Improving the Link Between the Pavement Design Process and Asset Management: Pavement Management Functions, Processes, Inputs, and Outputs

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16. Abstract

In 2018-2019, the FHWA conducted a review of its long-standing pavement design policy (23 CFR Part 626). Part of the review involved extensive stakeholder outreach to State Departments of Transportation (DOTs) and Industry partners to solicit feedback on the policy and related guidance. Participants at several outreach events commented that clarity was needed regarding how pavement design policies relate to other regulatory requirements such as the State's Transportation Asset Management Plan (TAMP).

FHWA recognized a need to further understand how project-level pavement design and network-level asset management could be better linked to help DOTs achieve long-lasting, safe, durable, cost-effective pavements. To identify potential strategies for improving the link between pavement design and asset management, FHWA conducted a case study of New Jersey DOT and reviewed practices at several other agencies. Upon completion of this effort, a workshop was held to bring the participating State DOTs together to discuss the identified strategies and assess how they could be adapted for use by other DOTs.

The primary output of the case study is a set of web pages that contains information on the key roles and responsibilities of pavement design, pavement management, and transportation asset management (TAM) units. The website also contains information on potential strategies for establishing links between these units including critical communications and feedback loops that may be helpful in ensuring that the agency's processes and procedures are focused toward common goals of maximining pavement performance while minimizing long-term costs.

The purpose of this document is to provide an overview of pavement management for pavement engineers and other transportation professionals. This document provides information on pavement management functions, processes, inputs, and outputs. More detailed information on pavement management can be found from numerous other sources that are referenced in this document.

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INTRODUCTION

Purpose

This document provides a brief overview of pavement management and the functions that pavement management staff typically perform within a State Department of Transportation (DOT). Additional information on pavement management can be found on the FHWA Pavement Management & Performance webpage or from the references and additional resources listed at the end of this document.

Background

According to the American Association of State Highway Transportation Officials (AASHTO), pavement management is "a set of tools or methods that assist decision-makers in finding optimum strategies for providing, evaluating, and maintaining pavements in a serviceable condition over a period of time" (AASHTO 2012). Pavement management informs and is informed by all agency decisions related to pavements, from short-term maintenance efforts to long-term strategies. DOTs in the United States and around the world have been using pavement management tools and practices for decades to manage the condition of their pavement networks. Practicing pavement management involves a specific set of functions that collect and analyze data to inform agency decisions on the maintenance, preservation, rehabilitation, and replacement of existing pavements.

The passage of MAP-21 (Public Law 112-141) in 2012 introduced Federal requirements for State DOTs to develop risk-based transportation asset management plans (TAMPs); 23 U.S.C. 119(e) and 23 CFR part 515 provide more detailed requirements including minimum standards for developing and operating pavement management systems (23 CFR 515.17). These Federal requirements are only applicable to pavements on the National Highway System (NHS) (see 23 CFR 515.5 definition for "Asset management plan"), but States may include other public roads in their TAMPs and pavement management systems (23 CFR 515.9(c)). Most State DOTs include all pavements located on the roadway network under their jurisdiction in their pavement management systems.

Pavement management helps to ensure pavement investments meet the agency's pavement condition goals and targets but practicing pavement management is not just about meeting Federal requirements. In fact, most highway agencies used pavement management to manage their pavement networks prior to the introduction of Federal requirements (Zimmerman 2017). Implementing pavement management involves establishing clear pavement management functions, policies, and procedures. Effective implementation connects pavement management recommendations to agency decisions so that resultant actions and investments align with goals and support the efficient use of resources.

PAVEMENT MANAGEMENT FUNCTIONS

The principal function of pavement management is to develop treatment strategies that provide the optimal pavement conditions at the least practical cost over the short and long term.

- In the short-term, pavement management informs decision makers on the current state of pavement assets including inventory, location, condition, and remaining service life.
- In the long-term, decisions are supported through performance forecasts. Pavement management provides forecasted conditions for given financial scenarios or required funding levels to meet a desired condition at a future time.

The ability to perform short- and long-term analyses allows pavement management to support a range of decision-making processes such as project selection, target setting, or establishing a desired state of good repair (DSOGR). Pavement management analyses support these processes by predicting the benefits and consequences of different alternatives. For example, pavement management can show the potential benefits of increasing funding or introducing a new treatment. It can also show the consequences of decreasing funding levels or making project selection decisions that do not align with life cycle planning strategies.

This ability to look at alternatives also enables pavement management to support risk management. Pavement management supports risk management by identifying critical assets, deterioration rates, and potential failures given financial or strategic scenarios. Pavement management can also serve multiple secondary functions such as:

- Calibration and validation of pavement design methodologies.
- Informing maintenance management systems.
- Providing systemic highway safety evaluations.

