)
1	1000	0.9346	934.58
2	1000	0.8734	873.44
3	1000	0.8163	816.30
4	1000	0.7629	762.90
5	1000	0.7130	712.99
6	1000	0.6663	666.34
7	1000	0.6227	622.75
8	1000	0.5820	582.01
9	1000	0.5439	543.93
10	1000	0.5083	508.35
TOTAL	**10000**		**7023.58**

WILLINGNESS TO PAY

Customers of road transport and, in turn, of road maintenance are willing to pay various amounts for different types of road maintenance. Road users and others do indeed pay gas taxes, property taxes, and other fees in order to support road maintenance costs. If the value they receive is less than the amount they pay, they seek tax reductions. If they perceive the value of maintenance is greater than what they currently pay, they may be willing to pay more. Often there is a difference between what people are willing to pay and what they actually pay. If the difference is positive, economists call this difference "consumer surplus."

As a part of its market research, including both surveys and its effort to develop a decision-support system for benchmarking maintenance activities, MnDOT sought to estimate what customers are willing to pay for different types of maintenance activities.

In one of its customer surveys, MnDOT asked respondents to allocate $100 among its different products and services as an indication of what customers are willing to pay for each.

In another market research study dealing with snow and ice control, MnDOT asked its customers how many miles travelers would be willing to go out of their way during a snow storm to drive a road that was maintained in different ways. Some of these ways included the following:

- Only the right lane plowed,
- All lanes plowed,
- Full road width plowed, and
- Only the right road edge visible.

With information on what customers are willing to pay in terms of driving distance to obtain different levels of service, MnDOT can estimate the travel time during winter conditions and can figure out how much travel time customers are willing to pay. MnDOT can then go one step further, apply standard estimates of the value of travel time in dollars, and calculate what people are willing to pay in monetary terms.

Another approach MnDOT has taken to estimate willingness to pay is to develop stated preference surveys and apply them in focus groups where alternative scenarios are displayed using digital imagery.

Stated preference techniques involve estimating models of consumer choice based on data derived from an experimental design (a mathematical pattern) embedded in a survey or derived from a laboratory simulation or experiment. In a large number of the stated preference surveys conducted in the transportation field, the experiments are designed so that each factor influencing a choice is independent, thus allowing an independent estimate of the strength of each factor that influences a choice.

Consultants assisting MnDOT developed stated preference survey instruments to assess willingness to pay for litter removal and various types of vegetation control. The basic idea was to pose to customers whether they would take Road A or Road B where Road A required less time to travel, but road B had more aesthetically attractive attributes, safer attributes, or both.

By systematically posing different scenarios regarding the attributes of Road A and Road B and recording the choice of survey respondents (i.e., focus group participants who represented the customers), one can apply statistical techniques (e.g., regression, logit estimation) to infer how much extra time people are willing to spend to drive a road having different levels of each attribute of interest.

Figure D-2 shows the relationship between MnDOT's litter indicator value and the amount focus group participants were willing to pay in travel time to obtain a particular level of litter removal.

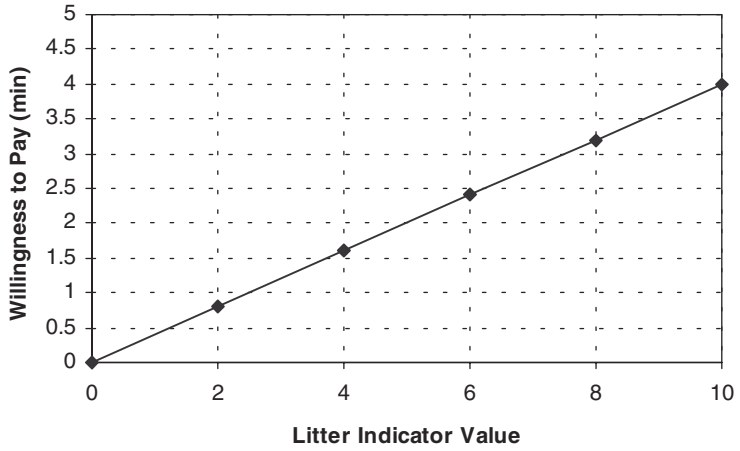

Figure D-2. Relationship Between Litter Indicator Value and Willingness to Pay

Once the travel time people are willing to pay is determined, one can calculate the monetary value of the travel time to obtain an estimate of the willingness to pay in terms of dollars.

Figure D-3 shows an example of a survey instrument that was used to estimate willingness to pay for litter removal. Different levels of litter correspond to different levels of the litter indicator measure that MnDOT uses to assess performance of litter removal from the standpoint of the customer. The results obtained from administering the stated preference survey were eventually incorporated into MnDOT's prototype decision-support system for benchmarking.

On average, how long does it take you to travel from home to work?

_____ minutes

Suppose you have a choice of driving two roads (A or B) to work. Road A takes an average length of time to travel. Road B takes more time to travel than does Road A, but Road B has less litter. Assuming that the two roads are identical in other respects, please indicate in the scenarios below whether you would take Road A or Road B:

	Litter Factors		***Travel Time Factors***	***Choose A or B***	
Scenario	*Litter on Road A*	*Litter on Road B*	*Extra Travel Time on Road B*	*(Please encircle)*	
1	*Some*	*Hardly any*	*1 minute*	*A*	*B*
2	*A lot*	*Hardly any*	*1 minute*	*A*	*B*
3	*A lot*	*Hardly any*	*5 minutes*	*A*	*B*
4	*Some*	*Hardly any*	*5 minutes*	*A*	*B*
5	*A lot*	*Hardly any*	*10 minutes*	*A*	*B*
6	*Some*	*Hardly any*	*10 minutes*	*A*	*B*
7	*Some*	*Hardly any*	*20 minutes*	*A*	*B*
8	*A Lot*	*Hardly any*	*20 minutes*	*A*	*B*

Hardly any litter: average litter count per 500 ft. is less than 20 pieces.
Some litter: average litter count per 500 ft. is more than 20 pieces, but less than 34 pieces.
A lot of litter: average litter count per 500 ft. is more than 34 pieces.

Figure D-3. Survey Instrument for Litter Control: Impact of Litter on Work Trips

This survey was administered to focus groups of rural and urban residents. Each scenario was illustrated using digital photos of Roads A and B that were systematically altered in accordance with the experimental design to show focus group participants each level of each factor that affects their choice of taking Road A or Road B. Figure D-4 presents examples of two such photographs.

Road B (hardly any litter)

Road A (a lot of litter)

Figure D-4. Visual Graphics for Litter Control Surveys

DOUBLE COUNTING

When calculating economic costs and benefits, it is important not to double count. Generally, the sum of avoidable user, life-cycle, and external costs exhausts all the benefits that might occur. You should not add to these other avoidable costs or to willingness to pay to get an estimate of total benefits.

In fact, an estimate of the sum of the willingness to pay of each customer is an estimate of the total potential benefits all customers receive. It would be double counting to add to this to an estimate equal to the sum of avoidable user, life-cycle, and external costs to obtain an estimate of the increase in total benefits—that is, the total increase in value customers receive.

