Pavement Management’s Role in an Asset Management World

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ABSTRACT

With the passage of the Moving Ahead for Progress in the 21st Century Act, commonly known as MAP-21, there has been increased focus and attention to asset management programs in transportation agencies and the development of risk-based asset management plans. These plans document the transportation assets being managed by the agency, summarize current and planned performance expectations, and outline the investment plans that the agency will make to meet performance targets. Although MAP-21 requires the plans to include only pavements and bridges on the National Highway System, state transportation agencies are encouraged to include all infrastructure assets within the right-of-way corridor in their plan.

With all this focus on asset management some agencies may draw the conclusion that pavement management is less important than it has been in the past. Is there any truth to that conclusion? Is there a future for pavement management beyond data collection activities? This paper addresses these questions by demonstrating the expanding role for pavement management in supporting an agency’s asset management initiatives and the importance of developing pavement management tools that are used for more than gathering and reporting pavement conditions. The authors illustrate the importance of pavement management analysis results to develop key components of an asset management plan. For instance, the paper illustrates how pavement management outputs are critical to being able to: a) conduct a life-cycle analysis showing the cost-effectiveness of different treatment strategies, b) evaluate trade-offs when making investment options across asset types, and c) identify and manage risks that might impact the agency’s ability to achieve its goals.

The paper concludes with recommendations for enhancements to existing pavement management systems that are needed to better support the asset management environment in which most transportation agencies operate. Specifically, the paper discusses the importance of integrating pavement management data with other asset data, incorporating the performance of preservation activities in prediction models, and capturing the impact of capital investments on future maintenance costs to truly evaluate the whole life costs of a given option.
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INTRODUCTION
The Moving Ahead for Progress in the 21st Century Act, commonly known as MAP-21, promotes the use of performance-based management, which increases the need for objective and reliable data for making decisions about investment priorities, demonstrating the effectiveness of investment decisions, and improving agency transparency and accountability. As a result, there has been increased focus and attention on programs for managing transportation assets and on the development of plans that outline investments that will be made and the corresponding level of service that can be expected.

One of the factors that has contributed to this increased emphasis on managing assets effectively in the United States is the new requirement for states to develop risk-based asset management plans for pavements and bridges on the National Highway System (NHS). These plans document the transportation assets being managed by the agency, summarize current and planned performance expectations, and outline the investment plans that the agency will make to meet performance targets. Although MAP-21 requires the plans to include only NHS pavements and bridges, transportation agencies are encouraged to include all infrastructure assets within the right-of-way corridor in their plan.

The increased emphasis on performance-based programs, and the requirement to develop Transportation Asset Management Plans (TAMPs) is expected to be a tremendous boost to pavement management and other computerized management systems used by transportation agencies to estimate funding needs, identify appropriate treatment strategies, and evaluate the long-term impacts of different investment decisions. These tools are instrumental to meeting legislative requirements, but also serve as the basis for an agency’s performance-based decisions.

This paper describes the use of a pavement management system in support of a transportation agency’s asset management activities. The paper illustrates the use of pavement management outputs for conducting a life-cycle analysis showing the cost-effectiveness of different treatment strategies, evaluating trade-offs when making investment options across asset types, and managing program risks. Examples are provided to illustrate the contributions that pavement management tools make to asset management.

The paper concludes with recommendations for enhancing an existing pavement management system to better support the asset management environment promoted under MAP-21. Based on experiences in developing TAMPs in state transportation agencies, the paper documents the importance of integrating pavement management data with other asset data, incorporating the performance of preservation activities in prediction models, and capturing the impact of capital investments on future maintenance costs to truly evaluate the whole life costs of a given option, as just a few of the enhancements needed.

USING PAVEMENT MANAGEMENT TO SUPPORT TRANSPORTATION ASSET MANAGEMENT ACTIVITIES
MAP-21 describes transportation asset management (TAM) as “a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on engineering and economic analysis based upon quality information, to identify a structured sequence of … actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost.”
The *Transportation Asset Management Guide – A Focus on Implementation* published by the American Association of State Highway and Transportation Officials (AASHTO) describes the relationship between management systems and the goal-setting responsibilities of performance management as a flow of information, illustrated in figure 1 (AASHTO 2011). As shown in the figure, management systems use the results of data collection processes, prediction models, treatment rules, and functionality to generate and evaluate projects and policies. However, one of the disadvantages is that most of these systems are silo-based, which fosters decisions on each asset individually.

![FIGURE 1 Flow of information from management systems to establish agency goals](AASHTO 2011).