Life-cycle planning means a process to estimate the cost of managing an asset class, or asset sub-group over its whole life with consideration for minimizing cost while preserving or improving the condition (23 CFR 515.5).

Risk management is the process and framework for managing potential risks including identifying, analyzing, evaluating, and addressing the risks to assets and system performance (23 CFR 515.5).

PAVEMENT MANAGEMENT PROCESSES

Pavement management uses quality data, accurate models, and highly qualified staff to analyze different approaches for managing the condition of pavements across a highway network. Supporting this analysis requires the coordination of several processes.

Data Collection

The complexity, precision, accuracy, and frequency of data collection can vary widely between DOTs and even within a DOT they can vary depending on the roadway functional classification or ownership.

Prior to the start of data collection, agencies should establish the criteria for acceptable data either by referencing national standards or by establishing standards of their own. These criteria could include completeness, correctness, validity, consistency, timeliness, and accuracy. Per 23 CFR 490.319(c), State DOTs must develop and utilize an FHWA-approved Data Quality Management Program (DQMP) to report the pavement condition metrics discussed in 23 CFR 490.311 and the data elements discussed in 23 CFR 490.309(c). The DQMP must include, at a minimum, methods and processes for:

- Data collection equipment calibration and certification.
- Certification process for persons performing manual data collection.
- Data quality control measures to be conducted before data collection begins and periodically during the data collection program.
- Data sampling, review, and checking processes.
- Error resolution procedures and data acceptance criteria.

Pavement Management Database Operations

Databases can range from simple spreadsheets to relational databases depending on the size and complexity of the network. Many agencies tie their data into their Geographic Information System (GIS) for ease of access and use. To support data management and operations, DOTs document procedures describing how pavement management data are stored, referenced, and accessed. The procedures also typically address integration with other agency data and management systems. Some key considerations for pavement management database operations may include (AASHTO 2012):

- Data sources and individuals responsible for maintaining the data.
- Methods and frequency of data collection.
- Location referencing systems associated with the data.
- Data structure, format, and size.
- Methods of data transmittal, processing, and storage.
- Use of data (e.g., in business processes and in relationship to other user needs).
- Applications that draw data from existing databases (e.g., bridge management systems and pavement management systems).
- Types of reports that are currently produced or are needed.

New Jersey DOT Pavement Database Operations

The pavement processes used by the New Jersey DOT (NJDOT) generate and use a plethora of data. These data are stored in multiple databases and files within the NJDOT including:

- Pavement Management Database.
- HPMS Database.
- dTIMS™ Database.
- Falling Weight Deflectometers (FWD) Testing Database.
- Pavement Skid Database.
- Materials Database.
- Pavement Core Logs.
- Rutgers' Soil Survey Subgrade Properties Data Set.
- Materials Database (existing asphalt properties).
- Rutgers' AC Testing Catalog (new asphalt properties).
- Traffic Database.

While NJDOT is data rich, these data are not readily available to the casual user. For example, the FWD Testing Database is available to the Pavement and Drainage Management and Technology Unit on a project specific basis. Other data, such as project cores, are available in project files or materials quality databases but not readily available to all. Work is underway to make these databases available using a geospatial reference where applicable.

The Iowa DOT is an example where geospatial referencing and data governance have been instituted to enhance a data rich environment.

Performance Modeling

Pavement performance models are mathematical functions developed by analyzing historic pavement condition data. Performance models play a key role in the functioning of a pavement management system by predicting the change in condition for a section of pavement if no work is performed to improve the condition. The predictions of future conditions can then be used to perform numerous pavement management functions, including but not limited to:

- Recommending appropriate treatments and timings.
- Estimating budget needs.
- Setting targets.
- Estimating service life.
- Developing long-term treatment strategies.

Performance Modeling Approaches

Performance modeling for pavement management is typically approached with either deterministic or probabilistic models. Deterministic models predict a single dependent, or response, value such as a pavement condition index based on one or more independent predictor variables in the pavement management database such as cracking, traffic, or pavement age. Probabilistic models are different in that they predict a range of possible values for the dependent variable. This is illustrated in figure 1, in which a deterministic model predicts a pavement condition index of 72 at year 14 whereas a probabilistic model indicates a predicted range of 62 to 74.