However, an increase in consumer surplus—the difference between what people are willing to pay and what they actually pay—is legitimate to add to these benefits. An increase in consumer surplus occurs when the price or disutility of purchasing or of using a product or service declines. Suppose the delay associated with maintenance work zones declined substantially; the price each person pays in terms of travel time will have declined, thus increasing the difference between the travel time a person is willing to pay and the travel time the person actually pays. This difference is the change in consumer surplus for each person. The sum of the change in consumer surplus over all people involved—both existing users and additional users induced to travel through the work zone because of the lower delay—represents the total change in what people are willing to pay as a result of the reduction in delay. In certain cases, it would be legitimate to add this to avoidable user costs without it being considered double counting.

Adding avoidable resource costs—labor, equipment, and material—is alright to do, provided you are not already accounting for them. Do not include these costs if they are already included in life-cycle costs. In the benchmarking procedure the project team advocates (i.e., Data Envelopment Analysis), resources are treated separately; therefore, to include avoidable resource costs among total avoidable costs would be double counting. It is also double counting to include resource costs among the benefits when resource costs are already accounted for in the denominator of a benefit-cost calculation.

An accounting framework that exhausts all benefits including avoidable agency costs and changes in consumer surplus would consist of the following:

- Avoidable user costs,
- Avoidable life-cycle costs,

- Avoidable external costs, and
- Change in consumer surplus.

The maintenance actions that minimize the sum of these the avoidable costs and that maximize consumer surplus would be the optimal set of actions.

Benefit and cost analysis can be confusing; it is easy to misstep. If you have any questions regarding how to proceed, consult an economist or someone who has had substantial experience doing highway benefit and cost estimation.

OTHER ISSUES IN CALCULATING CUSTOMER VALUE

There are three additional issues in attempting to assess customer value for purposes of benchmarking.

The first issue involves procedures for estimating economic value. The procedures have been applied for decades in the transportation field and to maintenance overseas, but only recently have they been applied to the area of maintenance in the United States. Therefore, methods for assessing the monetary value customers receive from maintenance are still experimental. It is desirable for maintenance managers and researchers to continue performing research and, as reliable methods are developed, to introduce the methods into practice. Otherwise, it will not be possible to achieve the objective of assessing the change in customer value caused by maintenance.

The second issue concerns the practicality of applying measures of customer value to benchmarking maintenance activities. In many respects, it is more appealing to be able to take physical measurements of customer-oriented outcomes than it is to assess changes in value received by customers. Physical measurements are easier to take, easier to interpret, lack the subjective component of value, and do not require making an imputation of monetary worth.

The third issue involves taking advantage of other models and management systems that have built-in procedures for calculating economic value to customers. One of the keys to success may be to use various management systems, such as a bridge management system, that apply optimization procedures to determine the actions that minimize user and life-cycle costs. The optimization procedure determines the right actions for each asset or element of an asset at each point in time. Any deviation from these actions, assuming the selection of actions is optimal, increases road user and life-cycle costs. These are the avoidable costs of optimal maintenance actions, ignoring, of course, externalities and changes in consumer surplus.

MNDOT PROTOTYPE DECISION-SUPPORT SYSTEM

This section concludes with a brief overview of MnDOT's prototype decision-support system, which was developed for purposes of customer-driven benchmarking of maintenance activities. The project was meant to lay the foundation for achieving the goal of allocating resources in accordance with the marginal increase in value to customers that is measured in monetary terms and is caused by an increase in input levels.

Rather than be content with benchmarking output and outcome measures, MnDOT held firm to its conviction that above all, the *value* to the customer of road maintenance is the fundamental issue and should be the focus of any benchmarking effort. Accordingly, MnDOT contracted with a private firm for the development of a benchmarking process and prototype software to explore the relationships among inputs, outputs, outcomes, and the value added of maintenance products and services in a manner that adjusts for uncontrollable environmental factors such as weather, terrain, and road type.

The MnDOT project focused on two of the seven products and services identified by the department: (1) clear roads and (2) attractive roadsides. The objectives of the MnDOT project were as follows:

1. **Develop a decision-support system** that permits maintenance managers to assess the resources deployed relative to the value delivered to customers,

2. **Identify best practices** in providing products and services considering the environmental factors impacting their delivery and the preferences of the customers, and

3. **Support continuous improvement efforts** through measurements and analysis of relative performance of work units in similar or related environments.

The MnDOT project used a number of innovative techniques to establish the relationships among inputs, outputs, outcomes, value added, and uncontrollable variables. The methods allow one to analyze how changing inputs that are consistent with a particular level of service for a maintenance activity affect outputs, outcomes, and value added.

Production Functions

The consultant team sought to develop two sets of production functions for each maintenance activity included in the two product and service areas that were the focus of the MnDOT effort. One set was to estimate outputs, and the other was to estimate outcomes. Production functions provide an estimate of the outcome or output with respect to changes in the level of one or more inputs (e.g., labor, equipment, or material) or uncontrollable variables.

Focus groups and expert elicitation were used to explore with MnDOT staff the various factors that affect outputs and outcomes. Maintenance superintendents from throughout the state were gathered together to discuss in detail the factors that affect production. The fact that the production functions had constant outcome and output elasticities (which were defined as the percent change in production for a 1-percent change in an input factor) enabled the consultant team to simply ask experts in the department by what percent they expected the outcome (or output) variable to change given a 10-percent change in an input or uncontrollable variable; this allowed the consultant team to quickly and easily obtain a preliminary estimate of each coefficient and corresponding production elasticity. Based on these focus groups, hypotheses were formed regarding the relative importance of factors affecting production and regarding whether there was a direct or inverse relationship between outcome (or output variables) and labor, materials, equipment, and each uncontrollable variable (such as weather).

Next, weather data from the National Weather Service and was merged with the standard maintenance activity, resource, and accomplishment data in the Operations Management System (OMS). Transportation Information System (TIS) data regarding roadway type, traffic volumes, and terrain was also merged with the OMS data. The combined OMS, weather, and other highway-related data were used to estimate production functions and to test hypotheses concerning the significance of the variables included in the production functions. Production functions for certain outcomes and outputs for selected activities in MnDOT's Clear Roads and Attractive Roadsides products and service areas were successfully estimated based upon the fact that their coefficients were found to be statistically significant.

Value Added

The benchmarking framework developed was carefully structured to permit an assessment of the additional economic value a customer receives because of some incremental change in resources or uncontrollable factors. Two approaches were used to assess the economic value of maintenance activities to customers:

1. **Assessment of avoidable road user costs:** avoided travel time and accident costs were calculated using standard methods of highway capacity analysis and economic analysis (see above).

2. **Assessment of willingness to pay:** willingness to pay was estimated using a stated preference market research technique (see above).

Prototype Software and Benchmarking Based on Differences

In order to support benchmarking, prototype software was developed to permit various comparisons within and among districts, areas, and sub-areas for various maintenance activities. The software was designed to examine differences in the results of production, whether expressed in terms of outputs, outcomes, or economic value added. To the extent that suitable production functions and value-added functions are estimated, software can be used to identify or calculate the following differences:

- **The difference between the best performer and the others within the state, a district, an area, or a sub-area** based on average outputs, outcomes, or economic value with or without adjusting for uncontrollable factors such as presence of shoulder, terrain, precipitation, and traffic.
- **The difference in the economic value (outcome or output) of an instance of an activity and the economic value (outcome or output) associated with estimated production** based on average or other prescribed levels of resources with or without adjusting for uncontrollable factors.