There are several aspects of pavement management that lend themselves to supporting the asset management features suggested in the MAP-21 definition. At the most basic level, the pavement condition information that serves as the basis for all pavement management functions provides the foundation to support a performance-based management approach. The analytical features of a pavement management system can provide input to the development of a structured sequence of actions that lead to a desired state of good repair. Additionally, the treatment histories and performance data provide valuable input to an analysis of life cycle costs to help determine cost-effective preservation and rehabilitation strategies. This paper illustrates the use of pavement management information for three important aspects of asset management: life cycle management, investment scenario development, and risk management.

**Life Cycle Management**

One of the requirements for a TAMP that is specifically identified in MAP-21 is the inclusion of a lifecycle cost analysis (LCCA). Although the Notice of Proposed Rulemaking (NPRM) has not been issued at the time this paper was written (so the exact requirements under the legislation are not known), the requirements are expected to:

- Describe lifecycle costs and explain why they are important.
- Provide an example of a typical deterioration model.
- Describe strategies for managing assets over their whole life. This includes activities from inception to disposal that demonstrate the use of a sequence of maintenance, preservation, and rehabilitation treatments.
- Document the typical lifecycle cost of the assets included in the TAMP.

In addition, some agencies are interested in using the results of a lifecycle cost analysis to convey the future maintenance costs associated with each new mile of pavement added as part of a system expansion project. These future maintenance costs are often not taken into consideration when capital projects are budgeted and a lifecycle analysis provides an
opportunity to begin to identify the magnitude of future maintenance implications on today’s
capital projects.

LCCA is an analytical technique used to assess the total cost of asset ownership by
taking into account all costs associated with construction, inspection, maintenance, and
ownership. A network-level LCCA was conducted as part of the development of a TAMP for
the Minnesota Department of Transportation (MnDOT). Unlike a project-level LCCA in which
an agency might use the results for project surface type selection, the network-level analysis
conducted for a TAMP is intended to demonstrate the cost effectiveness of various treatment
cycles for managing assets. In the case of the MnDOT analysis, a 70-year analysis period was
established to ensure that at least one complete reconstruction cycle would be included. No
initial construction costs were considered, since they were assumed to be equal for each strategy.
By focusing on treatments applied over the analysis period, rather than initial construction costs,
the analysis results highlight differences in the total cost of maintaining pavements using
different treatment strategies over the analysis period. The key inputs from the pavement
management system to support the analysis include the following:

- **Asset condition deterioration rates** – including the rate at which the condition of the
  pavement deteriorates over time with and without the application of routing, reactive,
  and preventive maintenance treatments.

- **Treatment types, costs, and cycles** – including the various types of treatments applied
to a pavement over the analysis period, including the type of treatment, the condition of
the pavement at the time the treatment is applied, the resulting condition level after the
application of the treatment, typical treatment cycles, and typical treatment costs.

Three different treatment strategies were considered in the lifecycle analysis, including
the following:

- A worst-first strategy in which major rehabilitation or reconstruction is applied at the end
  of the design life, which is approximately 25 years for flexible pavements and 30 years
  for rigid pavements.

- A “typical” strategy that reflects the Department’s current practices for repeated milling
  and overlaying treatments with crack sealing and surface treatments in-between.

- A “desired” strategy that includes a series of crack sealing, surface treatments, mill and
  overlays followed by a full-depth restoration or reconstruction project.

Different strategies were outlined for both flexible and rigid pavements, and a weighted
average cost was calculated based on the percent of the network with each surface type.

The results of the analysis are presented in figure 2 (MnDOT 2014). The results clearly
illustrate the cost-effectiveness of preserving pavements rather than let them deteriorate
significantly before repairs are made. The graph on the left of figure 2 presents the total lifecycle
costs of each of the three strategies over the 70-year analysis period. As shown, the total costs
associated with the “typical” and the “desired” strategies are very close, and both are
significantly less than the total cost of a worst first strategy. The graph on the right of figure 2
shows the future maintenance costs for each strategy, presented as a percentage as the initial cost
of the pavement construction. As shown, the future costs of maintaining and operating a
pavement are significant, ranging from 111 percent to 287 percent of the initial cost of
construction depending on the agency’s preservation strategy. In other words, this analysis
shows that for every dollar spent on an expansion project, the agency is committing to between
$1.11 and $2.87 cents for future maintenance expenditures. However, these future maintenance
costs are rarely considered when making capital investment decisions. To manage pavements effective over their entire service life, it is important that agencies begin to account for these future maintenance costs in their long-term plans. It is also important to note that the analysis is influenced by the discount rate adopted, the analysis period, the treatment cycles, and so on. Therefore, each agency should conduct its own life cycle analysis as part of the development of its asset management plan.