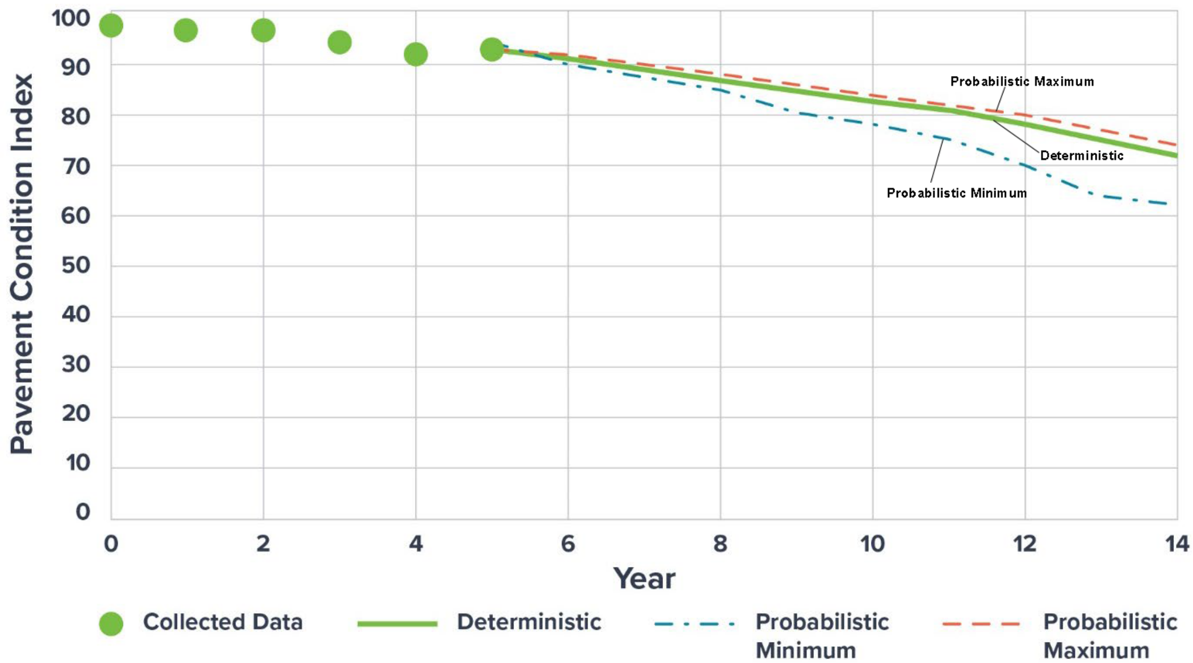

Figure 1. Example deterministic and probabilistic pavement performance models.

Pavement management systems typically use either a pavement family model approach or section-specific models, although some use a hybrid approach. In each method, regression analysis is applied to historic condition data to identify best-fit models of condition over time for certain types of pavements. In each approach, the pavement network is divided into homogeneous segments based on characteristics such as pavement type, thickness, age, substructure, traffic loading, roadside features, jurisdiction, route, or so on. Segments are typically between 0.5 and 10 miles long, although longer and shorter segments are possible.

To develop pavement family models, data from similar segments are combined into sets. The idea of a family is that the performance of the pavement sections within the family should be similar. Historic condition data from all pavement sections belonging to a specific family are used to develop a best-fit performance curve for that family. The resulting family deterioration curve is then used to predict future performance of all segments within that family.

For section-specific models, historic performance data for each section is used to develop a best-fit performance for that segment. Establishing a reliable performance model may require three or four data points for each segment. For newly paved segments, this historic data may not exist. As a result, agencies may use a performance curve from a similar section or employ a hybrid approach where a family model is applied to a segment until sufficient historic data are available to reasonably create a pavement-specific model.

Using a family approach typically requires fewer models to be developed and kept up to date, which reduces effort compared to a pavement-specific approach. However, the accuracy of the family approach is limited to the homogeneity of the segments included in the family.

Where agencies want to introduce expert opinion besides data, expert-based modeling can be used. Expert-based models rely on expert opinion to develop models to predict pavement performance, and these are often used on an interim basis while an agency collects the condition or performance data needed to develop deterministic or probabilistic models.

Updating Pavement Management Performance Models

Pavement performance models are based on the analysis of historical pavement performance. Over time, changes in materials, construction techniques, and design standards can alter performance. Therefore, part of the performance modeling process typically includes a method to test the reliability of the models and periodically update them. Reliability of the models can be assessed using any number of statistical approaches, but one of the easiest to understand involves plotting predicted versus measured values. These plots are useful for showing whether the model accurately represents the data over all the limits of the variable.

Models are typically updated on a recurring basis. The frequency of the update depends on results from reliability testing, the maturity of the pavement management system, and the types of models used. For example, if expert opinion weighs heavily in the model development due to a lack of data, the models should be updated as additional performance data become available. A mature system with consistent data collection would require less frequent updating.