Figure D-5 shows an example output screen from the MnDOT decision-support software that illustrates a comparison among the output, outcome, and economic value of an activity instance involving plowing and sanding compared with estimated production using the same level of resources.

PRODUCTION FUNCTION

Activity Number:	2406	District:	7
Activity Name:	Plowing and Sanding	Area:	Windom
Product Type:	Clear Roadway	Subarea:	St. James

Date	Rte. Class	Rte. No	# Lanes	EQ Code	Reg. Hrs.	OT	Output Measure	Outcome Measure
2/7/96	02	14	2	620	4.00	0.00	Lane-Mile	Minutes/Lane-Mile

Production Factors	Output Elasticity	Outcome Elasticity	Activity Instance
Labor:	0.16	-0.11	4.00
Equipment:			3.00
Material:			
Temperature:	0.72	-0.34	37
Shoulder:			gravel
Terrain:	-0.24	0.58	rolling
Precipitation:			
AADT/Lane		0.52	1410

Performance Measures	Activity Actual	Activity Estimate	Net Value
Output:	43.94	36.72	7.22
Maint. Cost:	$148.98		$29.28
Outcome:	5.46	10.46	-5.00
Delay Cost:	$2,585.99	$4,951.71	$2,365.72
Will. To Pay:			
Accident Cost:	$68.49	$131.15	$62.66
Indic. Value:	1.00		
Value of Time ($/hr)	$8.00	Cost/ Accident	$75,000.00

Return to Previous Menu

Figure D-5. MnDOT Production Function

The following is a description of various fields shown in the sample screen:

- Activity Number—activity code,
- Activity Name—name of activity,
- Product Type—MnDOT maintenance product category,
- District—district number,
- Area—area name,
- Subarea—sub-area name,
- Date—date work was performed,
- Rte. Class—route class,
- Rte. No—route number,
- # Lanes—number of lanes,

- EQ Code—equipment code number,
- Reg. Hrs.—number of regular labor hours,
- OT—number of overtime hours,
- Output Measure—lane miles of plowing or sanding, and
- Outcome Measure—minutes/lane mile to restore bare pavement.

The lower left quadrant of the screen shows the coefficients for two Cobb–Douglas production functions: one for the output production function and the other for the outcome production function. A Cobb–Douglas function has the property that the coefficients are equal to their elasticities:

$$\text{Output or Outcome } Y = a_0 X_1^{a1} X_2^{a2} X_3^{a3},$$

where X_1 is a factor input and a_1 is a coefficient. As stated above, elasticity is defined as the percent change in output (or outcome) for a percent change in the production factor. In this example, the following statistically significant coefficients, found in the first column of cells, were obtained for the output production function[2]:

- Labor (output elasticity is 0.16);
- Temperature (output elasticity is 0.72); and
- Terrain (output elasticity is –0.24).

The following statistically significant coefficients, found in the second column of cells, were obtained for the outcome production function:

- Labor (outcome elasticity is –0.11);
- Temperature (outcome elasticity is –0.34);
- Terrain (outcome elasticity is –0.58); and
- Average annual daily traffic (AADT)/lane (outcome elasticity is 0.52).

The third column of cells shows the actual values of each production factor that correspond to the road work actually performed:

- Labor (4 hours);
- Equipment (3 hours);

[2] Intriligator, M.D. (1971). *Mathematical Optimization and Economic Theory,* Prentice-Hall, Englewood Cliffs, NJ.

- Temperature (37°);
- Shoulder (gravel);
- Terrain (rolling);
- Precipitation (none); and
- AADT/lane (1,410 vehicles).

In the lower right quadrant of the screen are three columns of fields: the first concerns results for the actual activity, the second consists of estimated results, and the third is the difference or net value for the following:

- Output,
- Maintenance cost,
- Outcome,
- Delay cost,
- Willingness to pay,
- Accident cost, and
- Indicator value (bare pavement indicator).

In this example, there is a net savings of $29.28 in terms of maintenance cost based on the difference between the actual and estimated maintenance cost. There is also a net savings in road user delay costs based on the difference between the calculated delay costs associated with the estimated outcome and the actual outcome. There is also a net savings in accident delay costs based on the difference between the estimated accident costs and the calculated accident costs associated with the actual performance. Delay costs were estimated at $8 per hour and accident costs at $75,000 per accident.

Data Completeness and Quality

The completeness and the quality of the data used were an issue throughout the project. Both MnDOT staff and the consultant team recognized that the quality and completeness of the data would need to be improved over time and that the production functions would need to be re-estimated using less restrictive functional forms than the Cobb–Douglas production function. However, the feasibility of estimating production functions and making comparisons based on outcomes, outputs, and value added after adjusting for uncontrollable variables such as weather and terrain was established. Enhancements to the data and estimation of the production functions were viewed as an integral part of the process of continuous improvement.

APPENDIX E: SURVEYS ADMINISTERED BY THE STATES TO THEIR CUSTOMERS

ANALYSIS OF STATE SURVEYS

Numerous states have administered surveys to customers of road maintenance. This appendix is composed of a series of tables that that attempts to analyze the extent such surveys address each of the following:

- Activities;
- Products and services or other groupings of maintenance activities;
- Attributes of products and services;
- Different types of performance measures (e.g., inputs, outputs, outcomes, value added); and
- Whether the performance measure is focused on external or internal customers.

Information from these tables can be used in defining product and service categories, identifying attributes of products and services important to customers, mapping maintenance activities to particular product and services, and determining whether a particular type of survey question is focused on customer-oriented outcomes.

Arizona

Arizona DOT has administered a survey that has sought customer input regarding the levels of services for different groups of maintenance activities. The measures all are outcome measures and are externally focused.

ARIZONA: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/Services/Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
	Paved Roadway Surfaces		Perceived Level of Service (LOS); desired LOS	LOS (1-5)	Outcome	E
	Road Shoulders		Perceived LOS; desired LOS	LOS (1-5)	Outcome	E
	Roadside		Perceived LOS; desired LOS	LOS (1-5)	Outcome	E
	Vegetation		Perceived LOS; desired LOS	LOS (1-5)	Outcome	E

ARIZONA: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/Services/Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
	Landscaping		Perceived LOS; desired LOS	LOS (1-5)	Outcome	E
	Drainage		Perceived LOS; desired LOS	LOS (1-5)	Outcome	E
	Structures		Perceived LOS; desired LOS	LOS (1-5)	Outcome	E
	Traffic Control and Safety		Perceived LOS; desired LOS	LOS (1-5)	Outcome	E
	Rest Areas		Perceived LOS; desired LOS	LOS (1-5)	Outcome	E
	Snow and Ice Removal		Perceived LOS; desired LOS	LOS (1-5)	Outcome	E

California

Customer measures used in California are similar in some respects to those used in the Coopers & Lybrand survey done for the National Quality Review. However, many areas in which California has sought customer input pertain to maintenance services in storm and emergency conditions. Customer satisfaction is measured on a scale of 1 to 10, and the measures are all outcome measures and externally focused.

