Capital Preventive Maintenance

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The purpose of this guidebook is to offer a process for managers to follow that will assist in overcoming various perceived limitations currently preventing initiation or expansion of preventive maintenance efforts at all levels of government. This guidebook introduces a systematic approach that can be used to address a variety of obstacles, thereby providing insights to front-line transportation officials, administrative decision makers, and elected officials. This guidebook initiates a five-step process to use when developing and presenting the case for preventative maintenance, which incorporates the stages of education, challenges, environment, strategy, and delivery. The report presents a number of tools and techniques that can be utilized by managers and policymakers to promote broader use of preventive maintenance. Those tools and techniques are presented throughout the guidebook. Within the guidebook are case studies of preventive maintenance implementation in the Departments of Transportation of three Midwestern, cold weather states – Michigan, Kansas, and Nebraska. These case studies demonstrate how the states have recognized their environments to address issues in practice. The guidebook concludes with a quick checklist guide to assist in the initiation or expansion of preventative maintenance efforts.</td></tr>
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Capital Preventative Maintenance
Introduction

Throughout the past several decades, preventive maintenance has presented a series of challenges to pavement engineers, highway planners, and others involved in the construction and management of public infrastructure at all levels of government. At the moment, there is reason to believe that these managers share a common interest in expanding the scope of preventive maintenance activities beyond what is currently in use. However, a number of obstacles stand in the way of that expansion. They include, but are not limited to:

⇒ Lack of support for preventive maintenance among top management, elected officials, and the public.
⇒ The presence of more immediate and/or visible construction and reconstruction needs.
⇒ A lack of evidence supporting the cost-effectiveness of preventive maintenance.

Without a doubt, these political, institutional, and financial obstacles fall well outside many asset managers' scope of interest and/or expertise. Nonetheless, recent developments in maintenance engineering and other fields have provided a number of tools, techniques and concepts that can help to overcome those obstacles. Some of these developments include:

⇒ *Cost-Benefit Analysis*, a tool that provides managers with supporting evidence for the cost effectiveness of preventive maintenance
⇒ *Life Cycle Analysis*, a method for defining, costing, and monitoring asset condition. Unlike many of the asset condition assessment methods currently in practice, Life Cycle Analysis can provide a clear link between preventive maintenance activities and improved infrastructure condition. Such a link is a necessary first step toward widespread incorporation of preventive maintenance activities into infrastructure planning and budgeting. It also provides a method for describing preventive maintenance benefits to management, elected officials, and the public.
⇒ *Asset Reporting Requirements*, guidelines suggested by the Governmental Accounting Standards Board (GASB) in their recent *Statement #34 – Basic Financial Statements – and Management's Discussion and Analysis – for State and Local Governments.* Under this new financial reporting model, state and local governments will soon be compelled to report the "true cost" of all capital assets such as highways, bridges, transit systems, and other infrastructure. On the one hand, this new requirement places a tremendous burden on these governments because of the time and expense required to arrive at accurate assessments of infrastructure costs. On the other hand, those same cost estimates also create an opportunity for broader use of preventive maintenance. That is, under the previous financial reporting model, maintenance costs were reported as liabilities, and as a result, did not "add value" to infrastructure. However, under this new reporting model, maintenance costs are not reported as liabilities, but rather as an investment designed to maintain a minimum level of asset condition. As a result,

preventive maintenance becomes a value-added process. This fundamental change in financial reporting for preventive maintenance holds the potential to bring about an even more fundamental change in how managers, policymakers, and voters assess the value of investments in preventive maintenance.

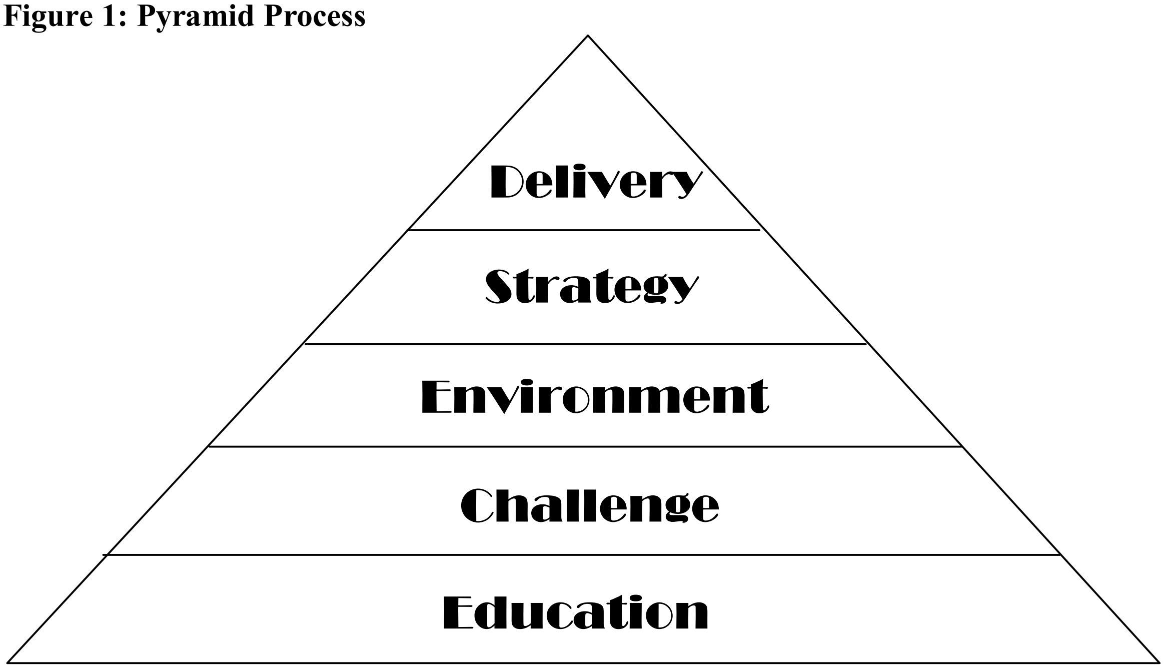
⇒ *Design-Build-Maintain Warrantees*, items that facilitate greater private sector involvement in preventive maintenance by requiring contractors to make an ongoing commitment to asset preservation.

Five-Step Process

The purpose of this guidebook is to offer a process for managers to follow that will assist in overcoming various perceived limitations currently preventing expansion of preventive maintenance efforts at all levels of government. This guidebook introduces a systematic approach that can be used to address a variety of obstacles, thereby providing insights to front-line transportation officials, administrative decision makers, and elected officials. This guidebook initiates a five-step process, which incorporates the aforementioned developments in preventative maintenance, to use when developing and presenting the case for preventative maintenance.

This guidebook follows the diagramed process presented in Figure 1. The guidebook follows the pyramid process shown below by beginning at the foundation of the pyramid with educating yourself in the next chapter and with subsequent chapters following the pyramid design up to the apex. This pyramid process provides an opportunity to specify the representational role of preventative maintenance, thereby permitting an opportunity to make available useful information for program development within the guidebook format. In the concluding section of the guidebook, we offer a quick checklist guide to assist managers within transportation organizations in making a case for the adoption or expansion a preventative maintenance program.

Figure 1: Pyramid Process



Capital Preventative Maintenance
Education

Introduction
One of the most fundamental and critical aspects in expanding preventative maintenance efforts is the role of educating others of the impacts and implications of this asset management system. Not only does educating others draw attention to the need for preventive maintenance in an asset management system, but it also informs others of the long-term benefits to be realized from preventive maintenance efforts. However, teaching others requires the instructor to become well educated with respect to the role of preventative maintenance in transportation infrastructure asset management. Therefore, the pyramid process presented in this guidebook for managers to make their case for preventive maintenance is built upon the foundation of education. Educating yourself is the crucial first step to making your case for the adoption or expansion of preventive maintenance efforts and to overcoming various obstacles to preventive maintenance at all levels of government. This section highlights information that managers can use to accomplish this first step in the process of making their case for preventive maintenance.

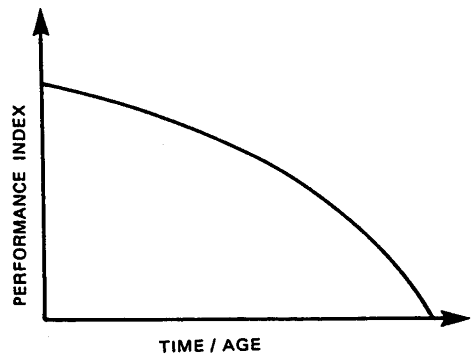
Preventive Maintenance Factors

Pavement Performance
One of the most fundamental concepts related to pavement performance is that both the quality and conditions of transportation infrastructure decrease with time and usage. This is the result of different factors including aging of infrastructure materials (e.g., oxidation of asphalt pavements), deterioration due to environmental conditions (e.g., freeze-thaw), and repeated loading (e.g., fatigue cracking due to repeated traffic loading). Along with transportation infrastructure deterioration, the performance or service level decreases with time until failure.

The purpose of laying down pavements is to provide safe (skid resistant) and smooth surface (transport without damage or discomfort) to the traveling public. When a highway is newly constructed, the pavement performance is expected to be excellent in terms of safety and smoothness. Unfortunately, pavements start to wear immediately after construction ends due to the reasons mentioned above. Maintenance and rehabilitation are the major activities executed to preserve the level of service of pavements.

Figure 2 presents a typical Pavement Performance Curve in which the pavement conditions are plotted against time or pavement age. The pavement performance is usually expressed by indices such as Pavement Conditions Index (PCI) or Pavement Serviceability Index (PSI). PCI scale ranges from 100 for pavements with excellent conditions to 0 for failed pavements, while PSI scale varies between 5 for very good pavement and 0 for very poor pavements. The shape of the pavement performance curve can be obtained by performing regression analysis on the actual conditions-time data for pavement section. Results of regression analysis indicated that the shape of the pavement performance curve can be curvilinear[1] or linear.[2]

Figure 2: Generalized Pavement Performance Curve.[3]



With new emphasis placed on pavement maintenance, it is important that state highway agencies employ effective maintenance strategies to improve the performance of the highway systems. Such strategies will enhance pavement performance for longer duration with cost savings although it is recognized that performance may be enhanced through technological changes in pavement mix (such as polymer binders) and construction innovation (such as road base mixes).

There are three types of pavement maintenance: preventive, corrective and emergency maintenance, as shown in Figure 3. Pavement preventive maintenance is a scheduled/planned strategy of surface treatments and activities applied to arrest minor deteriorations, retard progressive failures, and reduce the need for routine maintenance. The objective of preventive maintenance is to extend the service life of pavements before the pavement conditions deteriorate to a level requiring a corrective maintenance. Corrective maintenance is the activities and operations applied to correct pavement deficiencies after their occurrence. Corrective maintenance is also referred to as reactive maintenance. Emergency maintenance is an immediate activity applied in response to an urgent situation to correct pavement deficiencies such as high severity potholes.

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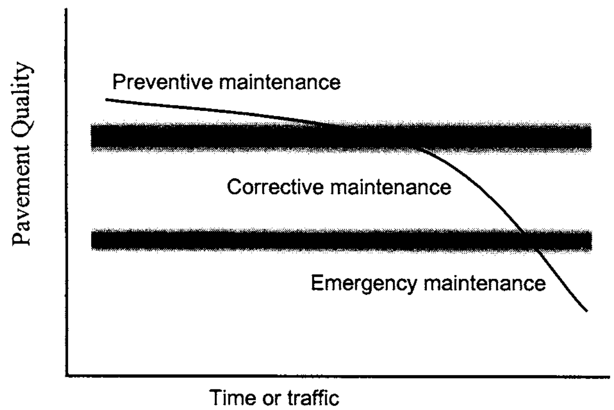
[1] Sharaf et. al. (1988). Ibid; Geoffroy, D.N., and J.J. Shufon, (1992), "Network Level Pavement Management in New York State: A Goal-Oriented Approach," in Transportation Research Record 1344: Pavement Management and Perfol1nance, Transportation Research Board, National Research Council, Washington, DC pp. 57-65; Joseph, P., (1992). "Crack Sealing in Flexible Pavements: A Life- Cycle Cost Analysis," Report PAV-92-04, Research and Development Branch, Ministry of Transportation, Downsvi1le, Ontario.

[2] Al-Mansour, A.I., and K.C. Sinha, (1994), "Economic Analysis of Effectiveness of Pavement Preventive Maintenance," Transportation Research Record 1442: Maintenance of the Highway Infrastructure, Transportation Research Board, National Research Council, Washington, DC pp. 31-37.

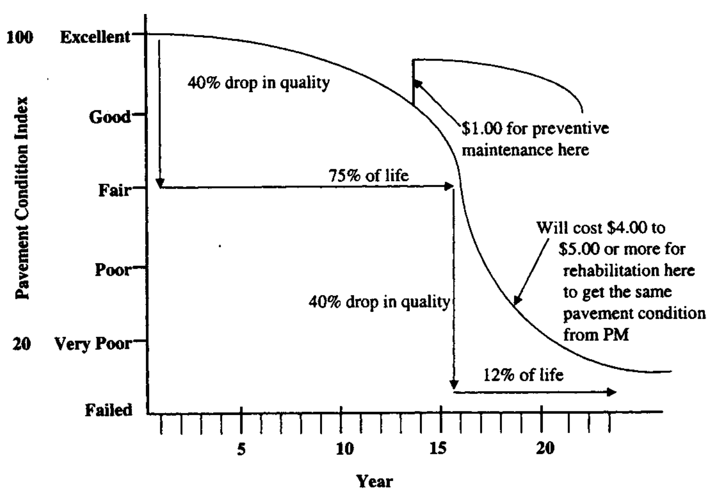
[3] Kher, R.K., and W.D. Cook, (1985). "PARS, The MTC Model for Program and Financial Planning in Pavement Rehabilitation," Proc., North American Pavement Management Conference, Toronto, Ontario, Canada. pp. 6.23-6.40.

Figure 3: Conceptual Performance of Preventive Maintenance Treatments.[4]



In a comprehensive pavement preservation program, preventive and corrective maintenance both are needed; however, the focus should be on the preventive maintenance since the costs associated with corrective maintenance are significant.[5] Figure 4 illustrates the cost effectiveness of applying a timely preventive maintenance program over corrective maintenance. Inspection of the figure demonstrates that spending $1.00 on timely preventive maintenance while the pavement is still in good condition will improve the performance and provides a savings of $3.00 to $4.00 in future corrective maintenance costs.

Figure 4: Typical Variation in Pavement Conditions as a Function of Time.[6]



[4] Zaniewski, J., and Mamlouk, M., (1999). "Pavement Preventive Maintenance, Key to Quality Highways" Journal of the Transportation Research Board, TRR 1680, National Research Council, Washington D.C., pp. 26-29.

[5] O'Brien (1989). Ibid.

[6] Hicks, R.G., Seeds, S.B., and Peshkin D.G. (2000), "Selecting a Preventive Maintenance Treatment for Flexible Pavements," Research Report FHWA-IF-00-027, Federal Highway Administration, Washington, D.C., pp 34.

Figure 5: Optimal Timing of Pavement Treatment Applications.[7]

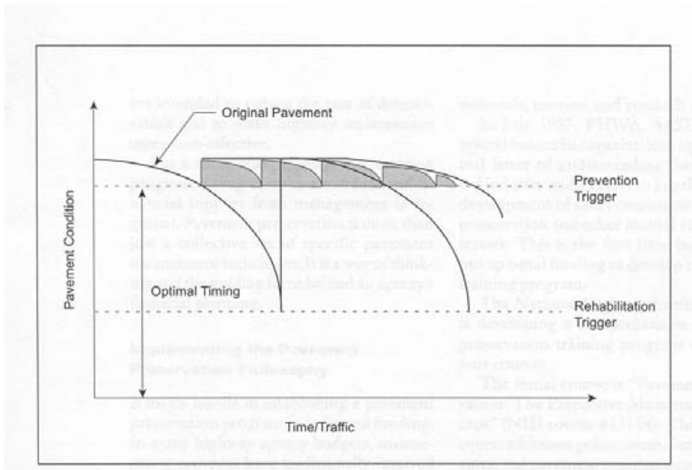


Figure 5 shows a trend of decreasing quality/conditions of pavements and demonstrates the following:

1. A pavement will perform for an estimated number of years with excellent conditions that are decreasing with time
2. Funds are required if an acceptable level of service and pavement conditions need to be restored or preserved
3. Funds can be invested in a preventive maintenance program to preserve the excellent pavement conditions
4. Funds can be invested when the quality/conditions deteriorate to an unacceptable level or until pavement failure

Therefore, maintenance and rehabilitation funds are required to keep pavements at an acceptable level of service. The issue is whether funds are paid through a preventive maintenance program or in response to corrective (reactive) maintenance programs. Figure 4 indicated that applying preventive maintenance treatments at the right time is the most efficient use of funds.