Arizona DOT Pavement Design Calibration and Validation

All pavement design methods typically require calibration and validation to ensure they are working properly. With a Mechanistic-Empirical (ME) pavement design process and its numerous inputs, a thorough calibration and validation is even more important. The Arizona DOT pavement management system (Deighton Total Infrastructure Management System, or dTIMS™) has been configured with a custom report that compares the predicted pavement performance from the pavement design using AASHTOWare Pavement ME Design™ software with pavement management system predictions and actual performance. This analysis is used to determine the general reliability of predicted versus actual pavement performance, judge the need to recalibrate their software, and provide data for the calibration process.

Scenario Analysis

A scenario analysis is a summary of the forecasted impacts on the pavement network condition associated with different funding levels or treatment strategies. This is also referred to as a “what if” or “trade-off” analysis. These analyses enable more informed decisions based on the consequences of each of the various options available. The results of the analysis can be reported in several ways, such as overall network conditions, future costs, or progress towards an agency goal. The impacts are usually forecast 10 years into the future, enabling agencies to better understand and communicate the long-term impacts of decisions.

Agencies establish processes to conduct scenarios that predict condition and the work needed based on variable funding with their standard treatment rules in place. The funding scenarios may include categories such as expected funding, expected funding plus ten percent, expected funding minus ten percent, and unrestrained funding. Conversely, constant funding could be applied in a scenario analysis with various amounts designated toward preservation, reconstruction, or various sets of treatment rules applied, ranging from heavily weighted to preservation or heavily weighted to reconstruction.

Generally, scenario analysis is used to determine needed funding levels to maintain a prescribed or desired network condition, to aid in target setting, or to optimize the split of funding to work types for a network. A key factor in developing and running scenario analysis is determining the measure that will be used to convey the results. The measures can be as a single index number to describe the overall pavement condition, a summary of the portions of the network in different condition categories (e.g., good, fair, or poor), or a summary of the backlog costs of unmet needs as discussed in the next section.

Establishing Pavement Measures, Objectives, and Targets

National performance measures have been defined for pavement condition and system performance under 23 CFR part 490. For assessing pavement condition, established performance measures consider ride quality, cracking, rutting, and faulting to assess the percentages of pavement segments in good or poor condition (23 CFR part 490, subpart C). In addition to national performance measures, many State DOTs have established their own measures for assessing and forecasting pavement conditions. Such measures employ different approaches to assessing the level of distress on the pavement surface (e.g., rutting, cracking) or assessing the integrity of the pavement structure (e.g., structural number).

When establishing processes for pavement performance measures, objectives, and targets, basic definitions and nomenclature should be identified and used consistently. For example, pavement distress metrics are a quantifiable indicator of pavement performance or condition; essentially something that can be measured. For pavements, these metrics may include roughness, rutting, cracking, deflection, faulting, and friction.

Pavement distress measures are derived from metrics and used to establish objectives and targets. Measures are typically thought of as miles or percent of network with a smoothness less than a certain threshold, or it could be a cost of deferred maintenance. The national performance measures for pavement condition are the percentage of pavements in good or poor condition (23 CFR 490.307(a)), based on the metrics for roughness, rutting or faulting, and cracking (23 CFR 490.311).

Metrics and Measures

The Federal regulation for Transportation Performance Management defines metrics and measures for the purposes of managing pavements on the NHS. According to 23 CFR 490.101:

- Metric means a quantifiable indicator of performance or condition.
- Measure means an expression based on a metric that is used to establish targets and to assess progress toward meeting the established target.

While the regulation only applies to the NHS (23 CFR 490.103), this concept of metrics and measures can be applied to other performance objectives and targets.

Working with individual metrics within a pavement management system can be challenging because it involves the cross comparison of various pavement distresses with different units of measure (e.g., comparing inches of rutting to linear feet of cracking and square feet of patching). To overcome this challenge, pavement management systems often contain index metrics that utilize a common scale, such as 1 to 10 or 0 to 100. For example, the average rutting for a pavement section in inches may be converted to a rut index, where a pavement section with no rutting would be assigned a rut index value of 100 while a section with 0.5 inches of rutting might be assigned a rut index of 75. Agencies establish these index values based on their perception of the damage or impact of a particular distress metric on the performance of the pavement. Individual indexes are typically used for making treatment decisions.

A composite index is used to simplify the multitude of individual distress indexes that may be utilized in a pavement management system. Composite indexes can be used to compare one pavement section to another and are typically used in pavement management systems to compare the benefits of different treatment scenarios. Some commonly used composite indexes are described below. Use of these or any other composite indexes is not a Federal requirement.