CALIFORNIA: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
Remove/clean spills, debris	Maintenance Response to National Disasters		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Detours of accidents/closures	Maintenance Response to National Disasters		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Response to natural disasters	Maintenance Response to National Disasters		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Signs about temp. hazards	Maintenance Response to National Disasters		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Ice and snow removal	Safety		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Chain controls	Safety		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E

CALIFORNIA: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
Debris removal	Safety		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Safety barriers	Safety		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Maintenance of shoulders & turnouts	Safety		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Sign visibility	Safety	visibility	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
	Pavement Conditions	smooth surfaces	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
	Pavement Conditions	surface traction	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
	Pavement Conditions	visibility of pavement markings	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Removal of old markings	Pavement Conditions	absence of old markings	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Pothole repairs	Pavement Conditions		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Pavement resurfacing	Pavement Conditions		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
	Traffic Flow	traffic information	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Maintenance scheduling	Traffic Flow	timing of maintenance work	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Maintenance delay	Traffic Flow	delay	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
	Bridge Conditions	approaches	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
	Bridge Conditions	lighting	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Restroom maintenance at rest areas	Travel Amenities		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Rest area grounds maintenance	Travel Amenities		Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
	Travel Amenities	safety and lighting at rest areas	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Landscape maintenance	Visual Appeal	visual attractiveness	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Weed control	Visual Appeal	visual attractiveness	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Litter removal	Visual Appeal	visual attractiveness	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Graffiti removal	Visual Appeal	visual attractiveness	Customer Satisfaction Rating	0 (extremely dissatis.)-10 (extremely satis.)	Outcome	E
Sign repair	Time-Sensitive Maintenance Activities	response time	Preferred amount of time for service	w/in 15, 30, 60 min; 1 day, 3 days, 1 wk	Preferred Outcome	E

CALIFORNIA: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
Guardrail and safety repair	Time-Sensitive Maintenance Activities	response time	Preferred amount of time for service	w/in 15, 30, 60 min; 1 day, 3 days, 1 wk	Preferred Outcome	E
Light repair	Time-Sensitive Maintenance Activities	response time	Preferred amount of time for service	w/in 15, 30, 60 min; 1 day, 3 days, 1 wk	Preferred Outcome	E
Traffic delays due to Maintenance	Time-Sensitive Maintenance Activities	response time	Preferred amount of time for service	w/in 15, 30, 60 min; 1 day, 3 days, 1 wk	Preferred Outcome	E
Notification of road closures	Time-Sensitive Maintenance Activities	response time	Preferred amount of time for service	w/in 15, 30, 60 min; 1 day, 3 days, 1 wk	Preferred Outcome	E
Graffiti removal on signs	Time-Sensitive Maintenance Activities	response time	Preferred amount of time for service	w/in 15, 30, 60 min; 1 day, 3 days, 1 wk	Preferred Outcome	E
Graffiti removal elsewhere	Time-Sensitive Maintenance Activities	response time	Preferred amount of time for service	w/in 15, 30, 60 min; 1 day, 3 days, 1 wk	Preferred Outcome	E
Pothole repairs	Time-Sensitive Maintenance Activities	response time	Preferred amount of time for service	w/in 15, 30, 60 min; 1 day, 3 days, 1 wk	Preferred Outcome	E
Update message: Road Condition	Time-Sensitive Maintenance Activities	response time	Preferred amount of time for service	w/in 15, 30, 60 min; 1 day, 3 days, 1 wk	Preferred Outcome	E

Connecticut

Connecticut conducted customer surveys regarding rest area maintenance.

CONNECTICUT: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/Services/Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/External**
	Rest Area Maintenance	cleanliness and sanitary		Y/N	Outcome	E
		adequate restroom supplies		Y/N	Outcome	E
		neat and litter free		Y/N	Outcome	E
		helpful personnel		Y/N	Outcome	E

Kansas

Kansas DOT has administered a survey to obtain information on customer satisfaction and on how good a job the state was doing. Both general types of measures are outcomes. The Kansas survey sought reactions to attributes of maintenance, not just to product or service areas or to maintenance activities. Kansas DOT also asked customers a question about the value of services provided to its customers.

KANSAS: TYPES OF MEASURES IN CUSTOMER SURVEYS

Products/Services/Group	Attributes	Measure	Scale	Measure Type	Internal/ External
Lighting	At intersections and interchanges	Customer Satisfaction	1 (Very Dis)–5 (Very Satis)	Outcome	E
	At intersections and interchanges	How Good a Job	1 (VP)–5 (VG)	Outcome	E
Debris/Litter Removal	Brush and animals	Customer Satisfaction	1 (Very Dis)–5 (Very Satis)	Outcome	E
	Brush and animals	How Good a Job	1 (VP)–5 (VG)	Outcome	E
Snow Removal		How Good a Job	1 (Very Dis)–5 (Very Satis)	Outcome	E
Maintain Pavement Markings	Striping on side of road	Customer Satisfaction	1 (VP)–5 (VG)	Outcome	E
	Centerline and no passing stripes	Customer Satisfaction	1 (Very Dis)–5 (Very Satis)	Outcome	E
Fixing Guardrail		How Good a Job	1 (VP)–5 (VG)	Outcome	E
Fixing Potholes		How Good a Job	1 (VP)–5 (VG)	Outcome	E
Fixing Cracks in Road		How Good a Job	1 (VP)–5 (VG)	Outcome	E
Pavements	Smoothness of road surface	Customer Satisfaction	1 (Very Dis)–5 (Very Satis)	Outcome	E
	Durability of road	Customer Satisfaction	1 (Very Dis)–5 (Very Satis)	Outcome	E
Maintaining Signs		How Good a Job	1 (VP)–5 (VG)	Outcome	E
	Reflectiveness and visibility at night	Customer Satisfaction	1 (Very Dis)–5 (Very Satis)	Outcome	E
	Frequency of posted signs	Customer Satisfaction	1 (Very Dis)–5 (Very Satis)	Outcome	E
	Condition of rest areas	How Good a Job	1 (VP)–5 (VG)	Outcome	E
	Frequency of roadside rest areas	Customer Satisfaction	1 (Very Dis)–5 (Very Satis)	Outcome	E
Maintaining Shoulders		How Good a Job	1 (VP)–5 (VG)	Outcome	E
	Having a shoulder along road	Customer Satisfaction	1 (Very Dis)–5 (Very Satis)	Outcome	E
	Having a paved shoulder along road	Customer Satisfaction	1 (Very Dis)–5 (Very Satis)	Outcome	E
Roadside Mowing		How Good a Job	1 (VP)–5 (VG)	Outcome	E
Maintaining Bridges		How Good a Job	1 (VP)–5 (VG)	Outcome	E
	Bridge condition	Customer Satisfaction	1 (Very Dis)–5 (Very Satis)	Outcome	E

KANSAS: TYPES OF MEASURES IN CUSTOMER SURVEYS					
Products/Services/Group	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
Overall Customer Service	Courtesy and helpfulness	Overall Customer Service	1 (Very Good)–5 (Very Poor)	Outcome	E
	Fulfill KDOT mission to meet Kansas's needs	Overall Customer Service	1 (Very Well)–5 (Very poor)	Outcome	E
	Keeping you informed about what you need to know	Overall Customer Service	1 (Very Well)–5 (Very poor)	Outcome	E
	Value of services provided by KDOT	Overall Customer Service	1 = Good Value;2 = OK Value;3 = Poor Value	Value Added	E

Kentucky

The Kentucky Transportation Cabinet commissions an annual customer survey to find out customer reactions to attributes of maintenance. Customers are asked to respond by using a 1 to 5 scale. The measures pertain to outcomes. The questions are nearly identical to those in the Coopers & Lybrand survey conducted for the National Quality Review and were intended to allow the state to compare the reaction of its road users with those throughout the nation.