Pavement Management Systems

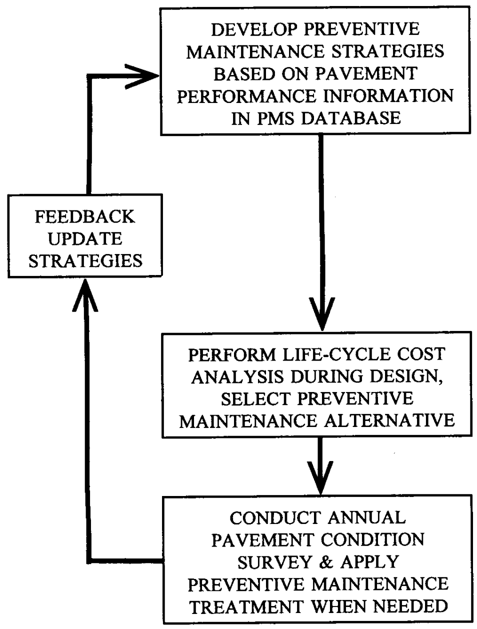
Preventive maintenance strategies are major elements of operational pavement management systems (PMS), which provide information regarding pavement performance. Figure 6 illustrates how preventive maintenance strategies are related to other activities within the pavement management process.

Pavement evaluation is the main step in successful planning to preserve pavements. Distress surveys and assessments of pavement conditions and performance need to be conducted on a regular basis. The collected pavement condition data allows pavement

[7] Davies, R.M., and Sorenson, J. (2000). "Pavement Preservation: Persevering Our Investment in Highways," Insights into Pavement Preservation, A Compendium, Federal Highway Administration, Washington D.C., pp 5-12.

managers to plan, evaluate and execute the preventive maintenance strategies needed to preserve the pavement.

Figure 6: Relationship Between Preventive Maintenance Strategies and The Pavement Management Process.[8]



Design-Build-Maintain-Warranty

In this highly competitive construction market, design-build-maintain-warranty strategy is another alternative project delivery method to owners rather than the design-bid-build strategy, or even design-build system, recently developed and becoming popular. Design-build-maintain-warranty strategy is a project delivery system creating a single contract between owner and organization to provide services including designing, building, maintaining, and warranting a facility. The central purpose of design-build-maintain-warranty strategy is quite similar to the design-build systems in that they tend to provide a one-stop process. However, this strategy can be seen as an expanded alternative to the design-build system. Several procedures, requirements, and criterions may be modified from the design-build strategy due to the similarity in design and build steps. The additional obligations of this method are to maintain the facility and warrant the project for a specific period of time. The design-build-maintain-warranty strategy consists of several elements such as establishing an organization, developing terms and agreements, defining roles and responsibilities among partners, selecting the venture by the owner, evaluating the project, developing performance specification, etc. Thus, there are a number of elements of design-build-maintain-warranty strategy that we should consider including team formation, partner relationships and terms and agreements among them, contribution of liability, project evaluation, etc.

[8] Geoffroy, D.N., (1996). "Cost Effective Preventive Pavement Maintenance," Synthesis of Highway Practice 223, National Cooperative Research Program, Transportation Research Board, National Research Council, Washington D.C., pp. 103.

Several advantages for these strategies are cost control, time savings and control of process and construction, marketing advantage, and sole responsibility from a venture. Although more risks and responsibilities are brought up by these strategies, they, on the other hand, potentially provide additional incomes and profits to their organizations than the traditional process. The design-build-maintain-warranty strategy definitely covers more tasks than design-bid-build and design-build systems since the venture is required to maintain and warrant the performance of a facility for a period of time after project completion. This issue brings more difficulty to the venture because in some type of construction, roads for example, it is difficult to predict the performance of a facility due to a number of factors such as traffic, percent of trucks, weather, etc. In spite of this concern, this strategy raises the owner's confidence that the facility would be functional for a projected period of time under a specific budget of investment.

Capital Budgeting

Capital Budgeting and Planning

In the highly competitive and political realm of state capital budgeting, capital budgeting reforms have been enacted to ensure accountability and long-term planning. These reforms have focused on strategies that include the development of performance-based budget and reporting systems and maintenance systems that spotlight the effectiveness and accountability of state services. Preventative maintenance can be seen in all aspects of the capital budgeting process, and it has been especially influential in the planning, needs assessment, and asset management aspects of the process. Recent changes in government financial reporting, namely those outlined in GASB 34, will also have lasting impacts on preventative maintenance implementation. In particular, these new financial reporting standards will act as the "guardian" of infrastructure quality in the asset portfolios of state departments of transportation.

The origins of capital planning in this country date back to the development of physical master plans in the 1920s.[9] While capital management has generally moved from the realm of planners to budget and finance departments, the planning component remains important since the role of the budget office is commonly as the provider of the overall coordination for the long-range plan. The principal capital planning document is usually noted by the nomenclature capital improvement plan (CIP). Ideally a prerequisite for the capital planning process is long-run economic forecasting of the project. Incorporation of economic forecasts helps define the fiscal constraints, including affordable debt burdens and operating costs, faced by any proposed capital program. In addition to economic fiscal forecasts, incorporation of future infrastructure requirements needs to be based on an assessment of the condition of public infrastructure in the state to assist the long-range capital planning process.

The capital budgeting goals include 1) assurance that the annual capital budget and five-year capital improvement program is affordable and finances only needed capital projects; 2) capital investment decisions are based on a fair, open and objective process;

[9] J. Lisle Bozeman, "The Capital Budget: History and Future Directions," *Public Budgeting & Finance* (Autumn 1984): 18-30

3) emphasis on long-term planning; 4) improve the linkage between the capital and operating budgets; 5) institute a practice of annual program budgeting that will result in planned biennial referenda (as needed) consistent with the capital budgeting process; 6) nurture accountability by publishing a document that will identify the individual projects to be funded during the capital-planning horizon; and 7) limit the use of debt for long-term capital improvements and decrease reliance on debt to allow for increased flexibility in difficult economic times.

Capital Budgeting and GASB 34

The Governmental Accounting Standards Board (GASB) Statement No. 34 defines infrastructure assets as long-lived capital assets that normally are stationary in nature and can be preserved for a significantly greater number of years than most capital assets. Examples of infrastructure assets are roads, bridges, tunnels, drainage systems, water and sewer systems, dams, and lighting systems.

Establishing and Capitalizing Costs

In implementing GASB 34 governments are required to capitalize and report major general infrastructure assets that were acquired (purchased, constructed, or donated) in fiscal years ending after June 30, 1980, or that received major renovations, restorations, or improvements during that period. The initial capitalization amount is based on historical cost. If determining the actual historical cost of general infrastructure assets is not practical because of inadequate records, a government may estimate their historical cost by calculating the current replacement cost of a similar asset and deflating this cost through the use of price-level indexes to the acquisition year (or estimated acquisition year if the actual year is unknown). There are a number of price-level indexes that may be used, both private and public sector, to remove the effects of price-level changes from current prices.

An example of estimated historical costs assumes that on June 30, 2003 a government has eighty-seven lane-miles of roads in a secondary road subsystem, and the current construction cost of similar roads is $500,000 per lane-mile. The estimated total current replacement cost of the secondary road subsystem of a highway network, therefore, is $43.5 million ($500,000 x 87). The roads have an estimated weighted-average age of eleven and one-half years (2003-1980/2); therefore 1991 is the average year of construction. Based on the U.S. Department of Transportation, Federal Highway Administration's *Price Trend Information for Federal-Aid Highway Construction* for 1991 and 2003, 1991 construction costs were 81.5 percent of 2003 costs. The estimated historical cost of the subsystem, therefore, is $35,453,000 ($43.5 million x 0.815 (rounded)). In 2003, the government reports the subsystem in its financial statements at an estimated historical cost of $35,453,000 less accumulated depreciation for thirteen years based on this deflated amount.

Other information may provide sufficient support for establishing initial capitalization. This information includes bond documents used to obtain financing for construction or acquisition of infrastructure assets, minutes of legislative meetings, newspaper articles, expenditures reported in capital project funds or capital outlays in governmental funds, similar assets purchased and/or constructed at the same time, and engineering documents. General infrastructure assets acquired after the effective dates of Statement No. 34 will be reported using actual historical costs.

Asset Depreciation and Preservation

Governments have a choice of either depreciating infrastructure assets or accounting for them in an alternative modified approach. Depreciation expense should be measured by allocating the net cost of depreciable assets (historical cost less estimated salvage value) over their estimated useful lives in a systematic and rational manner. It may be calculated for (a) a class of assets, (b) a network of assets, (c) a subsystem of a network, or (d) individual assets. Governments may use any established depreciation method. Depreciation may be based on the estimated useful life of a class of assets, a network of assets, a subsystem of a network, or individual assets. For estimated useful lives, governments use (a) general guidelines obtained from professional or industry organizations, (b) information for comparable assets of other governments, or (c) internal information. In determining estimated useful life, governments also consider an asset's present condition and how long it is expected to meet service demands.

Governments may use composite methods to calculate depreciation expense. Composite methods refer to depreciating a grouping of similar assets (for example, interstate highways in a state) or dissimilar assets of the same class (for example, all the roads and bridges of a state) using the same depreciation rate. Initially, a depreciation rate for the composite is determined. Annually, the determined rate is multiplied by the cost of the grouping of assets to calculate depreciation expense, e.g., based on experience, engineers may determine that interstate highways generally have estimated remaining useful lives of approximately twenty years and therefore the annual depreciation rate would be 5 percent. The composite depreciation rate is generally used throughout the life of the grouping of assets. However, it is recalculated if the composition of the assets or the estimate of average useful lives changes significantly. The average useful lives of assets may change as assets are capitalized or taken out of service.

The Modified Approach

Infrastructure assets that are part of a network or subsystem of a network are not required to be depreciated as long as two requirements are met. First, the government manages the eligible infrastructure assets using an asset management system that has the characteristics set forth below; second, the government documents that the eligible infrastructure assets are being preserved approximately at (or above) a condition level established and disclosed by the government. To meet the first requirement, the asset management system should:

- ⇒ Have an up-to-date inventory of eligible infrastructure assets.
- ⇒ Perform condition assessments of the eligible infrastructure assets and summarize the results using a measurement scale.
- ⇒ Estimate each year the annual amount to maintain and preserve the eligible infrastructure assets at the condition level established and disclosed by the government.

Determining what constitutes adequate documentary evidence to meet the second requirement for using the modified approach requires professional judgment because of variations among governments' asset management systems and condition assessment methods. These factors also may vary within governments for different eligible infrastructure assets. However, governments should document that:

- ⇒ Complete condition assessments of eligible infrastructure assets are performed in a consistent manner at least every three years.
- ⇒ The results of the three most recent complete condition assessments provide reasonable assurance that the eligible infrastructure assets are being preserved approximately at (or above) the condition level established and disclosed by the government.

If eligible infrastructure assets are depreciated, preservation costs are capitalized and depreciated. Only maintenance costs are expensed. For infrastructure assets that are not depreciated, all expenditures made for those assets (except for additions and improvements) are expensed in the period incurred. Additions and improvements to eligible infrastructure assets are always capitalized because they increase the capacity or efficiency of infrastructure assets rather than preserve the useful life of the assets.

Governments should provide detail in the notes to the financial statements about major classes of capital assets including:

- ⇒ Beginning and end-of-year balances (regardless of whether beginning-of-year balances are presented on the face of the government-wide financial statements), with accumulated depreciation presented separately from historical cost
- ⇒ Capital acquisitions
- ⇒ Sales or other dispositions
- ⇒ Current-period depreciation expense, with disclosure of the amounts charged to each of the functions in the statement of activities

Prospective reporting of general infrastructure assets in the statement of net assets is required beginning at the effective dates of Statement No. 34. Retroactive reporting of all major general infrastructure assets is encouraged at that date. Phase 1 governments (with total revenues = or > $100 million) will retroactively report all major general infrastructure assets for fiscal years beginning after June 15, 2005. Phase 2 governments (with total revenues = or > $10 million) will retroactively report all major general infrastructure assets for fiscal years beginning after June 15, 2006. Phase 3 governments (<$10 million in total revenues) are encouraged but are not required to report major general infrastructure assets retroactively. However, many governments are not waiting to report their capital assets in order to enhance their balance sheets in the current year.
While governments are applying the transition provisions, they are required to make these disclosures:

- ⇒ A description of the infrastructure assets being reported and of those that are not
- ⇒ A description of any eligible infrastructure assets that the government has decided to report using the modified approach

Governments may begin to use the modified approach for reporting eligible infrastructure assets as long as at least one complete condition assessment is available and the government documents that the eligible infrastructure assets are being preserved approximately at (or above) the condition level the government has established and disclosed.

The determination of major general infrastructure assets should be at the network or subsystem level and should be based on these criteria:

⇒ The cost or estimated cost of the subsystem is expected to be at least 5 percent of the total cost of all general capital assets reported in the first fiscal year ending after June 15, 1999, or

⇒ The cost or estimated cost of the network is expected to be at least 10 percent of the total cost of all general capital assets reported in the first fiscal year ending after June 15, 1999.

Summary

Education is a critical aspect to establishing preventative maintenance as an important program in an infrastructure asset management system. The key educational information that should be acquired not only includes the process and techniques associated with preventive maintenance and the benefits/costs of preventative maintenance, but also how this system is aligned with capital budgeting, design-build-maintain-warranty, and infrastructure reporting under GASB Statement 34. Knowledge and familiarity with capital budgeting, design-build-maintain-warranty, and infrastructure reporting with GASB Statement 34 provides the basis for addressing various challenges faced in the implementation of preventative maintenance. This knowledge allows management to look at the overall picture of preventative maintenance as a critical component in an infrastructure asset management system.

Capital Preventative Maintenance
Challenge

Introduction
There are a number of challenges and challengers that have been identified both throughout the preventive maintenance literature and in practical applications of asset management that can produce significance barriers to furthering preventive maintenance efforts. These challenges and challengers can vary significantly depending on the type and level of government and environmental context within which managers operate. Therefore, once managers have completed the first step of educating themselves with respect to preventive maintenance (so that they can subsequently educate others regarding its necessity and usefulness), the second step in making a case for preventive maintenance is to identify the unique challenges and challengers that act as potential barriers to the adoption of preventive maintenance. This section highlights a number of challenges and the related challengers and offers possible solutions that managers can use to overcome these barriers when making their case for preventive maintenance. The section ends with a summary table that can be used for quick reference as new challenges and challengers are identified throughout the process and into the future.

Defining Preventive Maintenance
One of the most significant challenges to broader adoption of preventive maintenance activities, especially with regard to capital infrastructure, is overcoming the subtle but significant differences in how the term is defined. This first challenge must be overcome for managers to be successful in making their case for preventive maintenance. To address this challenge, it is necessary to look at how preventive maintenance has been defined to date.

Consider, for example, the American Association of State Highway and Traffic Officials' (AASHTO) definition:

> *"Preventive maintenance is the 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 conditions of the system without increasing structural capacity."*

This definition, which was one of the first operational formalizations of this concept, is also one of the most widely adopted among transportation and other agencies. Its main elements are two-fold. First, it emphasizes that preventive maintenance is a planned activity. Unlike deferred or other maintenance strategies, it is designed to optimize the condition of existing infrastructure through routine treatments designed to preserve the asset until replacement becomes necessary. Further, this definition implies that as long as the demand for infrastructure remains constant, effective preventive maintenance will provide the added benefit of reducing the need for expansion. In both cases, significant cost savings can be expected.

However, many do not view the concept in such broad terms. O'Brien, for example, defines preventive maintenance as:

> *"…a program strategy intended to arrest light deterioration, retard progressive failure, and reduce the need for routine maintenance and service activities."*[10]

Although similar to AASHTO, this definition is not nearly as optimistic about the ability of preventive maintenance to preserve and/or extend asset condition. Instead, this and other definitions highlight the preventive aspect of the strategy. That is, they claim that preventive maintenance ought to occur primarily during the early stages of the asset's lifespan. If properly employed, they highlight the fact that these strategies can reduce the need for costly maintenance in the future.

The difference between these two perspectives is clear: where the AASHTO definition emphasizes cost savings by extending asset lifespan and reducing the need for future infrastructure expansion, others claim that preventive maintenance reduces maintenance costs by reducing the need for maintenance altogether. Although the differences are subtle, these two definitions represent opposing perspectives on precisely how these strategies ought to be utilized.

In order for managers to make a successful case for preventive maintenance, it is necessary to emphasize the potential for expanding the life of infrastructure assets, cost effectiveness of doing so, as well as an appropriate benchmark for asset performance that can be used to determine the success of the preventive maintenance program. As such, this guidebook provides the following definition for preventive maintenance that managers can use to make their case for adoption of this asset management program:

> ***"Preventive Maintenance is a planned program of cost-effective treatments to existing roadway systems and appurtenances that functions to limit deterioration, retard progressive failures, and reduce the amount of routine maintenance and other service activities required to maintain the functional conditions of the system."***

On the one hand, this definition recognizes that priority ought to be placed on the preventive component of the activity, in particular the need to prolong replacement. However, unlike AASHTO, this definition emphasizes "functional condition" as a benchmark for asset performance. As a result, it links preventive maintenance with a pre-determined asset performance measure (commonly associated with asset management programs), which is likely to increase the expected benefits derived from the program. Therefore, it incorporates both of the contemporary perspectives on what benefits can be reasonably expected from a preventive maintenance program.

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[10] L.G. O'Brien (1989), "Evolution and Benefits of Preventive Maintenance Strategies," *National Cooperative Highway Research Program Synthesis of Highway Practices 153* (Washington, DC: Transportation Research Board).

Identifying Your Challenges and Challengers

The literature has also identified a number of challenges and potential barriers to successful preventive maintenance programs.

Lack of evidence of cost-effectiveness of preventive maintenance treatments

Pavement engineers and others interested in the direct cost-benefit analysis of preventive maintenance frequently cite a lack of systematic evidence supporting the claim that it is cost effective. This is in part due to the longitudinal nature of preventive maintenance treatments, as well as the relative infancy of life cycle cost analysis and other tools used to assess true costs and benefits of those treatments across an asset's lifespan.

It is important that administrators and managers of highway agencies recognize the cost effectiveness of preventive maintenance. Managers are always looking for cost-effective programs to maintain pavements at good conditions. However, lack of information and data on costs and benefits of pavement preventive maintenance programs usually lead to cutting or deferring these programs. Lack of funding and deferring the pavement preventive maintenance programs result in a backlog of work and subsequent increase in the rate of pavements deterioration.[11] According to NCHRP Synthesis 58 "Evolution and Benefits of Preventive Maintenance Strategies," this results in higher costs to correct pavement problems.

One of the most challenging jobs is selling the preventive maintenance programs to the public/taxpayers. The main reason for this is the lack of performance data and cost effectiveness of pavement preventive maintenance. Zaniewski and Mamlouk emphasized on the importance of *educating* the public, federal and state legislators, and the highway personnel in order to develop awareness and understanding of the benefits of preventive maintenance programs. They also presented an example of *vehicle preventive maintenance* to demonstrate the importance and cost effectiveness of preventive maintenance to the public. Periodical oil and filter change is a cost effective practice to prevent engine overhaul.[12]

With time, however, a growing body of literature has in fact demonstrated preventive maintenance's cost effectiveness in a variety of settings.[13] In addition, the Departments of Transportation in Arizona, Montana, Pennsylvania and others have reported increased

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[11] O'Brien, L.G., (1989), "Evolution and Benefits of Preventive Maintenance Strategies," Synthesis of Highway Practice 153, National Cooperative Research Program, Transportation Research Board, National Research Council, Washington, D.C., pp. 69.

[12] Zaniewski, J., and Mamlouk, M., Ibid.

[13] Chong, G.J., and W.A. Phang, (1988). "Improved Preventive Maintenance: Sealing Cracks in Flexible Pavements in Cold Regions," in Transportation Research Record 1205: Pavement Maintenance, Transportation Research Board, National Research Council, Washington, DC, pp. 12-19; Joseph, P., (1992). "Crack Sealing in Flexible Pavements: A Life- Cycle Cost Analysis," Report PAV-92-04, Research and Development Branch, Ministry of Transportation, Downsvi1le, Ontario; Chong, G., (1990), "Rout and Seal Cracks in Flexible Pavement-A Cost-Effective Preventive Maintenance Procedure," in Transportation Research Record 1268: High- way Maintenance Operations and Research, Transportation Research Board, National Research Council, Washington, DC pp. 8-16; New York State Department of Transportation (1992), Comprehensive Report on Preventive Maintenance, Albany, New York.

expenditures for preventive maintenance. Montana DOT, for example, allocated $14 million annually for its pavement maintenance program. In 1995, $2 million was allocated for the newly established pavement preventive maintenance program and $12 million for the regular maintenance program. In 1997, the preventive maintenance program advanced and the total allocations were $7 million, which is half of the maintenance program budget. Thereafter, evaluation of the cost effectiveness of this preventive maintenance program was conducted. Results demonstrated that the preventive maintenance program is a cost effective strategy of extending the remaining service life of pavements. Based on the cost effectiveness analysis, Montana DOT expanded the preventive maintenance program and increased the budget in 1998 to $55 million. In all, these developments suggest that preventive maintenance can, and has been shown to provide numerous benefits.

Alternatives to preventive maintenance

Preventive maintenance must compete with a number of alternative maintenance activities, mainly deferred maintenance, rehabilitation/reconstruction, and the maintenance of more visible or salient assets. Each of these alternatives is described here.

Most preventive maintenance models suggest that maintenance treatments ought to begin almost immediately after the asset's construction is completed. In pavement construction, for example, one increasingly popular preventive maintenance technique – "saw and seal" – controls pavement cracking by making large transecting cuts in brand new pavement. This technique has been shown to significantly reduce pavement cracking, thus making it an effective preventive maintenance treatment. This and many other preventive maintenance techniques provide the most cost savings when applied within the first few years of the asset's lifespan. The problem with these sorts of treatments is that they require the holding agency to incur sizable maintenance costs within the first few years after construction. Despite the value added in doing so, these costs are difficult to justify, and often lead to a "… significant reluctance by agencies to program treatments on good quality assets when there is a large backlog of infrastructure in poor condition."[14]

Lack of top management commitment and experience

The preventive maintenance philosophy is somewhat contrary to that of traditional public administration for primarily two reasons. First, it requires "strategic" rather than "operational" analysis on the part of agency managers and elected officials.[15] That is, the benefits of preventive maintenance, which are best expressed in terms of future value, are intrinsically undervalued by management concerned with current operating costs. Although Life Cycle Cost analysis and other techniques have made progress toward

[14] John Zaniewski and Michael Mamlouk (1999), "Pavement Preventive Maintenance: The Key to Quality Highways," Paper presented at the Transportation Research Board 1999 Annual Meetings.

[15] R. Gary Hicks, James S. Moulthrop, and Jerry Daleiden (1998), "Selecting a Preventive Maintenance Treatment for Flexible Pavements," Paper presented at the Transportation Research Board 1999 Annual Meetings.

overcoming this difference in cost-benefit perceptions, the "operational" mode of thought stands in the way of broader preventive maintenance implementation.

Another problem that is unique to the public sector is the turnover that occurs among top management and elected officials.[16] This problem is especially pronounced in states where legislators and governors serve relatively short terms, where term limits create a constant rotation of elected officials, and where appointed department heads serve directly at the pleasure of the governor and his/her staff. This lack of continuity among top policymakers, coupled with their often short-term political agendas compounds the problem of demonstrating preventive maintenance's long-term benefits.

User inconvenience and delay costs during the work period
Like any maintenance effort, preventive maintenance causes delays and inconveniences users. However, traditional maintenance typically results in some tangible benefit for the user, most often in the form of improved performance of the infrastructure under maintenance. This is often not the case with preventive maintenance, as its various seals, coats, overlays, and other methods typically do not bring about any visible improvement. This lack of visibility, coupled with visible maintenance costs, diminishes the attractiveness of preventive maintenance.[17]

Intergovernmental politics
In order to plan for local maintenance needs within a diffuse asset network, some consensus must be reached on performance criteria, funding priorities, minimum service standards, and many other issues. In states where the state-local government relationship is not amicable, the possibilities for preventive maintenance are limited at best.

Internal Interest Groups
A significant portion of the contemporary literature in public administration has addressed the costs, benefits, and challenges associated with the adoption of performance measurement across the public sector. One frequently cited obstacle throughout that literature is the formation and persistence of internal interest groups. These groups tend to form around union interests, professional concerns, divisional/departmental lines, organizational norms and traditions, and many other characteristics.

Intra-organizational interests have been shown to have the most impact during the process of creating the sort of performance management infrastructure needed to facilitate preventive maintenance. On the one hand, such internal groups can help to clarify the goals, expectations, and inherent capabilities that underlie these systems. This is especially critical during the design phase, which provides an opportunity to create "buy in" among these groups that can help to facilitate system adoption and implementation. On the other hand, if incorporation occurs too late in the process, or if

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[16] Robert M. Davies and Jim Sorenson (2000). *Pavement Preservation: Preserving our Investment in Highways* (Washington, DC: Federal Highway Administration).
[17] Fazil T. Najafi and Valerie Paredes (2001), "Cost-Benefit Highway Pavement Maintenance," Paper presented at the Transportation Research Board 2001 Annual Meetings.

these groups are treated in a "top down" fashion, they have been shown to have the opposite effect.[18]

External Interest Groups

External interest groups such as other governments, professional associations, and national labor organizations have been said to have the most impact during the implementation of performance measures and other strategic management initiatives. In fact, there are many documented examples of sizable resources being committed to the creation of elaborate performance measure systems that are never implemented because of external political pressures. External interest groups have also been shown to impact the implementation of innovations and technologies that were not embraced at the intra-organizational level. This is often the case with state and federal mandates for a variety of reforms.[19] Although no research to date has directly examined the relationship between external interest groups and preventive maintenance implementation, the lessons learned from similar research strategic/performance management initiatives indicates that these same interest groups are likely to stand in the way of preventive maintenance adoption.

Summary

By identifying the unique challenges and challengers to preventative maintenance programs, managers can develop their case for preventive maintenance by clarifying the definition of preventive maintenance and emphasizing the long-term benefits of preventative maintenance programs. Depending on the unique challenges and challengers that managers face within their working environment, a number of actions can be implemented to address the potential barriers identified. These challenges, challengers and possible actions are shown in Table 1.

It is also important to keep in mind that not only are the various challenges and challengers that act as barriers to preventive maintenance programs unique to the manager's working environment, but new challenges and challengers may also arise throughout the process of making your case for preventive maintenance and implementing either a new asset management program or expanding an existing program. If new challenges and challengers arise, it is important to return to this step of the process and implement focused actions to address these new potential barriers. In such cases, Table 1 can be used as a quick reference for identifying new possible actions.

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[18] The accounting literature has documented these intra-organizational dynamics in the context of organizational adoption of new accounting methods and technologies. For example, see Vivian Carpenter and Ehsan Feroz (2001), "Institutional Theory and Accounting Rule Choice: An Analysis of Four US State Governments' Decisions to Adopt Generally Accepted Accounting Principles," *Accounting, Organizations, and Society* 26: 565-596.

[19] Patria de Lancer Julnes and Marc Holzer (2001), "Promoting the Utilization of Performance Measures in Public Organizations: An Empirical Study of Factors Affecting Adoption and Implementation," *Public Administration Review* 61(6): 693-703.

Table 1: Challenges, Challengers And Possible Actions To Overcome Barriers		
Challenge	Challenger	Possible Action
Defining Preventative Maintenance	Management, Politicians, and the Public	A focused definition that clearly defines preventative maintenance
Education	Public and Legislators	1. Focus on Cost/Benefit 2. Strategic Planning 3. Long-term costs reduction
Overcoming the statement "you are investing in good quality assets"	Internal Management	Focus on extended life of asset
Political Turnover	Management and Politicians	Long-run benefits to all
Overcoming "operational" analysis	Management and Politicians	Life-cycle cost analysis
Getting buy-in	Internal and External Interest Groups	Focus on incorporation at beginning avoiding a "top-down" system

Capital Preventative Maintenance
Environment

Introduction
Making a case for preventive maintenance requires knowledge and understanding of the political, institutional, and managerial environment in which you are operating. Variation between these environments not only affects the challenges and challengers that must be overcome as discussed in the previous section, but also affects the type of approach that should be used for making a successful case for preventive maintenance. Therefore, the third step in the pyramid process presented in this guidebook is to identify and understand the environment within which the case for preventive maintenance will be made.

The following case studies provide a discussion of preventive maintenance efforts in three different political, institutional, and managerial settings. The cases are discussed with respect to three questions surrounding the preventive maintenance implementation process in three states – Michigan, Kansas, and Nebraska. First, the cases examine the question: What institution(s) were/are involved in the planning and management of general highway maintenance within each of these states? As the case studies demonstrate, these planning, budgeting, and management processes have significant implications for how and when preventive maintenance occurred. Second, these studies describe how highway infrastructure needs are identified, and how preventive maintenance concepts have been incorporated into those identification processes. And finally, each case study includes a discussion of the advantages, disadvantages, and future prospects that are unique to each of these different implementation approaches.

Michigan – The "Top Down" Approach
The Michigan Department of Transportation (MDOT) underwent substantial changes throughout the 1990's. In 1991 MDOT consisted of more than 4,600 employees, and nearly every decision was made at the Central Office in Lansing. By 2000, staff levels were reduced by 25%. Decision-making authority had been decentralized from the Central Office to 32 offices located throughout Michigan, and regional offices had been reduced from nine to seven and 25 Transportation Service Centers have been established. These Transportation Service Centers currently provide a variety of multi-modal transportation services including coordination of maintenance, construction oversight and project scoping and design.[20]

Along with these changes in agency structure, MDOT also adopted a comprehensive asset management program designed to ensure proper use and performance of its transportation assets, which include 9,700 miles of state highway. Concurrent with the "Reinventing Government" philosophy of the time, which advocated increased use of strategic planning among state and local governments, this new asset management plan emphasized medium -and long-range construction and rehabilitation projects in a

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[20] State of Michigan (2000). *Transportation Asset Management Plan* (Lansing: Michigan Department of Transportation).

concerted effort to fix the worst roads and bridges first.[21] With time, and particularly in light of the new infrastructure reporting requirements suggested by the Governmental Accounting Standard Board (GASB) in its *Statement #34 - Basic Financial Statements – and Management's Discussion and Analysis – for State and Local Governments*, MDOT has made an equally concerted effort to develop and incorporate a capital preventive maintenance program into that asset management planning process. In doing so, it has capitalized upon the inherent strengths of its existing asset management infrastructure, namely strong managerial input and support, numerous mechanisms for coordinating the efforts of component agencies, and ongoing budgetary support among state policymakers. This "top-down" approach has numerous strengths and weaknesses, which are described here.

Developing and Coordinating the Asset Management Plan

A key aspect of Michigan's transportation asset management system is communication and coordination of expectations among the agencies, both inside and outside of MDOT that are involved in the system. MDOT's process uses three plans to achieve this goal: the Michigan Transportation Policy Plan, the MDOT Business Plan and the State Long-Range Plan.

The Michigan Transportation Policy Plan establishes the mission for the state's transportation system and provides the framework within which the mission can be accomplished. This plan is developed and presented by the State Transportation Commission, a governor-appointed, constitutionally mandated, nonpartisan body that provides oversight and acts as a public forum for development of transportation policy throughout the state. In 1992, MDOT began planning and implementing a reorganization strategy to reduce staff, improve agency performance, and coordinate the largest construction project in the state's history. As a part of this process, the agency developed a business plan that outlines four strategic objectives: become customer driven, meet customers' most important needs, promote employee excellence, and become flexible and responsive. Each of these objectives is an element in the overall asset management process.

The second, or State Long Range Plan (SLRP) is used as a "guiding document" for public sector transportation investment decisions. The Plan is intended to recognize that infrastructure performance must be measured with the realization that social objectives and a variety of stakeholders who use the infrastructure system should be recognized. The SLRP includes a public involvement process through which these stakeholders can have input, and is required by federal planning regulation.

Michigan also employs a Five-Year Road & Bridge Program. The document identifies MDOT's investment strategies and provides a specific list of the road and bridge projects that will be undertaken on a rolling five-year basis. Taken together, these three plans provide numerous opportunities for public input during MDOT's strategic planning

[21] Osborne, David and Ted Gaebler (1992). *Reinventing Government: How the Entrepreneurial Spirit is Transforming America* (New York: Penguin Books).

process. However, as previously mentioned, the emphasis throughout this asset management planning process is meeting the most immediate construction and reconstruction needs first.

Preventive Maintenance and Infrastructure Needs Assessment

In general, Michigan utilizes and coordinates a variety of infrastructure assessment tools to evaluate asset condition and maintenance needs. The primary decision-support tool, known as the Transportation Management System (TMS), is used to identify conditions, analyze usage patterns, and determine infrastructure deficiencies. During the development of the TMS, MDOT completed an analysis of how these infrastructure performance data are collected, stored and utilized. This effort resulted in a reduction of 20,000 files to five major databases. It also established standards for data collection and storage. In addition, the Michigan Architecture Program developed data modeling and naming standards, as well as quality assurance and configuration management procedures and standards.

Michigan's Pavement Management System (PMS) was one of the first systems to use an asset management approach. The system forecasts conditions based on the estimates of future annual types of repairs to pavements. PMS is also used to perform engineering and planning functions such as forecasting future network pavement conditions and estimating the costs associated with using various pavement repair strategies. The PMS also evaluates which pavement strategies will result in certain short-term and long-term network condition levels. Network strategy analysis is performed by the Road Quality Forecasting System (RQFS), a strategy analysis tool that is used to project the results of different pavement rehabilitation policies. The RQFS estimates future condition of pavement networks by examining current pavement condition, age, and type. Although it has been employed since before TMS was implemented, PMS has not yet been fully integrated into the TMS. MDOT pavement engineers and transportation planners use these data and analytical tools to develop cost-effective strategies.

As part of the PMS, the MDOT Pavement Preservation Program (PPM) balances reconstruction and rehabilitation (R&R) with capital preventive maintenance (CPM) and reactive maintenance. Typical CPM projects include crack sealing, surface seals, thin asphalt overlays, concrete patching and pavement profiling. CPM projects are intended to delay asset deterioration. Since 2000, MDOT has invested over $3.3 billion in its capital maintenance road and bridge program, utilizing a variety of approaches to maximize network conditions. According to MDOT standards, pavements with a Remaining Service Life (RSL) of up to two years are treated with reconstruction and rehabilitation, and pavements with a RSL of greater than two years are managed through capital preventive maintenance.

MDOT uses two complementary evaluation systems to identify pavement conditions: a Sufficiency Rating and a PMS Rating. The Sufficiency Rating is an annual subjective survey of the entire state system. It rates observable pavement distress condition and pavement ride on a scale of one to five. MDOT has collected these ratings since 1961.The PMS Rating is obtained through a biennial collection of pavement condition data. The data include distress and ride-quality ratings, as well as measurements of rutting and surface friction. The Distress Index data are used by PMS to compute the RSL. Ride Quality is classified by using the Michigan Ride Quality Index (RQI). An RSL of zero corresponds to a RQI of 50 or more. The pavement condition goal of MDOT' is to have 95% of the freeway and 85% of the non-freeway system in "good" condition by 2007. In all, these efforts appear to have been successful, as roadway conditions have improved from 64% in good condition in 1996 to 75% in good condition in 2002.

Discussion

At the moment, Michigan maintains one of the most advanced asset management systems in the country, and that system facilitates preventive maintenance in a number of ways. First, given that MDOT's current organizational structure was designed with an emphasis on inter-agency and intra-agency coordination, this agency has been very effective at consolidating and integrating a variety of infrastructure performance and demand information from across the state. With that system in place, transportation planners in this state have systematically advocated a preventive maintenance philosophy by emphasizing the application of preventive maintenance techniques to roads with higher than average remaining service life. By maintaining such a well-coordinated system that provides numerous points of access for management and policymakers, Michigan has also effectively dealt with the issue of securing managerial "buy in" and an ongoing budgetary commitment for preventive maintenance. And finally, advocates of this system point to drastically improved system conditions as evidence that the current mix of preventive and rehabilitative maintenance projects is an appropriate statewide strategy.

Nonetheless, each of these advantages may also become barriers to broader preventive maintenance implementation in the future. Given that the current system continues to operate within a "worse first" philosophy, there is little reason to believe that the portion of the state highway budget currently devoted to preventive maintenance will grow. Moreover, the access provided to policymakers and top managers within the current system seems to provide an ongoing opportunity for preventive maintenance projects to be superceded by more pressing or visible maintenance needs. In short, Michigan has set the stage for a comprehensive preventive maintenance effort. From this point forward, the costs and benefits of preventive maintenance in this state will be made very visible.

Kansas – The "Bottom Up" Approach

The highway preventive maintenance effort in Kansas has received a great deal of attention, including a recent Transportation Research Board conference paper.[22] In general, preventive maintenance in this state is part of the long-term strategic plan established by the Kansas Department of Transportation to manage infrastructure assets. Many of the elements of this plan are similar to the process observed in Michigan, namely public input, inter-agency coordination, the incorporation of local needs, and a concerted effort to gain managerial buy-in. However, the process of integrating

[22] Richard W. Miller (2002). "Why (Not How) Kansas DOT's Pavement Management System Works and How Preventive Maintenance Actions are Integrated." Paper presented at the Transportation Research Board 2002 Annual Meetings.

preventive maintenance into the existing asset management system in this state might be characterized as "bottom up," given that it is more closely related to the efforts of middle-level state highway officials and local highway planners than top managers or policymakers. The advantages and disadvantages of this approach are described here.

Developing and Coordinating the Asset Management Plan

Transportation program development in Kansas is guided by a policy document known as the Long-Range Transportation Plan. The Plan, which was published in 2002, is intended to guide the state's transportation needs over a 20-year period. It outlines trends in demographics, travel and transportation funding, and assists Kansas in meeting the requirements of the federal Transportation Efficiency Act for the 21st Century (TEA-21). Further, the Strategic Management Plan identifies strategic goals related to program delivery, organizational improvement, external relationships, workforce, technology, intergovernmental relations and other policy areas that are inextricably linked to state highways.

Development of the Long-Range Plan included input from the public and other stakeholders. KDOT conducted external Customer Surveys in 1997 and 2000 to identify how well the agency was meeting the transportation needs of Kansas residents. In 1998, the Transportation 2000 Study Group was formed to allow public input at twelve public hearings around the state. In 2001, KDOT conducted several Road Rallies to learn more about how the public perceives the conditions of Kansas' roads. To develop the Long-Range Plan, meetings were also held with Metropolitan Planning Organizations (MPOs), Indian Nations, and other interested agencies and transportation advocacy groups. While the Plan provides transportation programs with policy direction, actual project selection is based on a mix of needs criteria and local competitors. Specific projects are outlined in the Comprehensive Transportation Program (CTP), a $7 billion plan that identifies funding over a ten-year period ending in July of 2009.

In Kansas, local units of government are responsible for most of the state's transportation facilities. As such, KDOT continues to work with the federal government, local governments and the Kansas Turnpike Authority on planning, funding, constructing, and maintaining its transportation facilities. Federal legislation requires that MPOs be developed in urbanized areas with populations over 50,000 to determine transportation priorities in metropolitan areas.[23] MPOs act as regional decision-making bodies for local, state and federal transportation issues. They also develop long-range transportation plans that are coordinated with the State Transportation Plan. KDOT's Bureau of Local Projects and Bureau of Program Management work with cities and counties through Local Partnership Programs, the Geometric Improvement Program, and the Economic Development program. In addition, Kansas is currently considering developing a transportation planning assistance program for cities with populations below 50,000. This assistance could include travel demand modeling, forecasting, technical studies and

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[23] Kansas Department of Transportation (2002). *Long Term Transportation Plan* (Topeka, KS: Kansas DOT).

general planning assistance. The transportation planning process in Kansas also includes working with neighboring states to assess regional needs.

Preventive Maintenance and Infrastructure Needs Assessment

Kansas ranks fourth among the states in number of public road miles, with 134,724 miles. The rural State Highway System consists of 9,564 miles. Kansas reports travel on the State Highway System has grown significantly over the last 30 years. Since 1970, the population of this state grew ½% annually, while travel on the State Highway System grew an average of 3.2% annually. Commercial truck traffic has grown at an even faster rate. In light of that growth, Kansas has committed notable resources to a data collection, construction planning, and maintenance activities designed to improve state highway infrastructure.

To that end, KDOT employs its own Pavement Management System (PMS) to track pavement conditions, provide measures used for Performance-Based Budgeting and Asset Management, and for the reconstruction, rehabilitation, and maintenance of its pavements. The Kansas PMS is built around the goal of "maximizing the benefit of dollars spent on building, rehabilitating, and maintaining pavements," with the primary objective to identify preventive maintenance and other rehabilitation and reconstruction alternatives using a linear optimization model. Specifically, the System predicts the probability of a segment of road being in various conditions during particular time periods. In addition to a condition prediction, the PMS also identifies a set of maintenance alternatives that maximize benefits within the available annual budget.

One of the main advantages of the Kansas method, particularly with regard to the problem of intergovernmental relations, is the fact that the PMS system incorporates local input in the process of moving maintenance options from "optimal" to "feasible." Although the system may produce optimal solutions and maintenance projects, those solutions must be converted into practical solutions. This conversion is accomplished by providing local program managers with significant latitude over the actual size and scope of the projects recommended by the PMS. KDOT reports that for many years, scopes selected by program managers were typically more extensive and geographically divergent from those recommended by the System. Initially, this central-regional partnership facilitated a great deal of central-regional cooperation. As highway conditions have improved, preventive maintenance scopes recommended by the System have been accepted by program managers at a much greater rate.

KDOT has collected the data necessary to conduct PMS evaluations on roughness and surface distress since 1983. Roughness, rutting and faulting are collected using laser profilometer equipped vans that operate at highway speeds. Surface distresses like cracking and joint distress are observed manually. Following data collection, reports are developed and distributed. The reports include data used to support Performance-Based Budgeting documentation, Infrastructure Management Information, and the Interstate Maintenance Certification. The report is also used by management level field personnel to track the performance of routes for which they are responsible.

Beyond reporting, PMS data are also used to develop pavement replacement, rehabilitation, and maintenance programs. KDOT's pavement replacement prioritization process includes geometric, accident, and structural criteria in addition to the pavement surface criteria supplied by PMS. The Network Optimization System (NOS) uses the PMS data and construction and maintenance cost data to maximize benefits and minimize the budget for rehabilitation programs. Finding the balance between minimizing cost and optimal timing of rehabilitation protects against a "worst-first" strategy.

The KDOT Pavement Management System supports the Major Modification (reconstruction) program and the Substantial Maintenance (rehabilitation and maintenance) program. Although some of the projects included in the Substantial Maintenance program would be considered preventive maintenance, NOS is structured to choose between application of a preventive maintenance action and waiting until more substantial action is required. NOS provides preliminary scopes and maintenance program managers and district executives finalize the selection of location and scope. As the System has developed and highway conditions have improved, the pavement conditions are such that NOS predominantly recommends preventive maintenance actions and program managers are increasingly agreeing. In 1987, 35% of rehabilitation project locations were in Good condition. By 2000 the percentage increased to 78%. KDOT plans to implement a Project Optimization System as a sister program to NOS to further refine scopes and achieve maximum benefits from dollars spent on pavements.

Discussion

The Kansas preventive maintenance effort might be characterized as "bottom up" for primarily two reasons. First, it relies heavily on a maintenance needs assessment method that is traditionally accepted by engineers and other professionals at the ground level of the state transportation apparatus. By emphasizing the cost effectiveness of preventive maintenance options in a direct comparison to other maintenance options – in essence "letting the data speak for themselves" – the Kansas system has successfully built a constituency among one of the internal interest groups that typically oppose broad preventive maintenance planning. The same is true of external interest groups, many of which have the opportunity to provide their input during the previously mentioned long-term planning process. With this sort of "grassroots" support in place, preventive maintenance seems very viable at the base of the state highway planning organization, and among many of its key constituents. The Kansas effort is also "bottom up" in that the base of coordination for the entire system is at the local and regional level. By providing local decision makers the option of modifying project details, this system helps to overcome the intergovernmental disagreements that often stand in the way of cost-effective preventive maintenance treatments. Without a doubt, the "bottom up" implementation method carries with it these and other inherent advantages.

The obvious disadvantage to this approach is the lack of formalization, institutionalization, and prioritization of preventive maintenance. At the moment, the PMS and NOS systems provide cost-optimal maintenance options, a fact that generally increases the likelihood of preventive maintenance treatments earning equal consideration with rehabilitative maintenance and reconstruction. However, with the exception of the informal "implementation agreement" and departmental guidelines regarding the appropriate proportion of preventive maintenance to all other projects, there is no formalized process that guarantees preventive maintenance programming will occur on a regular basis. The obvious next step for the Kansas system is to bind state and local decision makers to the preventive maintenance options generated by these sophisticated pavement assessment systems.

Nebraska – The "Inclusive" Approach

In Nebraska, development and implementation of preventive maintenance policies and practices is a work in progress. Public administrators are grappling with the process of integrating preventive maintenance strategies with their budgeting, planning and management practices. While the state has moved toward developing minimum standards for maintenance activities, it still faces many challenges in implementing a comprehensive preventive maintenance program. As a result, Nebraska provides an interesting look at the forces acting upon preventative maintenance planning and implementation at its earliest stages.

Developing and Coordinating the Asset Management Plan

The Nebraska Department of Roads (DOR) was assigned the responsibility of reporting on the needs of the state highway system by the Nebraska State Legislature in 1988. The agency's initial 1988 Needs Study provided a 20-year plan for the Nebraska DOR. Since 1988, the Needs Assessment has built on the original 1988 Study by showing the anticipated needs of the state's highway system for the next 20 years. The Nebraska DOR does not suggest that every need identified in the Assessment can be corrected in 20 years. Rather, responses to needs are affected by changes in policy, technology, inflation, finance, increased capital improvement costs, availability of materials, and the agency's overall progress.

The Nebraska DOR began a thorough review of the Needs Assessment development process in January of 2002. The review was completed in September of 2002. Major participants in the review included the Department's executive level managers, Division Heads, and District Engineers, as well as staff from the Materials and Research and Information Systems Division. The major focus of the review centered on geometric and resurfacing needs. The review indicated that the Nebraska DOR has a "good" process in place for assessing the needs of the state highway system. It indicated that incorporating new technology and design standards will make the process "even better." Compiling the Needs Assessment is now the responsibility of the Materials and Research Division.[24]

The 2002 review of the Needs Assessment process focused on developing a flowchart of the many large computer programs used by the Nebraska DOR to compile geometric and resurfacing needs of the state highway system. The review led to the incorporation of Global Position Satellite (GPS) data for use in defining vertical curve deficiencies, and to the use of AASHTO recommended guidelines for calculating vertical curve sight distances, refining traffic criteria to align with new Superpave mixes for calculating

[24] Nebraska Department of Roads (2002). *2002 State Highway Needs Assessment* (Lincoln, NE: NDOR).

resurfacing costs, using a standard 4" overlay for calculating resurfacing needs, and adjusting performance lives of some resurfacing strategies.

Responsibility for compiling the Needs Assessment is assigned to the Materials and Research Division. The needs of the state highway system are divided into nine categories: Interstate, Expressway, Rural Geometrics, Resurfacing, Urban, Gravel Elimination, Missouri River Projects, Railroad Crossings, and Miscellaneous. The Department's Interstate Task Force develops the long-range plan for the Interstate System. This task force meets several times a year and conducts an annual field inspection with the District Engineers. Needs for the Expressway System are compiled by the Project Scheduling and Program Engineer. Staff from the Materials and Research Division compiles rural Geometric, Gravel Elimination, and Resurfacing needs.

The Bridge Division maintains the Bridge Management system while District Engineers review and update Urban Needs on an annual basis. The Missouri River Projects are reviewed by staff from the Bridge Division and the Planning & Project Development Division while Railroad Crossing needs are reviewed annually by staff from the Rail & Public Transportation Division. Information on Miscellaneous needs, which include highway planning and research, enhancement, landscaping, traffic signals, lighting, concrete repair, and armor coats are provided by the Finance Administrator and by staff from Materials & Research Division.

Therefore, Nebraska's needs assessment process appears to be adequate and inclusive, but spread over a number of different state agencies. As such, the initial and ongoing obstacle to more effective highway maintenance planning is the lack of an effective means of coordinating those agencies. As this next section will show, the desire for broader use of preventive maintenance treatments has recently emerged as that coordinating mechanism.

Preventive Maintenance and Infrastructure Needs Assessment

The Nebraska State Highway Commission and Department of Roads have given top priority to Nebraska's state and interstate highway systems. These departments have determined that the most effective strategy for meeting the needs of the highway system is to distribute 50% of state and federal funds for the State Highway, 25% for the interstate system, and 25% for the expressway system.

With that proportion established, the Nebraska DOR also reports that resurfacing needs are not constant from year to year. Rather, factors including extreme environmental conditions, traffic volume and loads, and yearly maintenance affect the number of miles in need of resurfacing. The Department predicts that approximately 8,285 miles of resurfacing needs will accrue over the next 20 years, including 545 backlog miles, which result from not resurfacing roads at the optimal time.

In order to reduce the number of backlog miles, a Pavement Extension Program (PEP) was implemented in fiscal year 1995. The data used to assess and recommend maintenance were collected as early as 1984 as part of the state's Pavement Management

System (PMS). There are two main parts to the Pavement Management System: a computer master file and interpreting programs. The master file contains data for rural and urban highways that is used to report existing pavement conditions, track progression of distress over the service life of a pavement, list deficiencies in pavement section surfaces, and report sections programmed for construction.

The Department uses the Nebraska Serviceability Index (NSI) and the Present Serviceability Index (PSI) as performance indicators in assessing the quality of highways. The NSI is a pavement condition index and the PSI is a ride quality index that measures factors including cracking, rutting, faulting, and panel and joint conditions.
With time, Nebraska's PEP and PMS programs have developed into the DOR's Pavement Optimization Program (POP). Much like Kansas' Network Optimization System (NOS), Nebraska's POP program is designed to provide cost-optimal maintenance suggestions. At the moment, the program is still in development, and currently has a limited distribution throughout the Department. The program is described as being at the "promotion or marketing" stage, in which DOR is actively seeking feedback from the districts, who are voluntarily working within the new Program.

The two fundamental differences between the optimization programs utilized in Nebraska and Kansas surround 1) the process by which "minimum" and "optimal" criteria for pavement performance have been identified, and 2) the point of contact for stakeholders and state agencies. In Kansas, this process has been very centralized among state highway engineers, and the criteria used to evaluate minimum system performance are borrowed almost exclusively from state and national engineering standards. In terms of stakeholders, the concerns of citizens, policymakers, and other state agencies have been posited almost exclusively within the planning and budget parameters that act as constraints within the Network Optimization model.

In Nebraska, however, the emphasis has been on arriving at performance standards that satisfy a much broader constituency that includes, at the very least, the nine different divisions within the Materials and Research Division. Under this model, citizens and policymakers have also participated in the development of the performance indicators. The resulting process has been much slower, but certainly more inclusive. In addition, the core concern throughout that process has been the incorporation of preventive maintenance techniques.

Discussion
The general conclusion to be drawn from the Nebraska case is that the development of a preventive maintenance program that is supported by the voluntary support of numerous stakeholders is slow and incremental. One of the central concerns throughout this process has been the development of an effective means of coordinating the various concerns into a unified framework to guide highway maintenance in general, and preventive maintenance in particular. In spite of these drawbacks, especially the time-consuming nature of the process, Nebraska appears to be making genuine progress toward a systematic preventive maintenance plan in which implementation concerns have been incorporated from the beginning.

Summary

These case studies provide a discussion of preventive maintenance implementation in three different political, institutional, and managerial settings. As can be seen from the cases, the organizational environment within each state played a key role in setting the stage for the activity base surrounding all three preventative maintenance applications. For example, both the planning and management of general highway maintenance within each of these states took on different roles. Therefore, these case studies show that the organizational environment within which managers operate often poses significant implications for how and when preventive maintenance efforts will occur, which necessitates distinct managerial approaches for successful preventative maintenance implementation.

These case studies have provided a descriptive and practical look at how highway infrastructure needs are identified, and how preventive maintenance concepts have been incorporated into those identification processes. Table 2 is a quick reference and concise discussion of the different organizational environments that management encounters. Table 2 also provides some of the advantages and disadvantages that are unique to each of these different environments and affect implementation of preventative maintenance, which allows managers to look at their particular environment and quickly assess its impact on preventative maintenance.

Table 2: The Environment and Impacts on Preventative Maintenance

Environment	Approach	Advantages	Disadvantages
Decision making at a "central" location Strong central managerial input and support Numerous mechanisms for coordinating the efforts of component agencies Ongoing budgetary support among state policymakers	"Top Down"	Very effective at consolidating and integrating a variety of infrastructure performance and demand information Secures managerial "buy in" System condition is evidence that the mix of preventive and rehabilitative maintenance projects is an appropriate statewide strategy	Set philosophy provides little reason to believe that the portion of the state highway budget devoted to preventive maintenance will grow Access provided to policymakers and top managers within the system seems to provide an ongoing opportunity for preventive maintenance projects to be superceded by more pressing or visible maintenance needs
Decision making by engineers and other professionals at the ground level of the state transportation apparatus Base of coordination for the entire system is at the local and regional level	"Bottom Up"	Builds a constituency among the internal interest groups and external interest groups Provides opportunity of multiple group input "Grassroots" support very strong	Lack of formalization, institutionalization, and prioritization may lead to "implementation agreements" and departmental guidelines that provide a limited formalized process that does not provide a utilization guarantee
Multiple agency decision making Voluntary support of numerous stakeholders In development of an effective means of coordinating the various concerns into a unified framework	" Inclusive"	Offers a systematic preventive maintenance plan in which implementation concerns have been incorporated from the beginning	Slow and incremental

Capital Preventative Maintenance
Strategy

Introduction

The fourth step in the process of making your case for preventive maintenance is to strategize your delivery. The strategy that is developed at this stage should incorporate the knowledge that you acquired in step one regarding preventive maintenance and related issues, while incorporating the unique challenges and challengers and the environment that have been identified in steps two and three. This strategy will provide the foundation for delivering your case for preventive maintenance to top managers, public officials and/or the public. Therefore, developing a strategy should be conducted on the basis of the target audience.

This stage of the process represents the development of information that highlights the usefulness and benefits of implementing or expanding preventive maintenance efforts in your unique circumstance. This section discusses some of the elements that should be incorporated into any strategy aimed at preparing a manager to deliver his/her case for preventive maintenance.

Costs and Benefits of Preventive Maintenance

A crucial aspect of the strategy stage of the pyramid process is to develop information that will be provided to the target audience that highlights the excess of benefits over costs of preventive maintenance. In order to accomplish this task, the manager must identify the costs and benefits associated with preventive maintenance adoption or expansion that are likely to be incurred and achieved by the organization.

Cost of Preventive Maintenance

The total cost of preventive maintenance activities includes the costs of the following items: labor, materials, equipment, contract services, and overhead. The cost associated with preparing contracts for preventive maintenance activities should be included when those activities are contracted. The costs associated with preparing a contract include: the cost of contract engineering, contract preparation, inspection, and overhead.[25] In determining the cost of preventive maintenance activities, it is recommended to use the larger cost data population, as it is more reliable in reflecting the average unit costs within the same management environment. According to NCHRP Synthesis 153, the unit costs of the state district should generally be used for cost analysis with the exception of special cases where preventive maintenance activities are limited to a few sub-districts.

In the cost analysis of preventive maintenance activities, it is important to include labor and overhead costs. The common error of not considering them in the analysis is because they are already accounted for in the budget. Another avenue for making wrong cost analysis is comparing alternatives based on first-cost basis with no consideration of

[25] O'Brien (2000). Ibid.

duration of preventive maintenance activities. This practice will result in ignoring the annual costs, simple present worth, the time cost of money, and the cost of life cycle. Comparing the costs of alternatives of preventive maintenance activities based on first-cost analysis can be done when those alternatives have similar short-term durations. When preventive maintenance activities have significant differences in costs and durations, then it is required to perform cost analysis based on annual costs and simple present worth.[26]

First-cost analysis is a simple concept based on the units of production. The unit cost is defined as:

$$\text{Unit Cost} = \frac{\text{Total Cost of PM Activity}}{\text{Production Units Achieved}}$$

The annual cost analysis recognizes expected service life of preventive maintenance alternatives. The annual unit cost is defined as:

$$\text{Annual Unit Cost} = \frac{\text{Unit Cost of PM Activity}}{\text{Expected Life of PM Activity in Years}}$$

The single compound amount analysis considers the time cost of money and the service life of preventive maintenance activities. The single compound amount (SCA) is defined as:

$$SCA = (1+i)^n$$

$$p \times SCA = f$$

where i = interest rate, n = number of interest payments, p = present worth, f = future worth

Benefits of Preventive Maintenance

Benefits of preventive maintenance programs vary depending on the strategic objective of the highway agency.[27] Benefits of successful preventive maintenance programs are recognized even though some of these benefits are difficult to measure. According to NCHRP Synthesis 153 survey, one of the recognized benefits of pavement preventive maintenance is the reduction of corrective (reactive) maintenance. The following are the most recognized benefits of preventive maintenance:

1. Users' satisfaction: studies/surveys on preventive maintenance programs were conducted nationwide as well as in states such as Arizona, California, and Washington. Results of studies/surveys demonstrated that users' satisfaction should be part of preventive maintenance programs. The studies/surveys indicated

[26] O'Brien (1989). Ibid.
[27] Foundation for Pavement Preservation (2001), "Pavement Preventive Maintenance Guidelines," pp. 13.

that users value a well-maintained highway in terms improved safety, ride quality, reduced discomfort due to disruptions for major rehabilitations, and savings in travel time.

2. Improved pavement conditions: successful preventive maintenance strategies resulted in improved pavement conditions and extended the performance cycle of pavements.
3. Cost savings: cost savings is the most significant benefit of preventive maintenance programs even though documenting the cost savings is among the difficult tasks. Highway agencies with preventive maintenance programs such as Michigan and California reported cost benefits of their preventive maintenance programs.
4. Increased safety: safety is the first priority from the users and agencies points of view. Preventive maintenance programs provide improved safety benefits since the strategy is not to wait until pavement failure. As an example, preventive maintenance programs result in preserving the pavement surface in good conditions to provide a good texture for skid resistance. Preventive maintenance lead to less disruptive repairs, which means less exposure of users and construction workers to the hazards of work zones.
5. Reduced operating and maintenance vehicle cost
6. Reduced impacts on adjacent businesses

Cost Benefit Analysis Tools

Quantification of costs and benefits of pavement preventive maintenance strategies, which is necessary for cost benefit analysis, can be achieved by the following methods: life cycle cost analysis (LCCA), cost effectiveness analysis, equivalent annual cost, and longevity cost index. These methods are described in detail below.

Life Cycle Cost Analysis

Life cycle cost analysis is commonly used in pavement engineering. It is an economic procedure that compares competing design/maintenance alternates that have different service lives considering all significant costs and benefits.[28] The results of LCCA can be expressed in terms of Present Worth (PW) or Equivalent Uniform Annual cost (EUAC).

LCCA is an economic tool used to compare competing alternates to determine which one has the lowest life cycle cost. In LCCA, all competing alternates are assumed to have the same performance over their service lives. LCCA can be divided into primary and secondary analysis. The primary analysis is used to determine if preventive maintenance activities should be applied. This analysis includes the option of "do nothing." In the secondary analysis, the competing options that satisfied the primary analysis are analyzed. The alternate with the lowest life cycle cost is selected.[29]

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[28] American Concrete Pavement Association (2002). Life Cycle Cost Analysis: A Guide for Comparing Alternate Pavement Design. Skokie, Illinois, pp. 50.

[29] American Concrete Pavement Association (2000). Ibid.

Darter et al. used LCCA to evaluate the cost effectiveness of maintenance and rehabilitation treatments for the Metropolitan Transportation Commission in Oakland, California.[30] That analysis followed these steps in their LCCA:

1. Selection of interest and inflation rates
2. Selection of analysis period
3. Selection of different maintenance strategies and determination of their unit costs
4. Estimation of the service life of each treatment in each maintenance strategy
5. Determination of the EUAC per unit area of pavement
6. Comparison of the EUAC of the different strategies
7. Selection of the strategy with minimum life cycle cost

Sharaf et al. used LCCA on data collected from U.S. military installations to determine the effects of deferring pavement maintenance and rehabilitation.[31] LCCA was also used by Mouaket et al. to determine the cost effectiveness of chip and sand seal coatings used by Indiana DOT.[32] LCCA was proposed for evaluating the cost effectiveness of preventive maintenance alternates for SHRP project H-101 Pavement Maintenance Effectiveness.

Cost Effectiveness Analysis

Adopting preventive maintenance strategies does not guarantee automatic cost effectiveness. Preventive maintenance strategies are cost effective when the proper surface treatments are applied in a timely manner. The main elements of cost effective preventive maintenance activities are:

1. Timing: preventive maintenance activities must be applied in a timely manner to prevent deterioration, correct weaknesses, restore ride quality, and extend the useful life of the pavement.
2. Trained personnel: proper execution of preventive maintenance activities requires well-trained personnel who perform high quality repairs, which will last for the intended service life.
3. Quality assurance of materials used and methods of construction
4. Planned programs: a cost effective preventive maintenance program must be planned, funded, and executed on a cyclic manner.

Cost effectiveness of preventive maintenance strategies can be demonstrated by comparing the cost of preventive maintenance and the cost of traditional maintenance techniques of pavements. Figure 7 presents two scenarios to maintain the pavement at an acceptable level of service. Implementation of preventive maintenance programs will

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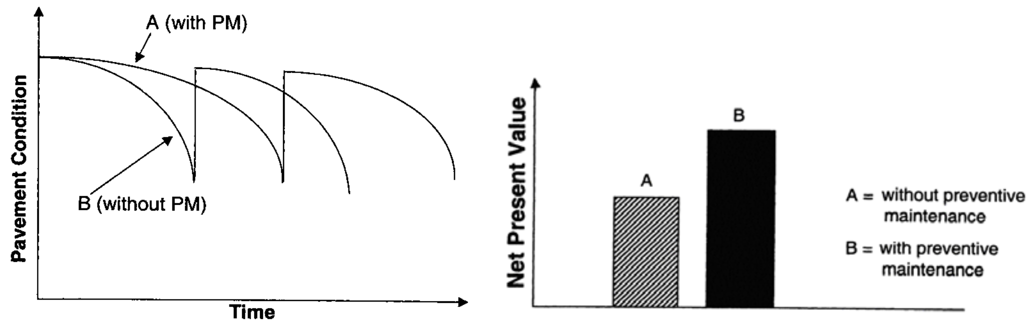
[30] Darter, M.I., R.E. Smith, and M.Y. Shahin (1985), "Use of Life Cycle Cost Analysis as the Basis for Determining the Cost-Effectiveness of Maintenance and Rehabilitation Treatments for Developing a Network Level Assignment Procedure," Proc., North American Pavement Management Conference, Toronto, Ontario, Canada. pp. 7.5-7.18.

[31] Scharaf et. al. (1988). Ibid.

[32] Mouaket, I.M., A. AI-Mansour, and K.C. Sinha, (1991), Evaluation of Cost-Effectiveness of Pavement Surface Maintenance Activities, Report No. FHWA/IN/JHRP-90-12, Joint Highway Research Project, Purdue University, West Lafayette, Indiana.

result in preserving the excellent level of service with less cost as compared to traditional corrective maintenance strategies.

Figure 7: Cost effectiveness of pavement preventive and traditional maintenance strategies.[33]



(a) Deterioration of pavement with and without preventive maintenance

(b) Net present value of alternates

Cost-effectiveness analysis accounts for user benefits and the costs of providing these benefits. Quantifying costs and benefits allows the analyst to determine the ratio of benefits to costs only when benefits can be expressed in monetary figures. Quantifying the users' non-monetary benefits from a well-maintained pavement is difficult. To overcome this obstacle, the Pavement Performance Curve (see Figure 2) is used to determine the non-monetary benefits of preserved pavements.[34]

Kher and Cook used the area under the pavement performance curve to quantify the user benefits as shown in Figure 8.[35] A pavement with good conditions will allocate a larger area under the pavement performance curve reflecting higher benefits compared to a pavement with poor condition. Joseph used the area under the pavement performance curve to determine the cost effectiveness of preventive maintenance strategies.[36] In the analysis, he also considered the average annual daily traffic (AADT) and the pavement length.

Sharaf et al. developed the following curvilinear model based on regression analysis of pavement conditions-time data[37]:

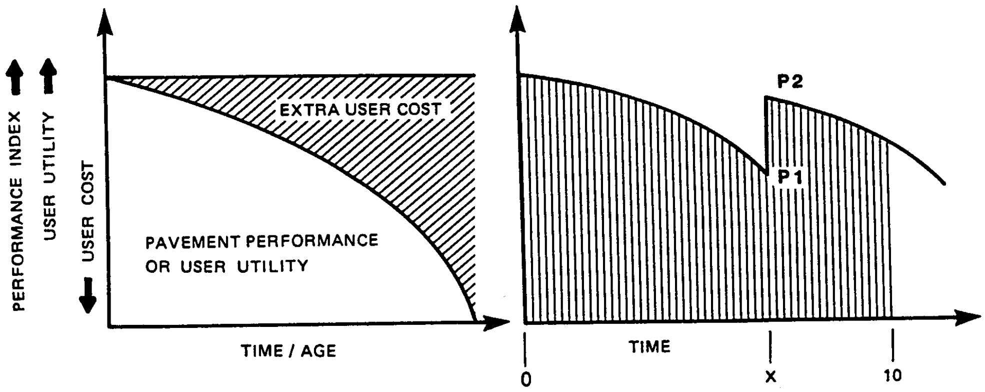
$$C = 100 - bx^m$$

where C is the pavement condition expressed in PCI, b is the slope coefficient, x is pavement age in months, and m is a parameter which controls the degree of curvature of the performance curve.

[33] Hicks, et. al. (2000). Ibid.
[34] Geoffrey (1996). Ibid.
[35] Kher and Cook (1985), Ibid.
[36] Joseph (1992), Ibid.
[37] Sharaf et. al. (1988), Ibid.

In support of this model, Geoffroy and Shufon reported that the model is consistent with pavement conditions-time data for full depth AC pavements in the Southern Tier Region of New York State.[38] In addition, Temple et al. used this model to evaluate the performance of pavement preventive maintenance treatments of chip seal and microsurfacing in Louisiana.[39]

Figure 8: Pavement performance as a surrogate for user benefits with the area under the curve as a measure of that benefit[40]



Equivalent Annual Cost

The equivalent annual cost (EAC) is the average cost of preventive maintenance treatment over its service life until another treatment or repair is required.[41] This method of analysis accounts for the difference in the performance of the different preventive maintenance treatments. Temple et al. used EAC to determine the cost effectiveness of preventive maintenance treatments of chip seal and microsurfacing in Louisiana.[42] This method is simple and requires the unit cost and expected life of the preventive maintenance treatment. The unit cost is given by Geoffrey[43]:

$$\text{Unit Cost} = \frac{\text{Cost of Manpower} + \text{Equipment} + \text{Materials}}{\text{Accomplishment per Day}}$$

$$\text{Equivalent Unit Cost} = \frac{\text{Unit Cost}}{\text{Expected Life of Treatment (Years)}}$$

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[38] Geoffrey and Shufton (1992), Ibid.

[39] Temple, W., Shah, S., Paul, S., and Abadie, C. (2002). "Performance of Louisiana's Chip Seal and Microsurfacing Program, 2002," Journal of the Transportation Research Board, TRR 1795, National Research Council, Washington D.C., pp. 3-16.

[40] Kher and Cook (1985), Ibid.

[41] Chong, G.J.,and W.A. Phang, (1988). "Improved Preventive Maintenance: Sealing Cracks in Flexible Pavements in Cold Regions," in Transportation Research Record 1205: Pavement Maintenance, Transportation Research Board, National Research Council, Washington, DC, pp. 12-19.

[42] Temple et. al. (2002), Ibid.

[43] Geoffrey (1996), Ibid.

Longevity Cost Index
The longevity cost index (LCI) was developed by Oregon DOT to evaluate the cost effectiveness of thin pavement treatments in different climates (Parker 1993). The longevity cost index is defined as:

$$\text{Longevity Cost Index} = \frac{\text{PRICE/sy} + \text{MCOST/sy}}{\text{LIFE} \times \text{Annual MEGASALs}}$$

where PRICE/sy is the initial unit price of the treatment, MCOST/sy is the present value of the unit maintenance cost during treatment life, LIFE is the average or median life of treatment, and MEGASALs is one million equivalent single axle loads.

Applications of Cost Benefit Analysis
A number of studies have been conducted to determine the accuracy of the above models as well as the cost effectiveness of various preventive maintenance strategies. These cases demonstrate the importance and cost effectiveness of scheduled and properly executed preventive maintenance programs. As such, these studies provide compelling evidence that can be provided in support of making a case for the adoption or expansion of preventive maintenance efforts.

Peterson reported on the cost effectiveness of pavement preventive maintenance in Utah.[44] The study indicated that early pavement preventive maintenance resulted in reducing the cost of pavement major rehabilitation by 75%. A pavement preventive maintenance strategy was also adopted by the Kansas Department of Transportation in which the preventive maintenance was given a funding priority over reconstruction of pavement of poor conditions. After 4 years, the strategy resulted in reduction of aggregate and asphalt needed for surface repairs and resurface.

Sharaf et al. performed research for the U.S. Army Corps of Engineers on the effect of deferring pavement maintenance. The study found that the equivalent uniform annual costs (EUAC) required to apply surface treatment at the proper time is 25% of that required for repairing deteriorated pavements.[45]

Chong and Phang reported the results of a study conducted to evaluate the cost effectiveness of route-and-seal treatment as a preventive maintenance measure.[46] Comparison of treated and control test sections indicated that the route-and-seal treatment of transverse cracks can extend the pavement serviceability by at least four years.

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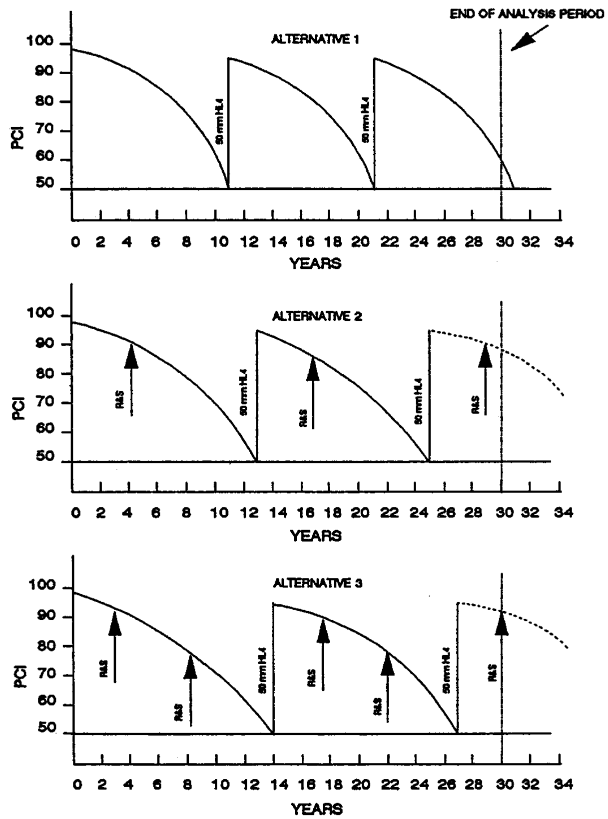
[44] Peterson, D.E., (1977), "Rehabilitation Decision Criteria," Utah Department of Transportation, Salt Lake City, Utah.
[45] Sharaf, A.S., Shahin, M.Y., and Sinha, K.C. (1988), "Analysis of the Effect of Deferring Pavement Maintenance," Transportation Research Record 1205, Transportation Research Board, Washington D.C., pp. 29-35.
[46] Chong and Phang (1988), Ibid.

Joseph used life cycle cost analysis and cost effectiveness analysis to evaluate three maintenance strategies.[47] As depicted in Figure 9, alternative 1 consists of applying 50 mm hot-mix overlay when PCI reaches 50 (no preventive maintenance and one major rehabilitation). Alternative 2 consists of one treatment of routing and sealing cracks followed by applying 50 mm hot-mix overlay when PCI reaches 50 (one preventive maintenance treatment and one major rehabilitation). And alternative 3 consists of two treatments of routing and sealing cracks followed by applying 50 mm hot-mix overlay when PCI reaches 50 (two preventive maintenance treatments and one major rehabilitation).

Figure 9: Performance histories of three alternative strategies in Ontario.[48]



The results of Joseph's analysis conducted to determine the cost effectiveness of the three alternatives are presented in Table 3. The results indicate that alternative 3, with 2 applications of preventive maintenance treatments, is the most cost effective option. Alternative 1 with no preventive maintenance cost is approximately 50% more expensive than the other alternatives with preventive maintenance measures. In order to maximize the cost effectiveness, Chong reported that the optimum timing for the first rout-and-seal

[47] Joseph (1992), Ibid.
[48] Joseph (1992), Ibid.

preventive maintenance treatment should be between the third and fifth years of the pavement service life and the second treatment between the eighth and ninth years.[49]
The effectiveness of preventive maintenance was further investigated through the Strategic Highway Research Program (SHRP) Project H-101. Evaluation of preventive maintenance treatments was conducted by comparing the treated sections and control sections. Results of evaluation demonstrated that sections with preventive maintenance treatments generally outperformed the control sections.[50]

Table 3: Summary of cost effectiveness of preventive maintenance treatment of routing and sealing crack in Ontario

Description	Alternative Strategies		
	1	2	3
Life Cycle Costs ($1,000)	855.26	623.95	584.23
Effectiveness* ($1,000)	31281	33745	32742
Cost-Effectiveness Factor	36.57	54.08	56.04
Cost-Effectiveness Ratio	1	1.48	1.53

*Effectiveness= A×AADT×PL
A=area under the performance curve in PCI year
AADT=average daily traffic volume between year 0 and the end of analysis period
PL=average of pavement section

Calculations for alternative 2:
A=A1+A2+A3=410+397.5+202.5=1010 PCI-year (area under three curves)
PL=21 km
AADT=1591
Effectiveness=1010×21×1591=33,745.1×10^3
Cost-Effectiveness Factor= 33754 /623.95 = 54.08
Cost-Effectiveness Ratio = 54.08/36.57 = 1.48

A well-planned bridge preventive maintenance program was adopted by New York City in the late 1980's. The objective of the program was to preserve the 1,424 bridges with a projected cost of $3 billion in capital funds and $60 million/year of maintenance funds for a period of 10 years. Robison reported that even though this program will initially result in an increase of the maintenance cost by 10 times, by the year 2000 a total savings in the maintenance cost of $250 million per year will be achieved.[51]

Subsequently, New York State DOT conducted a cost-effectiveness study of pavement preventive maintenance.[52] The study consisted of comparing two maintenance strategies on a mile of newly constructed flexible pavement. Alternative 1 consisted of applying preventive maintenance treatments of cracks filling during the years 4, 8, 16, and 20 of

[49] Chong, G., (1990), "Rout and Seal Cracks in Flexible Pavement-A Cost-Effective Preventive Maintenance Procedure," in Transportation Research Record 1268: High- way Maintenance Operations and Research, Transportation Research Board, National Research Council, Washington, DC pp. 8-16.
[50] Morian, D.A., Gibson, S.D., and Epps, J.A., (1997). "Marinating Flexible Pavements-The Long Term Pavement Performance Experiment, SPS-3 5-Year Data Analysis," Report FHWA-RD-97-102. FHWA, U.S. Department of Transportation.
[51] Robison, R. (1989). " Preventive Maintenance: Fixing What Ain't Broke," ASCE Civil Engineering, Volume 59, No. 9, pp. 67-69.
[52] New York State Department of Transportation (1992), Comprehensive Report on Preventive Maintenance, Albany, New York.

the pavement service life and 1.5 in. thin hot mix asphalt overlays at the years 12 and 24 of the pavement service life. Alternative 2 consisted of applying no preventive maintenance during the 24 years period of pavement life followed by a complete pavement reconstruction. Life cycle cost analysis was conducted to determine the cost effectiveness of the two alternate pavement maintenance strategies. The results are presented in Table 4. Cost life cycle analysis shows that the present worth of alternative 1 is 0.37 of the present worth of alternative 2. In addition, alternative 1 with preventive maintenance strategy is 3.65 times more cost effective that alternative 2 with no preventive maintenance.

Table 4: Summary of cost effectiveness of pavement preventive maintenance in New York (NYSDOT 1990)

Description	Alternative Strategies	
	1	2
Life Cycle Cost	$144,036	$382,590
Life Cycle Cost Ratio	0.376	1.0
Effectiveness (Condition Yrs)	176.0	128.0
Cost-Effectiveness Factor	1.22	0.335
Cost-Effectiveness Ratio	3.65	1.0

Finally, Baladi et al. reported on preventive maintenance programs adopted by Departments of Transportation in Arizona, Montana, and Pennsylvania. Montana DOT allocated $14 million annually for the pavement maintenance program.[53] In 1995, $2 million was allocated for the newly established pavement preventive maintenance program and $12 million for the regular maintenance program. In 1997, the preventive maintenance program advanced and the total allocations were $7 million, which is half of the maintenance program budget. Thereafter, evaluation of the cost effectiveness of this preventive maintenance program was conducted. Results demonstrated that the preventive maintenance program is a cost effective strategy of extending the remaining service life of pavements. Based on the cost effectiveness analysis, Montana DOT expanded the preventive maintenance program and increased the budget in 1998 to $55 million.

Design-Build-Maintain-Warranties

As noted earlier, design-build-maintain-warranty strategy is another alternative for project delivery in that it is a project delivery system that creates a single contract between owner and organization to provide services including designing, building, maintaining, and warranting a facility. There are a number of advantages and disadvantages of this type of warranty system. In addition, the design-build-maintain-warranty strategy consists of several elements such as establishing an organization, developing terms and agreements defining roles and responsibilities among partners, selecting the venture by the owner, evaluating the project, developing performance specification, etc. These elements should be considered at the strategy stage if this alternative is to be included in the delivery of making a case for preventive maintenance.

[53] Badaldi (2000), Ibid.

Advantages and Disadvantages
When first considering this strategy and whether it should be included in the delivery of your case for preventive maintenance, it is necessary to list as many advantages and disadvantages of design-build-maintain-warranty systems as possible to see what your organization would acquire or what the organization should be aware of from the system. This will allow for a decision to be made as to whether or not this strategy is suitable for your organization.

The advantages are presented as follows:

⇒ All responsibilities are solely in the hand of an organization
⇒ Time between processes is reduced because contribution of work is already allocated to its sub-units
⇒ Total cost is cheaper because the price can be controlled as the project is designed
⇒ Fewer claims from contractors are expected because the venture solely designs, builds, and maintains the facility
⇒ A number of alternatives for a project are possible without increasing the total cost
⇒ Owners can specify or control the cost of a project and an organization is possibly able to predict profit and loss from the beginning
⇒ Conflicts are likely to reduce through a project and continuity among technicians is provided during processes as a result of better communication
⇒ Maintenance program, guaranteed performance and warranty of a facility are available to owners at different levels based upon an investment
⇒ Marketing advantages
⇒ An organization is more likely to earn more revenues and potential profits through this strategy
⇒ More confidence is provided to the owner
⇒ The venture clearly has more control over the project

On the other hand, some disadvantages incurred from this strategy might include:

⇒ Substantial details and needs may be required from owners to prepare an entire plan
⇒ Plan preparation process is time consuming and monetary costs are high, which may consequently bring a loss to an organization in the case of project bidding failure
⇒ The selection process of an organization is complex according to several aspects such as past experiences of team members, financial issues, and ability to accomplish the requirements of the project in all processes
⇒ In the past, the owner has the designer to check the contractor for accuracy of the plan when constructing. Since, they have been coupled together, there would be a loss of management control and oversight
⇒ The owner also takes more risks in the case where the venture cannot deliver the project or is terminated
⇒ Because of the low cost, the quality is sometimes suspicious
⇒ The organization has to take longer liability

Elements of Design-Build-Maintain-Warranties

Once the advantages and disadvantages have been identified and a decision has been made that design-build-maintain-warranties would be suitable for your organization and should be included in the delivery of your case for preventive maintenance, it is important to consider several elements associated with this strategy. An understanding of these elements will help to highlight the benefits of adopting this strategy and to make a stronger case for the adoption or expansion of preventive maintenance efforts.

How to Structure the Design-Build-Maintain-Warranty Team

The first step of using this approach is to form an organization that can carry out this strategy including design, construction, and maintenance service. A number of aspects should be taken into consideration to form a venture such as relationships and terms and agreements among partner, types of business ventures, licensing or registration issue, insurance and bonding requirement, contribution of access to the project and liability among partners, and also legal issues raised by state law.

Partner Relationships

Generally, the partner relationships can be taken in many forms such as integrated company, one unit as a prime and others as subcontractors, one business organization as a prime and all units as subcontractors, or joint business from all units. The benefits from these formations can vary from one to another, and any formation may be selected varying by individuals due to its capability, funding, and promptness of the existing organization.

Team Selection Process

Selection of a design-build-maintain-warranty organization is a complex and extremely imperative process because that organization is subject to take on all duties and responsibilities before, during, and after the project. Several considerations, as many as possible, should be accounted and involved in this process such as past and related experiences, ability of the organization to manage the project, financial capability, and team members. Under the guideline recommended by the American Institute of Architects (AIA) and the Associated General Contractor of America (AGC), "two phase selection" can be modified and developed for the guideline for the selection of a design-build-maintain-warranty organization. The procedure for two-phase selection is shown as follows:

> Phase I - considering teams' qualifications accounting only for all factors mentioned earlier. Price quotation, technical plans, etc. should not be taken into account.
>
> Phase II - considering all design works, construction plans, safety programs during construction, maintenance plans, schedule of tasks, technical supports, cost proposal, etc.

In 1998, the state of Missouri developed "three-phase selection", which put more weight on the teams' qualifications and technical plans rather than the cost proposal. It is strongly recommended that to account for this significance 30% is distributed to each phase and the remaining 10% can be assigned by any means. The procedures are presented as follows:

Phase I- considering teams' qualification
Phase II - considering all of proposed plans and other technical specifications
Phase III - considering the cost proposal

Types of Business Ventures

Several types of business ventures can be established. Each of the following formations provides different benefits and limitations including a variety of issues such as ownership structure, licensing requirement, and tax and liability. Five categories of business ventures are presented as follows:

1. *Sole proprietorship*: an organization that has all of sub-units to provide this strategy. It is simple and does not require any partnership agreement. Nevertheless, it requires a large investment and resources to establish this type of organization.
2. *Joint venture*: a simple alternative to forming a venture organization. Normally, partners are joined together for a specific project under agreement terms. Due to state law, this sort of partnership is usually considered as a general partnership, even unintentionally by partners. One major result of this partnership is that the joint ventures are responsible for each other's misconduct including financial issues which occur during the project.
3. *Partnerships and Limited Liability Partnerships (LLP)*: a general partnership is established when two or more persons are joined together to share business under agreed terms and conditions. Partners' duties are prearranged to separate their roles during projects. Still, they are accountable for partnership obligations in any issue. A LLP is treated as a separate entity as well as a general partnership, but each partner in the LLP is specifically responsible only for their contribution to projects under written agreements. However, it still requires at least one member from each partner who is legally liable for each other's wrongful manner or carelessness. The LLP may not fully provide the service both design and construction to their clients due to ineligibility for architectural or engineering licensing or registration by state law unless subcontracting the design work to registered architect or engineer, which may possibly be done through their own partners.
4. *Limited Liability Companies (LLC)*: a separate entity whose owners are not individually responsible for the others' negligence during projects. The roles and duties for each partner are also first determined under specific terms and agreements. Similar to a LLP, a LLC is subject to subcontract its design work to registered architect or engineer due to state law.
5. *Corporations*: another alternative to form an organization to provide the service, which seems to be the firmest organization overall. The level of management and organizational structure is clearly defined by state law. Shareholders of a corporation are not accountable for the organization's obligations in any mean unless specified.

After the organization is completely formed, written terms and agreements defining partners' roles or responsibilities and limitations should be formally developed. This task will assure that none of the partners would resign until the project is completed. Also, the financial issues should be included in these written terms and agreements such as fees occurring at any process, or amount of money, payment contribution and conditions during or after the project. The contribution of liability is varied depending upon the type of business ventures described earlier.

Phase Services

Generally, the entire service for this strategy may be divided into three phases: (1) plan preparation and design service (2) construction service and (3) maintenance service. The plan preparation and design service are differentially performed by a professional registered architect or engineer, contractor, and maintenance division. The architects and engineers should provide all design details and construction plans, and alternative designs for the project. Then, the contractors should supply cost estimating, constructability analysis, preliminary scheduling of the construction, re-checking the design plans and details, providing information to the owner, and subcontracting the project and obtaining quotes from subcontractors, if necessary. In addition, the preliminary maintenance plan should be established in this phase so that the cost to keep the facility at the acceptable or desirable level of service or different maintenance alternative plans can be projected. This task should be performed by a professional unit specializing in the maintenance program.

All possible factors affecting the performance of the facility should be taken into account to insure that the maintenance program will cover those factors. Without an excellent maintenance program or method to predict the performance of the project, the design-build-maintain-warranty team would put themselves at high risk to warrant the facility and it could vastly produce a lot of losses to its organization due to warranty issues. All units including the owner are strongly recommended to communicate with each other and share information to obtain as many inputs as possible. Therefore, at the end of the design phase service, all needs before and after the project from the owner are well responded and included in the design and preliminary plans, and the total cost of the project including maintenance cost can be estimated accurately. Also, the timetable, constructability analysis, safety plan, and maintenance actions applied to the project can be approximated.

In the construction phase service, the design unit is still involved with the project by providing design information, approval of material substitution, and assistance, when needed. The contractors should construct the project as it was designed and minimize problems from the design plan. The timetable of the project should be followed strictly in order to deliver the project on time and avoid the fee for the delay. At any point, if there is a problem or conflict either from the design or construction plan, all units should talk and consult each other to solve the problem based upon professional judgment and then inform the owner for approval.

In the maintenance phase service, the maintenance program generated in the plan preparation and design phase is applied in order to reserve the project at the desirable level of service. It is imperative that proper maintenance actions and proper time be strictly used for the project. If the performance of the facility deteriorates faster than expected due to unanticipated factors, other maintenance actions should be immediately applied to prevent further damage of the facility.

The warranty program is the additional option that is clearly attractive to the owner and may produce higher possibility that the venture will get the project, compared to others who do not offer this option. It is a guarantee for the owner that the facility will be serviceable for a period of time within a specific budget although, on the other hand, the organization automatically bears more risks. The risks from the warranty program, however, can be prevented by defining the scope of the program and formally developing terms and agreements of the program between the venture and the owner to protect the organization from such an extra cost at the acceptable owner's agreements.

Performance Specification

The specification of the project is traditionally written as a part of the contract, and the contractor is bound to use the products and systems provided in the specification. However, with the fixed cost of the project in the design-build-maintain-warranty contract, this task might not be practical. Similar to the design-build system, the design-build-maintain-warranty contract allows the venture to broadly choose products and systems utilized in the project. From the owner's perspective, this allowance provides a means of assessing whether the requirements of the project will be met. Performance specifications for the design-build-maintain-warranty system are the method used to specify the required outcome of the project that can be measured. The venture is enforced to design, construct, and maintain the project based upon the required performance written in the contract, instead of required products. The required performance can be interpreted based upon the owner's instructions and needs before the bidding process. In reality, the performance specification is difficult and may be impractical. Due to the variety of product selections allowed by the venture, the question of how we verify if those products will meet requirements or will carry the acceptable performance is brought up. The venture may provide a product's characteristics, test reports, or product specifications to the owner. However, it is virtually impossible that the venture will provide information for every product used in the project. This problem may be solved by using part of the traditional system. The venture may first provide a list of products or systems that will be used in the project and the owner may then verify if those products can be used. In addition, the owner may first provide information for what cannot be used. Finally, both agree on what can or cannot be used in the project to eliminate conflicts that may happen after project completion.

Risk Management

The design-build-maintain-warranty venture incorporates preventative maintenance since the warranty is seen to assure that specific asset-level maintenance is achieved. There are other possible risks incurred in any process of the project that are managed by the design-build-maintain-warranty venture in five basic ways, presented as follows:

1. By shifting the risks or responsibilities to others such as subcontractors

2. By insuring with an insurance company for the risks that might possibly happen in the project
3. If total shifting is not available, sharing with others is another option to reduce the level of obligations
4. By considering all risks and trying to avoid or minimizing them in the project
5. If there are some risks that all options above do not address, then the venture has to accept it

Project Evaluation

Recommended by DPIC Companies, a loss prevention and risk management group, a number of considerations should be taken into account for a design-build-maintain-warranty venture to evaluate a project. Therefore, the venture may decide whether or not the project is appropriate for them. Those considerations include:

- ⇒ Institutional issues in places where a project will be constructed
- ⇒ Initial cost such as plan preparation cost which might be lost without compensation
- ⇒ Qualifications of the team to participate in a project
- ⇒ A project's owner
- ⇒ Comparing all issues involved in the project to other contestants such as their qualifications, team ability, financial capability, etc
- ⇒ Contractual relationship with the project's owner
- ⇒ Scope and size of the project
- ⇒ Financial issues
- ⇒ Team selection process
- ⇒ Scope and obligations of performance guarantees
- ⇒ Insurance and bond requirements

Guidelines for Design-Build-Maintain-Warranty Projects

Based upon *AIA/AGC Recommended Guidelines for Procurement of Design-Build Projects in the Public Sector*, published in January 1995, the guideline for design-build-maintain-warranty projects can be modified and developed as follows:

1. Adopt general criteria to determine what projects will be appropriate for design-build-maintain-warranty strategy
2. Formally adopt general procedures for selecting design-build-maintain-warranty venture
3. Review local laws and regulations that might limit design-build-maintain-warranty venture
4. Prepare a solicitation that clearly spells out the procedures to be followed in:
    a. Selection of the design-build-maintain-warranty venture
    b. Management of the project
5. Set out criteria to be used for selection, and identify the composition of the selection panel
6. Provide assurance that the project is fully funded
7. Set out the scope of work, program, equipment needs, etc.
8. Provide site information, survey and borings

9. Provided all budget requirements, MBE/WBE requirements, schedule and an outline specification including maintenance plan

Capital Planning and GASB-34

As noted earlier, recent changes in government financial reporting outlined in GASB Statement 34 are likely to have lasting impacts on preventative maintenance implementation. Governments now have a choice of either depreciating infrastructure assets or accounting for them in an alternative modified approach. For example, infrastructure assets that are part of a network or subsystem of a network might not be required to be depreciated (see page 14). However, using the modified approach offers both advantages and disadvantages to an organization considering its adoption. It is important to consider these factors during the strategy stage if the modified approach is being considered for your organization and will be included in the delivery of making your case for adoption or expansion of preventive maintenance efforts.

The Modified Approach – Advantages and Disadvantages

The required reporting of general infrastructure assets has been one of the aspects of the new reporting model of most concern to governments. Many of those who support the use of the new GASB Statement No. 34 economic resources measurement focus also believe that general infrastructure assets should be reported. Others, however, do not believe that reporting infrastructure assets for governments is important, and some do not believe depreciation expenses are relevant to users of financial statements. Constituents have argued that the benefits of complying with the requirement to report general infrastructure assets, especially retroactively, are not sufficient to justify the cost that would have to be incurred. Therefore, they believe that the reporting of general infrastructure assets did not meet the test of practicality.

Many are also acutely aware of the political risk of reporting condition information and the associated costs of falling below this predetermined condition. Although Statement 34 does not establish a minimum condition level, the government is required to establish the target condition leveling a formal, documented manner through appropriate administrative and/or legislative action. Some governments are concerned about the political futility of arguing for funding because of an accounting requirement. And, with the preponderance of decaying infrastructure in many state and local governments, there is reluctance to adopt a system that highlights infrastructure asset condition. Similarly, there is also a concern related to the required comparison of budget vs. actual amounts spent to maintain and preserve infrastructure assets. However, most agree that the new reporting requirements will foster improved asset management and reporting systems and raise awareness of required funding and adequate insurance coverage for infrastructure assets. These pressures will also highlight the expenditures needed in the coming years to preserve the network or subsystem at the condition level established by the government.

The assumptions underlying GASB 34 are that reporting infrastructure assets is essential to provide information for assessing financial position and changes in financial position, and for reporting the cost of programs or functions. Governments will provide better information on how assets are managed and financed. Specifically, GASB believes that capitalization and a measure of the cost of using infrastructure assets is important to assist users in:

- ⇒ Determining whether current-year revenues were sufficient to cover the cost of current-year services
- ⇒ Assessing the service efforts and costs of programs
- ⇒ Determining whether the government's financial position improved or deteriorated as a result of the year's operations
- ⇒ Assessing the government's financial position and condition
- ⇒ Assessing the service potential of physical resources having useful lives that extend beyond the current period

For phase 1 and 2 governments, GASB decided not to allow prospective-only application because of the effect it could have on the completeness and usefulness of the information reported. Prospective-only reporting would generally understate (a) total assets, the capital asset portion of net assets, and total net assets in the statement of net assets and (b) the amount reported as depreciation of infrastructure assets in the statement of activities (because depreciation on infrastructure assets acquired prior to the effective date of this Statement would be omitted). GASB concluded that retroactive reporting of infrastructure assets is essential for meeting many of the financial reporting objectives in Concepts Statement 1.

To help users assess the degree to which infrastructure assets are being maintained and preserved, governments disclose in the Required Supplemental Information (RSI) the assessed condition of eligible infrastructure assets and a comparison of estimated and actual expenses to maintain and preserve the assets. Governments may use a variety of methods to measure the condition of their infrastructure assets. For example, several different approaches may be taken to measure the condition of paved roads. Some measure only road smoothness, others measure the distress on the pavement's surface, and others use a combination of these or other measures. For purposes of Statement 34, any of these methods would be acceptable as long as they are capable of producing condition assessments that can be replicated.

Under the modified approach, there is no expense reported for a decline in an asset's condition. Therefore, if a government can no longer document that eligible infrastructure assets are being preserved approximately at (or above) a condition level established by the government, the government would stop reporting based on the modified approach and instead would report depreciation expense for those assets in subsequent years.

The GASB currently has a project to determine whether reported changes in asset condition levels that are associated with the modified approach of accounting for infrastructure assets can be measured in monetary terms that meet the qualitative characteristics for financial reporting. This additional research is needed to determine if a workable, comprehensive "preservation method" can be developed.

Summary

The strategy that is developed and used to promote or expand preventative maintenance programs should be based on the follow factors:

- ⇒ Benefits/costs of preventive maintenance
- ⇒ Cost effectiveness factors and ratios
- ⇒ Whether design-build-maintain-warranties are beneficial
- ⇒ Implication to the organization's capital planning and reporting objectives

Given that most studies agree that the strategy should be closely related to the benefit/cost aspect of preventive maintenance, managers developing a strategy to make a case for the adoption or expansion of preventive maintenance need to make a determination with respect to whether the other factors outlined in this chapter would enhance the traditional benefit/cost approach and make for a stronger case for preventive maintenance. To this avail, strategy should be determined through the inclusion of warranty factors and infrastructure reporting goals and objectives.

Capital Preventative Maintenance
Delivery

Introduction

The delivery of a case for the adoption or expansion of preventative maintenance efforts first and foremost requires a knowledgeable team. Implementation of preventive maintenance programs necessitates highway agencies to have knowledge of such factors as pavement history, current pavement conditions, and future performance of preventive maintenance strategies. In addition, a successful delivery requires knowledge about both the challenges and challengers that act as potential barriers to preventive maintenance efforts, as well as the environment within which the organization is operating in order to identify the most appropriate approach to preventive maintenance program implementation. Finally, a successful delivery is dependent upon a well-developed and structured strategy that acts as a guide for making a case for preventive maintenance.

So far, this guidebook has discussed the various factors relevant to making a case for the adoption or expansion of preventive maintenance efforts and preparing for the delivery of such a case. Once the first four steps in the pyramid process (education, challenge, environment, and strategy) have been accomplished, the case for preventive maintenance can be delivered to the appropriate audience. This delivery should be built upon and incorporate the information gathered and developed throughout the previous stages of this process. However, it is also important to bear in mind during the delivery stage a number of components that have been identified throughout the field, which are deemed essential for any successful preventive maintenance program. This section highlights those factors and offers two examples of good practices.

Desired Components of a Preventative Maintenance Plan

To date, previous work throughout the field has identified a number of program components that seem to positively impact various aspects of the preventive maintenance process. This prior work provides a useful guideline for the delivery of a case for the adoption or expansion of a preventative maintenance program.

A comprehensive education effort aimed at citizens/customers

Public support is perhaps the most critical aspect of any preventive maintenance effort. It is also one of the most difficult to achieve and sustain, given that the notion of preventive maintenance is counterintuitive to most citizens. Unlike most public works projects, which can be accompanied by public fanfare and opportunities for political credit claiming, preventive maintenance does not generate immediate and visible results. Despite its potential for tremendous long-run cost savings, citizens simply do not perceive it as “adding value” to their communities.

However, those involved in the creation and execution of transportation maintenance marketing strategies suggest that even though preventive maintenance may not provide immediate benefits, the tangible benefits it will provide in the future can be the basis for an effective marketing strategy. According to Bruce Schaller, a marketing consultant who has been involved in several public support-building efforts for large-scale maintenance and public transit projects, the results of focus group research tend to suggest that individual consumers' attitudes toward preventive maintenance have been changed noticeably when they are told that preventive maintenance can 1) reduce commuting time because it mitigates the need for large reconstruction projects that inevitably hold up traffic for long periods of time, and 2) reduce wear and tear on cars because it reduces the likelihood of potholes, chipping, raveling, etc. on roads.[54]

By contrast, Schaller also notes that this same focus group research shows that the business community responds better to messages highlighting preventive maintenance's long-term investment related benefits, rather than actual tangible benefits. In his experience, the key to building support for preventive maintenance within the business community is to highlight the cost-savings that result from investments in preventive maintenance treatments. Rather than tangible benefits, his experience suggests that business leaders are much more interested in preventive maintenance as a long-term investment. By marketing these unique messages to different preventive maintenance stakeholders, the probability of success seems much higher.

Both the importance of obtaining public support, as well as the difficulties in doing so, has been documented in various case studies. One recent study describes the sophisticated marketing and education strategy employed by the a public-private partnership, the Empire State Transportation Alliance (ESTA), in an effort to gain support for expansion and preventive maintenance of the New York City subway and bus system, Long Island Rail Road, and the Metro-North Commuter Railroad.[55] In this particular case, the Authority contracted with a leading marketing/public relations firm to conduct market research on citizen's use of the system, their overall perceptions of it, and their willingness to incur user fees and additional taxes in order to support its long-term viability. Using this information, the Alliance focused its educational outreach and public relations efforts in those "swing areas" with high use but lukewarm or negative perceptions of the system. The outreach was also designed to generate interest in expanding transit options by exposing citizens in high use areas to slogans such as "With livestock it's called animal cruelty; With people it's called a morning commute" in subway cars. In spite of its comparatively high price tag, this market research initiative allowed the Alliance to focus on those areas in which they believed citizen attitudes could be swayed.

The test of this outreach effort was a May 2000 vote on a five-year, $17.1 billion Capital Program that included state of good repair projects, long term preventive maintenance spending, investments in clean-fuel buses, and many other upgrades throughout the metro-area. Although that referendum was narrowly defeated, Alliance officials are

[54] Bruce Schaller, President/CEO of Schaller Consultants, phone interview with author, June 10, 2003.
[55] Bruce Schaller, Steve Weber, and Gene Russianoff (2001), "Mustering Public Support for Transit Investment in the New York Area." Paper presented at the Transportation Research Board 2001 Annual Meetings.

confident that the information and support generated throughout their outreach effort will carry a future initiative to fruition.[56]

Guidelines for integrating performance measures with needs, treatments, and assessments

From an administrative/managerial perspective, one of the most significant challenges to preventive maintenance is the integration of performance indicators with maintenance strategies and priorities.

Most large asset networks create and catalog large amounts of performance indicator information. Pavement engineers, for example, have devised tools such as the PASER (Pavement Surface Evaluation and Rating) system, the International Roughness Index, and many other universal measures designed to assess and facilitate road condition comparisons.[57] These systems also include systematic recommendations regarding treatment options. For instance, AASHTO recommends that a length of asphalt at PASER condition "5" undergo preservative treatments such as seal coating or overlay in order to prevent further cracking that will drastically shorten that asphalt's projected lifespan. In this and many other asset management settings, these systems of performance indicators leading to recommended courses of action are readily available to aid in the condition assessment and maintenance planning processes. Many asset managers have also created sophisticated methods of determining maintenance needs. Again in the context of highways, many state departments of transportation utilize elaborate reporting systems designed to allow local officials such as county road commissions and municipal public works departments the opportunity to express what they consider their most pressing maintenance needs. Similar methods can be found in virtually any large, decentralized asset network.[58]

Problems arise when local officials are asked to maintain a "minimum standard" for maintenance that is different from that standard prescribed by the adopted performance management system. For example, the recommendations supplied by the PASER system are based on the assumption that particular treatments will be employed at the appropriate stages of condition deterioration in order to maintain what pavement engineers consider to be minimum standards of performance. If followed correctly, this system is designed to generate cost savings by optimizing pavement's performance across its lifespan. However, systems such as these are not able to account for the political and fiscal realities of public sector asset management. As a result of these constraints, maintenance officials are often forced to adopt minimum standards that are dictated by budgetary

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[56] Robert M. Davies and Jim Sorenson (2000). *Pavement Preservation: Preserving our Investment in Highways* (Washington, DC: Federal Highway Administration).

[57] See http://www.aashto.org; R. Gary Hicks, James S. Moulthrop, and Jerry Daleiden (1998), "Selecting a Preventive Maintenance Treatment for Flexible Pavements," Paper presented at the Transportation Research Board 1999 Annual Meetings; Wisconsin Transportation Information Center (1987), Asphalt-PASER Manual, available at http://epd.engr.wisc.edu/centers/tic

[58] For a good discussion of system design and maintenance, see Robert S. Kravchuk and Ronald W. Schack (1996), "Designing Effective Performance Measurement Systems under the Government Performance and Results Act of 1993," *Public Administration Review* 56(4): 348-358.

constraints, legislators' agendas, and interagency politics rather than those standards prescribed by preventive maintenance models.

Therefore, a successful preventive maintenance strategy is one that incorporates local priorities, political and fiscal concerns, and industry standards. Moreover, given that these factors often fluctuate, that strategy must be flexible enough to adapt to the changing environment, but consistent enough to bring about the long term benefits of the maintenance plan.

Although this may appear to be a daunting challenge, various public agencies have experienced notable success by emphasizing different components of their respective preventive maintenance plans. The Kansas Department of Transportation, for example has managed to maintain a balance between preventive maintenance and what it considers to be "…more significant rehabilitation or reconstruction alternatives" by evaluating short and long-term costs and benefits within budget and performance constraints.[59] That balance has been achieved by devolving certain discretionary maintenance decisions to local road officials in order to balance immediate needs with long-term planning and maintenance strategies. State transportation agencies in two other states, Michigan and Pennsylvania, have made broad-reaching attempts to adopt the PASER system and AASHTO standards as the centerpiece of their respective highway maintenance planning systems. This relatively strict adherence to international standards has provided the consistency necessary to work within ever-changing political and fiscal conditions.

Multiple criteria for resource allocation decisions

Most performance indicator systems and their recommendations are designed to optimize a single outcome or criteria. For example, the outcome of interest in the previously mentioned PASER system is pavement condition over time. With time, however, maintenance engineers have devised models that allow managers to optimize other outcomes such as cost, equipment availability, downtime, and others. Although most of the work in this area has been in smaller asset networks (such as single factories) and is typically more sophisticated than single-criteria models, these multi-criteria systems hold great promise in the public sector, given that they provide decision makers the opportunity to balance competing demands within a single planning framework.

Private sector involvement

Traditionally, the private sector has limited its involvement in asset management to construction and redevelopment of new assets rather than maintaining existing infrastructure. However, the new reporting model proposed by the Governmental Accounting Standards Board's (GASB) Statement #34 requires all government agencies to report two new types of information that may facilitate greater private involvement in the preventive maintenance process. First, governments will be required for the first time to report the value of infrastructure assets such as roads, bridges, sewer systems, and

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[59] Richard W. Miller (2002), "Why (Not How) Kansas DOT's Pavement Management System Works and How Preventative Maintenance Actions are Integrated," Paper presented at the Transportation Research Board 2002 Annual Meetings.

others. Second, and perhaps more important, governments will be required to report depreciation costs on those assets. As a result, potential investors will have access to information about asset conditions, and how preventive maintenance investments may provide cost-beneficial solutions to asset preservation problems and issues regarding passing maintenance obligations on to future generations.[60]

Capital Budgeting and Planning

Capital planning in forty-one of the fifty states is a multi-year process ranging from three to ten years, with five years the most common time span for capital plans. The multi-year process indicates that many states have long-range plans, however; estimates for the out-year costs usually only provide a general trend for the project and are not as detailed as the current year estimate. The National Association of State Budget Officers (NASBO) surveyed the states in 1997 and 1999 and indicated that "good" capital planning and budgeting incorporated the following key items:

- ⇒ Establish a clear definition of capital expenditures.
- ⇒ Include specific operating costs for each capital project over a multi-year period.
- ⇒ Ensure that effective legislative involvement occurs throughout the process.
- ⇒ Strengthen the review of the years beyond the budget year in long-range capital plans.
- ⇒ Maintain centralized oversight for capital projects.
- ⇒ Identify the criteria used in selecting capital projects.
- ⇒ Define all program outcomes for capital investments and link them to overall state goals.
- ⇒ Evaluate cost estimating methods to measure their validity.
- ⇒ Establish a tracking system to keep projects on schedule and within budget.
- ⇒ Develop a clear debt policy and integrate capital planning with debt affordability.
- ⇒ Review cost-benefit comparisons for private sector participation in capital projects.
- ⇒ Review long-term leases.
- ⇒ Maintain an updated inventory system of capital assets.[61]

When giving consideration to infrastructure maintenance, NASBO suggests that the capital budget and planning process include the following objectives:

- ⇒ Define maintenance expenditures and specify funding of maintenance by formula or statute.
- ⇒ Develop a system to rate maintenance projects.[62]

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[60] See Governmental Accounting Standards Board Statement #34, *Basic Financial Statements – and Management's Discussion and Analysis – for State and Local Governments*; For a thorough discussion on infrastructure asset and deferred maintenance reporting, see Michael Granof (2001), *Government and Not-for-Profit Accounting: Concepts and Practices* (New York: John Wiley and Sons).

[61] National Association of State Budget Officers (NASBO), "Capital Budgeting in the States" November 1999.

[62] Ibid.

Although NASBO provides a list of suggestions, they point out that their analysis is not to provide a "model capital process," but to offer good practices applicable to the process. An example of a capital planning and budgeting process that follows the suggestions provided by NASBO is the State of Rhode Island. In this state, the CIP identifies each proposed capital project to be undertaken, the fiscal year in which the project will be started or the property acquired, the amount expected to be expended on the project each fiscal year, and the proposed method of financing these expenditures. These plans are derived with the capital budgeting goals as a guide. In addition to the capital budgeting goals, the Capital Development Planning and Oversight Committee, with the State Budget Officer as the Chair, evaluates all requests for capital expenditures and makes recommendations to the Governor with regards to the development of the Capital Improvement Plan.

The Rhode Island Example

The Rhode Island capital budgeting process defines maintenance as involving only asset protection as available for capital funding, while general maintenance, minor repairs or normal on-going maintenance, which do not add significant value to a facility and/or have an annual cost of under $50,000, are funded through the operating budget. Asset protection involves major renovations or improvements to existing facilities that would extend the useful life and/or add value to the asset. This type of maintenance is available for capital funding if it meets the criteria of extending useful life of the asset by at least ten years and must have a total costs of maintenance in excess of $50,000. The funding for this capital maintenance is allocated through the use of a Budget Reserve and Cash Stabilization Fund that was created in 1992. Each year two percent of general revenues are deposited into this "Rainy Day Fund" until the fund reaches three percent of total resources. Once this "3%" level has been reached, any additional revenues are deposited into the Rhode Island Capital Plan Fund and can be used to fund capital expenditures or debt service. A major portion of these resources has been dedicated in recent years to an asset protection program and other capital projects. In general, Rhode Island's capital planning and budgeting process follows the NASBO suggestions. However, funding from the capital budget to a preventative maintenance program would have to be shown to increase the life of the asset by at least 10 years, a hurdle that may not be achievable in preventative maintenance.

NASBO suggests that a key good practice is to define maintenance costs and specify funding of maintenance by formula or statute. Rhode Island's approach only meets these criteria if the "rainy day" fund exceeds the 3% threshold, a large task in the current and forecasted future environment of state funds. The defining of maintenance costs and funding, as suggested by NASBO, can dilute the political opportunities to sacrifice maintenance funds for budget balancing purposes. The formalization of maintenance needs, with a statute or formula, helps to break the cycle of choosing between preservation of existing facilities and the funding of new projects. This could be done in conjunction with the development of a system to rate maintenance projects, prioritizing the needed preservation of specific facilities, thereby minimizing deferred maintenance. If the rating system and the planning and budgeting are tied together, the direct impact of the assessment of the condition of the capital stock with the budget process can be accomplished by linking these to the asset management system. The asset management system (AMS) combines information about the condition of capital assets with typical depreciation or preventative schedules, and information on replacement costs. The AMS can then be used to develop estimates of both the full cost of bringing infrastructure up to "good" condition and the mix of repair versus replacement of capital assets that should take place.

<u>The Minnesota Example</u>

As an example, the State of Minnesota includes major maintenance projects above $25,000 in the capital budget and recurring maintenance costs in their operating budget. This is similar to Rhode Island, however, Minnesota's financial threshold is lower and the required impact on the asset's life is removed. The State of Michigan uses a lump sum maintenance appropriation. Michigan Department of Transportation (MDOT) reports that their program enables them to optimize the network condition with a given preservation budget, resulting in more stable funding needs of an effective pavement preservation program that integrates many preventive maintenance strategies and rehabilitation treatments. MDOT utilizes these links to the budget in their asset management program.

Summary

This section has highlighted a number of desired components of a successful preventive maintenance program that should be used as a guideline for the delivery of a case for the adoption or expansion of a preventative maintenance program. The components discussed in this section include:

⇒ A comprehensive education effort aimed at citizens/customers
⇒ Guidelines for integrating performance measures with needs, treatments, and assessments
⇒ Multiple criteria for resource allocation decisions
⇒ Private sector involvement
⇒ Capital budgeting and planning

Capital Preventative Maintenance
Conclusion

There is reason to believe that pavement engineers, highway planners, and others involved in the construction and management of public infrastructure at all levels of government share a common interest in expanding the scope of preventive maintenance activities beyond what is currently in use. However, there are a number of obstacles that often stand in the way of that expansion. Some of these barriers include: lack of support for preventive maintenance among top management, elected officials, and the public; the presence of more immediate and/or visible construction and reconstruction needs; and a lack of evidence supporting the cost-effectiveness of preventive maintenance. Unfortunately, many of these political, institutional, and financial obstacles fall well beyond many asset managers' scope of interest and/or expertise. However, recent developments in maintenance engineering and other fields have provided a number of tools, techniques, and concepts that can help to overcome these obstacles.

In light of those recent developments, this guidebook has offered a process for managers to follow that will assist in overcoming the various perceived limitations currently preventing expansion of preventive maintenance efforts at all levels of government. Based on a systematic approach, this guidebook initiated a five-step process to use when developing and presenting the case for preventative maintenance. The process is designed to help managers within departments of transportation address a variety of obstacles, thereby providing insights to front-line transportation officials, administrative decision makers, and elected officials.

The pyramid process presented in this guidebook is built upon the foundation of education and follows a process that ends with the delivery of a case for the adoption or expansion or preventive maintenance. The following quick checklist guide is to assist managers in following each step of the pyramid process. With specific questions categorized by each step of the pyramid process, the checklist is designed to first provide an indication of the organization's familiarity with preventative maintenance and then identify areas that should be addressed prior to delivering a case for preventive maintenance.

One of the primary factors associated with a successful preventive maintenance program is that it should be developed according to the organization's institutional setting, which includes a thorough understanding of the organizational environment and identification of the unique challenges and challengers that act as potential barriers to preventive maintenance efforts. This setting also provides the foundation for any necessary actions taken to address the challenges presented. The strategy section of the checklist provides an indication of the organization's ability to utilize the tools of benefit/cost analysis, cost effectiveness factors and ratios, and the role of warranties and capital planning. Finally, the delivery section of the checklist provides a quick check of the desired components of a preventive maintenance program that should be used as a guide in delivering the case for preventive maintenance. Therefore, all of the questions within this checklist are intended to assist in preparing the organization for implementation or expansion of a preventative maintenance program.

Quick Checklist Guide for a Preventative Maintenance Program		
Educational Setting		
1. Do we have an understanding of the process and benefits/costs of preventative maintenance?	____ Yes	_____No
2. Is preventative maintenance well aligned with our capital budgeting system?	____ Yes	_____No
3. Can we use design-build-maintain-warranty as part of our preventative maintenance program?	____ Yes	_____No
4. Does our infrastructure reporting under Statement 34 fit with our preventative maintenance program?	____ Yes	_____No
Challenges and Challengers		
5. Have we developed an accepted definition of preventative maintenance?	____ Yes	_____No
6. Have we identified the challenges?	____ Yes	_____No
7. Have we identified the challengers?	____ Yes	_____No
8. Have we established possible actions to address the challenges and challengers?	____ Yes	_____No
Understanding the Environment		
9. Is our organizational decision making centralized?	____ Yes	_____No
10. Is decision making by engineers and other professionals at the ground level?	____ Yes	_____No
11. Do we have multiple agency decision making?	____ Yes	_____No

Strategy

12. Do we have benefits/costs well established? ____ Yes ______No

13. Are we going to use cost effectiveness factors and ratios? ____ Yes ______No

14. Have we established whether design-build-maintain-warranties are beneficial? ____ Yes ______No

15. Are the implications of our capital planning and reporting objectives established? ____ Yes ______No

Delivery

16. Do we have a plan for a comprehensive education effort aimed at citizens/customers? ____ Yes ______No

17. Have we established guidelines for integrating performance measures with needs, treatments, and assessments? ____ Yes ______No

18. Have we established multiple criteria for resource allocation decisions? ____ Yes ______No

19. Do we have private sector involvement? ____ Yes ______No

20. Have we established a capital budgeting and planning process? ____ Yes ______No