- Pavement Condition Index (PCI) uses a scale of 0 to 100 with 100 representing a pavement exhibiting no distress (ASTM 2020).
- Present Serviceability Rating (PSR), which was developed at the AASHTO Road Test, is based on a visual rating of the pavement against a textual description of condition. PSR rates pavement conditions on a scale of 0 to 5.
- Present Serviceability Index (PSI) also uses a scale of 0 to 5, but the PSI is calculated based on measured distresses.

Another set of pavement management terms that are commonly used are remaining service life (RSL) and remaining service interval (RSI). The RSL concept has been used for decades, though there is no single, clear, widely accepted definition. One application of RSL is predicting the change in pavement condition as a function of time, traffic loading, and environment and using the result for comparing treatment alternatives for a given section of pavement. However, there is uncertainty associated with use of the term “life” to represent different points in a pavement’s construction history. “Life” is interpreted differently by stakeholders, and to use RSL a DOT develops a process that identifies the end of the life of a pavement so that the remaining years of service can be computed for every pavement section (FHWA 2013).

To overcome the RSL shortcomings discussed above, the concept of RSI uses the time remaining until a pre-determined construction event is required, such as resurfacing. The RSI concept does not provide an alternative to assessing the health of the network or making decisions about where to spend the available funds, but rather provides a clear and logical process that will create consistent construction-event-based terminology and understanding (i.e., types of construction events and the timing of those events within the concept of life-cycle cost [LCC], risk analyses, and other prioritization approaches based on streams of future construction events and benefits to facility users). This is similar to a life-cycle planning approach. To use RSI a DOT must establish the construction events corresponding to the intervals to allow computation of the remaining years of service until that construction must take place (FHWA 2013).

Program Development and Project Selection

A common output from pavement management systems is a listing of recommended projects, treatments, and timings for a particular funding level. This information may be broken down by districts or regions within a State or by the functional class of roadways being addressed. Background information may also be provided to inform decision makers of the existing pavement condition as well as the consequences of delaying, accelerating, or modifying the recommended treatment.

The recommendations from a pavement management system can be used to inform planning and programming processes such as developing a TAMP or a STIP. The NJDOT provides an example of how a pavement management system is used to develop a TAMP and then used in conjunction with the TAMP to update the capital program on a more frequent basis (NJDOT 2019). Figure 2 provides a simplified schematic view of the NJDOT statewide program development, but most DOTs have similar processes. NJDOT's process is a three-part process, as described below.

- Policy: Includes NJDOT's strategic plan and policy goals.
- Planning: Includes the Statewide Long-Range Transportation Plan and the Modal and Functional plans.
- Program Development: Includes performance management processes, annual capital program processes, statewide capital investment strategies, and 10-year capital plan and STIP (NJDOT 2019).