KENTUCKY: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
		Overall Visual Appeal (General Category)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Rest Area Design	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Environmental Compatibility	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Landscaping	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Sound Barriers	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Overall Safety Items (General Category)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Construction Signs	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Warning Signs	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Lane Width	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Safety Barriers	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Pavement Markings	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Shoulder Width	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E

KENTUCKY: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
		Detour Directions	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Roadway Lighting	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Wet Weather Conditions	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Overall Bridge Condition (General Category)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Visual Appearance	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Durability of Road	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Smooth Ride	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Travel Amenities (General Category)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Mileage/Destination Signs	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Service/Attraction Signs	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Number of Rest Areas/Plazas	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Variety of Rest Area/Plaza Services	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Number of Emergency Call Boxes	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Overall Pavement Conditions (General Conditions)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Surface Appearance	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Quiet Ride	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Smooth Ride	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Durability	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Maintenance Response Time (General Category)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Rest Area Cleaning Response Time	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Guardrail Repair Response Time	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Litter Removal Response Time	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Snow Removal Response Time	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Pavement Repairs Response Time	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E

KENTUCKY: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
		Overall Traffic Flow (General Category)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Toll Booth Delays	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Accident Clean Up	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Level of Congestion	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E
		Construction Delays	Customer Satisfaction	1=Extremely Dissatisfied; 5=Ext. Satisfied	Outcome	E

Minnesota

For some time, the Minnesota DOT (MnDOT) maintenance organization has been customer oriented. MnDOT was among the first states to categorize its maintenance activities into product and services that relate directly to the customer. The department has conducted a variety of different types of customer surveys, beginning with one that asked customers to rate the importance of each product and service area, to rate how well the department is doing regarding each product and service area, and to allocate $100 among different products and services. More recently, the department conducted a number of innovative surveying procedures that have used digital imagery to help assess customer satisfaction, customer expectations, and value added in regards to specific product and service areas, especially the snow and ice component of the MnDOT Clear Roadways and the Attractive Roadside product and service area.

MINNESOTA TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**External/ Internal**
	Clear Roadways	Clear of unplanned obstructions	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome	E
	Clear Roadways	Roadway clear of ice and snow	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome	E
	Clear Roadways	Roadway clear of ice and snow	Indicator for clear of ice and snow	Hrs. to restore bare pavement/length of storm	Outcome	E
	Clear Roadways	Trucks plowing as soon as snow appears	Importance to customer and customer satisfaction		Outcome	E
	Clear Roadways	Plowing frequency during average snowfall	Importance to customer and customer satisfaction		Outcome	E
	Clear Roadways	Ability to see shoulder striping during snowfall	Importance to customer and customer satisfaction		Outcome	E
	Clear Roadways	Ability to see road edge during snow fall	Importance to customer and customer satisfaction		Outcome	E

MINNESOTA TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**External/ Internal**
	Clear Roadways	Ability to make turns at crossovers/intersections	Importance to customer and customer satisfaction		Outcome	E
	Clear Roadways	Driving speed during snowfall	Customer expectations		Outcome	E
	Clear Roadways	Day versus night snow removal expectations	Customer expectations		Outcome	E
	Clear Roadways	Weekday versus weekend snow removal expectations	Customer expectations		Outcome	E
	Clear Roadways	Radio channels listed to for weather/road info	Customer expectations		Outcome	E
	Clear Roadways	Bare wheel baths	Importance to customer and customer satisfaction		Outcome	E
	Clear Roadways	Scattered slippery spots	Importance to customer and customer satisfaction		Outcome	E
	Clear Roadways	Only right lane plowed to bare pavement	Importance to customer and customer satisfaction		Outcome	E
	Clear Roadways	All driving lanes plowed to bare pavement	Customer importance and satisfaction; miles willing to drive for LOS		Outcome, value added	E
	Clear Roadways	All lanes plowed full width	Customer importance and satisfaction; miles willing to drive for LOS		Outcome, value added	E
	Clear Roadways	Fully cleared intersections/crossovers	Importance to customer and customer satisfaction		Outcome	E
	Smooth and Reliable Pavement	Availability of roadway for year-round use	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Smooth and Reliable Pavement	Roadride comfort	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Smooth and Reliable Pavement	Road reliability	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Available Bridges	Availability of bridges	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Safety Features	Guardrail and bridge rail condition	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Safety Features	Pavement markings	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Safety Features	Roadway lighting	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Safety Features	Signing	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Safety Features	Traffic signals functioning as designed	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Safety Features	Attractive woods by road and lack of clear space to woods	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E

MINNESOTA TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**External/ Internal**
	Safety Features	Vegetation on shoulders blocking site distance	Willingness to pay in travel time to avoid unsafe conditions	minutes and imputed economic value in $	Value added	E
	Safety Features	Vegetation blocking site distance at corners	Willingness to pay in travel time to avoid unsafe conditions	minutes and imputed economic value in $	Value added	E
	Safety Features	Vegetation blocking signs	Willingness to pay in travel time to avoid unsafe conditions	minutes and imputed economic value in $	Value added	E
	Attractive Roadsides	Amount of roadside litter	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Attractive Roadsides	Amount of roadside litter	Litter indicator	litter indicator scale of 1–10	Outcome	E
	Attractive Roadsides	Amount of roadside litter	Willingness to pay in travel time to avoid litter	minutes and imputed economic value in $	Value added	E
	Attractive Roadsides	Noxious weed control	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Attractive Roadsides	Noxious weed control	Noxious weed indicator	indicator value (1–10)	Outcome	E
	Attractive Roadsides	Vegetation control	Vegetation control indicator	indicator value (1–10)	Outcome	E
	Attractive Roadsides	Vegetation height control	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Attractive Roadsides	Vegetation by road not neat	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Highway Permits/ Regulations	Encroachments on Right-of-Way	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Highway Permits/ Regulations	Accessibility of permit office	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Highway Permits/ Regulations	Consistency of permit requirements	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Highway Permits/ Regulations	Time to issue permits	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Motorist Services	Motorist info on unplanned conditions	Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E
	Motorist Services	Rest area attractiveness	Cu Customer importance; how well DOT is doing; allocate $100	importance (1–10); how well DOT doing (1–10); $ tradeoff	Outcome, relative value	E

Montana

Montana conducted a customer survey that sought reactions to eight different groups of maintenance activities. Customers were asked to rate on a scale of 1 to 4 the current state, importance, and priority of each type of maintenance. All measures were externally focused outcome measures or measures of customer preferences.