![Figure 2](image.png)

**FIGURE 2** Results of the life cycle analysis for the MnDOT TAMP (MnDOT 2014).

The LCCA demonstrated that the typical strategy of placing asphalt overlays based on current pavement conditions (a lag indicator) did not appear to be a sustainable strategy in the long run since service lives continued to decrease as the pavement structure ages beyond a certain point (e.g., 40 to 50 years) when a major rehabilitation activity such as a full-depth reclamation could potentially be a more suitable treatment option. Such considerations can drive the development of investment scenarios, where an agency can choose to invest a certain fraction of the funding available for maintenance and preservation, and another portion of the funding on major rehabilitation activities triggered by factors such as pavement age, performance history, life-cycle sustainability, and treatment suitability.

While the pavement management data was able to easily provide most of the information needed to conduct the life cycle analysis, there were some gaps in the available data. For instance, one of the challenges came in trying to model maintenance expenditures over the analysis period since maintenance records are not easily integrated with the pavement management database. To overcome this issue, a process was developed to estimate routine maintenance expenditures (for activities such as crack sealing and patching) by condition category. This approach was suitable for purposes of the life cycle analysis, but highlighted the challenge in estimating whole life costs when databases are not integrated.

**Investment Scenario Development**

Many state transportation agencies have used the results of a pavement management analysis to identify funding needs and to recommend capital improvement projects that make the best use of available funding. The typical pavement management analysis typically focuses only on pavements and is used to develop a capital program after the budget for pavements has been established. A number of agencies have used the forecasted conditions from an investment analysis to show that a set of projects that includes preventive maintenance strategies is much more cost-effective than one in which pavements are allowed to deteriorate to the point that costly rehabilitation actions are needed.
These same types of analyses will be used in developing the investment strategies required in the TAMP. However, unlike the traditional pavement management analysis, the TAMP requires that 10-year investment strategies be established that are designed to achieve performance targets established by the state DOT, thereby holding each agency to its commitment to achieve the stated targets. The failure to meet these targets may result in penalties that impact the amount of federal funding received and/or the flexibility with which federal funds can be used. Therefore, unlike expected condition projections typically generated from a pavement management system, a TAMP sets targets that agencies will be held accountable to achieve.

Another difference from the traditional pavement management analysis lies in the possible use of the results to help establish the funding level for pavements, taking into account the investment needs for other assets such as bridges and culverts. For example, the TAMP developed by the Colorado DOT describes a Delphi process in which asset managers present their program performance projections and investment recommendations to a group of agency leaders (including senior management, regional directors, asset managers, and additional regional and headquarters staff) using graphs such as the one shown in figure 3 (CDOT 2014).

Based on presentations made by each of the asset managers, a consensus is reached to allocate funding across each of the asset classes. The recommendations are presented to the Transportation Commission for final approval before becoming part of the CDOT budget.

A project being conducted for the National Cooperative Highway Research Program (NCHRP) further illustrates the future use of pavement management as one source for evaluating investment trade-offs across assets. This project, *Cross-Asset Resource Allocation and the Impact on System Performance* (NCHRP 08-91), is aimed at developing a framework that will allow state DOTs to set performance targets and allocated resources based on agency priorities. The framework developed under this project is intended to help states evaluate the impacts of different resource allocation strategies on multiple performance criteria. For example, a treatment that improves pavement condition might also earn credit for improving safety characteristics if the friction characteristics of a treatment also improve. A key to the success of the framework that is being developed under this project is the availability of a management system, such as a pavement management system, to forecast improvements to the system for each candidate project that will be funded.
In the future, as states expand their TAMP to include assets beyond pavements and bridges, and as states embrace an asset management philosophy for making investment decisions, pavement managers should anticipate that the use of pavement management analysis results will increasingly be used to establish and defend budget allocations. The analysis will be strengthened by linking the results of the LCCA with the investment strategies generated by the pavement management system to not only achieve performance targets, but also to reduce the whole life cost of managing pavements. This link is important for using available funding more judiciously than in the past, regardless of the final amount of funding provided for pavements.

**Risk Management**

As agencies move forward in developing their asset management plans, there are efforts underway to better understand and manage risk as an important part of an asset management program. Internationally, risk management is an integral part of an asset management program. For instance, the New South Wales (Australia) Asset Management Committee defines risk management as “a systematic process to identify risks that may impact on the organization’s objective, analyze their consequences, and develop ongoing measures to treat them (FHWA 2012a).” As shown in figure 4, risks can occur at the project, program, or agency level (FHWA 2012b). Transportation asset management focuses primarily on risks at the program or agency level.

![FIGURE 4 Levels of enterprise risk.](image)

There are a number of different types of risks that can impact the management of pavements in a highway network, such as the unpredictability of budgets, poor construction practices that lead to shortened performance periods, improper treatment selection, inaccurate pavement condition forecasts, and inaccurate or incomplete pavement condition data (FHWA 2012b). Risk management involves quantifying the likelihood that these events will take place as well as the consequences if they do take place. In combination, these two factors provide the basis for a) assigning a risk level to each event, b) prioritizing the risks according to the risk level, and c) developing strategies for reducing or mitigating the highest risks. The information
is typically compiled in a risk register, which summarizes each risk event, the potential cause, the likelihood of the event, and the potential consequences to the agency in terms of economic impact, liability, and safety. A sample of a risk register is shown in table 1. An example of the likelihood and consequence ratings that might be used to score each risk event is presented in table 2.

### TABLE 1 Sample Risk Register for Financial Risks

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Cause(s)</th>
<th>Impact(s)</th>
<th>Likelihood</th>
<th>Economic Impact</th>
<th>Legal Expectations</th>
<th>Public Safety</th>
<th>Reputation</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of or Deferred Funding</td>
<td>Change in federal funding or reduction in fuel tax revenue</td>
<td>Reduction in available funding, reduction in present pavement program</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Volatility in Prices (Inflation)</td>
<td>Political or economic changes, or natural inflation</td>
<td>Reduction in available funding, reduction in present pavement program</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

### TABLE 2 Sample Likelihood and Consequence Ratings

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Likelihood</th>
<th>Consequence</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High or Almost Certain</td>
<td>Near Certainty (90%) or likely to occur within the year</td>
<td>Catastrophic Impact on System Performance</td>
<td>5</td>
</tr>
<tr>
<td>High or Likely</td>
<td>Highly Likely (70%) or likely to occur within 2 years</td>
<td>High/Large Impact on System Performance</td>
<td>4</td>
</tr>
<tr>
<td>Moderate</td>
<td>Likely (50%) or likely to occur within 3 to 5 years</td>
<td>Moderate/Noticeable Impacts on System Performance</td>
<td>3</td>
</tr>
<tr>
<td>Low or Unlikely</td>
<td>Unlikely (20-30%) or likely to occur within 6 to 10 years</td>
<td>Low/Some Noticeable Impacts on System Performance</td>
<td>2</td>
</tr>
<tr>
<td>Very Low or Rare</td>
<td>Remote (10%) or not likely to occur for 10 or more years</td>
<td>Insignificant/Little Noticeable Impacts on System Performance</td>
<td>1</td>
</tr>
</tbody>
</table>

Pavement management can support a risk analysis by providing objective information that can be used to quantify both the likelihood and the consequences of an event taking place. For example, a pavement management database provides a wealth of data that could be used to summarize the number of pavement sections where construction or other factors have contributed to getting less life out of a pavement than expected. Similarly, the data could be used to evaluate the accuracy of performance models by comparing actual and projected pavement conditions. The development of a Quality Management Plan for pavement collecting...
pavement condition data could also serve as the basis for a statistical analysis for determining the accuracy and precision of the survey procedure.

The Minnesota DOT has an enterprise risk management framework in place for evaluating and managing risks at the agency level. Therefore, during the development of MnDOT’s TAMP, the risk analysis focused primarily on program risk, especially what were considered to be under-managed risks. For pavements, several risks were identified, but two emerged as the top priorities to address. The first concerned that potential for not being able to meet targeted pavement conditions because of inadequate funding. This risk had the potential of damaging the agency’s reputation, creating unsafe driving conditions, and increasing the overall cost of maintenance. A second risk had to do with the fact that the ramps, access roads, auxiliary lanes, and frontage roads were not included in the pavement management database so they were not being “managed” to the lowest lifecycle cost. Strategies were developed for mitigating these risks and cost estimates were developed for each strategy. A similar consideration of risks was performed for the other assets included in the TAMP and a workshop was convened to prioritize all of the risks that were identified. For pavements, the risk of not being able to meet targeted conditions was identified as a top priority and a new process was established to monitor road segments that had been in poor condition for five or more years. The new process was intended to prevent these segments from being overlooked for funding. The strategies for collecting data on the ramps and access roads is still being considered for funding based on other agency priorities.

The use of pavement management to help identify, evaluate, and manage risks is expected to grow in terms of importance due to tightening budgets, competing priorities, and MAP-21 requirements.

**ENHANCEMENTS TO FURTHER SUPPORT TAM ACTIVITIES**

The paper concludes with recommendations for enhancing an existing pavement management system to better support the asset management environment promoted under MAP-21. Based on experiences in developing TAMPs in state transportation agencies, the following areas have emerged as pavement management features that could be enhanced in the future to improve the decision-making process and to better support an agency’s asset efforts.

- **Integrating Asset Data** – As the importance of asset management continues to grow, there will be an increased demand on pavement managers to be able to analyze situations that will involve merging separate data sets to provide better consideration of the wide range of factors that impact project selection decisions. For example, pavement condition data could be linked with crash data to identify areas for safety enhancements. Pavement condition data could also be combined with freight data to support state economic development initiatives. A geographic information system (GIS) serves as a valuable tool for linking different data sources. Pavement managers who recognize the value to linking disparate data sources will be better prepared to respond to these types of requests as they occur.

- **Developing an Asset Register** – An asset register provides a summary snapshot of important characteristics of an asset and some of the factors that are important in managing that asset. For example, an asset register might contain the mileage by road class, the replacement value, current asset conditions, performance targets, and an assessment of the confidence level in the data. The development of a robust asset register is useful in developing a TAMP, but also serves as a resource that will help provide
fundamental information needed for establishing investment needs, managing risks, and
evaluating trade-off options.

- **Improving Performance Modeling** – While most states have developed performance
  models for predicting future conditions, few states have developed models that reliably
  model the performance of preventive maintenance treatments such as chip seals or
  microsurfacing. The performance of these types of treatments is significantly impacted
  by the condition of the pavement at the time the treatment is applied, and this factor is
  often not taken into account when developing performance models. Since agencies are
  increasing the use of preventive maintenance treatments to stretch available dollars, it is
  crucial that strategies be developed for accurately modeling these types of treatments.

- **Capturing Maintenance Costs** – Asset management emphasizes the evaluation of the
  whole life costs of managing a pavement network. At present, there are few pavement
  management systems that capture all of the costs of managing pavements, from
  maintenance to rehabilitation and reconstruction. Efforts to improve the reporting of
  maintenance costs will enable states to better evaluate the whole life costs associated with
  different investment strategies and to better understand the future maintenance costs of
  capital investments.

- **Analyzing Tradeoffs Across Asset Classes** – As discussed in the paper, asset
  management is forcing asset managers to consider budget tradeoffs across asset classes.
  For pavement managers, this will place an increased emphasis on using pavement
  management information to defend budget needs and to consider performance impacts
  beyond pavement condition. The use of pavement management data for this purpose
  places additional emphasis on the quality and reliability of the data. Therefore, any steps
  that an agency can take to raise their confidence in the data and the analysis capabilities
  will strengthen the use of the data for this purpose.

- **Evaluating and Managing Risks** – In today’s environment, transportation agencies face
  difficult decisions in prioritizing investment needs. Internationally, transportation
  agencies have focused on the identification, analysis, and management of risk as a
  framework for ensuring that agency investments address agency priorities while showing
  due diligence in the decision-making process. Pavement management data can support
  the identification and evaluation of risks impacting the pavement program and the
  development of risk mitigation strategies that enable the agency to protect its investment
  in this important asset. However, this is a new application of pavement management and
  pavement managers will need to develop skills in this area to be most effective.

**CONCLUSIONS**

Pavement management systems are important tools within transportation agencies, since they
serve as the basis for making decisions about investment priorities, demonstrating the
effectiveness of investment decisions, and improving agency transparency and accountability.
Under MAP-21, and other legislation that supports the use of performance-based investment
decisions for managing transportation agencies, agencies are placing an increased emphasis on
the results of these types of tools. The paper demonstrates the use of pavement management to
support the development of a TAMP, but there are many other asset management functions that
pavement management supports.

Even though pavement management systems have been in place for many years, the use
of these tools to support asset management activities places demands on the program that differ
from past requirements. As a result, there are enhancements that are needed to many pavement management systems to address these new challenges. The paper concludes with some recommendations that will help keep pavement management relevant, enable the agency to meet legislated requirements, and improve the agency’s transparency and accountability efforts. These enhancements include improving data integration and better accounting for maintenance activities in a pavement management analysis. By recognizing these needed enhancements, and focusing effort on addressing these needs, pavement management will help to ensure the viability and long-term sustainability of one of the most valuable assets in any transportation agency.

REFERENCES