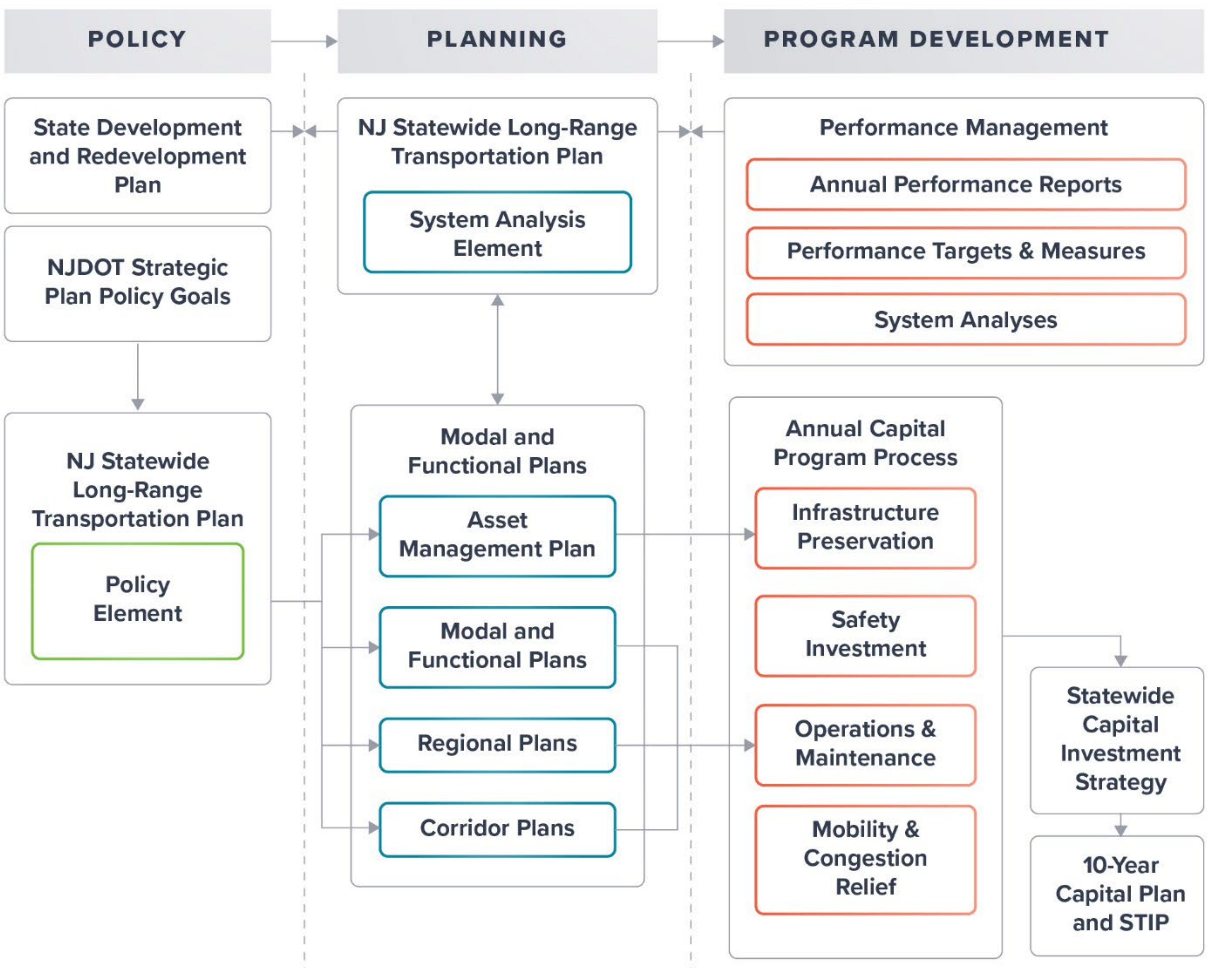

Figure 2. New Jersey DOT's statewide planning and programming process (modified from NJDOT 2019).

The primary products of the New Jersey program development process are the New Jersey STIP, the New Jersey Statewide Transportation Capital Program, Regional Transportation Improvement Plans, and the capital plans of authorities and commissions that own NHS pavement and bridge assets. Every 4 years, New Jersey DOT uses forecasts from its pavement management system to establish 10-year investment strategies in the TAMP. The investment levels for pavement maintenance, preservation, rehabilitation, and reconstruction are then used to support the annual capital program development process.

Supporting Performance Management

Pavement management systems can provide the data and information to support transportation performance management (TPM). This can include the existing condition as well as predicted condition under various funding and treatment scenarios. With the proper procedures, these predicted conditions can be used by decision makers in setting strategic performance targets for an agency and are useful in providing feedback on treatment selection and resource allocation.

To evaluate multiple options, DOTs develop and analyze scenarios that examine funding, investment strategies, performance measures, and targets. The scenarios are used to inform various decision-making processes such as developing the TAMP, STIP, or other programs.

Figure 3 provides an illustration of five scenarios for a pavement network trying to set a target for a performance measure of deferred maintenance. In this example, the network currently has $250 million in deferred maintenance, with the traditional funding levels that are expected to rise and level off at approximately $500 million (solid green line). The other four lines illustrate how the agency could reduce the future levels of deferred maintenance by increasing the amount of future pavement funding.

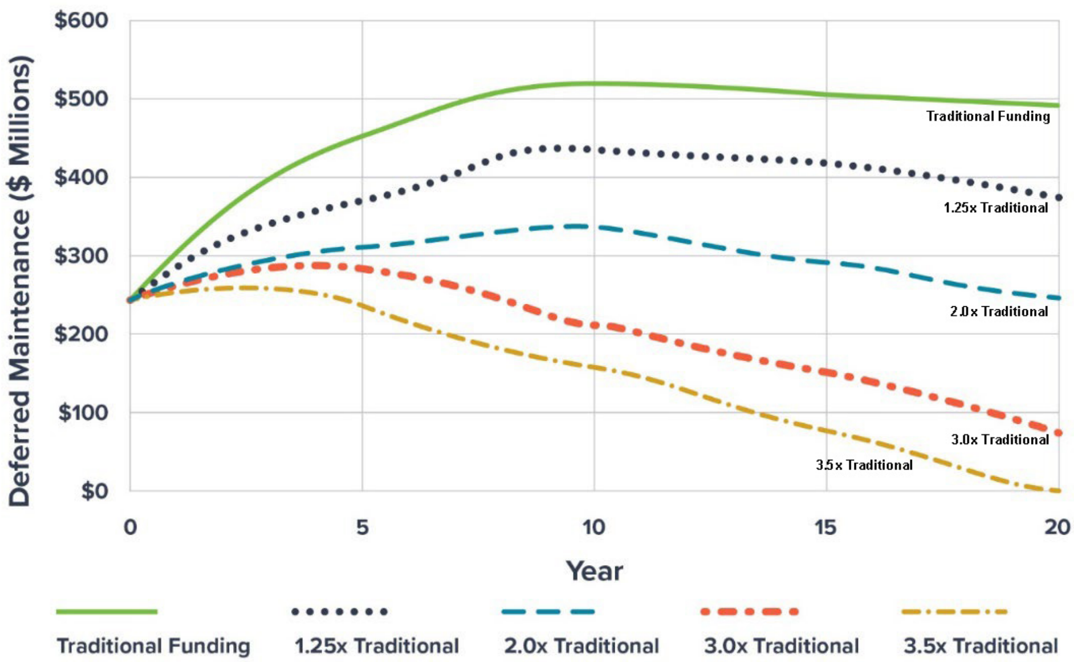

Figure 3. Scenarios of deferred maintenance by funding level.

PAVEMENT MANAGEMENT INPUTS

Pavement management systems use multiple types of inputs to develop forecasts of pavement conditions under different potential scenarios.

Pavement Inventory Inputs

Typical inventory data that may be included in a pavement management system are shown in Table 1.

Table 1. Typical pavement management inventory data (Source: AASHTO 2012).

Category	Pavement Management Data
Attributes	Geographic information system (GIS).
	Segment beginning and end points.
	Route designation along with the route type (Interstate, U.S., County, City).
	Functional classification of the road.
	Segment length.
	Average pavement width.
	Pavement type.
	Shoulder type.
	Shoulder width.
	Number of lanes in each traffic direction.
Pavement history	Work type (i.e., initial construction, maintenance, preservation, rehabilitation, reconstruction).
	Material.
	Thickness.
	Joint spacing.
	Quality of construction.
Traffic	Average annual daily traffic (AADT).
	Average annual daily truck traffic (AADTT) or percent trucks.
	Traffic growth rate.
	Vehicle class distribution.
	Axle load distribution.
	Truck directional and lane distributions.
	Calculated equivalent single axle loads (ESALs).
	Operational speed.
Surface conditions	Roughness.
	Rutting.
	Raveling.
	Oxidation.
	Faulting.
	Spalling.
	Cracking (load related and non-load related).
	Friction.
	Texture.

In addition to these typical inputs that are used by most pavement management systems, there are other inputs that may be used in limited applications. For example:

Structural evaluation of the pavement either through testing with FWD or traffic speed deflection devices (TSDD) may be used to analyze pavement performance.

Special conditions such a flood-prone areas, expansive and unstable subgrades, landslides, etc., can be used to support treatment recommendations or performance model development.

Safety data such as friction, surface texture, or geometric features may support treatment selection or prioritization.

Pavement Funding Inputs

Since agencies operate under budget constraints, it is helpful to forecast the potential conditions that could be achieved from different financial scenarios. The results of such scenario analysis can be used to inform planning and programming decisions.

When setting up a pavement management analysis, funding can be unconstrained or constrained based on several criteria. Depending on the specific pavement management system, funding constraints can be established for any single criterion or combination of criteria. The criteria differ depending on the configuration of each pavement management system but can be generalized as follows.

- Work type constrains limit the amount or portion of total funding that can be spent in each work type category, e.g., preservation, rehabilitation, and reconstruction.
- Time constraints can limit how funding may be budgeted for each year of the analysis. For example, funding can be provided for the entire analysis period (e.g., 10 years for a TAMP) so the system can determine the best way to spend the funding across each year. Alternatively, funding could be budgeted to shorter timeframes within the analysis period, e.g., annual budgets.
- Geographical constraints can limit funding within different geographical areas or organizational units of the agency, such as districts or regions.

In addition to the amount of future funding, pavement management systems can evaluate the impact of the changing purchase power using an inflation rate or a discount rate. Further information on inflation and discount rates can be found in *Using an LCP (Life Cycle Planning) Process to Support Transportation Asset Management: A Handbook on Putting the Federal Guidance into Practice* (FHWA 2019).

Treatments and Triggers

Pavement management systems use treatments to estimate the cost and benefit of doing work on the pavement network. Treatments can range from maintenance, preservation, rehabilitation, or reconstruction. Agencies generally specify multiple treatments within each work type, such as a 2-inch mill and fill overlay. Contractor availability, as well as agency experience, typically factor into the development of the treatment list. For example, hot-in-place recycling can be a practical treatment, but mobilization costs for out-of-state contractors may make it less practical.

For each treatment, the pavement management system includes unit cost data, warrants for use, improvement to condition after application, applicable deterioration model after application, and prioritization rules.

- **Unit costs** provide the cost to construct one unit (typically one lane-mile) of the treatment. Unit costs are normally calculated from actual bid costs. Pavement management systems can accommodate multiple unit costs per treatment to account for price variations across different facility types (e.g., Interstates v. local roads), or geographic regions. Other considerations for unit costs include scope creep and ancillary costs that inflate a pavement project budget but may not necessarily contribute to enhancing pavement network performance. Accounting for and controlling these additional project costs needs to be considered in the pavement program development.

- **Warrants for use** describe the pavement conditions for which the treatment is applicable. These are usually described in terms of trigger rules or decision trees. These establish the set of circumstances where a treatment is considered viable but not necessarily ideal. Warrants for use are generally established based on the pavement type and condition, traffic, class of roadway, and specific distress values.
- **Improvements to conditions after application** indicate the level of improvement to conditions that the system will assume if a treatment is selected. The improvement to condition will typically be applied in the year the treatment is selected. Different treatments will provide different levels of improvement. For example, a reconstruction will typically reset the surface and structural condition of a pavement segment to new condition. Other treatments, such as a chip seal, may provide a partial or complete resetting of surface conditions but not impact structural condition while crack sealing may not impact forecasted conditions at all.
- **Deterioration model after application** informs the system on how the pavement is expected to deteriorate after the treatment is selected. This may be based both on the treatment that is selected and the pavement type and conditions to which the pavement is applied. The pavement management system uses the indicated model to forecast pavement conditions beginning the year after the treatment is selected and continuing until another treatment is selected that uses a different model.
- **Prioritization rules** enable the system to determine which potential treatments are typically preferred when the total cost of potential treatments exceeds available funding. The Pavement Management Guide (AASHTO 2012) listed the three principal methods as ranking, prioritization (incremental benefit cost), and optimization. Key to any of these approaches is how an agency decides to calculate the benefits of a treatment over its service life. Benefits are typically identified in terms of pavement roughness over time, pavement composite surface condition index over time, or the remaining service life or index of a treatment.

PAVEMENT MANAGEMENT OUTPUTS

Commercially available pavement management software can produce multiple standards and customized reports. The typical outputs (AASHTO 2012) are:

- An assessment of the funding level needed to reach a targeted performance level.
- Recommendations for the optimal use of available funding.
- Estimated future pavement conditions for different treatment and investment scenarios.

Since the principal function of a pavement management system is to develop recommendations for treatments and projects that provide the best pavement condition at the least practical cost, the second bullet listed above is key. This analysis should be run beyond a single year to provide decision makers with the most meaningful information. A 10-year analysis should be considered as a minimum.

Users can also produce summaries of the data sorted in various fashions. Many users also find GIS representations of the data and analysis very valuable. A useful interface for the data and information to the end user contributes to the effective use of the pavement management system.

Utah DOT Example of a Pavement Management Output: A Plan for Every Section

A key to a successful pavement management system is the ability to use data to create meaningful, actionable information. The Utah DOT uses pavement management data to create a plan for every section of every road. For each road segment, the Utah DOT pavement managers develop a pavement preservation plan that takes into account the type of road, the amount of traffic, and the expected life of the roadway. Each surface maintenance treatment is tracked and the next optimal treatment is planned. Applying the right treatment at the right time prevents serious damage. A seriously damaged road will need costly major rehabilitation or full reconstruction sooner than anticipated (Zavatski 2008).

THE LINKS BETWEEN ASSET MANAGEMENT, PAVEMENT MANAGEMENT, AND PAVEMENT DESIGN

Pavement management provides the majority of organizational, procedural, and informational links between pavement design and transportation asset management (TAM). TAM is a strategic and systematic network-level process (23 CFR 515.5) that leads to the development of a TAMP and investment strategies over a 10-year period or longer (23 CFR 515.7). In contrast to TAM, pavement design is a project-specific process that seeks to establish the best engineering solution within project scope, budget, and other constraints. Pavement management supports both short- and long-term decision making through the analysis of current and historic pavement data.

Arizona DOT Example Linking Pavement Management to Asset Management

Effective feedback is a part of many management approaches adopted by companies and government agencies around the country. The State of Arizona and the Arizona DOT (ADOT) have adopted a lean management approach as part of their continuous improvement activities. Included in this approach is an eight-step Plan-Do-Check-Act (PDCA) process.

ADOT has initiated an Infrastructure Prioritization Team to apply the PDCA process to the management of bridges and pavements. The team includes representatives of the pavement management and design sections. Many improvements are being considered including steps that will improve the coordination between the pavement management and pavement design sections in the planning process.

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