MONTANA: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
	Signage		3 Measures: current state, importance, $ priority	Current state (1–4); Importance (1–4); Priority (1–4)	Outcome and Preference	E
	Information		3 Measures: current state, importance, $ priority	Current state (1–4); Importance (1–4); Priority (1–4)	Outcome and Preference	E
	Rest Stop Maintenance		3 Measures: current state, importance, $ priority	Current state (1–4); Importance (1–4); Priority (1–4)	Outcome and Preference	E
	Striping		3 Measures: current state, importance, $ priority	Current state (1–4); Importance (1–4); Priority (1–4)	Outcome and Preference	E
	Debris Removal		3 Measures: current state, importance, $ priority	Current state (1–4); Importance (1–4); Priority (1–4)	Outcome and Preference	E
	Winter Maintenance		3 Measures: current state, importance, $ priority	Current state (1–4); Importance (1–4); Priority (1–4)	Outcome and Preference	E
	Roadsides		3 Measures: current state, importance, $ priority	Current state (1–4); Importance (1–4); Priority (1–4)	Outcome and Preference	E
	Surfaces		3 Measures: current state, importance, $ priority	Current state (1–4); Importance (1–4); Priority (1–4)	Outcome and Preference	E

New Hampshire

A New Hampshire DOT survey of customers sought to address the relative value of different maintenance activities by asking respondents to allocate $100 dollars to each. The allocation indicates the relative value of each activity.

NEW HAMPSHIRE: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**External/ Internal**
	Research		Allocation	Allocation of $100	Relative Value	E
	Paving		Allocation	Allocation of $100	Relative Value	E
	Roadside Mowing		Allocation	Allocation of $100	Relative Value	E
	Trash Pickup		Allocation	Allocation of $100	Relative Value	E
	Roadway Signage		Allocation	Allocation of $100	Relative Value	E
	Roadway Striping		Allocation	Allocation of $100	Relative Value	E
	Bridge Inspection		Allocation	Allocation of $100	Relative Value	E
	Snow & Ice Removal		Allocation	Allocation of $100	Relative Value	E

Ohio

Ohio DOT reported that it uses professional spotters of snow and ice conditions to obtain a rating scale in regards to snow and ice control. This is an external outcome measure.

OHIO: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**External/ Internal**
Snow and Ice Control			Professional Road Condition Spotter Rating	10 (Excellent) to 1 (Poor)	Outcome	E

Pennsylvania

Pennsylvania DOT has conducted external customer surveys for a number of years. Most of the questions are focused on customer satisfaction.

PENNSYLVANIA: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
		Ride Quality of Interstate			Outcome	E
		Ride Quality of Numbered Traffic Routes Interstate			Outcome	E
		Ride Quality of Secondary Roads			Outcome	E
	Snow and Ice Removal		Customer Satisfaction	P-F/Average/ Meets Expectations/ Exceeds Expectations/ Excellent	Outcome	E
	Traffic Line Painting		Customer Satisfaction	P-F/Average/ Meets Expectations/ Exceeds Expectations/ Excellent	Outcome	E
	Highway Traffic Signs		Customer Satisfaction	P-F/Average/ Meets Expectations/ Exceeds Expectations/ Excellent	Outcome	E
	Work Zone Warning Signs		Customer Satisfaction	P-F/Average/ Meets Expectations/ Exceeds Expectations/ Excellent	Outcome	E
	Travel Lanes Clearly Identified		Customer Satisfaction	P-F/Average/ Meets Expectations/ Exceeds Expectations/ Excellent	Outcome	E
	Length of Delays		Customer Satisfaction	P-F/Average/ Meets Expectations/ Exceeds Expectations/ Excellent	Outcome	E

Virginia

Virginia DOT conducts external customer surveys in which respondents are asked to rate customer satisfaction on a 1 to 5 scale of an outcome measure. The survey focuses on attributes of maintenance.

VIRGINIA: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Groups**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
		Overall Visual Appeal (General Category)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Rest Area Design	Customer Satisfaction	1=Extremely Dissatisfied; 5= Extremely Satisfied	Outcome	E
		Environmental Compatibility	Customer Satisfaction	1=Extremely Dissatisfied; 5= Extremely Satisfied	Outcome	E
		Landscaping	Customer Satisfaction	1=Extremely Dissatisfied; 5= Extremely Satisfied	Outcome	E
		Sound Barriers	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Overall Safety Items (General Category)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Construction Signs	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Warning Signs	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Lane Width	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Safety Barriers	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Pavement Markings	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Shoulder Width	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Detour Directions	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Roadway Lighting	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Wet Weather Conditions	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Overall Bridge Condition (General Category)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Visual Appearance	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Durability of Road	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Smooth Ride	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Travel Amenities (General Category)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Mileage/Destination Signs	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Service/Attraction Signs	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Number of Rest Areas/Plazas	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Variety of Rest Area/Plaza Services	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E

VIRGINIA: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Groups**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
		Number of Emergency Call Boxes	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Overall Pavement Conditions (General Conditions)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Surface Appearance	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Quiet Ride	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Smooth Ride	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Durability	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Maintenance Response Time (General Category)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Rest Area Cleaning Response Time	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Guardrail Repair Response Time	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Litter Removal Response Time	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Snow Removal Response Time	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Pavement Repairs Response Time	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Overall Traffic Flow (General Category)	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Toll Booth Delays	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Accident Clean Up	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Level of Congestion	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Construction Delays	Customer Satisfaction	1=Extremely Dissatisfied; 5=Extremely Satisfied	Outcome	E
		Pavement Smoothness and Pothole Repairs on Major Roads	Customer Satisfaction	1 (Poor); 2 (Fair); 3 (Good); 4 (Excellent)	Outcome	E
		Pavement Smoothness and Pothole Repairs on Secondary Roads	Customer Satisfaction	1 (Poor); 2 (Fair); 3 (Good); 4 (Excellent)	Outcome	E
		Moving and Brush Removal on Major Roads	Customer Satisfaction	1 (Poor); 2 (Fair); 3 (Good); 4 (Excellent)	Outcome	E
		Mowing and Brush Removal on Secondary Roads	Customer Satisfaction	1 (Poor); 2 (Fair); 3 (Good); 4 (Excellent)	Outcome	E
		Snow Removal and Surface Treatment on Major Roads	Customer Satisfaction	1 (Poor); 2 (Fair); 3 (Good); 4 (Excellent)	Outcome	E
		Snow Removal and Surface Treatment on Secondary Roads	Customer Satisfaction	1 (Poor); 2 (Fair); 3 (Good); 4 (Excellent)	Outcome	E
		Signing Around Construction and Maintenance Activities	Customer Satisfaction	1 (Poor); 2 (Fair); 3 (Good); 4 (Excellent)	Outcome	E

VIRGINIA: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Groups**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
		Ditching and Shoulder Maintenance	Customer Satisfaction	1 (Poor); 2 (Fair); 3 (Good); 4 (Excellent)	Outcome	E
		Grading on Gravel Roads	Customer Satisfaction	1 (Poor); 2 (Fair); 3 (Good); 4 (Excellent)	Outcome	E
		Dust on Gravel Roads Near Houses	Customer Satisfaction	1 (Poor); 2 (Fair); 3 (Good); 4 (Excellent)	Outcome	E
		Traffic Signals and Pavement Markings	Customer Satisfaction	1 (Poor); 2 (Fair); 3 (Good); 4 (Excellent)	Outcome	E
		Informing the Public about VDOT Activities	Customer Satisfaction	1 (Poor); 2 (Fair); 3 (Good); 4 (Excellent)	Outcome	E

Washington State

Washington State DOT has administered external customer surveys to obtain input regarding perceived and desired levels of service (LOS). This input is for the department's Maintenance Accountability Process.

