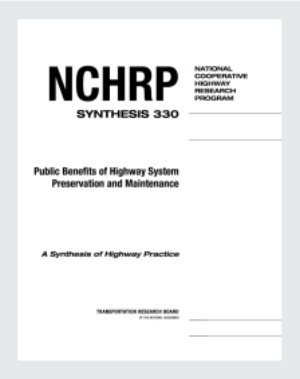

Public Benefits of Highway System Preservation and Maintenance

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

SYNTHESIS 330

Public Benefits of Highway System Preservation and Maintenance

A Synthesis of Highway Practice

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 330

Public Benefits of Highway System Preservation and Maintenance

A Synthesis of Highway Practice

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SUBJECT AREAS

Planning and Administration, Maintenance, and Highway Operations, Capacity, and Traffic Control

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

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FOREWORD

By Staff
Transportation
Research Board

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

Information exists on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice*.

The synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

This report of the Transportation Research Board is a study of the current practices for identifying, measuring, and articulating the public benefits of highway system maintenance and operation, and of communicating those benefits that are understandable and meaningful to stakeholders—road users, elected officials, and others who have an interest in the system's performance. It includes information on the difficulties public agencies encounter in explaining these benefits.

This synthesis report included a review of published literature on the measurement and communication of maintenance benefits, a formal survey of state transportation agencies, and informal interviews and discussions with a range of individuals engaged in highway system management.

A panel of experts in the subject area guided the work of organizing and evaluating the collected data and reviewed the final synthesis report. A consultant was engaged to collect and synthesize the information and to write this report. Both the consultant and the members of the oversight panel are acknowledged on the title page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

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Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Andrew V. Bailey, II, Richmond, Virginia; Rick Drumm, Federal Highway Administration, Indianapolis; Andrew S. Griffith, Research Coordinator, Oregon Department of Transportation; Dennis E. Lebo, Manager, Center for Program Development, Pennsylvania Department of Transportation; Frank N. Lisle, Senior Program Officer, Transportation Research Board; Wayne McDaniel, PB Consult, Inc., Washington, D.C.; Dave Schulz, Director, Infrastructure Technology Institute, Northwestern University; Jim Sorenson, Team Leader, Office of Asset Management, Federal Highway Administration; and Dean M. Testa, Chief, Construction and Maintenance, Kansas Department of Transportation.

This study was managed by Jon Williams, Manager, Synthesis Studies, who worked with the consultant, the Topic Panel, and the Project 20-5 Committee in the development and review of the report. Assistance in project scope development was provided by Donna Vlasak, Senior Program Officer. Don Tippman was responsible for editing and production. Cheryl Keith assisted in meeting logistics and distribution of the questionnaire and draft reports.

Crawford F. Jencks, Manager, National Cooperative Highway Research Program, assisted the NCHRP 20-5 Committee and the Synthesis staff.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance are appreciated.

PUBLIC BENEFITS OF HIGHWAY SYSTEM PRESERVATION AND MAINTENANCE

SUMMARY

Maintenance is work done to keep facilities and equipment in a state of repair or working efficiently. Many professionals responsible for highway management assert that this labor is regularly required to preserve facilities, even when they appear to be in good condition, and that its neglect can accelerate wear and aging, early onset of excessively rough pavements, corrosion on bridges, and other symptoms of unsatisfactory system performance.

This report, prepared under the auspices of the NCHRP, is a synthesis of current practices for measuring and articulating the benefits of highway system preservation and maintenance, and of communicating those benefits in terms that are understandable and meaningful to stakeholders—road users, elected officials, and others who have an interest in the system's performance. The study focuses particularly on pavements and bridges.

The report is based on a study that included a review of published literature on maintenance benefits measurement and communication, a formal survey of U.S. state highway agencies, and informal interviews and discussions with a range of individuals engaged in highway system management. The formal survey was sent to agencies in 50 states and the District of Columbia, with 19 agencies responding.

Precise definitions of "maintenance" and categories of work comprising maintenance vary among segments of the professional community and the general public. Many engineers, for example, define maintenance as any action required to keep a facility or its parts functioning as they were originally designed and constructed to do. The Government Accounting Standards Board, which influences how expenses appear in an agency's financial statements, defines maintenance as the act of keeping fixed assets in an acceptable condition; that is, keeping conditions at satisfactory, rather than initial design levels. For some professionals, maintenance means only relatively low-cost treatments; more aggressive action is termed "repair," "renewal," "rehabilitation," or "reconstruction."

"Preventive maintenance" (PM), for many people, is work done before there is a problem; for example, replacing a car's tires before they fail inspection. However, highway engineers often apply the term to actions that are taken when certain symptoms of larger problems appear; for example, applying thin overlays to cracked pavements. Failure to perform PM presumably accelerates deterioration and advances the time when rehabilitation is required. "Preservation" extends the life of a pavement or other highway system component.

This report focuses on work that is performed in anticipation of major problems, including preservation activities, and it uses the term maintenance to distinguish such work from repair, renewal, and reconstruction. Benefits attributed to maintenance include reduced total costs that a transportation agency incurs to deliver safe and smooth-riding roads, and reduced vehicle operating costs and greater comfort for road users. Analyses of these

benefits are typically based on an empirical model relating pavement or bridge deterioration to age and cumulative usage, and principles of discounted cash flow analysis are used to compute the "life-cycle cost," the total net cost of providing highway service for a specified period of years that constitute a facility's service life.

The empirical deterioration relationship, based on practical observation, has theoretical support, but researchers have not agreed on a single definitive model specification. The influence of maintenance activities on pavement deterioration rates is represented differently by different analysts, and it is not well documented. Some analyses do not explicitly recognize the influence of routine maintenance.

Pavement condition is typically characterized in terms of a "service level." The concept, meant to reflect physical facility characteristics that influence road-user comfort and vehicle operating costs (e.g., fuel usage and repairs) is typically measured by a single-number serviceability index or road rating. Several different indices are used by various agencies in the United States and abroad. Studies have shown that road users' perceptions of highway conditions, as measured by these indices, vary with the age, gender, and other demographic characteristics of those users. Other studies have shown that poor pavement conditions, as measured by the indices, are correlated with higher vehicle operating costs.

Maintenance benefits typically are estimated by forecasting higher anticipated service-level trajectories if maintenance is performed. Some agencies have concluded that total agency costs for roads on which PM is performed are lower than costs for roads that are permitted to deteriorate to levels that require repair and reconstruction. Agencies associate cost savings primarily with being able to defer reconstruction, a major capital expenditure.

Agency-sponsored surveys in several states and nationally indicate that road users generally have favorable opinions of highway conditions, although they are aware of deteriorated road conditions on specific routes or within particular geographic areas. Almost all state agencies responding to this study's survey reported that elected officials and the general public have positive opinions of agency maintenance programs. Although a number of states have adopted customer-based outlooks in their program planning and management, a majority of reporting agencies do not monitor public opinion about maintenance activities on a continuing basis. Only about one in five state agencies that use maintenance-oriented briefings or other public information instruments reported that customer opinions have had direct influence on maintenance program budgets or schedules. News media reports and some researchers indicate that public perceptions of maintenance are influenced by experience with traffic congestion and other conditions associated with maintenance workzones.

Experiences in several states, cities, and private companies give evidence that marketing and public relations activities are used to consider maintenance issues and can enhance public awareness of highway conditions and the roles of maintenance in effective system management. However, many agencies engage in activities that are primarily of sales rather than marketing (see Table 1 on page 5 for examples). They aim to persuade taxpayers and others to support legislative initiatives or agree that the agency is doing a good job, rather than determine what characteristics of maintenance road users particularly value or dislike, and then shaping the maintenance program to enhance customer satisfaction. Marketing and public relations techniques used in other aspects of transportation management and related fields may be useful in measuring the public's willingness to pay for maintenance benefits and building public appreciation of those benefits.

CHAPTER ONE

INTRODUCTION

Maintenance, dictionaries inform us, is the labor that keeps facilities and equipment in a state of repair or working efficiently. For highways and bridges, this labor may entail repairing damage caused by vehicle crashes, catastrophic natural events, or a variety of activities intended to slow or forestall the wear and tear of aging and normal use. Neglect of maintenance may accelerate the effects of wear and aging, including early onset of excessively rough pavements, corrosion on bridges, and other symptoms of unsatisfactory system performance. Public policy observers have noted, however, that maintenance often fares poorly in the political process that allocates scarce government resources (e.g., see Choate and Walter 1981; *The Nation's Public Works* . . . 1986; *Committing to the Cost of Ownership* . . . 1990). Public works historians report that problems of securing road maintenance funds predate the automobile's invention (*History of Public Works* . . . 1976).

Neglect of maintenance can have dramatic consequences. A routine inspection of New York's now notorious Williamsburg Bridge in 1988 discovered extensive deterioration of the steel girders—altogether some 400 areas where structural conditions required immediate attention. The bridge was closed first to mass transit trains and then to all traffic for 3 months as emergency repairs were made, making news headlines and extensively disrupting the city's commerce.

A 1994 U.S. General Accounting Office survey of public school officials found that approximately one-third of the nation's public schools (some 25,000 buildings) needed extensive repair or replacement (*School Facilities* . . . 1995a); whereas Settlemyer (1998) reported that schools are chronically neglected. An earlier analysis by the Association of Physical Plant Administrators of Colleges and Universities judged that the nation's higher education facilities had accumulated a capital renewal and replacement backlog amounting to 20% or more of the estimated current value of the inventory (Rush and Johnson 1989).

Citing state reviews, the ASCE reported that 2,100 dams in the United States were "unsafe," with deficiencies that make them highly susceptible to failure (*2001 Report Card for America's Infrastructure* 2001). The ASCE called for increased funding for repairs.

The FHWA has estimated that a significant fraction of the nation's federal-aid highway system is in poor, mediocre, or fair condition (e.g., the 1999 estimate was about 58%), and that similarly many of the system's bridges are structurally deficient or functionally obsolete (e.g., nearly 30% in 1998) (*1999 Status* . . . 2000). The FHWA has reported that conditions have improved somewhat over the past several years, a trend attributed by some government staff to the agency's efforts to encourage appropriate preservation and maintenance activities. The FHWA maintains an Internet website that presents recent information on the condition of the nation's pavements and bridges (see http://www.fhwa.dot.gov/policy/2002cpr/ch3.htm#3a).

Many blame the lack of maintenance, citing several reasons for the neglect (e.g., *The Nation's Public Works* . . . 1986; *Committing to the Cost of Ownership* . . . 1990). The long lives and slow aging of highways and other infrastructure mean that the effects of neglect may not be revealed for many years. Policy makers and the public at large, confronted with multiple demands for public funds, are easily persuaded to devote resources to issues for which there are vocal constituencies. Maintenance offers few opportunities for responsible officials to garner public recognition and support of the sort that comes when programs are initiated or new facilities are opened for service.

Nevertheless, responsible professionals assert that timely maintenance preserves the system; sustains and protects service levels, public safety, and environmental quality; prevents premature structural failures and loses of service; reduces the severity of losses incurred when elements of the highway system do fail; and reduces the total expenditures required to keep the highway system operating (e.g., *Pavement Preventive Maintenance Guidelines* . . . 2001). In so doing, maintenance is also said to forestall the need to make investments in new facilities by keeping roads open and in good condition and thereby reducing congestion. In the private sector, where maintenance can be linked more directly to facility reliability and company profits, the relationship can be more convincingly asserted (McNeil et al. 2000).

FHWA reports indicate that the annual cost of preserving the U.S. National Highway System's pavements at existing conditions is nearly $50 billion (pavement maintenance alone currently totals $25 billion). Improving the system from its current condition to a "good" level (and then, presumably, letting it deteriorate back to current conditions by doing nothing more) would cost $200 billion. Greater maintenance spending to prevent deficiencies would then be less costly, proponents assert, than a "fix it

only when it's broken" management approach (Hicks et al. 1999). The Intermodal Surface Transportation Act of 1991 (ISTEA) departed from previous national policy by allowing the use of federal highway funds for maintenance activities as well as new construction and major reconstruction, providing the incentive for highway agencies to enhance their efficiency of service through maintenance-based management strategies.

BACKGROUND AND SOURCE OF STUDY

Nevertheless, many federal and state officials suggest that poor public understanding of the benefits of maintenance restrains the ability of responsible agencies to adopt efficient maintenance-based management strategies. Participants at the 1998 TRB Conference on Transportation Issues of Central Cities called for research to "develop information on the benefits of proper maintenance and operations and . . . how the benefits can be portrayed to political leaders and the public" (*Transportation Issues in Large U.S. Cities* 1999, p. 17). That call motivated the definition of a study to be conducted under the auspices of NCHRP.

The broad purpose of the study was to prepare a synthesis of current practice for identifying, measuring, and presenting the public benefits of highway system maintenance and operations, in terms that are understandable and meaningful to people who have an interest in the system's performance—that is, people who are stakeholders. As the study progressed, it became clear that maintenance and related activities should be the focus of the work. "Operations," meaning such activities as traffic management, intelligent transportation systems development, and the like presented essentially different issues that could not be adequately addressed in this synthesis. The study's scope was revised to focus on highway system preservation and maintenance, concentrating primarily on pavements and bridges.

OBJECTIVES AND SCOPE

The objectives of the study were to collect information and assess state highway agencies' current practices in measuring and articulating the benefits of highway system preservation and maintenance, including the impacts (generally adverse) of deferring maintenance. Particular emphasis was to be placed on describing methods that agencies use to communicate the benefits of system preservation and maintenance to those in the political process—for example, elected officials and the general public. In addition, the study was to look beyond highways to seek practices from other areas of facility management that might be adapted to highway agency use.

Experiences in several states, cities, and private companies give evidence that marketing and public relations activities are used to highlight maintenance issues and can enhance public awareness of highway conditions and the roles of maintenance in effective system management (Table 1).

Underlying these objectives is the notion that if road users, the public at large, and elected officials really understood the benefits of maintenance, they would more readily make available adequate funds for the kinds of maintenance programs highway managers feel are needed. Maintenance generally influences highway service quality—ride roughness, noisiness, safety hazards, and the like—that road users may notice; these characteristics are typically difficult to measure and are perceived differently by disparate individuals. If the managers responsible for maintenance could do a better job of measuring and explaining these benefits the attitudes that underlie neglect would change. What then is the state of practice in defining and measuring maintenance benefits and conveying information about those benefits to technical and nontechnical audiences so as to influence opinion and decision making in support of maintenance budgets? The study's final scope specified that consideration be given at least to performance measures, service levels and standards, customer satisfaction surveys, marketing, dedicated funding, and legislative involvement.

Identifying Best Practices

This study sought particularly to highlight best practices, those that have been found to be effective in shifting public and legislative opinion. Evidence of success might be found, for example, in budgeting and voting decisions to make funds available for maintenance, or in positive media reports. In the absence of explicit evidence, the following three criteria were used to select practices to be described in this synthesis:

1. They provide credible arguments that maintenance yields benefits that are important to stakeholders,
2. They provide explicit and plausible estimates of the magnitude of those benefits, and
3. They communicate those estimates in terms readily understandable by responsible decision makers and other stakeholders.

Focusing on Preventive Maintenance and Preservation

This study focuses particularly on activities that highway managers term "preventive maintenance" (PM) or "preservation." AASHTO defines PM as a

TABLE 1
EXAMPLES OF DEMONSTRATION AND MARKETING OF MAINTENANCE BENEFITS

Activities	Adopters	Reported Consequences	Refs.*
Public information and marketing campaigns	Michigan, Minnesota, Oregon, cities of Cincinnati and Cleveland	Improved public relations and political capital, favorable voter outcomes in tax referenda	Study, Stein and Sloane 2001
Market research to identify customers, market segments	Arizona, Kansas, Minnesota, New Jersey, Oregon, Pennsylvania, Virginia	Improved responsiveness to agency communications activities	Stein and Sloane 2001, 2003
Mail and telephone surveys of road users to measure customer interest in and satisfaction with road quality or road maintenance activities	Arizona, Montana, Pennsylvania, Oregon, Utah, Wisconsin, others under auspices of NQI	Information used in agency public relations and legislative initiatives	Study, Poister et al. 1998, Robinson et al. 2000, Stein and Sloane 2003
Regular customer satisfaction surveys linked to maintenance programming activities	Union Pacific Railroad, South Dakota	Senior management links maintenance to agency performance and public safety, makes budgeting decisions responsive to customer interests	Study, McNeil et al. 2002, Stein and Sloane 2003
Computation of maintenance backlog	Oregon	Bolstered agency effort supporting voter referendum on gas tax increase	Study
Explicitly identified and aggressively applied preventive maintenance programs	Arizona, Michigan, Colorado, Pennsylvania, TTX Company	Extension of time before overlays and reconstruction are required, with consequent life-cycle cost reductions; regulatory approval to extend useful life of autorack cars from 50 years to 65 years	Madanat 1997, Galehouse 2002, McNeil et al. 2002

*"Study" refers to communications that were part of the current project.

> planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without substantially increasing structural capacity) (*Pavement Preventive Maintenance Guidelines* . . . 2001).

Building from this definition, an AASHTO-sponsored working group defined pavement preservation as

> the planned strategy of cost-effective pavement treatments to an existing roadway to extend the life or improve the serviceability of the pavement. It is a program strategy intended to maintain the functional or structural condition of the pavement. It is the strategy for individual pavements and for optimizing the performance of a pavement network (*Research Protocols* . . . 1999).

The term presumably may be similarly applied to bridges and other major highway system components, but at present is used primarily in discussion of pavements. For the purposes of this report the following definitions will be used:

- Preventive maintenance (PM)—planned strategy of cost-effective treatments . . . that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without substantially increasing structural capacity).
- Preservation—planned strategy of cost-effective . . . treatments . . . to extend the life or improve the serviceability; a program strategy intended to maintain the functional or structural condition.

As will be discussed in chapter two, how these terms are used in practice varies, even for pavements. Specific activities that highway management personnel undertake—such as sealing cracks in the pavement surface or placing an overlay to resurface a roadway—may be classified as preventive maintenance by one agency, preservation or repair by another, or normal or routine maintenance by a third.

Government Accounting Standards Board Statement 34, which determines how many government entities conduct their financial reporting, refers simply to annual spending required "to maintain and preserve" facilities "at or above the condition level established" and disclosed by responsible officials as a minimum acceptable (*Basic Financial Statements* . . . 1999). (That spending is reported in lieu of "depreciation" expenses, an accounting concept that is outside the scope of this study.) Such spending is considered an immediate expense. Spending that substantially enhances the capabilities of the facility or extends its anticipated service life would be considered a capital investment

and added to the system's asset value. Such spending generally is not termed maintenance (Hatry and Liner 1994).

The AASHTO definition of preservation encompasses extensions of life and improvements of serviceability. AASHTO's definition of PM allows for improving "functional condition," but without increasing "structural capacity." These definitions suggest that preservation is a more comprehensive term than PM. However, some highway professionals characterize PM as the broader category (see Figure 1).

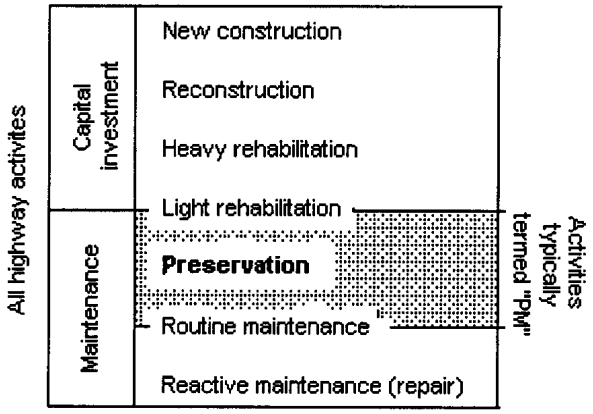

FIGURE 1 Maintenance, preservation, and preventive maintenance (*Source*: J. Sorenson, personal communication, June 17, 2002).

Both PM and preservation are defined as cost-effective treatments, and many studies have sought to confirm their economic efficiency or, conversely, that their deferral is inefficient (e.g., *NCHRP Synthesis of Highway Practice 58* . . . 1979; O'Brien 1989; Geoffroy 1996). Geoffroy's synthesis, in particular, is a thorough review of research and agency policies on cost-effective pavement PM.

However, PM may seem to road users to fly in the face of the popular adage, "If it ain't broke, don't fix it." Respondents to a survey of state agencies, asked to cite barriers to the adoption of PM programs, frequently mentioned "public perceptions," a concern that "motorists will not accept" a departure from a conventional "worst first" strategy of giving priority to repairing pavements in the poorest condition before spending to preserve already good conditions (*Pavement Preventive Maintenance Guidelines* . . . 2001).

Public Benefits Viewed Broadly

For maintenance activities to meet the economist's criteria for being judged cost-effective or efficient, they must produce benefits in excess of their costs. The benefits to be gained include enhanced service, reductions in other costs such as those for vehicle operations or roadway repairs, and mitigation of adverse impacts on the system's operation. In other words, spending for maintenance now improves the future performance of the highway system and thereby yields future public benefits that exceed today's spending. To compare these several costs and benefits that are realized at different times, analysts typically employ life-cycle cost analysis (LCCA).

LCCA is a method for evaluating project design alternatives and management strategies taking into account all costs arising from developing, owning, operating, maintaining, and disposing of facilities, equipment, and other assets that the project or strategies entail. The essentials of LCCA are as follows:

LCCA compares alternative projects or strategies that have different patterns, over time, of costs and perhaps savings by computing for each an equivalent single-number value. The *net present value* (NPV) is most commonly used:

$$NPV = InitialCost + \sum_{k=1}^{DSL} RecurringCost_k \left[\frac{1}{(1+d)^k} \right]$$

where

InitialCost	=	expenses incurred before the beginning of service (e.g., for planning, design, and construction);
RecurringCost	=	expenses incurred during the period of service (e.g., in year k for operations, maintenance, and repair); may also include road-user costs (e.g., fuel usage, vehicle maintenance and repair, estimated monetary value for safety improvements); savings or other benefits are measured as negative costs;
d	=	discount or interest rate, the time value of money or other resources, typically including consideration of investment riskiness; usually measured as an annual percentage rate; and
DSL	=	design service life or analysis time horizon, usually measured in years.

Alternatives are designed to provide comparable levels of service throughout the design service life; the alternative with the lowest LCC, typically measured by total net present value or equivalent annual value, is most efficient and therefore preferred. The underlying argument in favor of

PM and preservation is that management strategies, including either or both of these activities, will have a lower LCC than those that rely on making repairs after problems occur. Similarly, designs that make provisions for subsequent maintenance activities can avoid costly problems (Ceran and Newman 1992).

LCCA is used particularly as an aid to investment decisions, and it is required in certain situations to justify funding approvals under federal programs (e.g., projects intended to enhance energy efficiency and those that are to be part of the national highway system). As initially developed, LCCA was essentially a financial analysis technique and was applied only to actual monetary costs, and typically only those incurred directly by an entity responsible for developing, operating, and maintaining a facility (Steiner 1996).

In recent years, the scope of LCCA has been expanded in analyses of highway pavements and bridges to include costs incurred by others, such as road users' vehicle operating costs (Watanatada et al. 1987). As will be discussed in chapter two, some analysts view the potential public benefits of maintenance very broadly, as they might typically be defined in a highway project's environmental impact statement; for example, these benefits have financial, economic, environmental, and social dimensions. Such applications of LCCA may be essentially a comprehensive comparison of economic benefits and costs, that is, a benefit–cost analysis.

STUDY PROCESS AND CONTENT OF SYNTHESIS REPORT

The preparation of this synthesis had three principal elements:

1. Literature review—A search of selected libraries, recent professional and trade publications, and sources available on the Internet provided the basis for both the References and the Bibliography.
2. Agency survey—A formal survey was distributed by e-mail to state transportation agencies. The survey questionnaire, presented in Appendix A, was designed to elicit information in two areas: (1) the extent to which agencies estimate the public benefits of maintenance and use those estimates in management decision making; and (2) how agencies communicate information on maintenance benefits to senior management, road users, other government officials, and the broader public, and the value they place on this communication. A total of 19 agencies responded, approximately 37% of those receiving the survey. A statistical analysis of survey responses is presented in Appendix B.
3. Interviews and discussion—Informal discussions were conducted with a range of individuals whose perspectives could inform the synthesis. These individuals also provided guidance to the literature and experiences that might indicate best practices.

The text of this report is organized as follows:

- Chapter two discusses practices for measuring the public benefits of maintenance. The discussion includes what types of benefits are attributed to PM, along with models for how those benefits are related to highway conditions that are susceptible to control through PM activities.
- Chapter three considers how benefits, measured or estimated by highway professionals, are communicated to and perceived by other stakeholders.
- Chapter four looks beyond highway agency practices to methods used in other fields—particularly environmental economics and product marketing—that might be adapted to present or market the public benefits of highway maintenance to a broad stakeholder audience.
- Chapter five presents conclusions pertaining to state of agency practices and whether greater efforts to measure and communicate the public benefits of highway maintenance are warranted.

CHAPTER TWO

MEASURING PUBLIC BENEFITS

Although precise definitions of the term maintenance and its component types vary among researchers and practitioners, a substantial literature presents the basic logic, functional models, and empirical evidence underlying the premise that PM and preservation are both efficient management strategies. Over the past three decades, computational tools have been developed, and to some extent standardized, to assist highway system managers in estimating explicitly the cost-effectiveness of maintenance-based management strategies that entail PM activities.

CHARACTERIZING MAINTENANCE ACTIONS

The term "maintenance" refers broadly to any action intended to keep a facility or its parts functioning as originally designed and constructed (Hudson et al. 1997) or, less restrictively, "the act of keeping fixed assets in acceptable condition" (*Statement of Federal Accounting Standards No. 6* . . . 1997)—that is, keeping conditions good enough, rather than at initial design levels. Agencies make expenditures when they carry out maintenance actions; these expenditures will typically be recorded as recurring costs in the LCCA.

However, practitioners and even engineering textbooks do not agree on precise categories and definitions of activities that constitute maintenance. One text suggests, for example, that maintenance actions may be classified as routine, corrective, preventive, proactive, or reactive (Hudson et al. 1997). Another text distinguishes maintenance from "rehabilitation," the former term restricted to actions that prevent or slow the onset of unacceptable service conditions, whereas the latter denotes action that returns unacceptable situations to acceptability, although the same text suggests that maintenance may be corrective or preventive, as well as routine or major, planned or reactive (*Pavement Design* . . . 1997). "Preservation" is not yet widely used by maintenance practitioners. As previously mentioned, Figure 1 (see chapter one) illustrates how some practitioners view the relationships of the terms.

PM activities, a subset of maintenance, are planned and proactive (drawing on the AASHTO definition), in that PM "preserves the system, retards future deterioration, and maintains or improves the functional condition" (*Pavement Preventive Maintenance Guidelines* 2001). In building management, for example, managers may periodically replace all light bulbs in an electrical display to lower the probability that the light bulbs will fail at critical times. Similarly, certain moving parts on commercial aircraft will be replaced after a particular number of flight hours, regardless of the part's apparent condition.

Within the context of LCCA, PM- and preservation-based management strategy will be judged appropriate—that is, efficient or cost-effective—primarily under two conditions: (1) for a new installation or substantial reconstruction, when it enables substantial reduction of initial costs (e.g., through materials and design details); or (2) for an existing installation in service, when the costs of responding separately to problems as they seem impending or the losses when a problem does occur are high compared with the cost of the periodic maintenance action. In both cases, estimated net LCC reductions depend on the actual completion of planned maintenance programs and the validity of estimated characteristics of problems that may occur if maintenance is not performed as programmed, as well as the frequency of those problems' occurrence.

PM, intended to prevent or delay problems, might seem to be intrinsically proactive, but practitioners use the term to refer also to reactive actions. For example, extensive surface cracking of a pavement may motivate managers to place a thin overlay rather than undertake crack sealing. Because the overlay both improves riding conditions and prevents water from penetrating beneath the surface and, as a consequence, probably defers for several years the need for crack sealing, the action of placing the overlay may be judged part of a PM-based management strategy. Crack sealing might, in this case, be considered normal or routine maintenance rather than as PM.

However, as Table 2 illustrates, some highway maintenance analysts classify crack sealing as PM, presumably because the purpose of sealing is to forestall greater deterioration caused by water infiltration into the pavement's base and subbase courses. Some practitioners assert that most pavement maintenance, even when described as preventive, is ultimately remedial (Research and Technology Coordinating Committee 1997), and clearly, crack sealing, microsurfacing, chip seals, and thin overlays are unlikely to be initiated unless there are superficial symptoms such as cracking to suggest that more serious problems could develop if action were not taken. Others (e.g., Zaniewski and Mamlouk 1999) suggest applying a chip seal to a pavement in good condition as a preventive action, and FHWA publications suggest that the distinction between PM and other maintenance is a matter

TABLE 2
CLASSIFICATION OF PREVENTIVE MAINTENANCE ACTIONS

Types of Pavements	Common Pavement Problem	Preventive Maintenance Treatments
Flexible	Potholes	Drainage
	Edge cracking	Cracking sealing
	Lane-to-shoulder drop-off	Slurry seal
	Aging	Microsurfacing
	Thermal cracking	Chip seals
		Thin hot-mix asphalt overlays
Rigid	Blow-ups	Drainage
	Pumping	Joint and crack sealing
	Joint faulting	Retrofit load transfer
Composite	Potholes	Drainage
	Edge cracking	Cracking sealing
	Lane-to-shoulder drop-off	Slurry seal
	Aging	Microsurfacing
	Reflective cracking	Chip seals
	Thermal cracking	Thin hot-mix asphalt overlays
		Reseal sawed and sealed joints

Source: Geoffroy 1996.

of degree, referring to PM as "carefully timed, cost-effective treatments to roads experiencing only light to moderate distress" (*Focus*, June 2000, p. 1).

The Texas Department of Transportation (DOT), as an example, defines PM projects as "work proposed to preserve, rather than improve, the structural integrity of the pavement and/or structure." Examples include asphalt overlays no more than 2 in. thick, seal coats, microsurfacing, cleaning and sealing of joints and cracks, patching of concrete pavement, shoulder repair, scour countermeasures, cleaning and painting of steel bridge members, restoring drainage systems, cleaning and sealing of bridge joints, bridge deck protection, and more (*Guide to Design Criteria* 1999).

The distinction between "functional condition" and "structural integrity" of the pavement or other highway component is a theme that is common in discussions of PM. Although explicit definitions of these terms and their distinctions vary among practitioners, they refer generally to the ability of the roadway to provide a safe and comfortable trip versus the ability to withstand (i.e., without gross structural failure) the mechanical loads imposed by vehicles using the roadway. Currently used pavement and, to some extent, bridge design methods, however, typically use a pavement surface condition—that is, a functional condition—as a criterion or indicator of structural integrity, so it is unclear whether the distinction is truly useful. The Ohio DOT, for example, which defines structural integrity as the "ability of a pavement to carry anticipated loading," is silent on the meaning of functional condition, but defines PM as "work performed on a structurally sound pavement . . . intended to preserve the pavement, retard future deterioration, and maintain or improve the functional condition without substantially increasing the structural capacity" (*Pavement Design and Rehabilitation* 1999).

PAVEMENT CONDITION AND ITS INDICATORS

If functional condition is not always explicitly defined, it almost certainly has something to do with "service level." This term, used widely in facilities management, refers to a measure of how well the facility is able to perform the functions for which it was designed and built. By extension, service level often refers to the facility's condition, on the principle that condition and function are highly correlated. The concept may be applied to facilities as a whole (e.g., an entire building, gas transmission system, or highway); however, typically it is applied to a single component (e.g., the roof, a pipeline, or a pavement), largely because of the difficulties of measurement when the intended functions have several dimensions.

An early application of the service-level idea was the definition of pavement "serviceability" and development of a "present serviceability index" (PSI) to characterize the pavement's ability to serve traffic. Ride quality was identified as an important aspect of that ability, and the single-number PSI combined several measures of surface roughness and other observable physical characteristics of the pavement surface (*The AASHO Road Test* . . . 1962). That composite index was correlated with the judgments of riders in vehicles traversing the pavement, as to whether the pavement's condition was excellent, good, or poor, to yield what might now be termed the "standard model" for pavement performance (Figure 2).

In this standard model, pavement condition or service level declines over time as a result of wear and damage induced by traffic loads and aging of materials. At some level of service (LOS), presumably defined by road users' judgments that below this level the ride becomes poor, the condition is considered unacceptable. In the absence of any action to return the pavement's serviceability to acceptable levels, the pavement has reached the end of its service life

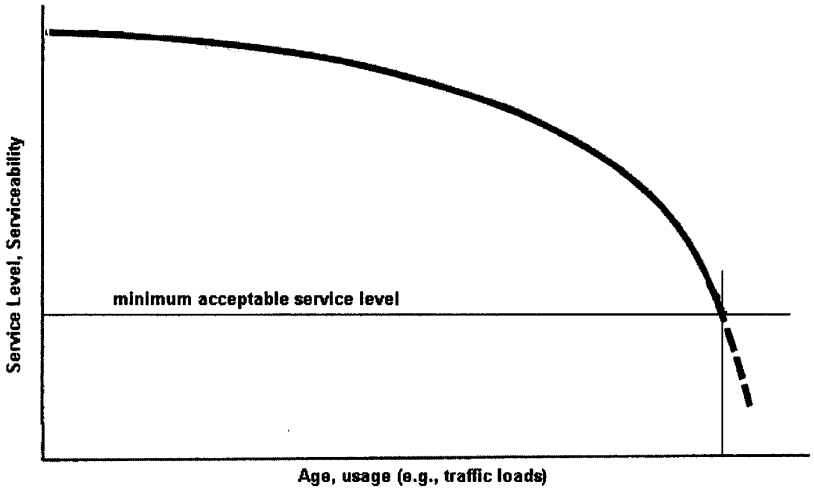

FIGURE 2 The "standard model" of pavement performance.

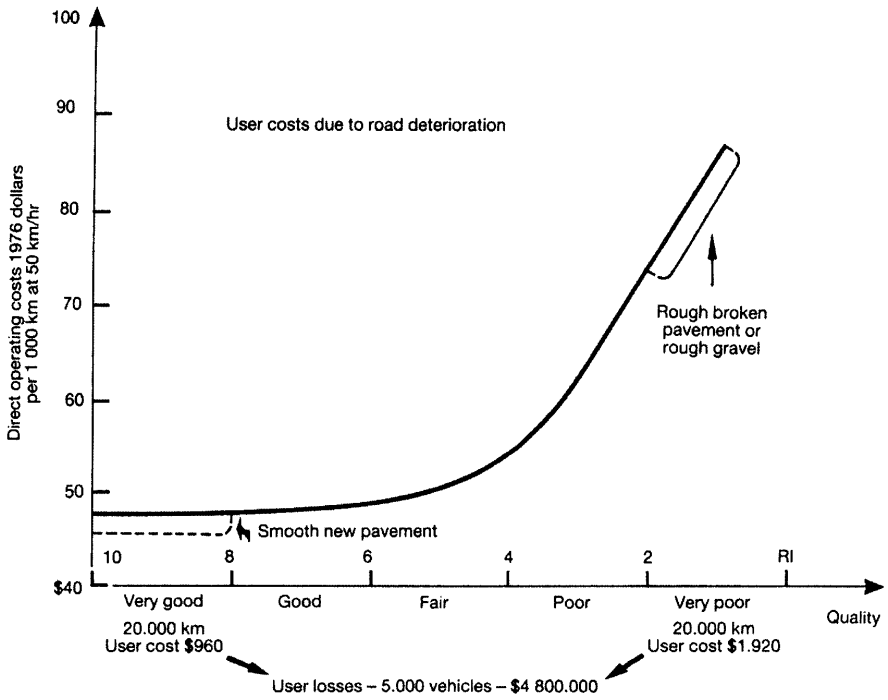

FIGURE 3 Example of the relationship between road-user costs and pavement condition (*Source*: *Pavement Management Systems* 1987).

(although that service life is typically a period of time simply chosen for analysis) (Haas et al. 1994). In principle, road-user costs increase as service level declines.

With subsequent work, the PSI has been supplemented by a variety of other service-level measures, and ride quality-based indices are generally used in highway management. No single measure has been generally accepted as a basis of pavement evaluation or design, although the International Roughness Index (IRI) may be the most widely used in the United States (Ksaibati et al. 1999).

The various indices generally reflect engineers' assumptions that smoother pavements improve road-user riding comfort, vehicle safety, and operating costs. The indices themselves have typically been constructed to correlate with road users' perceptions of ride comfort and stability (Liu and Herman 1998). Research has confirmed a strong correlation between rougher pavements and higher vehicle operating cost (see Figure 3). Surface roughness also has been shown to have a significant effect on single-vehicle and multivehicle crash rates (Karan et al. 1976; Al-Masaeid 1997).

Specific relationships between surface condition and road-user well-being, however, may not be straightforward. For example, a particular index may not apply equally well to all types of pavements (Wu 2000). Such parameters as gender of the observer and conditions under which the observations are made significantly influence how individual observers judge the acceptability of a particular pavement's condition (Chou and Wu 1997). Data collection methods and analysis procedures confound comparisons of service-level information from different agencies, even when the same index is used (*Transportation Infrastructure* . . . 1999).

The variety of functions a highway is meant to provide further complicate the practical measurement of service level. Traffic operating conditions and congestion, for example, are measured by the aforementioned LOS rating (*Highway* . . . 1994). The LOS is correlated with travel speeds and vehicle delays, factors directly related to road-user costs, safety, and environmental quality. In contrast to pavement condition indices, the LOS grading system for traffic is used almost universally for design and management.

Condition indices for highway bridges have been devised and are regularly reported, reflecting primarily bridge inspection observations that may indicate deteriorating structural integrity of the bridge's superstructure, deck, and support structure. No single health index has been generally adopted, however, although the National Bridge Inventory sufficiency ratings of load-bearing capacity must be periodically reported by states to the FHWA and are used in allocating federal funds for bridge maintenance activities. The index employed in the Pontis bridge management computer program is popular; FHWA personnel report that 38 of 50 state DOTs use the Pontis program (Small et al. 1999).

This synthesis review failed to find any widely used service-level indices either for highway drainage systems and appurtenances or for other types of facilities that might readily be adapted to highway system use. This failure is consistent with other reviewers' findings (Hatry and Liner 1994; *Transportation Infrastructure* . . . 1999).

MAINTENANCE AND THE SERVICE-LEVEL TRAJECTORY

In the analysis of highway pavements and other components, service-level deterioration in the standard model is assumed to be a function of environmental conditions and loading, and its trajectory will be roughly as shown in Figure 3. The model has gained wide acceptance as empirically reasonable, but there is no theoretical or statistical basis for specifying precisely a generally applicable shape of the service-level curve (e.g., Hudson et al. 1997; Prozzi and Madanat 2000).

Within this model, maintenance is typically presumed to slow the rate of service-level deterioration or to increase service level or both. Some analysts presume that a minimum level of maintenance activity (e.g., normal or routine maintenance) is always implicit in the model, and failure to perform such tasks as, for example, cleaning drains, will increase the probability of damage and could accelerate observable deterioration rates. Unacceptable conditions would then occur sooner than otherwise expected (see Figure 4). Geoffroy (1996) reports, for example, that studies by several agencies showed that such activities as crack sealing do reduce the amount of more serious deterioration observed later, and may add 1 to 2 years to the average time before the condition index reaches unacceptable levels. Some analysts imply that more substantial maintenance is required to avoid the precipitous onset of unacceptable service conditions, and suggest that certain key levels of the condition index should trigger various types of maintenance (e.g., see Figures 5 and 6).

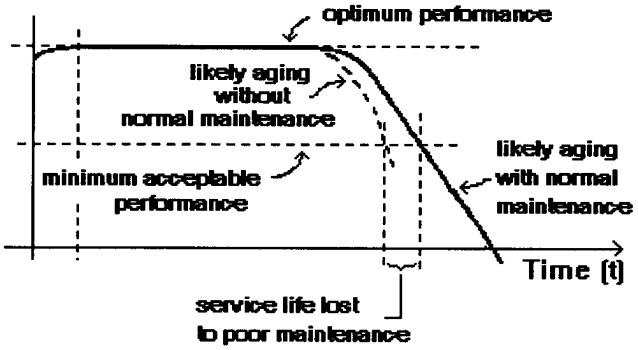

FIGURE 4 Effect of preventive or "normal" maintenance (*Source*: Lemer 1996).

More typically, the standard model is used to illustrate the impact of actions (termed variously rehabilitation, repair, or reconstruction) that result in a substantial service-level increase and possibly a reduction of the deterioration rate. Such actions are presumed to rejuvenate the pavement (Figure 7). Some explanations seem to suggest that maintenance, preservation, and rehabilitation are distinguished primarily by the size of the increase in condition index and the frequency of action (Figures 8–10).

TYPES OF BENEFITS ATTRIBUTED TO MAINTENANCE

Viewed within the context of the service-level standard model and LCCA, maintenance-based management strategies yield benefits by ensuring higher service levels and avoiding unacceptably low service levels, and doing so at a lower total cost than would be incurred if maintenance were not performed. These benefits, summarized in Table 3, accrue

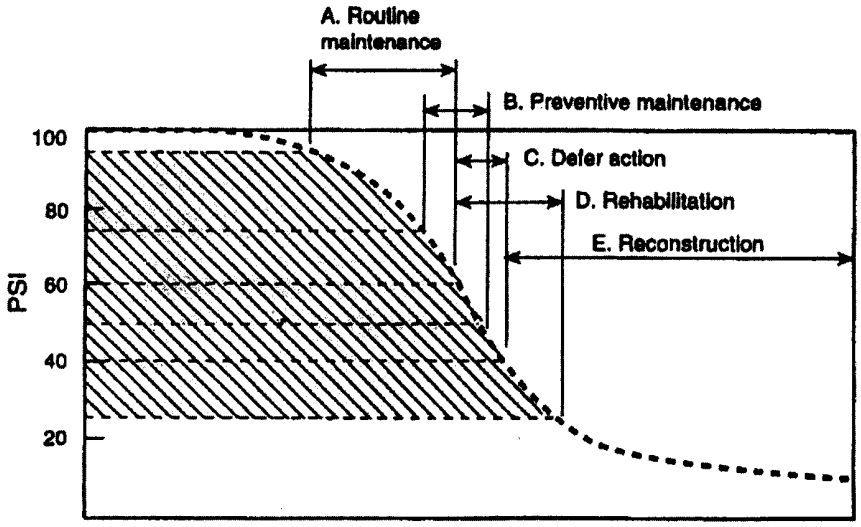

FIGURE 5 Relationship of maintenance activities to stages of the service-level trajectory, example 1 (*Source*: Hicks et al. 1999).

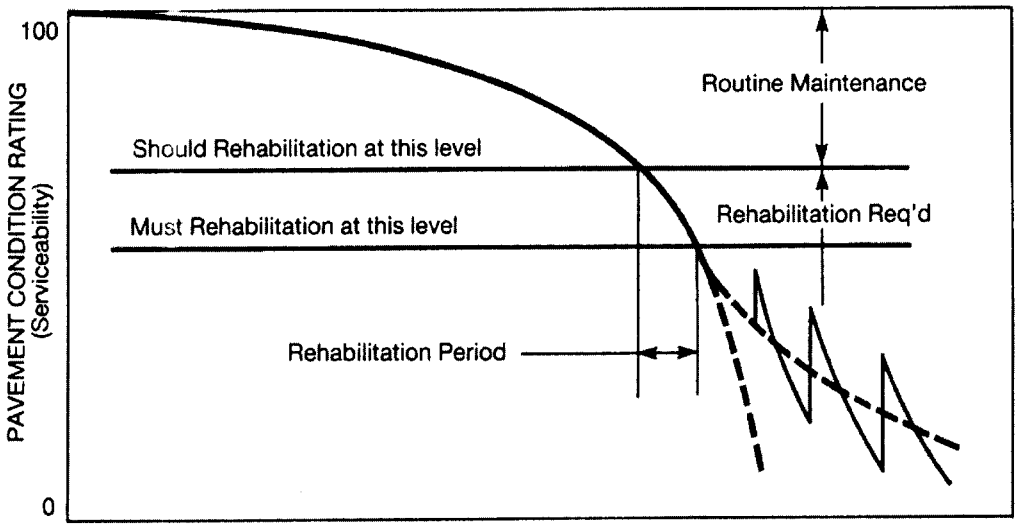

FIGURE 6 Relationship of maintenance activities to stages of the service-level trajectory, example 2 (*Source: Pavement Management Systems* 1987).

to both highway agencies and road users, or occasionally to the public at large.

Savings in the direct costs of providing good roads—that is, reductions in the net present value of total expenditures that an agency must make to keep its highways at acceptable service or condition levels—were the earliest and most immediate benefits attributed to PM. Geoffroy (1996, p. 5), for example, cites a 1977 Utah DOT study finding that every dollar invested in PM early in the life of a pavement avoids expenditures of $3 later for major rehabilitation. Geoffroy cites other reports indicating that PM can extend the service life of portland cement concrete pavements by 9 to 10 years and asphalt concrete pavements by 5 to 6 years, presumably reducing agency costs by deferring the need for more costly rehabilitation. Geoffroy cited some agencies that reported that PM reduces the total time and money spent on pavement, compared with spending for on-demand maintenance activities only (i.e., making repairs when problems are reported) by 5% to 10% for pavements that have not yet been overlaid, and 16% to 20% for overlaid pavements. Such analyses, although possibly controversial (e.g., see Dasgupta 2001), have provided sufficiently convincing results that such states as Colorado, Michigan, and Pennsylvania have adopted explicitly identified PM as an integral part of their agencies' highway programs (Galehouse 2002).

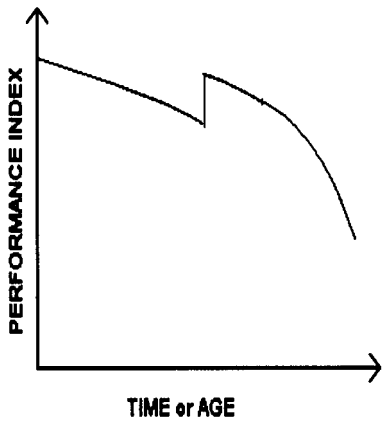

FIGURE 7 Effect of repair or rehabilitation, example 1 (*Source*: Geoffroy 1996).

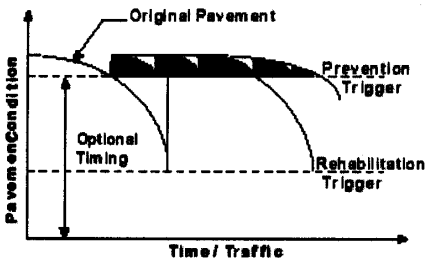

FIGURE 9 Preventive maintenance as preservation strategy (*Source*: *Optimizing Highway Performance: Pavement Preservation* 2000).

The Michigan Road Preservation Association, representing the state's contractors that specialize in such PM treatments as crack and joint sealing and surface seals for bituminous pavements and joint sealing on concrete pavements, for example, cites the FHWA in asserting that "for every dollar spent on PM to extend pavement life, a savings of $6 to $10 can be realized." The association also quotes a former director of the Michigan DOT: "This is a little bit of biting the bullet and spending the money on preventing problems, rather than 6 to 8 times more (money) to reconstruct or rehabilitate (the road) after the problem becomes serious" ("Introduction to Preventive Maintenance" 1999).

Road users are presumed to realize savings through reduced vehicle operating costs and reduced damage from crashes when roads are kept at higher LOS. Much of the empirical support for these presumptions has come from studies of low-volume intercity roads (*HDM Model Description . . .* 1981; *Pavement Management Systems* 1987; Watanatada et al. 1987; Alfelor and Markow 1997; *Pavement Design and Management Guide* 1997).

Widely used decision support tools (discussed in the next section) rely on these savings. Oglesby and Sargent (1962) concluded that reconstruction of older roads to new standards that were widely adopted in the 1950s and 1960s could not be rationally justified on the basis of direct financial and accident cost reductions alone. They recommended that inferred improvements in noncommercial vehicle operations should be included in the LCCA. Other benefits have subsequently been added to the analysis, including fuel savings, reductions in vehicle maintenance costs, pollution reduction, and other environmental enhancements (Hallaq and Pettit 1982).

Opportunities to realize savings by using roads offering higher LOS might be expected to influence road users' travel behavior. Wachs (1967) reported that smoother

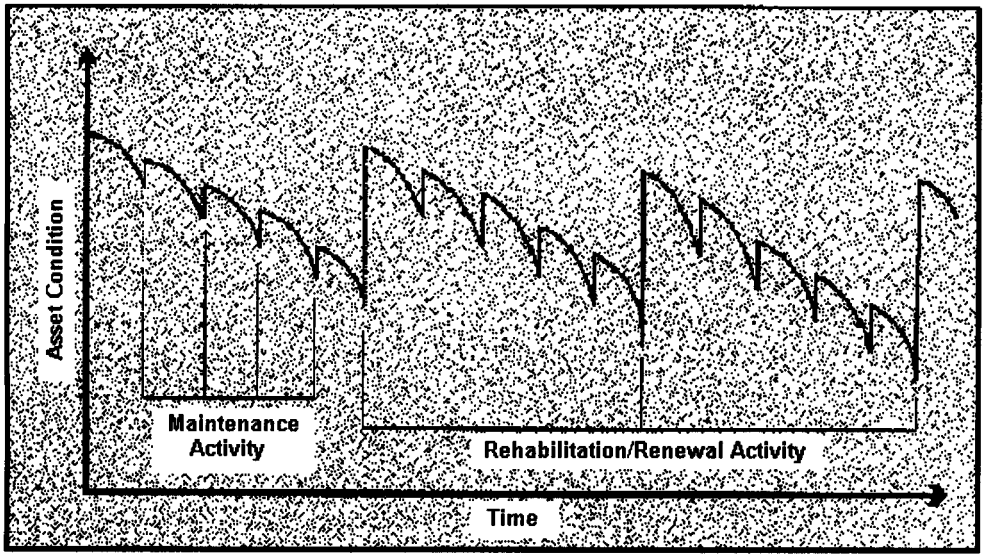

FIGURE 8 Effect of repair or rehabilitation, example 2 (*Source: Managing Public Infrastructure Assets to Minimize Cost and Maximize Performance* 2001).

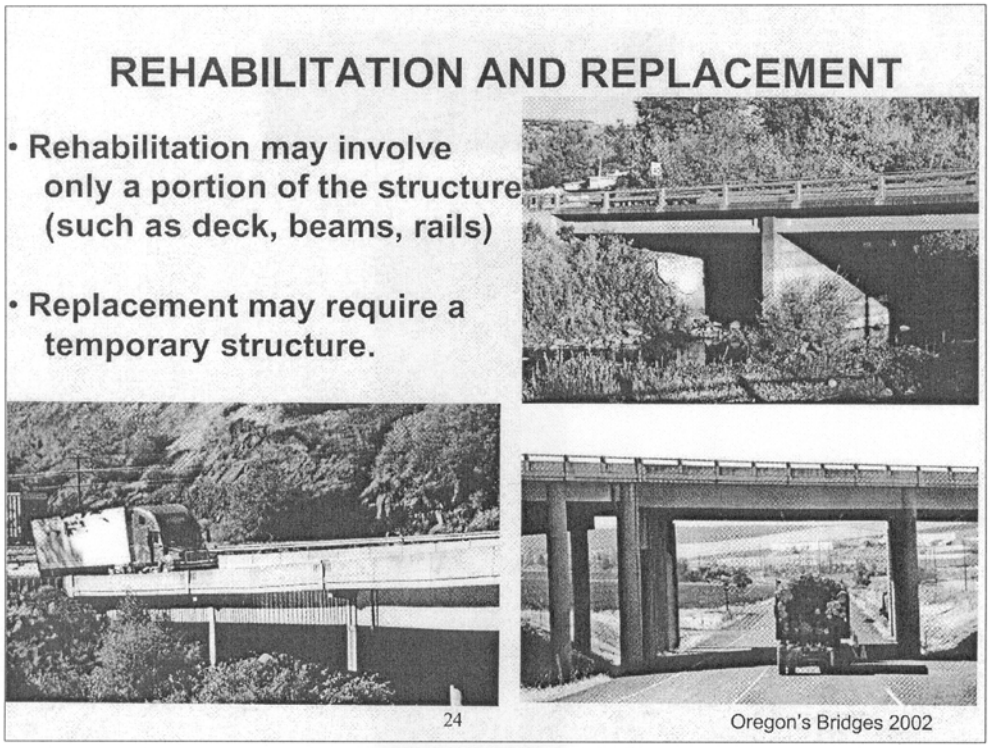

FIGURE 10 Oregon DOT public information presentation panel.

TABLE 3
SUMMARY OF PUBLIC BENEFITS ATTRIBUTED TO PREVENTIVE MAINTENANCE OF HIGHWAYS

Class of Benefit	Recipient—Nature of Impact	Problems and Limitations in Assessment or Realization
Highway O&M cost reduction	Agency—obviates or delays need for repairs, so that total expected agency expenditures over analysis period are reduced	Savings calculation depends on forecast of need for repair. Savings calculation depends on assumed discount factor. Requires trade-off between present and future budgets.
Service-life extension	Agency—reduces deterioration rate or time-dependent probability of failure, so that anticipated need for repair is delayed	Immediate impact of maintenance action may not be apparent. Service life is uncertain; failure may occur earlier or later than anticipated, regardless of maintenance.
Service reliability improvement	Agency—reduces statistical variability in observed service conditions, so that likelihood and frequency of unanticipated need for repair are reduced	Requires substantial data to verify statistics and inferred correlation of service conditions with maintenance actions.
Vehicle cost reduction	System user—improves service conditions, so that road-user vehicle operating costs are reduced; workzone delays and hazards may increase costs	Magnitude of savings depends on factors outside the control of transportation agency; e.g., vehicle fleet, traffic levels, assumed discount factor, assumed time values. Users may not fully perceive cost variations. No mechanism for agency to capture portion of savings; may actually reduce agency revenue.
Ride quality/comfort improvement	System user—improves service conditions so that user experience is enhanced; e.g., smoother ride, more pleasant views	Recognition of improvement depends on factors outside the control of transportation agency; e.g., user demographics, traffic levels, vehicle characteristics.
Traffic flow improvements	System user—smoother surfaces enhance flow; workzone and detour delays and speed reductions and crash hazards occur during maintenance	Directly perceived by road users.
Safety improvement	System user—improves service conditions, so that crash frequency or severity are reduced; workzone crash risk and expected severity may be greater	Requires substantial data to verify statistics and inferred correlation of crash experience with service conditions and maintenance actions. No mechanism for agency to capture portion of savings.
Environmental amelioration	Public at large—directly or indirectly reduces stormwater runoff pollutants, air pollution emissions, noise; may be offset by pollution (e.g., sediment, herbicides) associated with PM	Requires substantial data and sophisticated simulation models to verify inferred correlation of environmental conditions with service conditions and maintenance actions. No direct bases for estimating economic value of improvements.

Note: Data are derived from the literature; see for example, Wachs 1967; *NCHRP Synthesis of Highway Practice 58* . . . 1979; Fwa and Sinha 1986; *Pavement Management Systems* 1987; and Adams and Sianipar 1998. O&M = operations and maintenance.

pavement is among the characteristics of controlled-access routes that road users appreciate. Others have found that pavement roughness has an observable influence on vehicle speeds (Karan et al. 1976).

Adverse impacts of maintenance activities on traffic conditions—such as workzone delays, hazards, and travel speed reductions—are definitely perceived as such by road users (Vadakpat et al. 2000). The review for the current synthesis found no instances of analyses that included these unfavorable impacts in LCCA comparisons of maintenance-based management strategies.

MANAGEMENT ANALYSIS OF MAINTENANCE BENEFITS

Computer-based decision support tools have been developed to help agencies devise management strategies that maximize the net benefits of a highway system. These tools have been based largely on LCCA principles—the service-level indices and the standard model described in the preceding sections. The World Bank's Highway Design Model (HDM), for example, was an early and very popular example for pavement design and management (*HDM Model Description* . . . 1981). The HDM, widely used internationally (Vincent et al. 1994), is now owned and maintained by the World Road Association (PIARC). A similar model, MicroPAVER, was developed by the U.S. Army's Construction Engineering Research Laboratory in cooperation with the American Public Works Association (APWA). According to APWA, MicroPAVER is used by cities and counties throughout North America. A number of consulting firms have developed similar but proprietary models.

Those models explicitly represent the influence on road surface condition of neglect or maintenance performed, as a function of road design characteristics, traffic loads, environmental conditions, and maintenance strategy (*Pavement Management Systems* 1987; Watanatada et al. 1987). They then project pavement conditions anticipated in the future, as a result of forecast vehicle loads and maintenance policies, and calculate estimates of road-user costs. Users of the HDM may attest to influence of different pavement designs and maintenance strategies on the net LCC.

The HDM was intended initially for use primarily in developing countries with lower-volume roads. A version of MicroPAVER has been developed for airfield pavement. Some agencies conduct testing or use their own collected observations to customize deterioration curves embedded in the available generic models (e.g., as reported by the TRB Data Analysis Working Group, an international forum for the discussion of methods of analysis of pavement performance data).

In 1989, the FHWA issued a requirement—expanded by ISTEA (Section 1034)—that state DOTs must maintain some form of pavement management system to remain eligible for federal funds. FHWA officials report that the requirement was withdrawn in subsequent legislation, but many agencies continue to use such models in their pavement management activities.

Bridge management tools based on similar reasoning have been developed as well, for example, under the aegis of AASHTO, through the AASHTOware program. The Pontis model is widely used, but the newer Bridgit model now offers an alternative tool.

Using the approach embodied in these decision support tools, some state agencies—notably in Michigan and California (*Pavement Preventive Maintenance Guidelines* . . . 2001)—have attributed substantial financial benefits to their PM programs. The Michigan DOT reported having spent $80 million on the PM of 2,650 mi (4260 km) of highway since adopting its PM strategy in 1992, and it estimates that $700 million of spending would otherwise have been required during the same period for rehabilitation and reconstruction projects to bring pavement conditions to comparable levels. More recently, the agency reported significant service life gains in both flexible and rigid pavement as a result of PM activities (Galehouse 2002). The Arizona DOT reported saving more than $200 million in maintenance and rehabilitation costs in the first 5 years after the agency implemented a pavement management system (Madanat 1997). Federal officials reported that Michigan's analyses have influenced other states to develop pavement preservation programs ("Forum II . . ." 2002).

AGENCY USE OF PUBLIC BENEFITS ESTIMATES IN MANAGEMENT DECISION MAKING

The survey of agencies conducted for this study confirms what the literature indicates: that use of pavement and bridge management software incorporating the concepts of public benefits of maintenance is nearly universal among state agencies (Table 4). A variety of customized packages are used for analysis of pavement maintenance strategies, but the Pontis model prevails in bridge management. Most agencies also use general maintenance management software (e.g., primarily work order processing) and fleet management packages; the latter tools facilitate consideration of PM strategies in fleet operations.

Widespread use of such analysis tools would seem to indicate that road-user costs are a significant factor in agency decision making. Many agencies (63%) have gone further by adopting construction bidding and award practices—such as "lane rental" and "A+B" bidding—that

TABLE 4
SURVEY RESULTS OF HIGHWAY AGENCY USE OF ESTIMATED PUBLIC BENEFITS IN MAINTENANCE DECISION MAKING

Uses of Public Benefits	Percentage of Agencies
Use pavement or bridge management software that embodies public benefits	94
Have used bidding or contracting methods that reflect road-user cost or other public benefits (e.g., "lane rental," "A+B" bidding)	63
Use benefit–cost or LCC methods in maintenance management	37
Use such methods, but only for major maintenance projects	21
Compare all maintenance with new construction in agency-wide programming and budgeting	21
Make such comparison, but only for major maintenance projects	17
Report maintenance program accomplishments in terms of outcome measures (e.g., pavement condition) and report outcome information to the public	21
Use benchmarking in maintenance management and report benchmarking information to the public	21

make attention to road-user costs explicit to stakeholders outside the agency. Nearly three-quarters of agencies that had used such methods (approximately 47% of all agencies) claim also to have ongoing activities to identify public interests and concerns related to the agency's highway programs.

Such widespread adoption of practices that explicitly recognize road-user costs would seem to imply that agencies are particularly sensitive to the public benefits of various maintenance practices. Nevertheless, only one-third of agencies reported that life-cycle costing or other benefit–cost methods are used in their maintenance program planning. Those that do use such methods in maintenance apply them for the most part only in assessing major projects (e.g., reconstruction). Only one-third of agencies reported that maintenance analyses are compared with new construction in agency programming and budgeting. Approximately one-half of these agencies make the comparisons for major projects only.

SUMMARY

- The literature and surveys of current practice revealed three sets of issues pertaining to the measurement of public benefits of highway maintenance:

- Definitions of maintenance, PM, and preservation—AASHTO publications offer definitions of the terms maintenance, preventive maintenance (referred to as PM in this report), and preservation; nevertheless, precise usage varies among practitioners and researchers. Determinations of what specific types of actions (e.g., overlays and crack sealing) qualify as maintenance rather than repair, renewal, or reconstruction vary as well. Maintenance activity overall is widely regarded as not adding significant capacity to the highway system or enhancing the structural capacity of pavements and bridges; however, studies show that poor service levels (which maintenance could improve) may effectively reduce capacity. Highway management professionals are likely to classify as PM those actions that repair low levels of damage, to forestall the onset of more serious deterioration of service conditions. The lack of consistent definitions makes the comparison of various agencies' PM practices difficult.
- Maintenance impact on facility condition as a source of public benefits—Measures have been developed that characterize pavement and bridge conditions. Facilities in better condition, as indicated by higher levels of these measures, are shown to be related to lower road-user costs, greater road-user comfort, safer traffic operations, reduced need for major maintenance and repairs, and other benefits. Condition measures used to rate and manage facilities vary to some extent among agencies, although the IRI is widely used for pavements and the National Bridge Inventory sufficiency rating is periodically reported for larger bridges. An empirical model relating condition to facility design characteristics, age and use, and maintenance strategy is widely accepted. That conceptual model has been used to devise computer-based decision support tools. Data used in these tools have been drawn from a few studies.
- Estimating net benefits of maintenance—Arguments in favor of maintenance-based management strategies rely on principles of discounted cash-flow theory and LCCA procedures that embody those principles. LCCA is used to demonstrate that periodic agency spending for maintenance yields savings in agency construction, repair and rehabilitation expenditures, reductions in road-user costs, and other economic benefits, such that the total net LCC of providing adequate service conditions is lower than would be the case without such maintenance.

CHAPTER THREE

PUBLIC PERCEPTION OF MAINTENANCE BENEFITS

Although responsible officials and researchers argue that highway maintenance yields significant public benefits, funding for maintenance, compared with funding for construction of new roads, has been problematic in the United States at least since the close of the Revolutionary War (*History of Public Works* . . . 1976). The situation is not unique to this country; the World Bank has for many years recognized the lack of effective road maintenance as an "intractable" and complex problem threatening national development (*The Road Maintenance Problem* . . . 1981). Geoffroy (1996, p. 8) found that only 18% of agencies reported any earmarking of funds to ensure that PM would be performed. Some professionals propose, as the background and scope of this study suggest, that the problem stems from a lack of appreciation—particularly among public officials, political leaders, and the general public—of the benefits of effective maintenance and the costs of neglecting maintenance.

Respondents to a Foundation for Pavement Preservation (FP^2) survey of state agencies most frequently cited public perceptions as a barrier to adoption of PM programs (Davies and Sorenson 2000). The survey may be biased however, as the form itself suggests as a response that "motorists will not accept" a departure from a conventional approach of giving highest priority to maintenance of those pavements in the poorest condition—the "worst first" strategy. The FP^2 survey form also suggests that the low regard for maintenance felt by senior agency management may be another barrier to establishing PM programs, and several respondents agreed.

A lack of appreciation of maintenance benefits is linked by many highway professionals with inadequate commitment to PM and preservation. FHWA staff suggests, for example, that establishing dedicated funding is a major hurdle that agencies encounter when considering the creation of pavement preservation programs. More than 90% of respondents to the FP^2 survey anticipated that pavement PM will increase customer satisfaction. However, fewer than 30% of those respondents had some system of measurements that could confirm that expectation. More than two-thirds of agencies responding to the survey conducted for this synthesis study reported having undertaken surveys to identify public interests and preferences generally, but just more than half reported having tried within the past 5 years to assess public opinions about maintenance in particular (Table 5).

PUBLIC PERCEPTIONS AND OPINIONS OF MAINTENANCE

A search of the literature revealed only a few studies offering insight into the opinions of various segments of the public with regard to the benefits or importance of maintenance. Attitudinal studies are frequently used in transportation planning and management, particularly considering road users' concerns about traffic and safety conditions (e.g., Fulton 1988). Some investigators (e.g., Heine 1990; Cuevas 1997; Jackson and Ruehr 1998) have examined drivers' attitudes regarding workzone safety or vehicle maintenance as a safety issue. A search of TRIS (Transportation Research Information Services) and other on-line da tabases, however, yielded only a single reference to the relationship of maintenance to long-term facility service levels (Jefford et al. 1988).

TABLE 5
SURVEY RESULTS OF HIGHWAY AGENCY USE OF OUTREACH AND CUSTOMER RESEARCH IDEAS

Activity	Percentage of All Agencies
Use surveys or other methods to assess public interests and preferences regarding agency activities	68
Have used surveys or other methods within the past 5 years to assess public perceptions regarding maintenance activities	58
Definitely use information in agency management	21
Have conducted maintenance-targeted briefings for elected officials within the past 5 years	42
Do so at least annually	26
Have conducted maintenance-targeted briefings for local officials within the past 5 years	32
Do so at least annually	16
Regularly report to public on maintenance program output or productivity (e.g., lane-miles patched)	21
Regularly report to public on maintenance program accomplishments in terms of outcome measures (e.g., pavement condition)	11

Anecdotal evidence suggests how maintenance and service-level characteristics influence road users' opinions. For example, *Overdrive,* a magazine serving the long-haul trucking community, conducts an annual survey of the "best and worst roads." Factors considered in their survey include truckers' opinions about potholes, cracking and patching, traffic and congestion, and construction. Roads in Florida and that state's stretch of Interstate 75 were favorably rated in 2001, along with roads in Georgia, Tennessee, and Texas. Pennsylvania's roads also ranked well in 2001, after that state was reported as having the worst roads for the previous 7 consecutive years.

A writer for *Overdrive*, however, had visited Pennsylvania in 1997 and traveled these roads, observing only 50 mi of aged pavement in two counties that she judged needed serious attention (Hatfield 1997). State officials, seeking to explain the low ratings in the 1990s, had suggested that "truck drivers, angry about high tolls, rigid police enforcement and length and weight restrictions" in Pennsylvania, might "have an ax to grind." On the other hand, the state spent heavily on repairs during the mid-1990s, which suggests that poor facility conditions and repair-related workzone delays could have accounted for these complaints. In any case, a state highway official stated, "We've changed the reality; now we've got to change the perception" of the state's highways following completion of their extensive repair work.

Opinions by a broader segment of the public are explored in a series of surveys conducted in 2000 by the FHWA (Keever et al. 2001). Asked to rate their satisfaction with "the major highways you most often use," 65% of highway travelers reported that they were satisfied or very satisfied. However, as the researchers acknowledged, the level of satisfaction was not strong; only about 10% of respondents indicated they were "very satisfied," whereas more than 20% were dissatisfied or very dissatisfied. Approximately 15% expressed no opinion. Users of nonurban highways were more satisfied than those using urban highways, suggesting that traffic volumes and congestion may have been influential in their responses. Heavy traffic and related delays were frequently cited as reasons for dissatisfaction. The 2000 results, compared with a similar survey in 1985, showed increased polarization of opinions; that is, increases in percentages of both satisfied and dissatisfied travelers (Keever et al. 2001).

CORRELATING PERCEPTIONS, OPINIONS, AND MEASURABLE ROAD CONDITIONS

The FHWA surveys asked travelers to rate their satisfaction with pavement and bridge conditions that might be influenced by maintenance, including durability, ride quietness (pavements) or smoothness (bridges), and (for bridges only) visual appearance. The percentage of respondents satisfied with these factors was similar to that expressing an overall level of satisfaction, just over 60%. In contrast, fewer than 50% were satisfied with traffic-flow conditions. Other frequently cited sources for dissatisfaction included workzones (presumably associated with both highway maintenance and expansion) and pavement conditions.

However, the researchers noted that pavement durability and smoothness account for only approximately 20% of the dissatisfaction, suggesting that factors not measured in the survey may be more important than these in explaining traveler opinions. Also, participants were not asked to respond to specific statistics, numerical measures of pavement condition or durability, or examples that might standardize their responses. In the absence of specific measures, it is not clear what levels of smoothness, quietness, or durability would produce substantial satisfaction or dissatisfaction.

Recent NCHRP studies of DOT activities undertaken to enhance their public relations noted that a few agencies (e.g., Montana, South Dakota, and Utah) have included pavement conditions or pavement maintenance among the characteristics about which they survey public opinion. Asphalt and concrete maintenance and road striping were occasionally mentioned. DOTs in Montana and South Dakota went further, asking explicitly about road user's interest in certain maintenance activities. The South Dakota DOT asked users how they would allocate $100 spent on roads among various activities and then used that information to shape agency programs (Stein and Sloane 2001, 2003). The Union Pacific Railroad is noteworthy for establishing a particularly strong link between maintenance and customer satisfaction and company profitability (McNeil et al. 2002).

Some agencies have made an effort to correlate public perceptions or opinions with measurable characteristics of road conditions. The Pennsylvania DOT, for example, conducted a large-scale mail survey of licensed drivers, focusing on highway and bridge conditions, maintenance workzone activities, and customer service at county-level maintenance units (Poister et al. 1998). Just over half of the respondents rated the state's Interstate highway and primary highways as satisfactory—meeting or exceeding expectations—although the ratings varied dramatically among counties. Approximately 42% of respondents rated the state's secondary roads as satisfactory. Measurements of the IRI as an indicator showed that pavement conditions on secondary roads were significantly poorer than on the Interstate system and primary routes. However, statistical analysis was unable to show a significant relationship between average IRI measurements and motorists' satisfaction ratings. Conversely, engineering estimates of maintenance spending needed to bring the roads to a level judged

acceptable by the estimators (including considerations of shoulder, guardrail, and drainage conditions as well as pavement roughness) were found to be significantly related to motorists' ratings. No effort to explain statistically the large variations in motorists' satisfaction among counties was reported.

The Wisconsin DOT (WisDOT), in its efforts as part of a three-state research project (with Minnesota and Iowa), undertook a staged exploration involving focus group discussions followed by telephone surveys (Robinson et al 2000). That work found that drivers had a generally high opinion of WisDOT's general competence, concern for safety and drivers' convenience, and responsiveness to the concerns of average drivers. This satisfaction with WisDOT seemed to make respondents more inclined to be satisfied with pavement conditions as well. However, although almost one-third of the respondents believed that pavement conditions on a road segment they knew well could be improved, more than half also felt that conditions on that segment were better than is typical on other roads in the state. When asked how limited funds should be allocated among several choices proposed, more than one-half of the respondents favored building longer-lasting pavements. Only 38.3% selected any one of the three suggested choices clearly identifiable as maintenance: fixing bumpy highways, resurfacing patched pavement, or correcting noisy pavement.

The WisDOT survey also posed hypothetical questions to explore drivers' preferences about delays caused by roadway maintenance and repair work. Respondents generally preferred more frequent, shorter delays rather than longer delays less frequently imposed.

A 2001 telephone survey conducted by the Oregon Survey Research Laboratory ("Transportation Need") asked participants how they would "compare the overall condition of Oregon's highways, roads and bridges to other states." Just over 31% of respondents rated Oregon's condition as "better," slightly more than 46% rated it as "about the same," and 12% felt it was "worse." Approximately 83% of respondents were "very satisfied" or "somewhat satisfied" with "how ODOT maintains Oregon's highways, roads, and bridges." Nearly 77% rated the agency's overall performance as "excellent" or "good," and 68% believed that conditions on the state's highways, roads, and bridges were "better" or "about the same" as they were 10 years earlier.

In response to a direct question as to whether the Oregon DOT (ODOT) should give priority to maintaining existing facilities instead of building new ones, nearly 37% answered "yes" and slightly less than 7% said "no." However, more than half refused to answer the question, gave no answer, or answered that they "don't know." A question asking whether "it is more important for ODOT to make system improvements to reduce congestion, or to preserve and maintain the highways Oregon already has" found respondents about equally divided (just under 21% each). Again, more than half refused to answer the question, gave no answer, or answered that they "don't know." For subsequent questions, respondents overwhelmingly reported that maintaining the state's existing system is "very important" or "somewhat important" (99%), as is expanding and improving the system (89%) and reducing congestion (91%).

The National Quality Initiative (NQI) has motivated such studies. The NQI is a collaboration formed in 1992 by the FHWA, AASHTO, APWA, and several other groups, "to focus attention on continuous quality improvement within the highway industry" (*National* 1997). One of the NQI's objectives has been to "promote customer focus and measurement of quality in the highway industry," and emphasis in at least one set of demonstration projects has been on a "least cost approach to maintenance/systems preservation activities" (*Quality Accomplishments* 1997).

Initial guidance on how to implement customer-based definitions of quality was provided to state DOTs in 1995, through the NCHRP (Stein-Hudson et al. 1995). Telephone interviews are the most frequently cited method for collecting public opinion information and are used by 64% of agencies that reported using any method (Table 6). Mail and e-mail questionnaires are next in popularity, used by 45% of responding agencies.

TABLE 6
SURVEY RESULTS ON METHODS USED FOR MAINTENANCE OUTREACH AND MARKET RESEARCH

Method	Agencies Using Method (%)
Telephone survey	64
Mail-back or e-mail survey	45
Focus groups	36
Telephone and mail-back survey	27
Other (website, state fair)	27

The Arizona DOT (ADOT), for example, commissioned a telephone survey of state residents and selected community leaders to obtain information on the opinions of customers with regard to the types of transportation services they want. The survey found that only 11% of those polled judged transportation to be among the most important problems facing the community. The results were similar to those of the national NQI surveys: approximately 60% of respondents rated their highways, roads, and streets as "excellent" or "good," and only approximately 15% rated them as "poor" or "very poor." A significant portion of the Arizona sample expressed a desire for more lane-miles of freeways and major highways, but they opposed all options for increasing funding for transportation improvements.

Maintenance and repair was the most frequently cited means for improving transportation (Hernandez 1997).

A 1996 telephone survey for the Montana DOT asked highway users' opinions of the relative importance of seven maintenance activities, including debris removal, maintenance of signs, roadsides, rest stops, and striping. Not surprisingly, winter maintenance was rated highest (scoring 3.56 on a scale of 1 to 4). Maintaining surface smoothness rated lowest among the seven areas (scoring 2.51) (*Quality Accomplishments* 1997).

CONSEQUENCES OF PERCEPTIONS AND OPINIONS

The idea that transportation agencies should make particular efforts to communicate with the road-using public, elected officials, and others, and should listen to these customers in setting management priorities is widely reported (e.g., Lockwood 1998; Hagler Bailly Services 1999). To distribute information about its programs, each state agency maintains an Internet website, and most agencies make a variety of printed materials available to elected officials and the general public. The influence of public opinion on maintenance programs is nevertheless difficult to track. Although 68% of agencies responding to the survey for this study reported having conducted surveys to identify public interests and preferences, only about one-third reported that information about public opinions of their maintenance and performance is definitely used in agency management (see Appendix B, Table B8).

However, approximately 79% of agency respondents felt that the public at large had definitely or somewhat favorable views of their agency's maintenance programs. All respondents, without exception, believed that elected officials and their own senior management held positive views of their maintenance programs. Survey respondents most frequently cited news reports, comments made at public hearings, and favorable legislative action on agency budget requests as evidence of public favor. Approximately 40% of respondents listed the results of public opinion surveys.

Computing an estimate of the agency's maintenance backlog or funding gap is a frequently used basis for trying to convince elected officials and the general public that additional funds are needed for maintenance and repair (e.g., Hatry and Liner 1994). The backlog is generally defined as the estimated cumulative cost of raising the condition of all roads in a system up to a level defined—typically by the agency—as an acceptable minimum.

ODOT personnel, for example, explained that the agency used backlog as part of its argument for a proposal to increase the state's gasoline tax, which went to statewide ballot in 2000. Agency personnel prepared a series of documents and public presentations to explain the terminology of maintenance (e.g., rehabilitation versus replacement, as shown in Figure 10), the idea of the backlog, and the magnitude of the backlog. The agency adopted the theme "Pave me now or pay more later" for its roads and bridges, explaining that the costs of repair once failure occurs (i.e., unacceptable service levels) will be several times greater than the costs for maintenance to preserve acceptable conditions. Agency engineers used the standard model to explain that state roads were approaching the age at which steeply declining service levels could be expected, and estimated a need for at least a 10% increase in maintenance spending to ensure that preservation at current levels. Presentations to state legislators and the public included projections, 15 years in the future, of what fraction of the state's roads would exhibit service levels of "fair" or below, with and without the desired funding increase and compared with current conditions. Although agency personnel judge the campaign to have been effective in influencing public opinion, the gasoline tax increase ultimately was defeated.

Although PM is shown in theory to be a cost-effective strategy for highway management, relatively few agencies promote their PM programs in their public communications. This appears to be true in the private sector as well, owing to the difficulty of proving that PM spending will reduce the total costs of providing goods or services. TTX Company is a notable exception, because its PM practices yielded clearly measurable benefits; the manager of railcars gained regulatory approval from the FTA to extend the usable lifetime of autorack cars (used for shipping new automobiles) from 50 to 65 years (McNeil et al. 2002).

SUMMARY

Published literature, the study survey, and anecdotal evidence gathered during this synthesis study revealed information about public views on highway maintenance activities and agencies' efforts to publicize the benefits of those activities:

- Public perceptions of maintenance and its benefits—Surveys show that a majority of the general public holds favorable views of highway conditions generally and of the operations of their highway agencies. There is evidence that public perceptions are linked to specific characteristics of pavement or other roadway conditions, but that such evidence is limited. Officials of many agencies believe that elected officials as well as the general public have favorable views of agency maintenance activities.
- Influence of public opinion—The idea that customer opinion should influence agency management deci-

sions is widely espoused. Many agencies have used surveys or other market research techniques to assess public opinions of their highways and maintenance operations. The influence of such information on agency decisions about maintenance budgets and program management is not well documented.

- Efforts to communicate with the public and market maintenance—Some agencies routinely hold briefings or make other efforts to inform legislators or the general public about maintenance issues. Some agencies routinely report maintenance program productivity or other performance measures to the general public, although most agencies calculate such measures only for their internal management.

CHAPTER FOUR

MARKETING THE PUBLIC BENEFITS OF MAINTENANCE

Many factors undoubtedly contributed to the defeat of Oregon's gas tax increase, as mentioned in chapter three; however, ODOT's campaign to inform and influence public opinion is an important example of marketing maintenance that several analysts have suggested is needed (e.g., Kraft 1998; Niemi 1999). Marketing, according to specialists in the field, is "the process of planning and executing the conception, pricing, promotion, and distribution of ideas, goods, services, organizations, and events to create and maintain relationships that will satisfy individual and organizational objectives" (Boone and Kurtz 2001). Marketing (or market) research, an element of marketing, entails the collection and analysis of data relevant to marketing decision making, and communicating the analysis results to management. Marketing concepts and market research have frequently been used in transportation management—for example, to attract and retain transit riders (Elmore-Yalch 1998) and to encourage the wider use of new techniques to improve maintenance practices (Beimborn et al. 1986).

Many agencies, particularly at local government levels, post billboards along routes undergoing major maintenance or reconstruction, alerting vehicle occupants that they are observing their tax dollars at work, and naming the elected official whose leadership is presumably responsible for the effort. The literature review and interviews conducted for this study did not reveal evidence that such signage enhanced public appreciation of the benefits of maintenance.

A few agencies make more active efforts to market their maintenance activities; in doing so, they seek to present to the public a cogent description of the public benefits of these activities. The Oregon "Pave me now or pay more later" campaign is one example. Another is the Minnesota DOT's (MnDOT's) "maintenance business planning" program and publication of brochures and information summaries for use by the news media (Figure 11).

The Michigan Road Preservation Association maintains what it characterizes as "an aggressive program to inform the public, MDOT, and the legislature of the importance and cost-effectiveness of the preventive maintenance processes in preserving Michigan's road system." As this contractor's organization describes it, the program relies largely on lobbying and published informational materials. MDOT reported that $16 million spent on PM in the 1999 to 2000 period, to treat 3,710 route-miles of road, increased the life span of the pavements by up to 7 years ("An Overview of Statewide Accomplishments 1999–001" 2002).

MARKET RESEARCH

The survey for this study found that agencies use a range of methods commonly employed in market research (see Table 6). MnDOT, for example, conducted a survey (its market research) of state residents, licensed drivers, and highway-district residents that became the basis for preparing its brochures and media information.

Approximately three-quarters of responding agencies prepare maintenance program reports at least annually. However, only 21% of respondents actively provide maintenance program output or productivity information to the public. Some 58% of agencies responding to the study survey make an official estimate of the maintenance backlog; however, almost one-half of these agencies do so less than annually. Only 11% actively present outcome measures such as pavement condition indices. Results of this reports' undirected sampling of agency websites was consistent with the survey results. The survey, part of a joint study with agencies in Wisconsin and Iowa, was similar to that of the Pennsylvania DOT (described previously).

The MnDOT marketing materials described selected results of the customer opinion survey, pertaining to what the department was doing well or where improvement was needed. The agency sought to educate customers by listing seven products and services the agency provides: clear roadways, smooth and reliable pavement, available bridges, attractive roadsides, safety features (such as guardrails, functioning traffic signals, and signing), highway permits and regulations, and motorist services (such as information on road conditions and attractive rest areas). Agency personnel asserted that these materials have been well received by the public.

INFORMING THE PUBLIC

A particularly aggressive marketing campaign—exemplifying conventional marketing wisdom that salesmen make a difference (e.g., Davidow 1986)—was mounted by the public works officials of Cincinnati, Ohio, with private-sector assistance. In the 1980s, the city was faced with serious deterioration of roads and other infrastructure and a declining revenue base as employees of city-based corporations moved to the suburbs. In response, public works officials prepared an illustrated annual report "The Public Works Story" (*In Our Own Backyard* . . . 1993). This

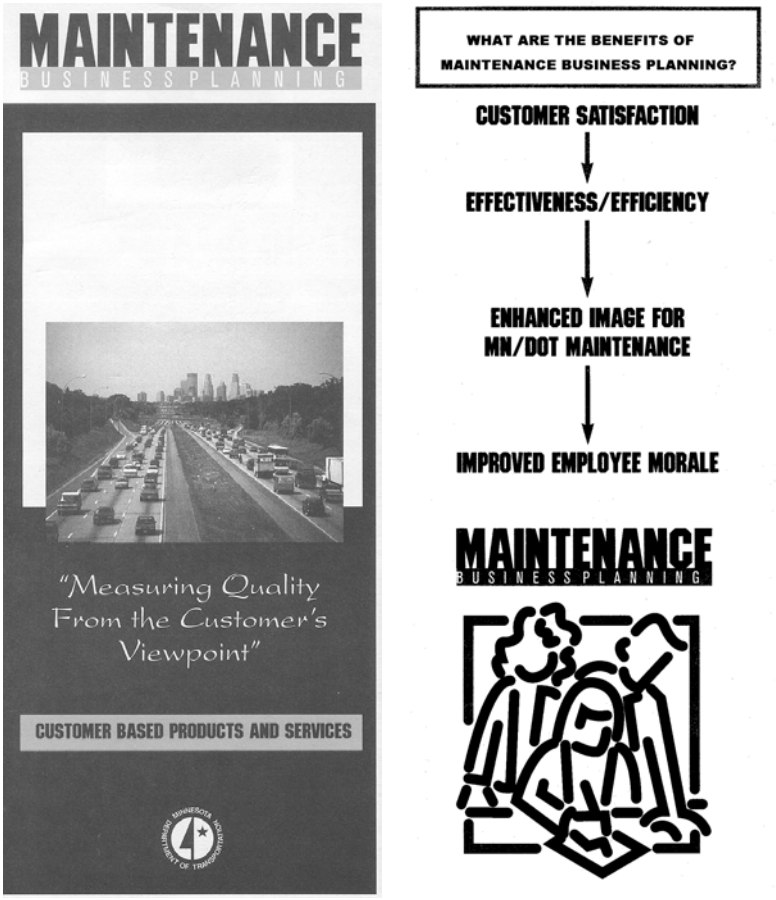

FIGURE 11 MnDOT maintenance-marketing brochure (two of six tri-fold panels).

widely circulated report, published from 1983 through 1989, included numerous photographs of facility conditions throughout the city's neighborhoods, taken from viewpoints that citizens and other road users could identify and verify. Also included were estimates of the costs to repair specific problems—effectively a backlog estimate.

At about the same time a similar process was begun in Cleveland, Ohio. By the 1980s, infrastructure deterioration was so advanced that streets were disintegrating, nearly 30% of the county bridges were in need of major repair, and the Cuyahoga River had become so polluted that it caught fire. In 1981, the Greater Cleveland Growth Association (a chamber of commerce organization) and the city's mayor initiated discussions of the city's physical and economic problems among public-sector and business leaders. After 2 years of discussion and negotiation, the participants developed a capital investment strategy and formed a new organization, Build Up Greater Cleveland (BUGC), to inform the public and to implement and periodically update the strategy. Community leaders now give credit to BUGC's systematic program of coordinated advocacy for the community's success in mobilizing substantial investment funding for infrastructure revitalization. For example, BUGC leaders worked for the passage of a state referendum establishing the Ohio Public Works Commission and its local funding program. That program provided approximately $13.5 million annually for the maintenance and rehabilitation of sewers, roads, and bridges in Cuyahoga County.

City leaders in Cincinnati similarly credit "The Public Works Story" reports with shifting public opinion toward recognition that action was needed. A partnership developed between the city's public works leadership and senior management of Procter and Gamble, the city's largest employer. In 1986, the city council asked Procter and Gamble Chief Executive Officer John Smale, to chair an independent commission to assess the city's infrastructure problems. The Smale Commission's report included proposals for a tax increase to fund infrastructure renewal and preservation. The business community, led by Mr. Smale, took responsibility for ensuring voter approval of the increase by donating funds to prepare and circulate a videotape presentation, a television commercial, and newspaper advertising. Mr. Smale and George Rowe, the public works director, appeared as a team before dozens of neighborhood and community groups to present the case for approval. Voters

in a 1988 referendum voted in favor of the tax increase, although the margin of victory was narrow, fewer than 300 votes out of some 50,000 ballots cast.

A less formal use of the techniques embodied in the Cincinnati and Cleveland experiences was reported by a senior military officer who had been responsible for securing Congressional committee approval of budgets for maintenance and renewal of base housing. The officer showed committee members photographs of deteriorating barracks and explained the likely impact of such conditions on morale. After considerable discussion, grudging approval was given for improvement. To consolidate his case, the officer appeared before the committee at the next approval cycle and initially showed committee members the same photographs. Questioned by the members as to why the repairs had not been made, the officer then distributed new photographs of the newly renovated and now well-maintained facilities, thanking the legislators for their earlier actions. He then presented the next budget request. Experiences reviewed in chapter three give evidence that the opinions of elected officials and the public in general can be influenced toward favorable views of maintenance. School facilities managers have been encouraged to adopt methods that will similarly communicate the "vital role of facility management, maintenance, and capital improvement planning on educational delivery" (*Effective Facility Management* . . . 2001).

SHIFTING ATTITUDES

Accomplishing such shifts is a primary objective of marketing and public relations, which work to build and maintain an organization's relationships with customers, potential customers, and others, who may influence the organization's prosperity, to create and protect product and organization identity and reputation (Davidow 1986; Caywood 1997). Marketing and public relations techniques move customers away from competitors' products or from positions unfriendly to the organization by increasing "dissonance" between the person's opinions and positive information about the competition, and by enhancing "consonance" or comfort with the idea that the organization and its products are good (Festinger 1957). Consonance—the complement of dissonance—increases when the customer's observations and expectations match.

When considering the use of consonance, marketing professionals have found, for example, that a person buying an expensive car is less likely to conclude the car is a "lemon," owing to poor performance during the first month or two, if the new car dealer has strengthened the buyer's opinion that the car's higher price is an indicator of higher quality. The dealer seeks to maintain in the buyer a conviction that the problems are unusual, an aberration. Swift, courteous service and an effective resolution of the problems increases positive feelings toward the manufacturer and the dealership—that is, consonance—and retains customer loyalty, leading to repeat business. If the problems are poorly handled or persist too long, however, dissonance increases, the customer's views generally become negative, and the now unsatisfied customer may talk to other potential customers about his or her displeasure. The next car purchased will likely be a different brand, and the next service appointment might be with a different local provider, not only on the part of the original buyer but possibly of others as well.

When considering the use of dissonance, Cincinnati's annual publication of "The Public Works Story" may be understood as a successful effort to shift public opinion away from comfort with current conditions and toward the view that greater maintenance spending was needed. Oregon's "Pave me now or pay more later" campaign had a similar purpose. The military officer's use of photographs of deteriorating barracks made legislators less comfortable. In each case, the marketing effort was meant to increase dissonance and convert the audience into customers for the competition—a change in maintenance practices and the actions needed to pay for the change. Officials in Cincinnati and the military officer were then able to close the sale.

A more extreme use of dissonance to build demand for maintenance was reported by economist A.O. Hirschman (1958). He described a highway project in South America where a decision had been made to build the road with light-duty paving rather than a gravel surface, although conventional analysis showed the latter to be a more efficient design. The consulting engineer explained, "We assumed that, with the increasing truck and bus industry in Colombia, local pressure would be applied to the Ministry of Public Works to repair the deep holes that will develop in cheap bituminous pavements if maintenance and retreatment are delayed, and that the pressure would be greater than if a gravel and stone road is allowed to deteriorate." Road users expect the paved road to provide better riding conditions than a gravel road, regardless of the design characteristics of the pavement. When these expectations are not met, dissatisfaction leads to complaints, which consistently leads to more maintenance, repair, and reconstruction than would have been the case with a gravel road. Poor conditions were anticipated to serve the same purpose as marketing publications.

INFLUENCING DECISIONS

The proof of marketing and public relations success lies in the decisions that people make to purchase a particular product, vote for a particular candidate, and so on. Important information that may be gathered through market re-

search is the "price point" at which potential customers are likely to make the decision. In the case of commercial products and services it is the customer's "willingness to pay." This willingness depends on the characteristics of the product. The color of an automobile, for example, does not change mechanical performance, however, it can dramatically influence the car's market potential. Similarly, shorefront building sites sell for higher prices than otherwise equivalent pieces of property some distance from the beach. When observable market transactions establish prices, statistical methods can be used to attribute values to such unpriced characteristics as color and location amenity. In the absence of observable transactions, market researchers and economists use such methods as "contingent valuation" to estimate willingness to pay (see e.g., Carson et al. 1996 or *Valuing Environmental Preferences . . .* 1999).

In their simpler forms, such methods seek to elicit meaningful answers to direct questions about how much people would be willing to pay to have access to or not to lose the quality in question—for example, smooth-riding highway pavements. The answers are meaningful if they can be used to set realistic policies or estimate appropriate price levels. For example, water resource planners use such methods to estimate appropriate fees for fishing and boating on reservoirs; the fees represent a value that the public places on these recreational uses of the infrastructure (e.g., Piper 1998). In highway transportation, willingness-to-pay methods have been used in valuing safety improvements (e.g., *1996 Valuation . . .* 1997) and new technology (Polydoropoulou et al. 1998), and for planning toll facilities. Researchers have proposed broader applications to transportation planning (e.g., McFadden 1997).

ODOT's 1998 survey (see chapter three) asked whether people would be willing to pay higher gas taxes to relieve congestion, and 57% of respondents answered affirmatively. This synthesis study failed to find any instances in which surveys or other contingent valuation techniques were employed to estimate appropriate maintenance budgets or to value the benefits of PM or preservation, from the public's perspective.

The listening and learning done by skilled professionals determine the distinctions between sales and marketing. A good salesperson determines how best to convince potential buyers that they want and need the product. A good marketing person learns about the customers' preferences and communicates what is learned, ultimately to the product development department, so that products are designed to match customers' desires. As products leave the factory, the marketing person finds ways to alert potential customers to the match and helps the products sell themselves.

From this perspective, it can be seen that the methods currently used by state and local agencies for communicating maintenance activities and their benefits to stakeholders, as identified in literature, surveys, and interviews (see the following bulleted list), are more of sales than marketing; they aim to persuade taxpayers to support legislative initiatives intended to raise additional money for infrastructure maintenance and rehabilitation.

- Roadside billboards,
- Printed materials (brochures, reports),
- News releases and directed articles in the press,
- Public service messages,
- Internet-published materials (web pages, reports),
- Videotapes,
- Displays at public gatherings (e.g., state fairs),
- Directed briefings and presentations (legislative, public), and
- Lobbying.

The surveys conducted by some states, which included questions about road-user or taxpayer preferences, are a step toward developing what might be termed an attractive and salable maintenance product.

CHAPTER FIVE

CONCLUSIONS

This synthesis report provides an assessment of the state of practice regarding the estimation and communication of the public benefits of highway maintenance. This assessment was derived from a literature review, a formal survey of highway agency practices, and discussions with professionals in several fields, and is summarized in the following conclusions.

- Benefits of maintenance—A wide range of public benefits have been postulated and analyzed in the literature. The literature presents limited empirical evidence to support claims that the net public benefits of preventive maintenance (PM) and preservation are positive. Research indicates that the perceived value of a smooth ride varies substantially among subsets of road users. Research supports the correlation between poor pavement condition and high vehicle operating costs. Little evidence was found that road users—other than commercial truckers—or other stakeholders perceive this correlation to be significant. Some private-sector companies have tied company profitability and management incentives to maintenance performance.
- Service conditions influenced by maintenance—Many highway professionals accept the concepts that (1) single-number indices may be constructed to characterize the overall condition of pavements and bridges and (2) declines in these indices (e.g., over time and with traffic) are indicators of reductions in the net public benefits produced by roads. These concepts are embodied in an empirical model, termed in this synthesis the "standard model," which relates service deterioration to age or facility usage. This standard model is the foundation of most analyses of the public benefits of maintenance. At this time however
  - No single index has yet gained universal acceptance for use by all U.S. agencies and researchers.
  - Comparisons of the results of studies about user benefits based on different indices consequently are often difficult.
  - Research indicates that road users' appreciation of factors reflected in pavement condition indices may vary substantially with age, gender, trip purpose, and other road-user characteristics.
  - Research indicates that road users perceive maintenance-induced travel delay to be associated with waiting time, speed reductions, and detours; however, these delays are typically not included in the analyses of maintenance benefits.
- Analysis of maintenance benefits—The empirical model relating pavement condition to cumulative effects of traffic loads and materials aging is generally accepted by highway professionals and used as a basis for estimating the benefits of maintenance strategies. Analyses showing the positive net public benefits of PM or preservation rely generally on principles of discounted cash-flow theory embodied in a life-cycle cost analysis that compares diverse benefits and costs incurred at different times during the service life of a facility. At this time however
  - No single precise specification of the empirical condition deterioration model has been generally accepted and applied in such analyses.
  - Assumptions made regarding the relationship of the empirical model's functional characteristics (e.g., slope and functional form) to the completion of periodic, routine maintenance vary among research studies.
  - Life-cycle cost analyses of maintenance benefits typically include benefits for and costs to road users and the road agency, and sometimes those analyses include items for which monetary values must be inferred.
  - Little evidence was found to confirm that road users and other stakeholders prefer or attribute greater value to efficient highway maintenance strategies, that is, to those with lower total life-cycle cost.
- Definitions of what maintenance is—There is little consistency among practitioners and researchers regarding definitions and distinctions among various maintenance activities. Also, various analyses of benefits are not necessarily comparable. In particular
  - Frequently used terms for categorizing maintenance actions are defined differently by various authorities.
  - Various maintenance actions may be placed into different categories or classes by various authorities, even within a seemingly common set of categories.
  - Definitions of "preventive maintenance" and "preservation" have been published by AASHTO committees, but are not necessarily used consistently by all practitioners.
- Consideration of maintenance benefits in agency decision making—Current practices concerning the benefits of PM and preservation vary among state highway agencies. Although the theoretical benefits

of maintenance are embedded in the pavement and bridge management software used by most state highway agencies, those management tools are used for the most part only as required by federal regulation. Consequently

  - Only one-third of these agencies reported the use of life-cycle costing or other benefit–cost methods to assess maintenance priorities; two-thirds of these agencies use such methods only for major projects.
  - Only one-third of these agencies directly compare maintenance and new construction in their budgeting process; of these, two-thirds do so only for major maintenance projects.

- Marketing of maintenance—Some agencies have used sales, marketing, and public relations tools to inform elected officials and road users generally about the net benefits of maintenance, and to persuade voters to approve legislative initiatives to increase funding for maintenance and rehabilitation. Some agencies cite anecdotal evidence that marketing or public relations efforts build support for maintenance programs. Such evidence includes favorable legislative outcomes, favorable media coverage, and reductions in numbers of complaints received, following the publication of brochures, conducting of legislative briefings, and other specific actions. Experience in other areas of transportation management and other fields suggests that marketing and public relations techniques could be used to raise public awareness of maintenance benefits and to develop estimates of the value that people place on smooth roads and other service characteristics that maintenance can influence. This study found little evidence that marketing techniques that have been applied to define PM and preservation programs that road users and other stakeholders appreciate yield public benefits.

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APPENDIX A

Agency Survey Questionnaire

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Project 20-5, Topic 32-06

PUBLIC BENEFITS OF HIGHWAY SYSTEM MAINTENANCE AND OPERATIONS

Elected officials, senior managers, and the general public sometimes fail to appreciate fully the importance of regular highway maintenance. Some observers suggest that highway professionals could do a better job of measuring and explaining the public benefits of maintenance. This survey is part of a project to document the state of current practices and examples of best practices in evaluating these benefits, presenting them to decision makers, and ensuring that these benefits are appropriately reflected in management decisions. Through this survey, we wish to learn about your agency's activities in three primary areas:

1. **Understanding your customers' perceptions of maintenance activities and their outcomes (e.g., through surveys, road-user focus-group discussions),**
2. **Assessing the net benefits of highway maintenance (e.g., through life-cycle costing, cost-of-ownership analysis, willingness-to-pay studies), and**
3. **Presenting these benefits so as to influence decision making and public opinion (e.g., through legislative briefings, press releases, brochures, websites).**

"Maintenance" in this study means periodic activities intended to ensure the satisfactory performance of highway structures and associated equipment. Such activities may be termed routine, corrective, preventive, proactive, or reactive; examples include crack filling, drain cleaning, pavement striping, bridge painting, and mowing. "Operations" in this study means traffic controls and operational measures related to maintenance, such as detour routing, workzone speed controls, signal retiming, and lane closures.

Please complete this questionnaire and return it with any supporting documents, by **July 20, 2001**, to

Andrew C. Lemer, Ph.D.
The MATRIX group, LLC
4701 Keswick Road
Baltimore, MD 21210-2322
Telephone: 410-235-3307
Fax: 410-235-0838
Email: alemer@ecostructure.com

Please provide the name of the person completing the questionnaire or another agency representative who may be contacted for clarification or additional information:

Name: _____

Title: _____

Agency: _____

Address: _____

City/State/Zip: _____

Telephone: _____ Fax: _____ Email: _____

Thank you for your help and participation. Your individual responses will be kept confidential; your candor will help improve maintenance management practices!

Please add comments on separate pages if you wish, but use the question numbers at the right on the following pages to make clear where your comments apply. We would welcome copies of relevant studies and examples of your agency's successful and not-so-successful programs.

A. AGENCY BACKGROUND

		Question No.
What systems (e.g., software) does your agency use for		
pavement management?		1
bridge management?		2
maintenance management (e.g., for work-orders, crew scheduling)?		3
vehicle-fleet management?		4
Within the past five years, has your agency conducted "customer satisfaction" surveys or other activities to identify public interests and preferences?	Yes ___ No ___ Don't know ___	5
If so, were maintenance activities explicitly included?	Yes ___ No ___ Don't know ___	6
Does your agency use contracting methods that include road-user costs in bidding and award (e.g., lane rental, "A+B" bidding)?	Frequently ___ Experimental ___ No ___ Don't know ___	7
Does your agency have continuing activities to *inform* the public about agency activities, other than those required for environmental reviews of specific projects or regional plan development?	Yes (please describe) _____ No ____	8
If so, are maintenance issues regularly included in these activities?	Yes ___ No ___	9
Is an agency staff member assigned explicitly to deal with maintenance issues in communicating with elected officials and the public?	Yes ___ No ___	10
Does your agency have continuing activities to *solicit* public opinion about agency activities, other than those required for environmental reviews of specific projects?	Yes (please describe) _____ No ____	11
If so, are maintenance issues regularly included in these activities?	Yes ___ No ___	12

B. MAINTENANCE PROGRAM STATUS

In your opinion, are highway system maintenance activities of your agency viewed favorably, in general, by

top-level agency management?	Definitely ___ Somewhat ___ No___ Can't say ___	13
responsible elected officials?	Definitely ___ Somewhat ___ No ___ Can't say ___	14
the public at large?	Definitely ___ Somewhat ___ No ___ Can't say ___	15

Please give the basis for your opinion (e.g., survey data, news media reports, legislative resolutions).		16
Does your agency have dedicated or earmarked funds for highway maintenance?	Yes ___ No ___	17
Does your agency delegate to other agencies or contract with them to perform maintenance of federal-aid (provincial) highways?	Yes ___ No ___	18
If yes, what parts of the system are maintained by others?	Secondary system only ___ Secondary and other ___	19
Does your agency make an official estimate of highway system maintenance backlog?	Yes ___ No ___	20
If yes, how frequently is it updated?	Monthly ___ Annually ___ Less than annually ___	21
Is the estimate made public?	Yes ___ No ___	22
If yes, by what means? (check all that apply)	News release ___ Briefing for elected officials _____ Direct mail ___ Website ___ Other (please specify) _____	23

C. MAINTENANCE OUTREACH AND "MARKET RESEARCH"

Within the past five years, has your agency conducted maintenance-targeted briefings for *state or provincial legislators* to discuss agency highway-system maintenance program activities and their impacts?	At least annually ___ Yes, less frequently ___ No ___	24
Within the past five years, has your agency conducted maintenance-targeted briefings for *local-government officials*?	At least annually ___ Yes, less frequently ___ No ___	25
If your agency has conducted maintenance-targeted surveys or briefings within the past five years, how have these activities influenced your agency's maintenance programs? (check all that apply)	Not at all ___ Results were discussed by managers _____ Influenced program budgets ___ Influenced work scheduling ___ Other (please specify) _____	26
Does your agency use road users' notifications or complaints as a basis for issuing maintenance work orders?	Regularly ___ Occasionally ___ Seldom or never ___	27
Does your agency publicly acknowledge or reward such notifications or complaints?	No specific response _____ Individual response to informant ____ Reports in local press ___ Other (please specify) _____	28
Within the past five years, has your agency conducted "customer satisfaction" surveys or other activities to assess public perception and preferences with respect to highway maintenance and highway system performance?	Yes ___ No ____	29

If yes, what groups were targeted? (check all that apply)	Road-user groups (AAA, trucking) __ Travel and tourism ___ General public ___ Other (please specify) _____	30
What methods were used? (check all that apply)	Focus group discussions ___ Telephone survey ___ Mail-back or email survey ___ Web-based or "hotline" system ___ Other (please specify) _____	31
Are such activities repeated or updated at least annually?	Yes ___ No ____	32
Is the information used in agency management (e.g., maintenance planning, budgeting)?	Definitely ___ Somewhat ___ No ___ Can't say ___	33
Does your agency issue at least annually a public report on highway maintenance program activities and accomplishments? (check all that apply)	Yes, exclusively for maintenance ____ Yes, as part of agency-wide reports __ No ___	34
If so, does the report include estimated maintenance program benefit measures? (check all that apply)	Maintenance backlog reductions ____ Other dollar-valued benefits _____ Travel- or delay-time savings _____ Crash and crash-severity reductions _____ Other non-monetized benefits ___	35
Does your agency brief elected officials at least annually on highway maintenance program activities and accomplishments? (check all that apply)	Yes, exclusively for maintenance ___ Yes, as part of agency-wide reports ___ No ___	36

D. ASSESSING NET BENEFITS OF HIGHWAY MAINTENANCE

Does your agency regularly report output or productivity measures to monitor maintenance program activities (e.g., tons of asphalt placed monthly, lane-miles of crack sealing completed monthly)? (check all that apply)	No, not at all ___ Yes, in operations management ___ Yes, in agency-level management ___ Yes, in reporting to the public ___ In other ways (please specify) _____	37
If so, how frequently are these measures reported?	At least quarterly ___ Annually ___ Less frequently ___	38
Does your agency regularly report outcome or performance measures to monitor maintenance program activities (e.g., lane-miles with "acceptable" or better roughness, numbers of "high accident" locations)? (check all that apply)	No, not at all ___ Yes, in operations management ___ Yes, in agency-level management ___ Yes, in reporting to the public ___ In other ways (please specify) _____	39
If so, how frequently are these measures reported?	At least quarterly ___ Annually ___ No ___	40

Does your agency use benchmarking to monitor maintenance program activities?	Yes, period-to-period self-comparison __ Yes, inter-agency comparison _____ No benchmarks ___	41
If so, are benchmark comparisons reported to the public?	Yes ___ No ___	42
Does your agency routinely use life-cycle costing or other benefit–cost methods to plan and program highway system maintenance activities?	Yes, for all maintenance ___ Yes, but for major projects only ___ Not for maintenance activities ___	43
If so, are maintenance analyses compared with new construction in agency-wide programming and budgeting?	Yes, for all maintenance _____ Yes, but for major projects only ___ No ___	44

E. OTHER COMMENTS

Do you have any comments or suggestions you wish to add? Please refer to specific question numbers if your remarks apply to preceding questions. 45

Please send any reports or other documents to support your responses or that you feel may be useful to your colleagues in other agencies. **Thank you again for your help and participation.**

APPENDIX B

Survey Analysis

As part of NCHRP Project 20-5, Topic 32-06, *Public Benefits of Highway System Maintenance and Operations*, a formal survey was undertaken to assess the current attitudes and practices of state departments of transportation. The survey (see Appendix A) was distributed by e-mail to transportation agencies in each of the 50 states and the District of Columbia. Responses were received by e-mail and post. Summary statistics were prepared by TRB staff as requested by the consultant, and further analysis was undertaken by the consultant.

SURVEY RESPONSE SAMPLE CHARACTERISTICS

A total of 19 agencies responded to the survey, 37% of all agencies contacted (Table B1). This response level represents a relatively low rate compared with responses to other surveys conducted for the synthesis program. In addition, some respondents did not reply to all questions.

A representative for one agency that did not complete the survey commented in an e-mail communication that responsibilities for maintenance and maintenance-related communications with the public are distributed too widely within his organization for a coherent response to be prepared. That opinion, if representative of conditions in other agencies, could help explain the low overall rate of response.

Responses were received from all regions of the country. Table B1 summarizes the distribution of responses among states grouped into regions frequently used for federal government social and economic statistics. No responses were received from the East North Central states, whereas New England and Mountain states are somewhat disproportionately represented in the response sample. Table B2 and Figure B1 summarize the distribution of responses among states grouped into regions by typical annual minimum temperature. As shown, a relatively high proportion of Southern states are represented in the response sample. Because of the limited response and potential geographic bias in the response sample, no analysis was made of regional differences among survey responses.

TABLE B2
GEOGRAPHIC DISTRIBUTION OF SURVEY RESPONSES, BY CLIMATIC REGIONS

Climatic Regions	Total No. of States	Responses	Response Rate (%)
Northern	12	4	33
Middle	22	8	36
Southern	17	7	41
Total	51	19	37

Notes: See Figure B1.

One agency was represented by two responses, completed by two different individuals. A close comparison of the two responses provided some insight into the degree to which an individual's perspective might influence responses on those questions soliciting opinions (e.g., Question 20, regarding the public's views on the agency's maintenance activities). Several questions involving seemingly factual information (e.g., "Does your agency make an official estimate of highway system maintenance backlog?") elicited substantially different answers from the two respondents. These responses were discarded in the summary analysis.

The following sections correspond to the principal sections of the survey form. Each section presents analyses of

TABLE B1
GEOGRAPHIC DISTRIBUTION OF SURVEY RESPONSES, BY CENSUS REGIONS

Census Regions	New England	Mid-Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
All States	6	3	5	7	9	4	4	8	5	51
	12%	6%	10%	14%	18%	8%	8%	16%	10%	100%
Responses	3 CT, ME, NH	1 NY	0	2 KS, MN	4 DC, GA, MD, WV	1 MS	1 AR	4 AZ, NV, UT, WY	3 CA, HI, OR	19
	17%	6%	0%	11%	22%	6%	6%	22%	11%	100%
Responses as percentage of all states										37%

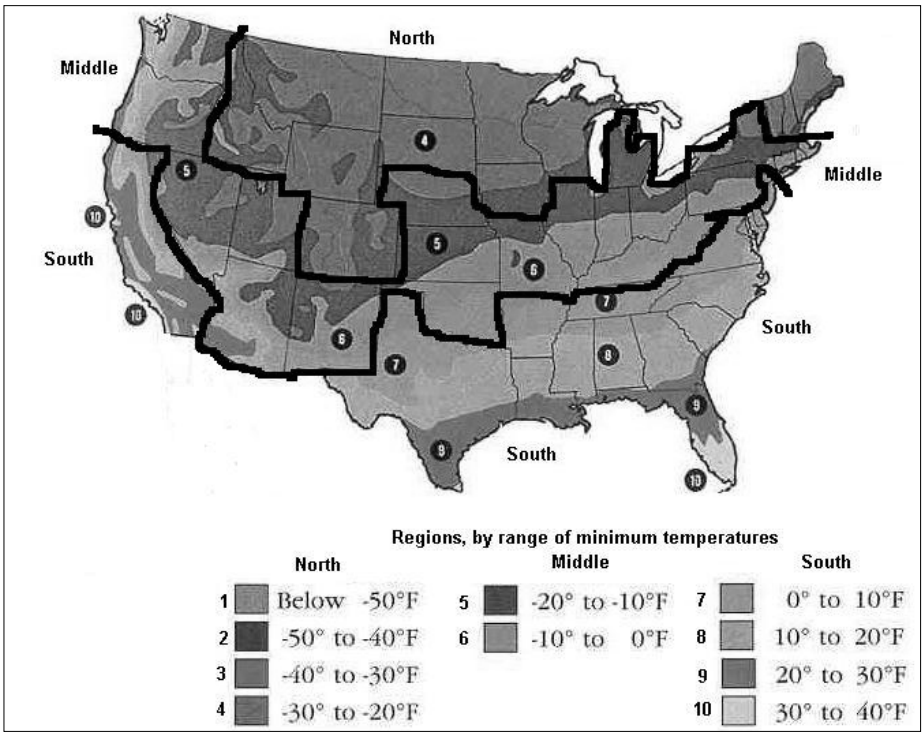

FIGURE B1 Climatic zones, based on range of annual minimum temperature.

the responses to questions in that section and issues related to the validity and interpretation of those responses.

AGENCY BACKGROUND

Section A of the survey was designed to determine the extent to which agencies have implemented management tools and policies incorporating such principles as benefit maximization, cost minimization, and the theoretical trade-off between investment and maintenance costs.

Questions 1–4—All but one of the reporting agencies use some type of computer-based pavement and bridge management tools. As summarized in Table B3, the pavement management systems in use are largely custom applications written for the agency or adapted by consultants to meet the agency's particular requirements. Custom applications are less frequently used for bridge management; the Pontis program is prevalent. One might infer that the agencies that use such programs are not only aware of the theoretical trade-offs that life-cycle cost analysis entails, but they are prepared (at least in principle) to make management decisions aimed at reducing total life-cycle costs.

Questions 5–12—As summarized in Table B4, more than 80% of the responding agencies reported having continuing activities or tools to inform the public about agency activities, other than those required for environmental reviews of projects and preparation of regional transportation plans. Such public information activities include news releases, open houses, presentations to civic groups, and Internet websites; slightly more than 25% of those reporting specific techniques mentioned press releases only. Rather than using such agency-to-public communication mechanisms, approximately two-thirds of the responding agencies reported that they have undertaken customer satisfaction surveys or other activities to identify public interests and preferences. Of those respondents that did report activities intended to learn about public preferences, approximately 60% included maintenance explicitly.

Some agencies have adopted construction bidding and award practices that take account of road-user costs that may be avoided through more rapid project completion; for example, "lane rental" and "A+B" bidding. Adoption of such practices may imply that these agencies are particularly sensitive to the broader range of public benefits of various maintenance practices, which may warrant making higher financial expenditures. Three-quarters of survey respondents that had used such methods also conduct activities to identify public interests. A majority of these respondents include maintenance concerns in their public relations activities.

Although two-thirds of respondents reported conducting surveys or other activities to identify public interests and preferences, fewer than half reported efforts to actively so-

TABLE B3
AGENCIES' USE OF PAVEMENT AND BRIDGE MANAGEMENT PACKAGES

Management Activity	Cited Program or Consultant	Percentage (fraction) of Respondents
Pavement	Custom application	41 (7/17)
	WiseCrax	29 (5/17)
	(Roadware)+Deighton	12 (2/17)
	Cambridge Systematics	6 (1/17)
	HPMA/Stantec	6 (1/17)
	Texas Research Development Foundation	6 (1/17)
	None	—
Bridge	Pontis	72 (13/18)
	Custom application	17 (3/18)
	Bridgit + custom application	6 (1/18)
	None	6 (1/18)
Maintenance	Custom application	50 (9/18)
	None	33 (6/18)
	Hansen	11 (2/18)
	MAXIMO (MRO Software)	6 (1/18)
Vehicle Fleet	Fleet Anywhere (Peregrine)	25 (4/16)
	Fleetfocus M4 (Maximus)	19 (3/16)
	None	19 (3/16)
	Custom application	19 (3/16)
	MAXIMO (MRO Software)	6 (1/16)
	MESIS (IBM Canada) Synergen	6 (1/16)

TABLE B4
AGENCIES' APPROACHES TO PUBLIC INFORMATION AND OPINION REGARDING MAINTENANCE

Activity or Tool Used (survey question)	Percent (fraction) of Respondents	Conditions or Qualifications (survey question)	Percentage (fraction) of Respondents
Continuing efforts to inform the public regarding agency activities (8)	84 (16/19)	Maintenance regularly included (9)	75 (12/16)
No efforts reported	16 (3/19)	Maintenance not regularly included (9)	25 (4/16)
Surveys or other activities to identify public interests and preferences (5)	68 (13/19)	Maintenance included (6)	62 (8/13)
No activities reported	32 (6/19)	Maintenance not included (6)	38 (5/13)
Have used contracting methods that include road-user costs in bidding, award (7)	63 (12/19)	Agencies that have conducted activities to identify public interests, maintenance explicitly included (5 and 6)	58 (7/12)
		Agencies that have conducted activities to identify public interests, maintenance not included (5 and 6)	17 (2/12)
		Agencies that have not conducted activities to identify public interests	25 (3/12)
Have not used contracting methods including road-user costs in bidding, award	37 (7/19)		
Staff member(s) assigned to communicate with elected officials and the public regarding maintenance (10)	37 (7/19)		
No staff member assigned	67 (12/19)		
Continuing efforts to solicit public opinion regarding agency activities (11)	50 (9/18)		
No efforts reported	50 (9/18)		

licit public opinion on agency activities. One-third of respondents have staff assigned to deal with maintenance issues in communicating with elected officials and the public.

MAINTENANCE PROGRAM STATUS

Section B of the survey solicited agency staff opinions on how agencies' maintenance programs are viewed by others, as well as factors that might influence how the programs are viewed.

Questions 13–17—All respondents claimed that top-level agency management holds positive views of the agencies' maintenance program (see Table B5). However, only about half of the respondents felt that elected officials and the general public held such definitely positive views. Highway user surveys were most frequently mentioned (7 of 18 responses) as evidence of positive public views. Lack of complaints and favorable legislative reports or resolutions were each cited by several respondents. However, all respondents reported that their agencies have dedicated or earmarked funds for maintenance.

Questions 18–19—One-third of respondents (7 of 19) reported that some maintenance activities are delegated to other agencies. For just over half of those agencies that delegate (4)—that is, one-fifth of all agencies—this delegation extends beyond the secondary system of highways (see Table B6).

Questions 20–23—More than half of respondents reported that their agencies make an official estimate of maintenance backlog; more than half of those making such estimates update them at least annually. About half of those making estimates reported making them public. However, legislative briefings are the primary mechanism for doing so, which may or may not inform the general public.

MAINTENANCE OUTREACH AND MARKET RESEARCH

Section C was designed to learn about agencies' specific efforts to inform and learn from their customers.

Questions 24–26—Fewer than half of respondents reported that their agencies have briefed legislative bodies or local officials on maintenance-related matters within the past 5 years (see Table B7). However, more than half of those agencies that do provide such briefings do so at least annually. Only 1 of 11 respondents whose agencies have provided such briefings believed that neither briefings nor surveys had in any way influenced the maintenance program.

Questions 27–28—The majority of respondents' agencies regularly use information provided by road users as a basis for issuing work orders, and all agencies do so at least occasionally. However, between one-quarter and one-third of respondents reported that their agencies make no particular response to the provider of the information.

Questions 29–33—Slightly more than half of respondents reported that their agencies have used customer satisfaction surveys or other techniques within the past 5 years to assess public perceptions regarding highway maintenance and system performance (see Table B8). Several re-

TABLE B5
VIEWS OF AGENCY MAINTENANCE PROGRAMS

Agencies' Highway System Maintenance Activities Are Viewed Favorably by . . . (question)	Percentage (fraction) of Respondents			
	Definitely	Somewhat	No	Can't Say
Top-level agency management (13)	100 (19/19)			
Elected officials (14)	47 (9/19)	53 (10/19)		
Public at large (15)	37 (7/19)	42 (8/19)		5 (1/19)

TABLE B6
MAINTENANCE PROGRAMS CHARACTERISTICS

Survey Question	Percentage (fraction) of Respondents	Conditions or Qualification (survey question)	Percentage (fraction) of Respondents
18. Delegates maintenance on federal-aid highways	37 (7/19)	Secondary system only (19)	43 (3/7)
		Secondary and other	57 (4/7)
20. Makes official estimate of maintenance backlog	58 (7/12)	Update annually (21)	57 (4/7)
		Update less than annually	43 (3/7)
		Makes estimate public (22)	57 (4/7)
		Does not make public	43 (3/7)

TABLE B7
MAINTENANCE OUTREACH TO GOVERNMENT OFFICIALS

Survey Question	Percentage (fraction) of Respondents	Conditions or Qualifications (survey question)	Percentage (fraction) of Respondents
24. Maintenance-targeted legislative briefings within last five years	Yes—42 (8/19) No—47 (9/19) Don't know—11 (2/19)	Annually or more frequently (24) Less frequently	63 (5/8) 37 (3/8)
25. Maintenance-targeted briefings for local officials within last five years	Yes—32 (6/19) No—63 (12/19) Don't know—5 (1/19)	Annually or more frequently (25) Less frequently	60 (3/5) 40 (2/5)
24 & 25. Legislative and local officials briefings within last five years	Both—35 (6/17) Neither—53 (9/17)	Annually or more frequently (24, 25) Less frequently	67 (4/6) 33 (2/6)
26. Surveys or briefings have influenced maintenance program	Not at all—9(1/11) Results discussed by managers—45 (5/11) Influenced program budgets—55 (6/11) Influenced work schedules—45 (5/11)		
27. Use road-user notifications or complaints to issue work orders	Regularly—68 (13/19) Occasionally—32 (6/19)	Responds to individual (28) No specific response Responds to individual (28) No specific response	77 (10/13) 23 (3/13) 67 (4/6) 33 (2/6)

TABLE B8
MAINTENANCE OUTREACH AND MARKET RESEARCH FOR THE PUBLIC

Survey Question	Percentage (fraction) of Respondents	Conditions or Qualifications (survey question)	Percentage (fraction) of Respondents
29. Surveys or other methods to assess public perception regarding maintenance and performance within last five years	Yes—58 (11/19) No—42 (8/19)	Annually or more frequently (32) Less frequently	45 (5/11) 55 (6/11)
31. Methods used		Focus groups Telephone survey Mail-back or email survey Telephone and mail-back survey Other (website, state fair)	36 (4/11) 64 (7/11) 45 (5/11) 27 (3/11) 27 (3/11)
33. Information used in agency management		Definitely Somewhat No	36 (4/11) 55 (6/11) 9 (1/11)

spondents noted that their efforts had been aimed at special groups (e.g., road-user or travel and tourism organizations), but the general public was typically the only target. However, only 45% of the agencies reporting such opinion research activities conduct them at least annually. Four of the 11 respondents reported that the information gathered had a definite influence on its use in agency management.

Questions 34–36—More than three-quarters of respondents reported that their agencies prepare an annual report on maintenance program accomplishments, either exclusively or as a part of the agency's annual report (see Table B9). However, only one-third of these reports include some estimate of benefits derived from the maintenance program. Although the number of agencies preparing reports matches the number that brief elected officials, two agencies prepare reports but do not brief officials, and two do brief officials but do not prepare a public report.

ASSESSING NET BENEFITS OF HIGHWAY MAINTENANCE

Section D of the survey was intended to discover the extent of numerical measurement and benchmarking activities in agencies' maintenance management.

Questions 37–40—Most respondents noted that their agencies report both output and outcome-oriented measures of maintenance program accomplishment, although approximately one-fifth to one-quarter reported neither (see Table B10). One-half of the agencies that do report output measures do so at least quarterly, whereas outcome

TABLE B9
MAINTENANCE REPORTING TO THE PUBLIC

Survey Question	Percentage (fraction) of Respondents	Conditions or Qualifications (survey question)	Percentage (fraction) of Respondents
34. Annual maintenance program report to public	Yes, exclusively maintenance—16 (3/19) Yes, part of agency-wide report—63 (12/19) No—22 (4/19)	If "yes," includes some benefit measure (35)	33 (5/15)
36. At least annual legislative briefing on maintenance program accomplishments	Yes, exclusively maintenance 16 (3/19) Yes, part of agency-wide report 63 (12/19) No—21 (4/19)	(Note: Two agencies prepare annual report but do not brief; two brief but do not prepare annual report)	

TABLE B10
MAINTENANCE REPORTING TO THE PUBLIC

Survey Question	Percentage (fraction) of Respondents	Conditions or Qualifications (survey question)	Percentage (fraction) of Respondents
37. Regularly report maintenance output or productivity measures	Yes—79 (15/19) In operations management—80 (12/15) In agency-level management—47 (7/15) In reporting to public—27 (4/15) Not at all—21 (4/19)	In operations management only In operations and agency-level At least quarterly (38) Annually	64 (7/11) 36 (4/11) 50 (7/14) 50 (7/14)
39. Regularly report maintenance outcome or performance measures	Yes—74 (14/19) In operations management—71 (10/14) In agency-level management—64 (9/14) In reporting to public—14 (2/14) Not at all—26 (5/19)	In operations management only In operations and agency-level At least quarterly (40) Annually	50 (5/10) 50 (5/10) 14 (2/14) 86 (12/14)

TABLE B11
MAINTENANCE MANAGEMENT METHODS

Survey Question	Percentage (fraction) of Respondents	Conditions or Qualifications (survey question)	Percentage (fraction) of Respondents
41. Use benchmarking	Yes—53 (10/19) Period-to-period comparison—100 (10/10) Inter-agency-comparison—20 (2/10)	Reported to public (42)	40 (4/10)
43. Life-cycle costing or other benefit–cost method for maintenance planning	Yes—37 (7/19) No—53 (10/19) Don't know—11 (2/19)	For all maintenance (43) For major projects only No response	29 (2/7) 57 (4/7) 14 (1/7)
44. Maintenance analyses are compared with new construction in agency-wide programming and budgeting	Yes—37 (7/19) No—53 (10/19) Don't know—11 (2/19)	For all maintenance (43) For major projects only	57 (4/7) 43 (3/7)

measures are presented primarily on an annual basis. The agencies reporting such measures use them within the agency but for the most part do not present them to the general public.

Questions 41–42—Approximately half of responding agencies use benchmarking to monitor maintenance program activities (see Table B11). A small fraction of those using benchmarking compare themselves with other agencies, whereas all respondents make internal period-to-period comparisons.

Question 43—Approximately one-third of respondents reported that life-cycle costing or other benefit–cost methods are used in maintenance program planning, for the most part only in assessing major projects.

Question 44—Approximately one-third of respondents reported that maintenance analyses are compared with new construction in agency programming and budgeting. Of these, half (i.e., 16% of all respondents) make such comparisons for major projects only. Those that do make such comparisons for all maintenance do employ life-cycle costing as the basis.

Abbreviations used without definition 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
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