WASHINGTON STATE: TYPES OF MEASURES IN CUSTOMER SURVEYS						
Activities	**Products/ Services/ Group**	**Attributes**	**Measure**	**Scale**	**Measure Type**	**Internal/ External**
	Paved Roadway Surfaces		Perceived LOS; desired LOS	LOS (1–5)	Outcome	E
	Road Shoulders		Perceived LOS; desired LOS	LOS (1–5)	Outcome	E
	Roadside		Perceived LOS; desired LOS	LOS (1–5)	Outcome	E
	Vegetation		Perceived LOS; desired LOS	LOS (1–5)	Outcome	E
	Landscaping		Perceived LOS; desired LOS	LOS (1–5)	Outcome	E
	Drainage		Perceived LOS; desired LOS	LOS (1–5)	Outcome	E
	Structures		Perceived LOS; desired LOS	LOS (1–5)	Outcome	E
	Traffic Control and Safety		Perceived LOS; desired LOS	LOS (1–5)	Outcome	E
	Rest Areas		Perceived LOS; desired LOS	LOS (1–5)	Outcome	E
	Snow and Ice Removal		Perceived LOS; desired LOS	LOS (1–5)	Outcome	E

IMPORTANCE OF MAINTENANCE

The project team examined a number of customer surveys to assess how customers rank the relative importance of different types of maintenance. The results are as follows.

IMPORTANCE OF CUSTOMER SURVEYS			
State	**Attributes**	**Activity**	**Importance**
Kansas		Fix Potholes	1
		Snow Removal	2
		Maintain Lighting	3
		Bridge Maintenance	4
		Pavement Markings	5
		Remove Debris	6
		Shoulder Maintenance	8
		Fix Cracks	9
		Maintain Signs	7
		Maintain Rest Areas	12
		Roadside Mowing	11
		Fix Guardrail	10
	Roadside stripes		2
	Roadside smoothness		7
	Center stripes		1
	Roadside shoulders		3
	Road durability		8
	Interchange lighting		4
	Paved shoulders		10
	Bridge conditions		5
	Sign reflection		6
	Sign accuracy		9
	Sign location		11
	Rest area frequency		13
	Sign frequency		12
Kentucky	Pavement conditions		1
	Safety		2
	Maintenance response time		3
	Visual appeal		4
	Traffic flow		5
	Travel amenities		6
	Bridge conditions		7
	Rest area frequency		8
Ohio (northeastern)	Roadways clear of snow and ice		1
	Roadway safety items (guardrails, signals, debris)		2
	Roadway lighting in working order		3
	Pavement markings and signs visible		4
	Smooth pavement		5
	Roadside appearance		6

APPENDIX F: BLANK WORKSHEETS

WORKSHEET 1.
BENCHMARKING UNITS OF EACH PARTNER

Name of Benchmarking Partner: _____
Identification Code: _____
Number of Benchmarking Units: _____
Organizational Level of Benchmarking Units: _____
Benchmarking Agreement #: _____

No.	Name of Benchmarking Unit	Lane Miles	No. of Employees	Budget ($000s)	Terrain (F,H,M)	Weather/ Env. Region
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						

WORKSHEET 2.
ROLE OF CUSTOMER IN VISION

YOUR VISION STATEMENT

KEY PHRASES	RELATIONSHIP TO CUSTOMER
1.	1.
2.	2.
3.	3.
4.	4.

ASSESSMENT OF VISION STATEMENT

- Customer(s) directly addressed? ☐ Yes ☐ No
- Key transportation attributes explicitly addressed? ☐ Yes ☐ No
- Addresses quality/continuous improvement? ☐ Yes ☐ No
- Others: _____

REVISED VISION STATEMENT (for Agency or Road Maintenance)

1.	1.
2.	2.
3.	3.
4.	4.

WORKSHEET 3.
ROLE OF CUSTOMER IN MISSION

YOUR MISSION STATEMENT

KEY PHRASES	RELATIONSHIP TO CUSTOMER
1.	1.
2.	2.
3.	3.
4.	4.

ASSESSMENT OF MISSION STATEMENT

- ❑ Customer(s) directly addressed? ☐ Yes ☐ No
- ❑ Key transportation attributes explicitly addressed? ☐ Yes ☐ No
- ❑ Addresses quality / continuous improvement? ☐ Yes ☐ No
- ❑ Others: _____

REVISED MISSION STATEMENT (for Agency or Road Maintenance)

KEY PHRASES	RELATIONSHIP TO CUSTOMER
1.	1.
2.	2.
3.	3.
4.	4.

WORKSHEET 4.
FIGURING OUT YOUR PRODUCTS AND SERVICES: EXAMPLE

Attributes	Attributes by Category	Product/Services Name
1. Legibility of signs 2. Guardrail and bridge rail condition 3. Posted loads 4. Signpost condition 5. Plowing frequency during snow fall 6. Clear of unplanned obstructions 7. Nighttime visibility of signs and markings 8. Condition of bridge components 9. Traffic detoured x detour length 10. Bridge open and closed 11. Clear intersections and crossovers 12. Clear of ice and snow 13. Obstruction of safety features 14. Ride comfort	a. Clear of unplanned obstructions b. Clear of ice and snow c. Plowing frequency during snow fall d. Clear intersections and crossovers	Clear Roadways
	a. Ride comfort	Smooth Pavement
	a. Bridge open and closed b. Posted loads c. Traffic detoured x detour length d. Condition of bridge components	Available Bridges
	a. Guardrail and bridge rail condition b. Nighttime visibility of signs and markings c. Legibility of signs d. Signpost condition e. Obstruction of safety features	Safe Guidance

WORKSHEET 4.
FIGURING OUT YOUR PRODUCTS AND SERVICES

Attributes	Attributes by Category	Product/Services Name
1. 2. 3. 4. 5. 6.	a. b. c. d. e. f.	_____
7. 8. 9. 10. 11. 12.	a. b. c. d. e. f.	_____
13. 14. 15. 16. 17. 18.	a. b. c. d. e. f.	_____
19. 20. 21. 22. 23. 24.	a. b. c. d. e. f.	_____
25. 26. 27. 28. 29. 30.	a. b. c. d. e. f.	_____
31. 32. 33. 34. 35. 36.	a. b. c. d. e. f.	_____

Worksheet 5.
Mapping Maintenance Activities to Products and Services

Name & Code of Partner:_____

Benchmarking Agreement #:_____

Organizational Level of Benchmarking Unit:_____

Number of Benchmarking Units:_____

Product/Services	Maintenance Activity Description	Activity Code
1.		
2.		
3.		
4.		
5.		
6.		

WORKSHEET 6.
IDENTIFYING MEASURES FOR ATTRIBUTES: EXAMPLE

Product/Service: Smooth Pavements

Attributes: Ride Comfort

OUTCOME, CONDITION MEASURES	AVAILABLE?	PRIORITY
1. International Roughness Index (IRI)	☑ Yes ☐ No	✓
2. Maintenance Ride Quality Index	☑ Yes ☐ No	
3. Longitudinal Profile	☑ Yes ☐ No	
4. Number of Potholes per Lane Mile	☑ Yes ☐ No	
5.	☐ Yes ☐ No	
6.	☐ Yes ☐ No	

OUTCOME, CUSTOMER SURVEY QUESTIONS	AVAILABLE?	PRIORITY
1. Satisfaction with pavement smoothness (1 = very unsatisfied; 5 = very satisfied)	☑ Yes ☐ No	✓
2. Satisfaction with ride comfort	☐ Yes ☑ No	
3.	☐ Yes ☐ No	
4.	☐ Yes ☐ No	
5.	☐ Yes ☐ No	
6.	☐ Yes ☐ No	

WORKSHEET 6.
IDENTIFYING MEASURES FOR ATTRIBUTES: EXAMPLE

Product/Service:_____
Attribute(s):_____

OUTCOME, CONDITION MEASURES	AVAILABLE?	PRIORITY
1.	☐ Yes ☐ No	
2.	☐ Yes ☐ No	
3.	☐ Yes ☐ No	
4.	☐ Yes ☐ No	
5.	☐ Yes ☐ No	
6.	☐ Yes ☐ No	

OUTCOME, CUSTOMER SURVEY QUESTIONS	AVAILABLE?	PRIORITY
1.	☐ Yes ☐ No	
2.	☐ Yes ☐ No	
3.	☐ Yes ☐ No	
4.	☐ Yes ☐ No	
5.	☐ Yes ☐ No	
6.	☐ Yes ☐ No	

WORKSHEET 7.
OUTCOME MEASURES

Product/Service: _____

Attribute(s): _____

Name of Measure	How Measure Calculated/Scale	Month Data Available	Where Data Stored	Roadway Network Coverage	Data Quality H, M, L, N

WORKSHEET 8.
RESOURCE MEASURES

Product/Service:_____

Activity Code	Name of Activity	Labor (UOM)	Equipment Type	Equip. (UOM)	Material Type	Material (UOM)	Quality of Data H,M,L	Cost Data Available (L,E,M,T,OH)	Lowest Org. level & #

WORKSHEET 9.
HARDSHIP FACTORS

Product/Service:_____

Factor	Possible Measures & Description of How Each Is Calculated	Specific Data Required & Source	Lowest Org. Level	Time Period	Data Quality

WORKSHEET 10.
OUTPUT MEASURES

Product/Service:_____

Name Measure	How the Measure Is Calculated	Data Required & Timing of Availability	Organization Level & # of Orgs.	Data Quality (H, M, L)

Worksheet 11.
Benefits versus Cost of Measures

Product/Service: _____

BENEFITS	HIGH	MEDIUM	LOW
HIGH			
MEDIUM			
LOW			

COST

WORKSHEET 12.
SUMMARY OF RECOMMENDED MEASURES: EXAMPLE

Product/Service: Smooth Pavements

Name & Code of Partner: Department of Transportation, Code 00031
Benchmarking Agreement #: B1234567
Organizational Level of Benchmarking Unit: County
Number of Benchmarking Units: 13

MEASURE CODE	MEASURE NAME	DESCRIPTION OF THE MEASURE	UOM	SCALE	SUMMARY STATISTIC	PROTOCOL
OC 1	IRI	Deviation in the elevation of a pavement from a fixed horizontal plane	Inch per Mile	50–210	Section Mean in County	FHWA
OC 2	Survey Q on Smoothness	Semi-annual drivers survey rating their satisfaction with the smoothness of the pavement	Rating	1–5	Mean County Response	Survey Design & Interview Instruct.
R 1	Labor	Total hours of labor for activities 150–165	Hrs		Total Hrs	Maint. Manual
R 2	Equipment	Total hours of equipment usage, activities 150-165	Hrs		Total Hrs	Maint. Manual
H 1	Degree Days	Number of degrees below freezing summed for the year	Degrees	0–50	Sum	Maint. Manual Section 4.2
OP 1	Lane Miles Treated	Numbers of lane miles treated with activities 150–165 for the season	Lane Miles	0–500	Sum	Maint. Manual Section 5.6

Worksheet 12.
Summary of Recommended Measures

Product/Service: _____

Name & Code of Partner: _____
Benchmarking Agreement #: _____
Organizational Level of Benchmarking Unit: _____
Number of Benchmarking Units: _____

Measure Code	Measure Name	Description of the Measure	UOM	Scale	Summary Statistic	Protocol

Worksheet 13.
Availability of Data and Measure

Product/Service:_____

Name & Code of Partner:_____
Benchmarking Agreement #:_____
Organizational Level of Benchmarking Unit:_____
Number of Benchmarking Units:_____

Code	Measure Name	Descriptions of Data Being Collected	J	F	M	A	M	J	J	A	S	O	N	D

WORKSHEET 14.
BENCHMARKING RESULTS—OUTCOME MEASURES

Product/Service: _____

Name of Partner: _____

Identification Code: _____

Organizational Level of Benchmarking Units: _____

Benchmarking Agreement #: _____

Period of Performance: **From:** _____ **To:** _____

		OUTCOME MEASURES				
NO.	NAME OF BENCHMARKING UNIT	OC 1	OC 2	OC 3	OC 4	OC 5

WORKSHEET 15.
BENCHMARKING RESULTS—RESOURCE MEASURES

Product/Service: _____

Name of Partner: _____

Identification Code: _____

Organizational Level of Benchmarking Units: _____

Benchmarking Agreement #: _____

Period of Performance: **From:** _____ **To:** _____

NO.	NAME OF BENCHMARKING UNIT	RESOURCE MEASURES (Cost in Thousands of $)				
		R1	R2	R3	R4	R5
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						

WORKSHEET 16.
BENCHMARKING RESULTS—HARDSHIP (UNCONTROLLABLE) FACTORS

Product/Service:_____

Name of Partner:_____

Identification Code:_____

Organizational Level of Benchmarking Units:_____

Benchmarking Agreement #:_____

Period of Performance: **From:**_____ **To:**_____

NO.	NAME OF BENCHMARKING UNIT	HARDSHIP MEASURES				
		H 1	H 2	H 3	H 4	H 5
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						

WORKSHEET 17.
BENCHMARKING RESULTS—OUTPUT MEASURES

Product/Service:_____

Name of Partner:_____

Identification Code:_____

Organizational Level of Benchmarking Units:_____

Benchmarking Agreement #:_____

Period of Performance: **From:**_____ **To:**_____

		OUTPUT MEASURES				
NO.	NAME OF BENCHMARKING UNIT	OP 1	OP 2	OP 3	OP 4	OP 5
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety 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
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation