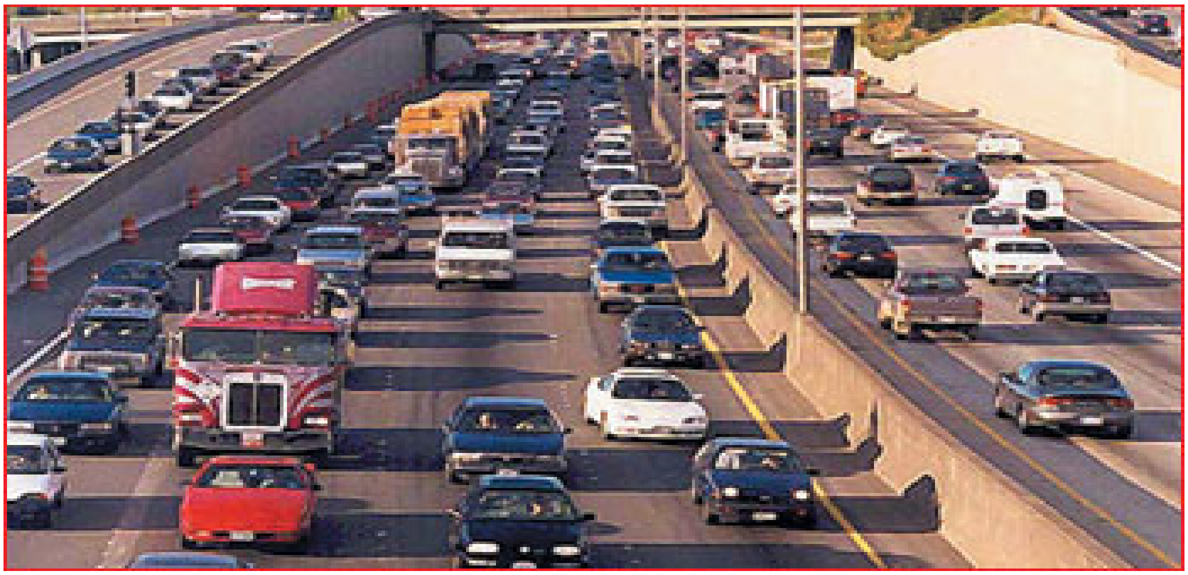
Report

WSDOT's Estimate of Long-Term Highway Maintenance and Preservation Needs



Prepared For:

Joint Legislative Audit and Review Committee

Scanlan Consulting

Applied Pavement Technology

Paul D. Thompson

September 2, 2014

Recommendations in “WSDOT’s Estimate of Long-Term Highway Maintenance and Preservation Needs” represent consultants’ professional opinions and do not necessarily reflect the opinions of the Legislative Auditor. The Legislative Auditor’s recommendations can be found in JLARC’s summary report, available through this link. .

Executive Summary

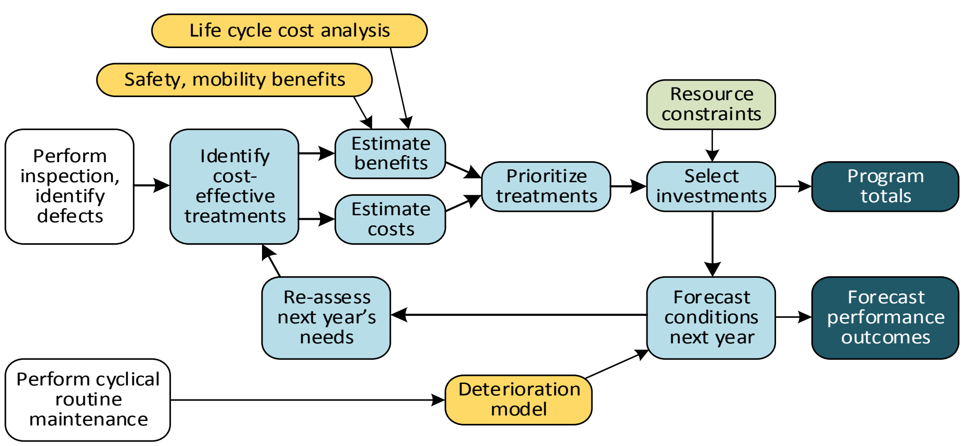
The Legislature in the 2013-15 biennium transportation budget directed the Joint Legislative Audit and Review Committee (JLARC) to review the methods and systems used by the Washington State Department of Transportation (WSDOT) to develop asset condition and maintenance service level needs and subsequent funding requests for highway preservation and maintenance programs. This report is part of the second phase of the JLARC review and addresses four research questions:

1. Are the methods and systems WSDOT uses to develop long-term (10-year) estimates of highway maintenance and preservation needs consistent with industry practices and other appropriate standards?
2. Are practices in place to minimize life cycle preservation and maintenance costs?
3. How accurate is the information that is used to develop long-term estimates of maintenance and preservation need?
4. How does WSDOT quantify risks to its need and cost estimates?

This report also includes a review of how other state Departments of Transportation report long-term pavement and bridge maintenance and preservation needs to state legislatures.

Transportation needs assessment

As shown in the figure below, pavement, bridge, and other transportation asset needs assessment begins with identifying defects and performing cyclical routine maintenance to slow the rate of deterioration. Investments are selected based on life cycle cost analysis of alternative treatments, the use of deterioration models to forecast conditions, and resource constraints. Over ten years (the period in Research Question 1), the needs each year depend on the work that can be completed in earlier years (given fiscal constraints), combined with the deterioration that occurs at the same time. All of the steps are necessary in order to capture the combined effects of multi-year decision making (on funding and programming) and deterioration.



Steps in Transportation Needs Assessment. Source Paul D. Thompson from AASHTO Guide for Transportation Assessment Management: Volume 2 – A Focus on Implementation (Gordon et al 2011)

Pavement

WSDOT manages 18,500 lane-miles of mainline pavement. WSDOT's performance goal is for 92 percent of its mainline pavement to be in fair or better condition. WSDOT was near this goal in FY 2012, with 91.8 percent of its mainline pavement in fair or better condition. With the predicted reduction in funding, WSDOT projects that 74 percent of its mainline pavement will be in fair or better condition by 2018.

Research Question 1.

Are the methods and systems WSDOT uses to develop long-term (10-year) estimates of maintenance and preservation needs consistent with industry practices and other appropriate standards?

The methods and systems WSDOT uses to develop long-term estimates of pavement maintenance and preservation needs ***are consistent*** *with industry practices and other appropriate standards*.

WSDOT's Washington State Pavement Management System (WSPMS) is a state of the practice system. The WSPMS, which develops pavement performance models for each individual pavement section in the highway network, is robust and is continuously updated and re-calibrated as new performance data is collected.

The WSDOT pavement condition estimating practices were assessed based on five business practices in the American Association of State Highway and Transportation Officials (AASHTO) Pavement Management Guide: pavement inventory and data collection; pavement condition assessment and reporting; pavement management system framework; pavement performance modeling; and project and treatment selection.

Two small gaps between best practices in the Pavement Management Guide and WSDOT's practices were found. One of these gaps is in the documentation of treatment selection options and the other is in the consideration of earlier pavement treatments. The gap in the consideration of earlier pavement treatments is discussed in Research Question 2 Life Cycle Cost Analysis.

The findings on how WSDOT's pavement condition estimating practices conform to industry practices and other appropriate standards is summarized in the figure below.

WSDOT has a solid base	• In managing the state's pavements, it meets or exceeds typical state practice in most areas, including condition collection and processing, performance modeling, and program development
Areas for improvement	• Consideration of additional, early preventive maintenance treatments • Documentation of treatment selection criteria to guide decision makers • Incorporation of maintenance costs into pavement life cycle cost analysis
Importance	• WSDOT accurately projects long-term pavement needs that minimize life cycle cost • WSDOT employs an effective pavement preservation program • The Legislature has the ability to consider fiscal and program alternatives based on accurate data and thorough analysis

Summary of pavement Research Question 1 findings.

WSDOT, in conformance with the Pavement Management Guide:

- Programs and prioritizes projects through an objective, data-driven process that includes documentation of the expert opinions of WSDOT region and State Material Laboratory staff.
- Programs pavement projects only when they are due to ensure that the maximum service life from a given treatment is realized. WSDOT's primary objective is to avoid complete reconstruction activities. By avoiding or significantly deferring reconstruction WSDOT decreases overall life cycle costs and long-term network funding needs.
- Develops the biennium list of projects in a comprehensive fashion that produces reliable and accurate estimates of the needs.
- Has an institutional framework in which pavement needs can be systematically, completely, and consistently developed and reported to the Legislature and other stakeholders.
- Has a process to consider network-level investment alternatives; to optimize the allocation of resources; to estimate the cost of a given set of performance targets; and to estimate the performance and backlog which might result from a given investment level.
- Has reasonably well documented its needs estimation process and that process is repeatable.
- Ensures consistency in data management, analysis and reporting practices through a user manual and data dictionary. WSDOT also inspects 100 percent of selected lane(s) of the pavement network. This improves the overall accuracy of the pavement condition data reported when compared to agencies that use a sampling approach. The WebWSPMS application dynamic segmentation also helps WSDOT better distinguish between localized maintenance needs and planning-level needs and generate reliable needs estimates.

Pavement recommendation 1. WSDOT could improve its pavement management practice by documenting its treatment selection process to guide future decision-makers.

Research Question 2.

Are practices in place to minimize life cycle preservation and maintenance costs?

*WSDOT **incorporates life cycle cost analysis** in its pavement management process.*

WSDOT's use of life cycle analysis in its pavement management process was compared with four life cycle capabilities provided by AASHTO and Federal Highway Administration (FHWA) guides. These capabilities are: project-level treatment criteria; network-level life cycle cost; integrating maintenance and preservation; and backlog estimation and scenarios.

WSDOT follows best practices by:

- Planning the application of pavement preservation treatments (such as mill and overlay for flexible pavements and dowel bar retrofit for concrete pavements) to occur during a due year. The due year is the estimated optimum point in time that extends the service life of the existing pavement at the lowest life cycle cost.
- Prioritizing projects using a multi-criteria decision making approach so that, under constrained budget scenarios, it can target the available funds on projects which provide the greatest return on investment. This prioritization approach is employed by most state highway agencies within their pavement management processes and is considered best practice.

WSDOT could improve its practices by:

- Giving greater consideration to relatively low-cost preventive maintenance treatments such as fog seals and microsurfacings for its hot mix asphalt and chip seal pavements that can be placed earlier in the life of the pavement (or after a late-in-life preservation treatment) to further extend pavement life and defer costly rehabilitation and reconstruction. These treatments would need to be analyzed in Washington State conditions to determine whether they would improve pavement life here.
- Including the cost of routine or reactive maintenance in its life cycle cost analysis process. Although these maintenance costs are difficult to extract and are also relatively small (in comparison with other life cycle cost elements), they should be included within the cost analysis. WSDOT has developed some new tracking software and procedures that should help it incorporate routine maintenance costs in the future.

Pavement recommendation 2. Pavement life cycle cost analysis could be improved by considering earlier treatment timing for asphalt and chip seal pavements and by incorporating operating and routine maintenance costs into the analysis.

Research Question 3.

How accurate is the information that is used to develop long-term estimates of maintenance and preservation needs?

*The information that WSDOT uses to develop long-term estimates of pavement maintenance and preservation needs **is accurate.***

To determine the accuracy of pavement data, the calibration of the automated pavement data collection equipment used by WSDOT was reviewed. The calibrations are in line with industry standards and practices and ensure that the data collected is accurate.

The consultants also undertook an independent review of pavement surface condition ratings. WSDOT uses three pavement condition measures to develop its long-term needs projections. Of the three condition ratings, only the pavement surface condition rating involves review by WSDOT pavement surveyors. The pavement data collection van is used to collect high resolution downward and right of way imagery that are then visually inspected by WSDOT pavement condition surveyors in the office to develop condition ratings.

The consultants' independent evaluator reviewed eight 1-mile sections (four asphalt and four concrete), examining the same electronic images and using the same software tools as the WSDOT surveyors. The resulting pavement surface conditions ratings by the independent evaluator were similar to those of the WSDOT surveyors.

Research Question 4.

How does WSDOT quantify risks to its need and cost estimates?

WSDOT ***incorporates systemic risk*** *in its long-term estimates of pavement needs but* ***does not incorporate site specific risk. Not incorporating site specific risks*** *into pavement long-term needs estimates* ***is industry practice and is not recommended.*** *WSDOT* ***is exceptional*** *in its consideration of* ***risk in pavement project priority setting****.*

Two categories of risk were reviewed: systemic risks, which include market fluctuations, budget restrictions, and insufficient or inaccurate data; and site-specific risks, which include sudden condition-related failure, natural hazards and climate change impacts, and man-made hazards.

WSDOT considers systemic risk in its long-term estimates of pavement needs. The Department does not consider site-specific risks in its long-term estimates, which is appropriate. Site specific risks are localized and, in the rare circumstances where catastrophic failure occurs, have little to no impact on network level conditions.

WSDOT is exceptional among state Departments of Transportation in its integration of risk into its pavement project prioritization process.

Bridges

WSDOT manages nearly 3,800 bridge structures. WSDOT's performance goal is to have 97 percent or more of its bridges in fair or better condition. In FY 2013 WSDOT was near this goal, with 96 percent of its bridges in fair or better condition. A projection of anticipated changes in condition as a consequence of reduced funding in the 2013-15 biennium 16-year capital plan is not available.

Research Question 1.

Are the methods and systems WSDOT uses to develop long-term (10-year) estimates of maintenance and preservation needs consistent with industry practices and other appropriate standards?

The methods and systems WSDOT uses to develop long-term estimates of bridge maintenance and preservation needs ***are not completely consistent*** *with industry practices and other appropriate standards.*

Similar to the way in which WSDOT uses the WSPMS to conduct the transportation needs assessment steps for pavements, most state Departments of Transportation use bridge management systems to perform these same needs assessment steps for bridges. A bridge management system is:

- A *set of* procedures, data, and analysis tools.
- Used *to support agency decision making* in the planning of future preservation, maintenance, improvements, and replacements of existing structures.
- Intended to *achieve a desired level of service in the most cost-effective manner.*

Although WSDOT collects and maintains bridge data, it does not use a bridge management system to support the development of a needs assessment or manage state bridges, unlike most other states.

A 2010 FHWA survey found that states vary in the degree to which they use bridge management system capabilities. The survey identified a number of issues that FHWA is working on to encourage the adoption of bridge management system standards by states, including: greater use of life cycle cost analysis; use of analytical software products, methods, or tools to predict deterioration; and documentation of bridge management practices.

> *Emphasizing the use of a bridge management system to assist bridge owners in being able to do the right activity, to the right bridge, at the right time and at the right cost is paramount to preserving our transportation infrastructure in general and our highway bridges in particular*. (FHWA http://www.fhwa.dot.gov/Bridge/management/index.cfm.)

WSDOT licensed an AASHTO bridge management system that was discontinued by AASHTO in 2009. WSDOT uses its Washington State Bridge Inventory System, that aggregates bridge inventory and condition data, and a biennial process that relies heavily on professional judgment to develop project lists, prioritize needs, and estimate future performance.

WSDOT's bridge needs estimation practices were assessed based on 17 steps derived from AASHTO and FHWA guides. These 17 steps are categorized into four business processes: bridge inventory and condition data; estimation of current needs; estimation of future needs and performance; and prioritization.

The findings on how WSDOT's bridge condition estimating practices conform to industry practices and other appropriate standards is summarized in the figure below.

WSDOT has a solid base	• Excellent bridge inventory and condition data • Strong ability to estimate current needs
Areas for improvement	WSDOT can partially • Project future needs and conditions (for some areas such as bridge painting) • Objectively prioritize program-wide needs (by broad category) WSDOT cannot • Calculate life cycle costs • Consider alternative fiscally-constrained programs • Relate levels of funding to long-term bridge conditions
Importance	• Limits WSDOT's ability to accurately project long-term bridge needs that minimize life cycle cost • Limits the Legislature's ability to consider fiscal and program alternatives

Summary of bridge Research Question 1 findings.

WSDOT is compliant with industry norms in its inventory and condition data. With a few exceptions it is also compliant in the development of current needs based on past inspection data. This provides WSDOT with a strong foundation for projecting long-term needs.

WSDOT's capabilities are much more limited in assessing needs over a long-term (10-year) period. The ability to consider needs over a 10-year period is important – it allows state Departments of Transportation to provide accurate projections of the impact of funding and program decisions on the future condition of state bridges and it allows legislatures and other decision-makers to consider data-driven alternatives. Key areas in which WSDOT does not meet industry practices and other standards include:

- WSDOT does not have the deterioration models used by most states for forecasting future needs. The lack of these models limits the ability of WSDOT to forecast: 1) the future cost of needs resulting from deterioration; and 2) the future condition of the inventory that results from the combined effects of deterioration and on-going investments in preservation and maintenance.
- WSDOT uses professional judgment to project changes in the condition of bridges at the network level at various funding levels. The use of judgment for this type of network-level forecast is not common practice and is not supported by industry guidebooks. Network-level projections should be based on validated, quantitative analysis of bridge deterioration and the effectiveness of alternative treatments. The projections should be able to consider network-level investment alternatives; to optimize the allocation of resources; to estimate the cost of a given set of performance targets; and to estimate the performance and backlog which might result from a given investment level.
- WSDOT does not have an institutional framework in which bridge needs can be systematically, completely, and consistently developed and reported to the Legislature and other stakeholders.

Bridge recommendation 1. WSDOT should improve its bridge analysis methods, decision support tools, documentation and staff training in order to provide systematic, complete, and consistently developed estimates of bridge needs. WSDOT should implement best practices including deterioration models from element condition data, unit costs from statistical analysis of capital and maintenance work accomplishment data, effectiveness metrics from statistical analysis of work accomplishment and inspection data, and life cycle cost analysis.

Research Question 2.

Are practices in place to minimize life cycle preservation and maintenance costs?

WSDOT ***does not incorporate life cycle cost analysis*** *in its bridge management process.*

WSDOT's use of life cycle analysis in its bridge management process was compared with five life cycle capabilities provided by AASHTO and FHWA guides. These capabilities are: asset-level life cycle cost; project-level treatment criteria; network-level life cycle cost; integrating maintenance and preservation; and backlog estimation and scenarios.

WSDOT does not have practices in place to routinely estimate or to minimize bridge life cycle preservation and maintenance costs. WSDOT:

- Uses preservation and maintenance strategies at the project level that are based on staff understanding of best practice rather than on a WSDOT calculation of life cycle cost.
- Has not documented the tradeoff between routine bridge maintenance and longer-term preservation expenditures.
- Has prepared estimates that are not clearly defined, and do not consider sustainable fiscal scenarios or life cycle costs for addressing bridge preservation and maintenance backlogs.

Bridge recommendation 2. WSDOT should establish a routine framework where calculations of life cycle cost are expected as a justification for bridge maintenance budgets or bridge needs estimates. WSDOT should compute, and document, the performance levels and policies that minimize life cycle costs, and should compute its backlog as the additional near-term cost required in order to attain optimal long-term performance.

Research Question 3.

How accurate is the information that is used to develop long-term estimates of maintenance and preservation needs?

The information that WSDOT uses to develop long-term estimates of bridge maintenance and preservation needs ***is accurate.***

The consultants reviewed the 2008-13 annual FHWA Quality Assurance Review reports which include 23 metrics.

With the exception of some fracture critical bridges, the quality of bridge inventory and condition data within the National Bridge Inspection Standards as audited and monitored by the FHWA Quality Assurance Review Process is excellent for needs assessment purposes. For fracture critical bridges, WSDOT is currently implementing a best practice of bridge washing that will, by January 2017, improve the quality of data on these 187 bridges for needs assessment purposes.

Research Question 4.

How does WSDOT quantify risks to its need and cost estimates?

WSDOT ***quantifies*** *the effect on bridge preservation and maintenance needs* ***of systemic risks and site-specific risks from structural deficiency and natural hazards. It does not consider risk from man-made hazards****. WSDOT* ***does not*** *consider* ***risk in bridge project priority setting*** *which is an exceptional practice in some states.*

Two categories of risk were reviewed: systemic risks, which include market fluctuations, budget restrictions, and insufficient or inaccurate data; and site-specific risks, which include risks from structural deficiency, natural hazards and climate change impacts, and man-made hazards.

WSDOT considers systemic risk in its long-term estimates of bridge needs. WSDOT has projects and processes to address major site-specific risks from structural deficiency, scour, and earthquakes. WSDOT does not have a process for estimating risks from man-made hazards such as collisions and truck overloads. WSDOT does not consider risk in bridge project priority setting.

WSDOT would benefit from an objective process to determine how much it should spend on earthquake and scour projects and similar site-specific risk projects. Such a process would consider other Department priorities and fiscal constraints. This is not yet common practice, but it is best practice.

Bridge recommendation 3. WSDOT should develop a bridge risk register and quantitative tools for risk assessment and risk management to enable it to consider risk in priority setting.

Legislative Reporting

WSDOT is not required to routinely provide information to the Legislature on long-term bridge and pavement preservation needs. Such information is provided to the Legislature on a periodic basis in the Gray Notebook and in response to specific legislative mandates.

A 50 state web based review of state Departments of Transportation found seven exceptional states in which the Legislature receives regular reports on long-term bridge and/or pavement preservation and maintenance needs. These states have, in the consultants' judgment, the following key practices:

- Use of pavement and bridge management systems to project network level conditions.
- The long term condition projections relate condition to alternative future funding levels.
- The long term projections are tied to the budget process.
- The long term projections are tied to performance goals and performance measures.

Legislative reporting recommendation. The Legislature should consider requiring that WSDOT provide it reports on long-term bridge and highway preservation needs as part of the budget process and/or in the biennial Transportation Attainment Report.

Table of Contents

Introduction

Washington State faces declining revenues to support state transportation needs and increasing costs to maintain and preserve the existing highway system and make safety, capacity and multi-modal improvements. These financial constraints are reflected in projected reductions in state highway preservation funding in the 2013-15 biennium 16-year capital plan. The Legislature has been considering options to fund transportation and to make the delivery of the transportation program more efficient.

Against this backdrop, the 2013 Legislature directed the Joint Legislative Audit and Review Committee to review the methods and systems used by the Washington State Department of Transportation (WSDOT) to develop asset condition and maintenance service level needs and subsequent funding requests for highway preservation and maintenance programs.

This report addresses four interrelated research questions about how WSDOT estimates and reports to the Legislature the long-term preservation and maintenance needs of state highway pavements and bridges. WSDOT's 18,500 miles of state highways and its nearly 3,800 bridge structures form the bulk of state-owned transportation infrastructure. The maintenance and preservation of these assets is critical to the state's economy and to the mobility and safety of drivers.

This report finds that for pavements, WSDOT meets, and in many ways, exceeds industry standards for estimating its long-term (10-year) maintenance and preservation needs, in minimizing life cycle costs, and in quantifying risk. The information on which it bases these assessments is accurate. Projections provided about the impact of funding reductions on pavement conditions can be relied upon to be reasonable and accurate data-driven projections.

In contrast, this report finds that for bridges, WSDOT does not meet all industry standards. Importantly, WSDOT meets or exceeds industry standards in its collection of bridge inventory and condition data. The accuracy of its bridge data means that WSDOT has a strong foundation upon which it can build the capacity to improve its estimation of long-term bridge maintenance and preservation needs, ensure that its management results in the lowest life cycle costs, and consider risk in project prioritization. Projections provided about the impact of funding reductions on bridge conditions reflect the professional judgment of the WSDOT staff. These projections can be improved with stronger analytical systems and capability.

This report recommends that the Legislature consider requiring WSDOT to provide regular reports on long-term pavement and bridge maintenance and preservation needs as part of the budget process or as part of the on-going legislative performance reporting in the biennial Transportation Attainment Report. Such reports would provide the Legislature with vital information about the effect of its funding and other decisions on the performance of the state's pavements and bridges.

Purpose and Approach

Purpose

The Legislature in the 2013-15 transportation budget (Engrossed Substitute Senate Bill 5024) directed the Joint Legislative Audit and Review Committee (JLARC) to review the methods and systems used by WSDOT to develop asset condition and maintenance service level needs and subsequent funding requests for highway preservation and maintenance programs.

The Legislature directed JLARC to conduct its review in two phases, with the first phase being an overview of the methods and systems WSDOT uses to develop estimates of maintenance and preservation needs and documentation for those methods and systems.[1] An examination of the reliability and validity of WSDOT's methods and systems for assessing maintenance and preservation needs is the second phase.

This report addresses four research questions specifically focusing on state highway pavements and bridges in support of the second phase effort:

1. Are the methods and systems WSDOT uses to develop long-term (10-year) estimates of highway maintenance and preservation needs consistent with industry practices and other appropriate standards?
2. Are practices in place to minimize life cycle preservation and maintenance costs?
3. How accurate is the information that is used to develop long-term estimates of maintenance and preservation need?
4. How does WSDOT quantify risks to its need and cost estimates?

This report also includes a review of how other state Departments of Transportation report long-term pavement and bridge maintenance and preservation needs to state legislatures.

Approach

This report relies on information from interviews with WSDOT staff, reviews of WSDOT reports, and the consultants' research and documentation of industry standards and practices. Industry standards and practices were drawn from Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO), Transportation Research Board (TRB), National Cooperative Highway Research Program (NCHRP), American Society for Testing and Materials (ASTM), and other publications.

The consultants conducted a web search of the fifty state Departments of Transportation to review legislative reports on long-term preservation and maintenance needs.

A complete list of references is included at the end of this report.

[1] Joint Legislative Audit and Review Committee, Total Highway Maintenance and Preservation Estimates Are Available, Phase 1 Briefing Report, January 7, 2014.

Transportation Needs Assessment

The four research questions addressed in this report are related to assessing long-term transportation needs. The AASHTO Guide for Transportation Assessment Management: Volume 2 – A Focus on Implementation (Gordon et al 2011) shows the progression in developing long-term transportation needs assessments for pavements, bridges, and other transportation assets.

As shown in figure 1 below, needs assessment begins with identifying defects and performing cyclical routine maintenance to slow the rate of deterioration. Investments are selected based on life cycle cost analysis of alternative treatments, the use of deterioration models to forecast conditions, and resource constraints.

Carrying out these steps provides a year-by-year estimate of program resource requirements, and a year-by-year forecast of performance outcomes. Over ten years the needs each year depend on the work that can be completed in earlier years (given fiscal constraints), combined with the deterioration that occurs at the same time. All of the steps are necessary in order to capture the combined effects of multi-year decision making (on funding and programming) and deterioration.

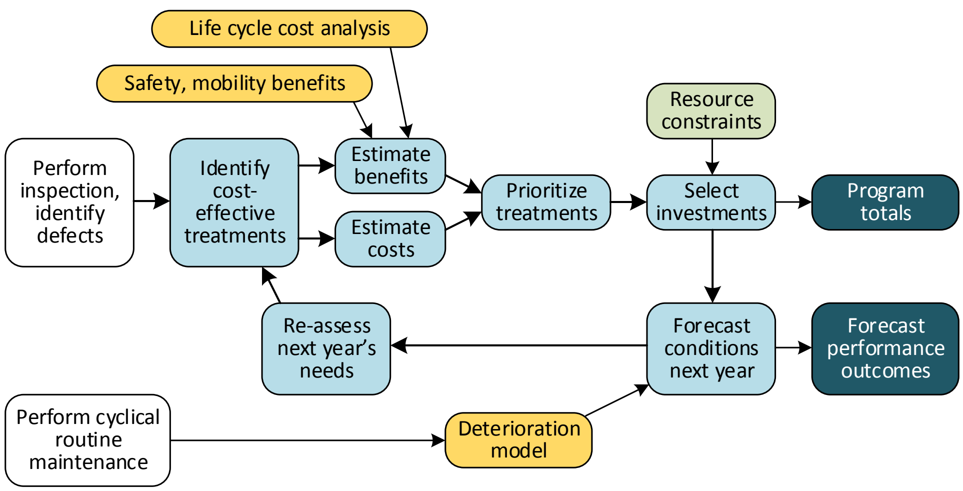


Figure 1. Steps in Transportation Needs Assessment. Source Paul D. Thompson from AASHTO Guide for Transportation Assessment Management: Volume 2 – A Focus on Implementation (Gordon et al 2011)

State Departments of Transportation use databases and an accompanying set of automated analysis procedures to develop long-term estimates of highway maintenance and preservation needs. These databases and analysis procedures are referred to as pavement management systems and bridge management systems. All state Departments of Transportation have separate systems and methods for pavements and bridges.

MAP-21

The Moving Ahead for Progress in the 21st Century Act of 2012, MAP-21, imposes new requirements on states that make transportation needs assessment more critical. MAP-21 requires each state to establish performance targets for the National Highway System, and provides sanctions for states which do not achieve the targets. For bridges, the law specifies that a maximum 10 percent of the total deck area of

National Highway System bridges may be classified as structurally deficient. Other targets, including for pavements, may be set by the states under rules that FHWA is currently developing.

To describe how each state intends to develop and meet its targets, MAP-21 requires a Transportation Asset Management Plan. The language of the Act makes clear reference to the requirement for analysis of life cycle cost and performance, and explicitly ties funding to performance.

Life cycle cost and life cycle cost analysis

Life cycle cost analysis is a critical step in transportation needs assessment. Life cycle cost (LCC) refers to a range of costs, which can include user and agency costs, associated with initial construction and future maintenance, rehabilitation, reconstruction, and salvage value of an asset.

Life cycle cost analysis (LCCA) is a tool to support long-term pavement and bridge management decisions. LCCA involves defining specific alternatives for a given asset or assets and then computing the stream of costs over time resulting from each alternative. By comparing two or more alternatives, LCCA can be used to identify the alternative that is most cost effective.

LCCA is used at the project, network, and systems level.

- *At the project level,* LCCA is used to identify the most cost-effective design for a new, reconstruction, or rehabilitation project.
- *At the network level*, LCCA is used in the development of maintenance policies and in the development of ten-year needs estimates to allocate the correct amount of funding to preservation and maintenance activity (as opposed to rehabilitation and replacement) to minimize long term costs.
- *At the systems level*, LCCA is for used multi-objective prioritization of projects. When a project has safety, mobility, or environmental benefits, these benefits can be monetized.

Pavement

Summary Research Questions Responses & Recommendations for Improvement

Research Question 1. The methods and systems WSDOT uses to develop long-term estimates of pavement maintenance and preservation needs **are consistent** with industry practices and other appropriate standards.

> *Pavement recommendation 1. WSDOT could improve its pavement management practice by documenting its treatment selection process to guide future decision-makers*.

Research Question 2. WSDOT **incorporates life cycle cost analysis** in its pavement management process.

> *Pavement recommendation 2. Pavement life cycle cost analysis could be improved by considering earlier treatment timing for asphalt and chip seal pavements and by incorporating operating and routine maintenance costs into the analysis.*

Research Question 3. The information that WSDOT uses to develop long-term estimates of pavement maintenance and preservation needs **is accurate**.

Research Question 4. WSDOT **incorporates systemic risk** in its long-term estimates of pavement needs but **does not incorporate site specific risk. Not incorporating site specific risks** into pavement long-term needs estimates **is industry practice and is not recommended.** WSDOT **is exceptional** in its consideration of **risk in pavement project priority setting**.

WSDOT pavements

WSDOT manages 18,500 lane-miles of mainline pavement and over 2,000 additional lane-miles of special use and ramp pavements. The mainline pavements are composed of three types:

- *Hot mix asphalt (HMA).* Fifty-eight percent (58%) of the state's mainline pavements are hot mix asphalt, which is a pavement that typically has an asphalt surface and a granular (stone) base. The average life of asphalt in Western Washington is 16-17 years and in Eastern Washington it is 10-11 years.
- *Chip seal.* Twenty-nine percent (29%) of the state's mainline pavement surface is chip seal, which is constructed by rolling stones into a thin layer of asphalt emulsion, which when cured provides a durable pavement surface for 6-8 years.
- *Concrete.* Thirteen percent (13%) of the state's mainline pavement surface is concrete. New concrete pavements are designed for a 50-year life and are typically constructed where high volumes of truck traffic occur.

Figure 2 shows the distribution of mainline pavement inventory by pavement type.

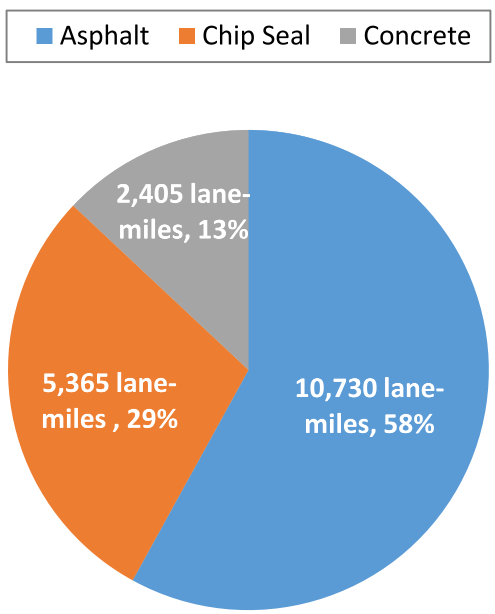
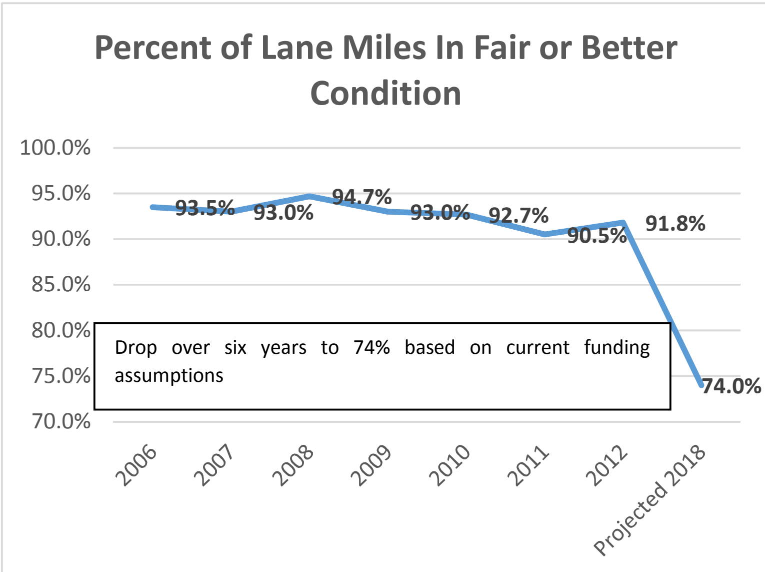


Figure 2. Distribution of mainline pavement inventory by pavement type. (Source WSDOT Pavement Asset Management Report, March 2014)

Pavement performance goals

The preservation goal for WSDOT pavements in the December 2013 Gray Notebook is to have 92 percent or more of WSDOT pavement in fair or better condition.



As shown in figure 3, WSDOT met the 92 percent goal until 2011. The December 2013 Gray Notebook projects a decline in the percent of pavements in fair or better condition over a six-year period to 74 percent by 2018 with existing funding.

Figure 3. Percent of mainline pavement inventory in fair or better condition. (Sources WSDOT Gray Notebook, Dec. 2013 and Dec. 2014 and Office of Financial Management 2012 Biennial Transportation Attainment Report)

Pavement preservation funding

2013-15 biennium 16-Year Capital Plan

The 2013-15 biennium 16-year capital plan projects a decline in funding for pavement preservation from $259.5 million in the 2013-15 biennium to a low of $103.2 million in the 2017-19 biennium. The average biennium funding for pavement preservation is $177.0 million from the 2015-17 through the 2027-29 biennium.

Table 1. 2013-15 16-year capital plan for pavement and bridge preservation. (Source Legislative Evaluation and Accountability Program 2014-2 Program P)

($ in millions)	13-15	15-17	17-19	19-21	21-23	Three Biennia 23-29
Chip Seal Roadways Preservation	62.9	43.5	0.6	2.4		
Asphalt Roadways Preservation	141.6	36.0	16.9	157.0	186.8	415.1
Concrete/Dowel Bar Retrofit Preservation	55.0	144.9	85.7	48.2	28.8	73.1
Total Pavement Preservation	**259.5**	**224.4**	**103.2**	**207.6**	**215.6**	**488.2**

Unfunded System Investments

In the 2014 legislative session, the Legislature considered additional funding for transportation. To inform that exercise, WSDOT prepared a list of its priorities for new revenue referred to as the Orange

List.[2] As shown in table 2, the list included funding to provide a 10-year preservation investment to achieve pavement condition in excess of 97 percent fair and good or 99 percent in the optimal higher investment level.

Table 2. WSDOT Priorities for New Revenue – 2013

WSDOT 2014 Orange List	**Recommended Priority Investment Level ($ millions)**	**Optional Higher Investment Level ($ millions)**
Pavement Preservation	$1,392 *10-year investment 97% fair and good*	$1,819 *10-investment 99% fair and good*

Research Question 1.

Are the methods and systems WSDOT uses to develop long-term (10-year) estimates of maintenance and preservation needs consistent with industry practices and other appropriate standards?

WSDOT's pavement management system and business practices are compared with the practices described in the *AASHTO Pavement Management Guide* (AASHTO 2012). WSDOT's practices were determined from interviews and reviews of: *Pavement Asset Management* (WSDOT 2014a), *Modeling and Analyzing Budget Constrained Pavement Preservation Strategies* (WSDOT 2014b), *Evaluation of Maintenance Effectiveness for WSDOT Pavement Network* (WSDOT 2013), *WSDOT Strategies Regarding Preservation of the State Road Network* (WSDOT 2010), *Maintenance Accountability Process (MAP) Manual* (WSDOT 2012), and *Pavement Surface Condition Rating Manual* (NWPMSUG 1992).

Pavement management system

Since their conceptualization in the late 1960s, and initial implementation by state Departments of Transportation in the 1970s, the use of pavement management systems has grown considerably, with most states using such systems. The benefits of adopting pavement management systems include:

- Enhanced planning ability at strategic, network, and project levels.
- Decision-making based on observed and forecasted conditions rather than opinions.
- The ability to generate alternative scenarios for future pavement conditions.

The implementation of pavement management systems has assisted in advances in pavement management including:

- *Emphasis on pavement rehabilitation.* With the information and analysis provided by pavement management systems, state Departments of Transportation went from emphasizing reconstruction projects to more cost-effective rehabilitation projects. This was a departure from the "worst first" strategies that consumed all the available funds and left very little for other maintenance and rehabilitation treatment options for pavements that were in better condition. The transition of funding emphasis from the "worst first" strategies to earlier-timed, lower cost strategies extended pavement lives and deferred reconstruction costs.

[2] WSDOT, Priorities for New Revenue – 2013

- *Keeping good roads in good condition.* A second major improvement in managing pavements is the emergence and growth of pavement preservation programs, whose philosophy is succinctly captured in terms of "keeping good roads in good condition." Pavement preservation takes the treatment timing another step earlier in the life of the pavement in order to extend service life. Figure 4 shows how pavement preservation extends the life of pavement, delaying the need for rehabilitation and reconstruction.
- *Perpetual and long-life pavements.* A third improvement is to design new (or reconstructed) HMA and concrete pavements to have enough load-carrying capacity for 30, 40, and even 50 years. Although the initial construction of these pavements is high, the future costs are low.

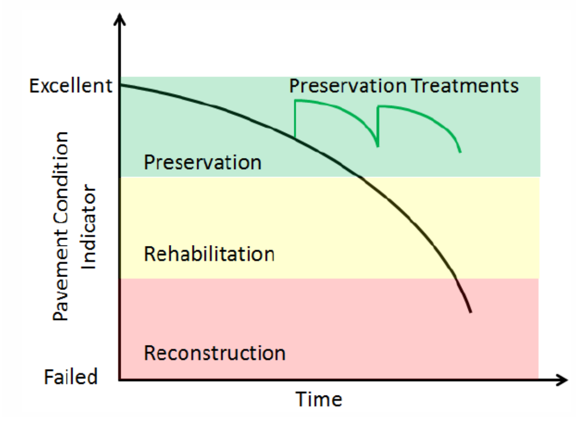


Figure 4. Illustration of the potential impact of pavement preservation on pavement performance (Applied Pavement Technology)

Interpretation of WSDOT practice. The Washington State Pavement Management (WSPMS) is a state of the practice system. Pavement condition information is available at three levels – survey, preservation and planning - in the WSPMS, which allows the generation of reliable needs estimates at the planning and project levels through a data-driven approach. WSPMS develops pavement performance models for each individual section in the highway network. These models are updated every time new performance data are collected and inputted into the WSPMS. After a treatment is placed, the details are updated in the WSPMS to ensure that the performance models and other data moving forward are specific to the type of treatment placed. This results in continuous re-calibration of the models, improving their robustness and accuracy in forecasting future needs.

AASHTO Pavement Management Guide and WSDOT Practices

The AASHTO Pavement Management Guide (AASHTO 2012) describes five business processes for an effective pavement management and preservation program.

AASHTO Pavement Management Guide Business Practices

1. Pavement inventory and data collection
2. Pavement condition assessment and reporting
3. Pavement management system framework
4. Pavement performance modeling
5. Project and treatment selection

Table 3 compares WSDOT systems and methods with the Pavement Management Guide.

Table 3. Comparison of WSDOT systems and methods for estimating long-term pavement needs and the AASHTO Pavement Management Guide.

	WSDOT Status	Gap exists	Gap size
1. Pavement inventory and data collection			
Inventory information	Yes	No	n/a
Location referencing system	Yes	No	n/a
Data integration	Yes	No	n/a
Data management	Yes	No	n/a
2. Pavement condition assessment and reporting			
Pavement distress measurement	Yes	No	n/a
Surface characteristics	Yes	No	n/a
3. Pavement management system framework			
Supports strategic, network, and project decisions	Yes	No	n/a
Capabilities of pavement management system	Yes	No	n/a
4. Pavement performance modeling			
Modeling approaches	Yes	No	n/a
5. Project and treatment selection			
Treatment types and categories	Partial	Yes	Low
Establishing trigger values and decision trees	Partial	Yes	Low
Project prioritization	Yes	No	n/a

WSDOT status: Ability of WSDOT to consistently and efficiently repeat this function each year or each cycle as required.
Gap exists: Improvement needed in order to produce accurate 10-year estimate
Gap size: Relative effort to expand, automate, and document the capability for repeatable use

The consultants found two small gaps between best practices in the Pavement Management Guide and WSDOT's practices. One of these gaps is in the documentation of treatment selection options and the other is in the consideration of earlier pavement treatments. The gap in the consideration of earlier pavement treatments is discussed in Research Question 2 Life Cycle Cost Analysis.

The findings on how WSDOT's pavement condition estimating practices conform to industry practices and other appropriate standards is summarized in figure 5 below.

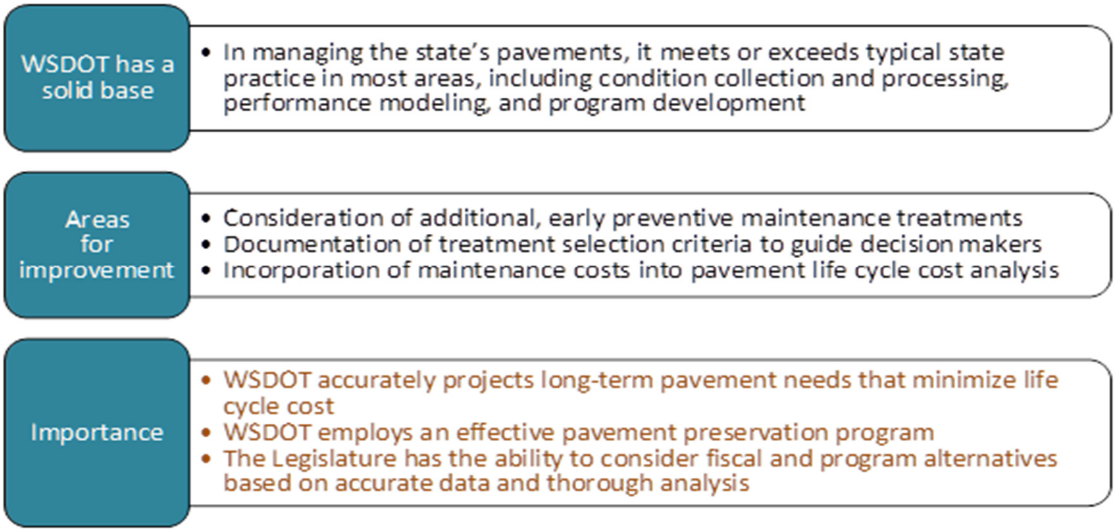


Figure 5. Summary of pavement Research Question 1 findings.

WSDOT, in conformance with the Pavement Management Guide:

- Programs and prioritizes projects through an objective, data-driven process that includes documentation of the expert opinions of WSDOT region and State Material Laboratory staff.
- Programs pavement projects only when they are due to ensure that the maximum service life from a given treatment is realized. WSDOT's primary objective is to avoid complete reconstruction activities. By avoiding or significantly deferring reconstruction WSDOT decreases overall life cycle costs and long-term network funding needs.
- Develops the biennium list of projects in a comprehensive fashion that produces reliable and accurate estimates of the needs.
- Has an institutional framework in which pavement needs can be systematically, completely, and consistently developed and reported to the Legislature and other stakeholders.
- Has a process to consider network-level investment alternatives; to optimize the allocation of resources; to estimate the cost of a given set of performance targets; and to estimate the performance and backlog which might result from a given investment level.
- Has reasonably well documented its needs estimation process and that process is repeatable.
- Ensures consistency in data management, analysis and reporting practices through a user manual and data dictionary. WSDOT also inspects 100 percent of selected lane(s) of the pavement network. This improves the overall accuracy of the pavement condition data reported when compared to agencies that use a sampling approach. The WebWSPMS application dynamic segmentation also helps WSDOT better distinguish between localized maintenance needs and planning-level needs and generate reliable needs estimates.

The sections below describe in more detail how WSDOT compares with best practices in the Pavement Management Guide. In each area, the italics *yes, no*, or *partial* correspond to the summary of the comparison of WSDOT systems and methods for estimating long-term pavement needs and the AASHTO Pavement Management Guide shown in table 3.

Practice 1. Pavement inventory and data collection

Pavement inventory and data collection includes inventory information needed, local referencing systems, data integration, and data management.

Inventory information needed

Interpretation of WSDOT practice. *Yes.* The WSPMS inventory database contains all of the minimum amount of information and most of the other pavement characteristics identified in the Pavement Management Guide and, in the consultants' judgment, meets the standard of practice of most highway agencies.

Location referencing systems

The location referencing system is used to identify the location of a pavement section, intersection, traffic count, or International Roughness Index measurement.

Interpretation of WSDOT practice. *Yes.* The location referencing system employed by WSDOT is a linear system based on mileposts with a dynamic segmentation capability and conforms to best practices.

Dynamic segmentation divides the pavement network into manageable segments/units including: 0.1 mile survey units, preservation units of 1 mile aggregated from survey units based on similar condition, and planning units which are typically 2 miles long and are units likely to be acted upon around the same time period.

Figure 6 illustrates the dynamic segmentation process used within the WebWSPMS application.

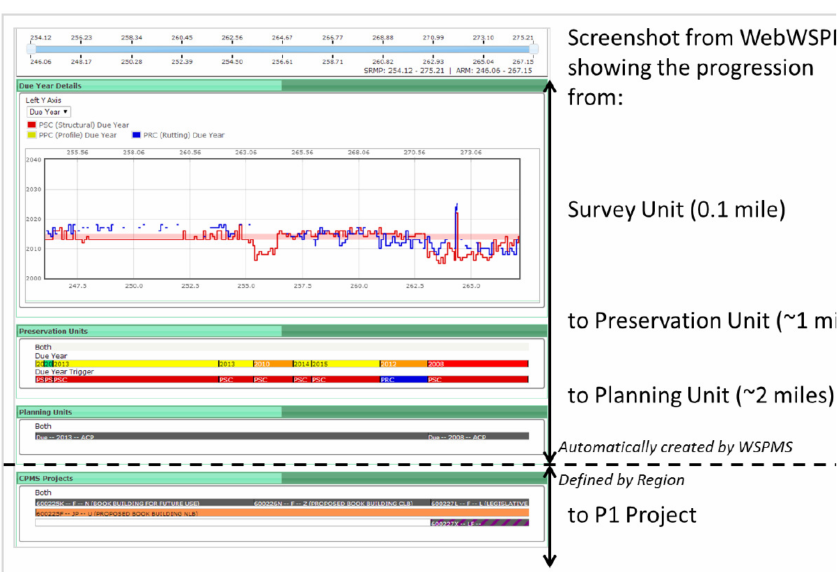


Figure 6. Illustration of the dynamic segmentation used in the WebWSPMS application.

INVENTORY INFORMATION PAVEMENT MANAGEMENT GUIDE

Minimum amount of inventory information needed for pavement sections:

- Segment beginning and end points
- Route designation along with route type
- Functional classification of the road
- Segment length
- Average pavement width
- Pavement type
- Shoulder type and width
- Number of lanes in each traffic direction
- Traffic volume and loading

Other pavement characteristics that may be included:

- Layer type
- Layer thicknesses
- Layer material properties
- Joint spacing
- Transverse joint load transfer
- Subgrade type and material classification
- Drainage information
- Environmental or location information
- Pavement history data
- Cost data
- Ownership information

Data integration

Data integration is defined by FHWA as the "Data integration is defined by FHWA as "the method by which multiple data sets from a variety of sources can be combined or linked to provide a more unified picture of what the data mean and how they can be applied to solve problems and make informed decisions that relate to the stewardship of transportation infrastructure assets." (FHWA http://www.fhwa.dot.gov/asset/dataintegration/if10019/dip00.cfm.)

Interpretation of WSDOT practice. *Yes.* WSDOT's data integration is consistent with best practices. The WSPMS software, User's Guide and data dictionary (which explain the various components and how they are integrated) and WebWSPMS, give WSDOT the ability to interactively enter, gather, and integrate data online.

Data management

Data management involves developing and maintaining the right software, hardware, and communications strategies and developing and maintaining the documentation, or metadata. The Pavement Management Guide defines metadata as a set of information that is needed to best access, understand, and use other information in database or information environments. Metadata may be information (or codes) that the software can interpret to organize the location, delivery, and storage of data. It can also refer to records that describe information that is available electronically.

Interpretation of WSDOT practice. *Yes.* WSDOT maintains a user's guide and data dictionary to support its WSPMS program. These documents are readily available to the users for consistent data management.

Practice 2. Pavement condition assessment and reporting

FHWA Benefits of Data Integration

- Availability/accessibility
- Timeliness
- Accuracy and integrity
- Consistency and clarity
- Completeness
- Reduced duplication
- Informed and defensible decisions
- Greater accountability

Pavement condition assessment includes collecting, processing, and measuring pavement distress and surface characteristics. Condition assessment surveys are carried out at the network level over a large portion (or all) of the agency's pavement network. The results of the survey are used to characterize pavement condition, predict future deterioration, identify and prioritize treatment needs, determine funding requirements, and allocate funds.

Pavement distress measurement

The Pavement Management Guide references two standard pavement distress rating procedures that can be used as a basis for gathering pavement distress measurements, FHWA's *Distress Identification Manual for the Long-Term Pavement Performance Program* (FHWA 2003) and American Society for Testing and Materials (ASTM) D 6433, *Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys*. Both of these procedures call for pavement distress to be characterized by type, severity, and extent and both include a comprehensive list of pavement distresses. The Pavement Management

Guide refers to three other documents – AASHTO R48 (rut measurement), AASHTO R36 (fault measurement), and AASHTO R55 (crack measurement) – that were developed to improve the consistency of distress measurements.

Interpretation of WSDOT practice. *Yes.* The *Pavement Surface Condition Rating Manual* (NWPMSUG 1992) was developed in the early 1990s under a cooperative effort by WSDOT and local agencies in Washington for specific use in the state. It includes multiple distresses that characterize all the key forms of pavement deterioration experienced in the state. Most of the distresses are contained in the ASTM and FHWA methods and the rating process is based on same criteria, i.e., type, severity, and extent of distress.

Based upon information in the Pavement Management Guide, WSDOT is in conformance with best practices with regard to measuring distress quantities and rating severities. Quantities are determined based upon a 100 percent sample of the distress data (compared to the small sample approaches inherent in the ASTM and FHWA methods) and the data are obtained using automated equipment in selected lane(s).

Surface characteristics

The Pavement Management Guide identifies three pavement surface characteristics (ride quality, friction, and noise) that can have an impact on pavement performance. It also indicates only one, ride quality (also referred to as roughness and longitudinal profile) is typically incorporated into an agency's pavement management program. The most common measure of ride quality is the International Roughness Index (IRI).

Interpretation of WSDOT practice. *Yes.* WSDOT measures roughness as part of its automated pavement distress data collection process. The data are processed and used to project the year when a critical roughness level is reached—at which time a rehabilitation treatment is triggered.

Practice 3. Pavement management system framework

The Pavement Management Guide discusses the pavement management system framework in two parts: supporting strategic, network, and project decisions; and capabilities of the pavement management system.

Supports strategic, network and project decisions

Table 4 summarizes the types of decisions made at the strategic, network and project level.

Table 4. Differences in strategic, network, and project-level decisions with a pavement management system framework

Decision Level	Examples of Job Titles at this Level	Types of Decisions/Activities	Range of Assets Considered	Level of Detail	Breadth of Decisions
Strategic	• Legislator • Commissioner • Chief Engineer • Council Member	• Performance targets • Funding allocations • Pavement preservation strategy	All assets statewide	Low	Broad
Network	• Asset Manager • Pavement Management Engineer • District Engineer	• Project and treatment recommendations for a multi-year plan • Funding needed to achieve performance targets • Consequences of different investment strategies	A single type of asset or a range of assets in a geographic area	Moderate	Moderate
Project	• Design Engineer • Construction Engineer • Materials Engineer • Operations Engineer	• Maintenance activities for current funding year • Pavement rehabilitation thickness design • Material type selection • Life cycle costing	Specific assets in a specific area	High	Focused

Source: AASHTO Pavement Management Guide

Interpretation of WSDOT practice. *Yes.* Figure 7 summarizes WSDOT's pavement management system framework. WSDOT's practices are closely aligned with the best practice guidelines documented in the Pavement Management Guide with strategic, network, and project decisions interconnected.

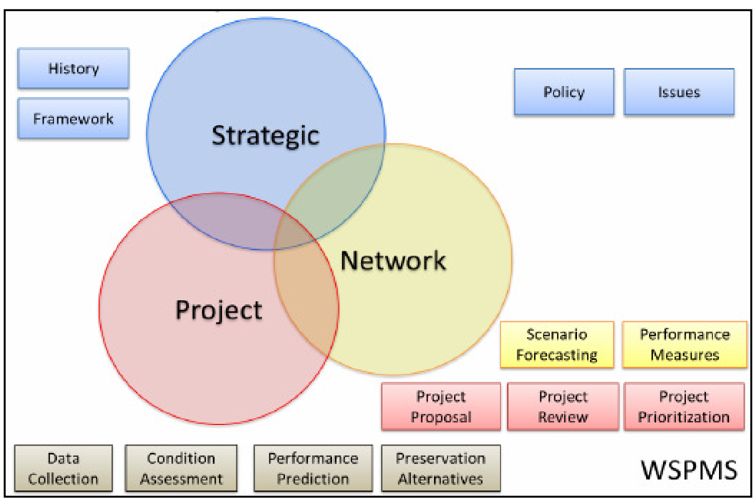


Figure 7. WSDOT's pavement management framework

Capabilities of pavement management system

The key components of a pavement management system are:

- *Inputs.* The basic foundation for any pavement management system is the data upon which decisions are based. The basic inputs include inventory and condition information.
- *Database.* The type of database for a pavement management system can range from a simple spreadsheet interface to a relational, self-contained database that enables the user to query and

report data. Some agencies also use a geographical information system (GIS) database to share data on inventory, conditions and needs.

- *Analysis.* The pavement management system should be able to model pavement performance and estimate future conditions, assess funding levels needed to reach a targeted level of performance, and estimate future pavement conditions for different treatment and investment scenarios.

Figure 8 illustrates the key components of a pavement management system.

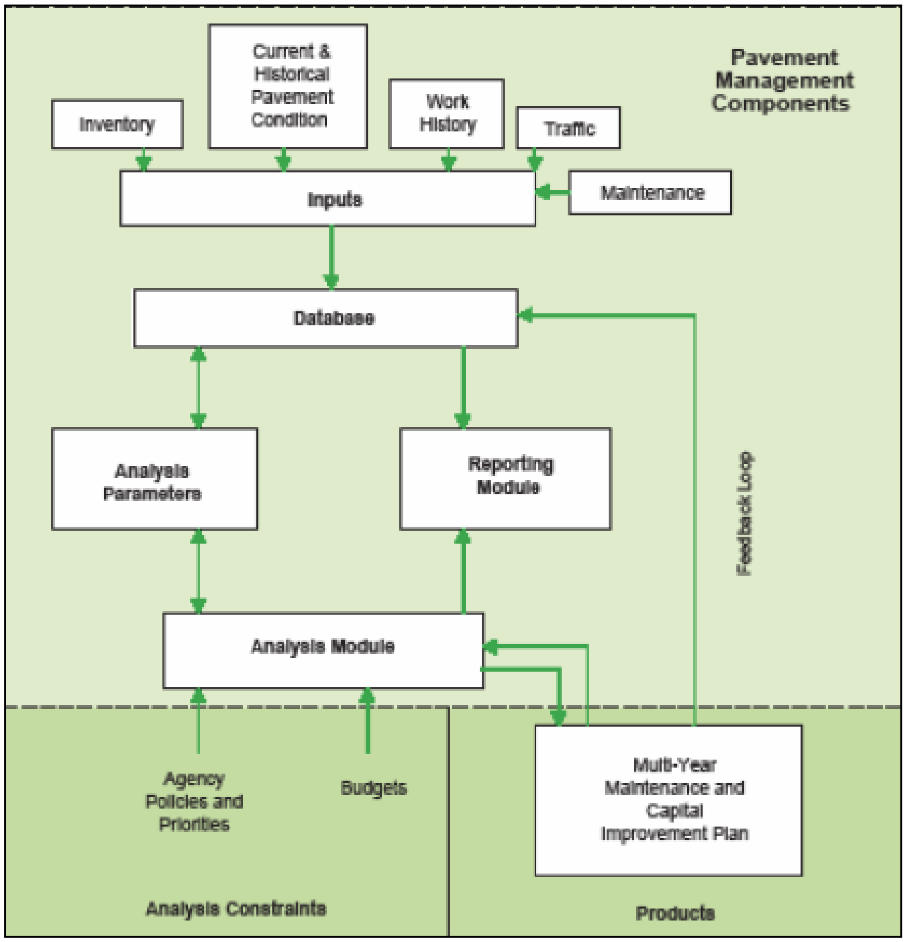


Figure 8. Key components of a pavement management system

Interpretation of WSDOT practice. *Yes.* The WSDOT pavement management system has the capabilities that are required in a pavement management system.

- *Inputs.* WSPMS includes pavement inventory and condition, traffic, contract history, roadway configuration, and maintenance data.
- *Database.* WSPMS is a set of distributed computing tools that are integrated within a semi-automated process. WebWSPMS is the principal tool used for pavement asset management within the WSPMS. WebWSPMS contains data from several sources within WSDOT and provides a user-friendly, intuitive interface for accessing, viewing, and reporting the data. The list of offices and the types of data available within and used by the WSPMS are summarized in figure 9.

Office	Data
GIS and Roadway Data Office (GRDO)	• Roadway configuration • Location history • Contract history
Statewide Travel and Collision Data Office (STCDO)	• Traffic and crash data
Capital Program Management and Development (CPMD)	• Inventory of capital projects
Maintenance	• List of activities completed by the mai
Construction	• Construction contract costs and miles
Pavements	• Inventory, and performance history da • Right of way and pavement surface in • Data synthesis and analysis results

Figure 9. Types of data handled by the WSPMS and the offices that generate the data

- *Analysis.* The WSPMS Forecaster is the computational engine of the pavement management system used by WSDOT. It provides needs estimates and helps assess alternative scenarios.

Practice 4. Pavement performance modeling

Performance models are used in a pavement management system to predict pavement performance over time, helping to determine the appropriate time to apply maintenance or rehabilitation. By projecting the rate at which the pavement condition will change over time, a life cycle cost analysis can be performed to compare the costs of different rehabilitation alternatives.

The accuracy and robustness of performance models are critical in ensuring that the long-term estimates of highway maintenance and preservation needs developed by the agency are reliable.

The role of performance models includes:

- Estimating future pavement conditions.
- Identifying the appropriate timing for pavement maintenance and rehabilitation actions.
- Identifying the most cost-effective treatment strategy for pavements in the network.
- Estimating statewide pavement needs required to address agency-specified goals, objectives, and constraints.
- Demonstrating the consequences of different pavement investment strategies.
- Establishing performance criteria for performance specifications and warranty contracts.

MODELING APPROACHES

Pavement management systems model

- Distress severity and extent. (e.g., alligator cracking, joint spalling, rutting, faulting, etc.)
- Individual pavement condition indices
- Composite indices

Modeling Approaches

- Deterministic models. A single dependent value is predicted based on one or more independent variables
- Probabilistic models. Predict a range of values for the dependent variable

Deterioration Curves

- Family models. One model represents the deterioration rate for a group of pavement sections that are expected to perform similarly
- Site-specific models. Based on the unique characteristics of a particular pavement section.

- Provide feedback on pavement designs or on the effectiveness of different maintenance strategies.

Interpretation of WSDOT practice *Yes.* WSDOT performs regression analysis to develop deterministic site-specific performance models for the composite indices developed to characterize and predict performance:

- *PSC (pavement structural condition, a cracking index).* Model to assess the structural health of a pavement based on cracking and patching. This is modeled using a power function (non-linear model).
- *PPC (pavement profile condition, a roughness index based on IRI).* Model to assess the roughness of a roadway using the IRI. This is modeled as a linear function.
- *PRC (Pavement rutting condition, a rutting index).* Model used to assess the rutting on asphalt pavements using a linear model.

These indices are quantified on a scale of 100 (perfect condition) to 0 (complete failure). The time-series data of historical performance indices are used to perform a regression analysis in order to develop the performance model for each of the three indices.

The default models (documented in *The WSDOT Pavement Management System – A 1993 Update* and updated periodically since 1993) are used as a starting point for developing site-specific models using actual performance data specific to each section in the pavement management database. Using site-specific models in lieu of default models improves the overall accuracy of the performance prediction process. The performance models are updated every time new performance data is collected and inputted into the WSPMS.

A pavement section is considered due for rehabilitation in the year when the performance index value reaches the threshold limit (between 45 and 50). The due year assigned to a section is based on the minimum year computed from each of the three indices modeled. This is illustrated in figure 10.

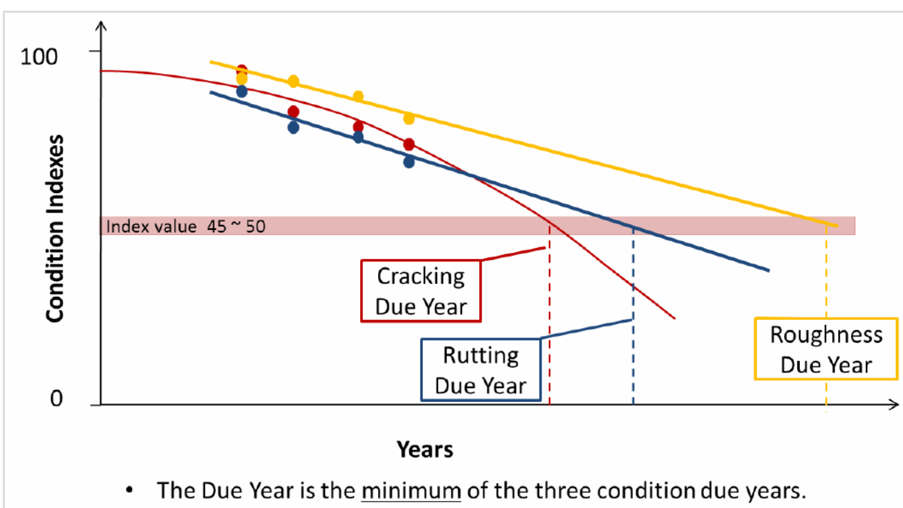


Figure 10. Graphic illustrating the computation of the "due year". (Pavement Asset Management Report, March 2014).

WSDOT's practices are on par with current industry standards.

Practice 5. Project and treatment selection

Treatment types and categories

The first step in determining treatment need is identifying treatments to be considered for various types and severities of pavement distresses and deterioration.

Tables 5 and 6 summarize some of the common pavement preservation treatments used by state highway agencies on HMA and concrete-surfaced pavements.

Table 5. Typical preservation treatments for HMA-surfaced pavements and their capabilities

	Prevention		Restoration				
Treatment	**Seal/Waterproof Pavement**	**Rejuvenate Surface/ Inhibit Oxidation**	**Eliminate Surface Defects[a]**	**Eliminate Stable Ruts**	**Improve Texture for Friction**	**Improve Profile (Lateral Surface Drainage and Ride)**	**Improve Texture for Noise**
Crack filling	√		√				
Crack sealing	√		√				
Cold milling			√			√	
Profile milling				√	√	√	
Rejuvenation		√					
Fog seal	√	√					
Scrub seal	√	√			√		
Slurry seal	√	√			√		
Microsurfacing	√	√		√	√	√	
Sand seal	√	√			√		
Chip seal	√		√		√	√ (minor)	
Ultra-thin HMAOL	√		√		√	√	√
Ultra-thin bonded wearing course	√		√		√	√	√
Thin HMAOL							
Dense-graded	√		√	√	√	√	√
Open-graded (OGFC)[b]					√		
Gap-graded (SMA)				√	√	√	√
Mill and thin HMAOL	√		√	√	√	√	√
Hot in-place recycling							
Surface recycling		√	√	√		√	
Remixing		√	√	√		√	
Repaving			√	√	√	√	
Cold in-place recycling		√	√	√		√	
Ultra-thin whitetopping			√	√	√	√	

Source: Peshkin et al. 2011

Table 6. Typical preservation treatments for concrete-surfaced pavements and their capabilities

Treatment	Prevention: Seal/Waterproof Pavement	Prevention: Prevent Intrusion of Incompressibles	Restoration: Remove/Control Faulting	Restoration: Improve Texture for Friction	Restoration: Improve Profile (Lateral Surface Drainage and Ride)	Restoration: Improve Texture for Noise
Crack sealing	√	√				
Joint resealing	√	√				
Diamond grinding			√	√	√	√
Diamond grooving				√		
Partial-depth patching	√	√	√		√	
Full-depth patching	√	√	√[a]		√[a]	
Dowel bar retrofit			√		√	
Ultra-thin bonded wearing course	√	√		√	√	√
Thin HMAOL	√	√		√	√	√
Thin PCCOL	√	√		√	√	√

Source: Peshkin et al. 2011

Interpretation of WSDOT practice. *Partial.* The timing of the treatment is determined by identifying the year (or due year) when one of three pavement performance indices is forecasted to deteriorate to a critical level. In WSDOT's analysis, any treatment placed earlier than the due year will have a higher annual cost due to wasted service life. Similarly, any treatment placed after the due year will result in higher costs because of poor condition. The treatments required in the due year are generally not expensive. For HMA pavements, they typically include thin overlays, mill and overlay, and cold in-place recycle with a thin overlay. WSDOT staff indicate that they have experimented with microsurfacing as a pavement preservation treatment earlier in the pavement life (before the due year); however, the treatments did not perform well. The potential for earlier treatments is discussed in more detail in Question 2 – Life Cycle Cost Analysis.

Establishing trigger values and decision trees

Agencies typically develop decision trees (or tables) to help visualize the rationale behind selecting a particular treatment for a pavement section. These decision trees are programmed into pavement management software systems. Trigger values are established for the distress type and severity, individual distresses indices, and composite indices. Agencies routinely calibrate and update the treatment triggers to ensure that the decision trees take into account the actual performance levels observed in the field.

Table 7 shows an example of trigger values for various preventive maintenance treatments used by the Ohio Department of Transportation.

Table 7. Condition criteria for preventive maintenance treatments used by Ohio DOT (from Peshkin et al. 2011)

PM Treatment	Pavement Condition Rating (PCR) Range[a] Flexible Pavements	Composite Pavements
Crack sealing	75 to 95	75 to 95
Chip seal	75 to 90	75 to 90
Microsurfacing (single course)	75 to 90	75 to 90
Microsurfacing (double course)	75 to 90	75 to 90
PMAC overlay	75 to 90	75 to 90
Thin HMA overlay	75 to 90	75 to 90

Source: ODOT 2001.
Note: PMAC = Polymer-modified asphalt concrete.
[a] Condition categories listed in ODOT Pavement Condition Rating Manual: 90–100, very good; 75–90, good; 65–75, fair; 55–65, fair to poor; 40–55, poor; 0–40, very poor.

Interpretation of WSDOT practice. *Partial.* WSDOT uses a treatment trigger value of 45 to 50, based on the lowest of three condition indices, to establish a due year for a treatment. The type of treatment is determined through a collaborative effort between the regions, the pavements branch of WSDOT's central office and the Capital Program Management and Development (CPMD) division. The preservation project flow is illustrated in figure 11.

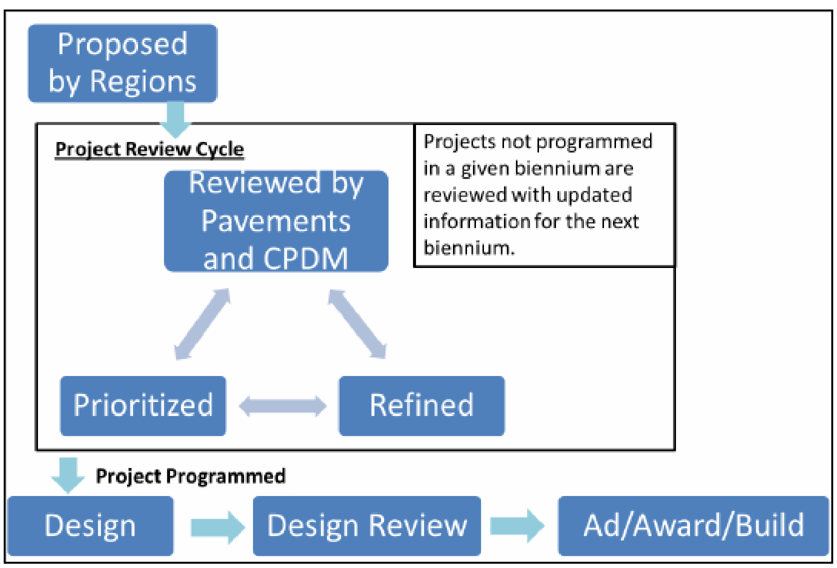


Figure 11. Flowchart for selection of preservation projects

As figure 11 shows, the selection of projects (and treatments) are based on communication between the regions, the pavements branch, and the CPMD in the project review cycle.

WSDOT does not have a treatment selection matrix to guide decision makers on the type of treatments to select for a given set of constraints or condition trigger values. The absence of decision trees/treatment selection matrices is a gap in the overall business process for developing biennium programs, making the process less replicable than it would be if the alternatives were documented.

Pavement recommendation 1. WSDOT could improve its pavement management practices by documenting its treatment selection process to guide future decision-makers.

Project prioritization

Table 8 compares approaches used for prioritizing projects.

Table 8. Comparison of prioritization method (from Haas et al. 1994)

Method	Description	Advantages and Disadvantages
Ranking	Simple, subjective ranking of projects based on judgment, overall condition index, or decreasing first year cost (single- or multi-year)	Quick, simple; subject to bias and inconsistency; may be far from optimal
	Ranking based on condition parameters, such as serviceability or distress; can be weighted by traffic (single- or multi-year)	Simple, easy to use; may be far from optimal, particularly if traffic weighting is not used
	Ranking based on condition parameters and traffic, with economic analysis including decreasing present worth-cost or benefit-cost ratio (single- or multi-year)	Reasonably simple, may be closer to optimal
Prioritization	Near-optimization using heuristic approaches including incremental benefit-cost ratio and marginal cost-effectiveness (maintenance, rehabilitation, and reconstruction timing taken into account); usually conducted as a multi-year analysis	Reasonably simple; suitable for microcomputer environment; close to optimal results
Optimization	Annual optimization by mathematical programming model for year-by-year basis over analysis period	Less simple; may be closer to optimal; effects of timing not considered
	Comprehensive optimization by mathematical programming models taking into account the effects of maintenance, rehabilitation, and reconstruction timing	Most complex and computationally demanding; can give optimal program (maximization of benefits or cost-effectiveness)

Interpretation of WSDOT Practices. *Yes.* WSDOT's project prioritization process (see figure 12) combines elements of all three approaches. WSDOT considers:

- Project costs and life cycle costs
- Risk of rapid pavement deterioration due to heavy truck traffic
- Treatment benefit

The practices used by WSDOT demonstrate sound engineering practices with minimal amount of subjectivity in the overall decision making process.

Step 1: Project Categorization (lowest number has highest priority)

- Category 1: Projects already programmed
- Category 2: Projects where high risk of major expense is identified (delayed rehabilitaion poses risk of reconstruction)
- Category 4: Asphalt to chip seal conversion (chip seal surfaces have lower life cycle costs)
- Category 5: General category (no specical considerations)
- Category 6: Projects that can be deferred with maintenance
- Category 8: Ramps

Step 2 (Cost, Treatment Benefit, Truck Traffic)

- **Cost per lane-mile** for construction (including engineering and traffic control). When other factors are equal, a higher cost per lane-mile reduces priority
- **Lane-Mile Years Gained**: Lane miles paved multipled by expected years of life gained by the project (discussed in the next section). When other factors are equal, a lower value of lane-mile years gained will reduce priority.
- **Annual Number of Trucks**: Higher number of trucks per year indicates commerical and economic importance and potential for rapid pavement deterioration. When other factor factors are equal, a lower truck traffic reduces priority.

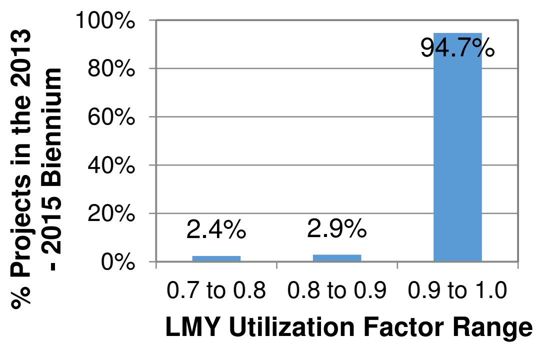
Step 3: Sort by Ranking Factor ($ per lane-mile truck [LMT])

- **$ per LMT** = (Cost per lane-mile) / (annual number of trucks)

Figure 12. WSDOT's Project prioritization methodology

The consultants reviewed WSDOT's 2013-15 biennium flexible (i.e. chip seal and HMA) pavement preservation projects to assess how the project prioritization process is reflected in the project list.

WSDOT reports a metric called the "Lane-Mile-year (LMY) Utilization Factor" which is the ratio of the expected lane-mile-years gained to the maximum lane-mile-year gain possible. The primary purpose of using the LMY Utilization Factor metric is to communicate the fact that the projects are being prioritized only when they are triggered based on the due year. A very low value for the LMY Utilization Factor indicates that WSDOT is placing the treatments earlier than required, which could increase life cycle costs. Figure 13 illustrates the distribution of the flexible pavement projects in the 2013 – 2015 biennium project list by LMY Utilization Factor ranges. The figure shows that WSDOT is programming flexible pavement projects to maximize their life cycle costs, with approximately 95 percent of projects with a Lane-Mile-Year Utilization factor of between 0.9 and 1.0.



Lane-Mile-Year (LMY) Utilization Factor

The maximum lane-mile-years gained is calculated as the average life extension associated with the treatment multiplied by the lane-miles it is applied to. The expected lane-mile-years gained is this total after deducting the lane-mile-years that are due in future years.

Example:

A two-lane section that is 1 mile in length (two lane miles)

- 80% of the section was due in 2013
- 20% was due in 2017.

Treatment is expected to gain 15 years of lane miles gained.

This section would get a LMY Utilization factor of 0.97, which is computed as follows:

Miles addressed in due year= 2 miles * 80%=1.6

LMY Maximum Gain = [1.6 x 15[1] + 0.4*15] = 30

LMY Actual Gain = [1.6 x (15 – 0) + 0.4* (15 – 2)] = 29.2

LMY Utilization Factor = LMY Actual Gain/ LMY Maximum Gain = 29.2/30 = 0.97

Since 20% of the section was due only in 2017 but was programmed in the 2013 – 2015 biennium (for which the pivot year for LMY penalty calculation is 2015), a penalty of 2 years was applied. If the same section was due in 2018 or 2019, a penalty of 3 or 4 years, respectively, would apply.

Figure 13. LMY Utilization Factor ranges for the flexible pavement project priorities in the 2013 – 2015 Biennium

Research Question 2.

Are practices in place to minimize life cycle preservation and maintenance costs?

Guidelines provided by AASHTO and FHWA establish four pavement life cycle cost analysis capabilities.

AASHTO and FHWA Life Cycle Cost Capabilities

1. Project-level treatment criteria – decision rules to plan future actions on individual assets, intended to minimize life cycle cost but without regard to fiscal constraints or optimal timing
2. Computation of network level life cycle cost – total cost that is economically sustainable and developing and evaluating alternative policies and multi-year programs to find solutions with the lowest long-term network costs
3. Integrating maintenance and preservation – policies that consider both preservation and maintenance in order to make best use of each approach in minimizing life cycle cost
4. Backlog estimation and scenarios – procedures to compute the additional multi-year investment required in order to attain long-term optimal condition and to consider alternative fiscal constraints and performance targets to find realistic policies and multi-year programs that minimize long term costs.

Table 9 summarizes the comparison of WSDOT's pavement life cycle cost practices with industry practices.

Table 9. Comparison of WSDOT pavement life cycle cost practices with industry practices.

Ingredient	WSDOT Status	Gap exists	Gap size
1. Project-level treatment criteria	Yes	No	n/a
2. Network level life cycle cost	Partial	Yes	Low
3. Integrating maintenance and preservation	No	Yes	Low
4. Backlog estimation and scenarios	Yes	No	n/a

WSDOT status: Ability of WSDOT to consistently and efficiently repeat this function each year or each cycle as required.

Gap exists: Improvement needed in order to produce an accurate estimate of 10-year needs

Gap size: Relative effort to expand, automate, and document the capability for repeatable use

WSDOT incorporates life cycle cost analysis into its pavement management process but could make improvements. Specifically WSDOT:

Has the following best practices:

- Plans the application of pavement preservation treatments (such as mill and overlay for flexible pavement and dowel bar retrofit for concrete pavements) to occur during a due year, the estimated optimum point in time that extends the service life of the existing pavement at the lowest life cycle cost.
- Prioritizes projects using a multi-criteria decision making approach so that, under constrained budget scenarios, it can target the available funds on projects which provide the greatest return on investment. This prioritization approach is employed by most state highway agencies within their pavement management processes and is considered best practice.

Could improve its practices by:

- Giving greater consideration to relatively low-cost preventive maintenance treatments such as fog seals and microsurfacings for its HMA and chip seal pavements that can be placed earlier in the life of the pavement (or after a late-in-life preservation treatment) to further extend pavement life and defer costly rehabilitation and reconstruction.
- Including the cost of routine or reactive maintenance in its LCCA process. Although these maintenance costs are difficult to extract and are also relatively small (in comparison with other LCC elements), they should be included within the cost analysis. (WSDOT has developed some new tracking software and procedures that should help it incorporate routine maintenance costs in the future).

The sections below provide more detail on each life cycle cost analysis practice. The italics *yes, no*, or *partial* correspond to the comparison of WSDOT practices and industry practices in Table 9.

Practice 1. Project-level treatment criteria

State Departments of Transportation typically use software tools (e.g., FHWA's RealCost Tool) to conduct a detailed life cycle cost analysis for pavement type selection and/or to determine the most cost-effective pavement design alternative at the project level. For new pavement, reconstruction, and major rehabilitation projects, a detailed LCCA is essential to developing a cost-effective pavement design.

Interpretation of WSDOT practice. *Yes* WSDOT routinely performs a project-level LCCA using FHWA's RealCost tool on all new design, reconstruction, and major rehabilitation projects to determine the most cost-effective structural design alternative. A conventional present worth analysis approach is used in which a 50-year analysis period is used and all future costs are discounted to net present value using a discount rate of 4 percent. The costs typically included are initial construction, pavement preservation (i.e., treatments that are timed for application during the due year), salvage value, and (in some urban freeway instances) user costs.

The typical process flow used by WSDOT for project-level LCCA is shown in figure 14. WSDOT's practice is typical of most states and is considered best practice.

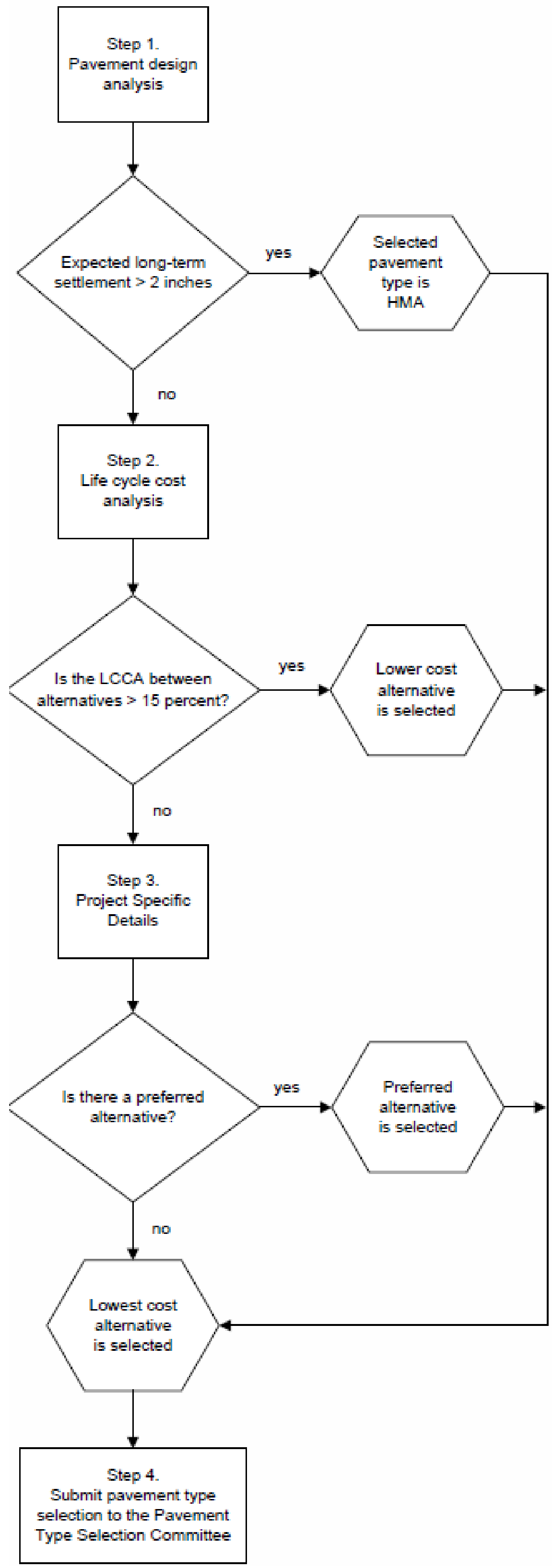


Figure 14. Flowchart illustrating WSDOT's approach to pavement type selection using LCCA. [Source: WSDOT]

Practice 2. Network level life cycle cost

As highway agencies have shifted their focus from pavement rehabilitation and reconstruction to pavement preservation and preventive maintenance, the application of LCCA in the pavement management process has become more comprehensive. More importantly, the combination of LCCA along with performance models that accurately account for the effect of various preventive maintenance treatments has helped demonstrate the value of adopting a true pavement preservation program. Figure 15 conceptually illustrates the growth of LCC over time for three typical pavement maintenance and rehabilitation strategies. The Do-minimum Strategy corresponds to a major rehabilitation or reconstruction approach while the Programmed Strategy corresponds to a time-based preventive maintenance approach. The Preventive Maintenance Strategy corresponds to an approach where maintenance treatments are triggered by certain pavement condition levels.

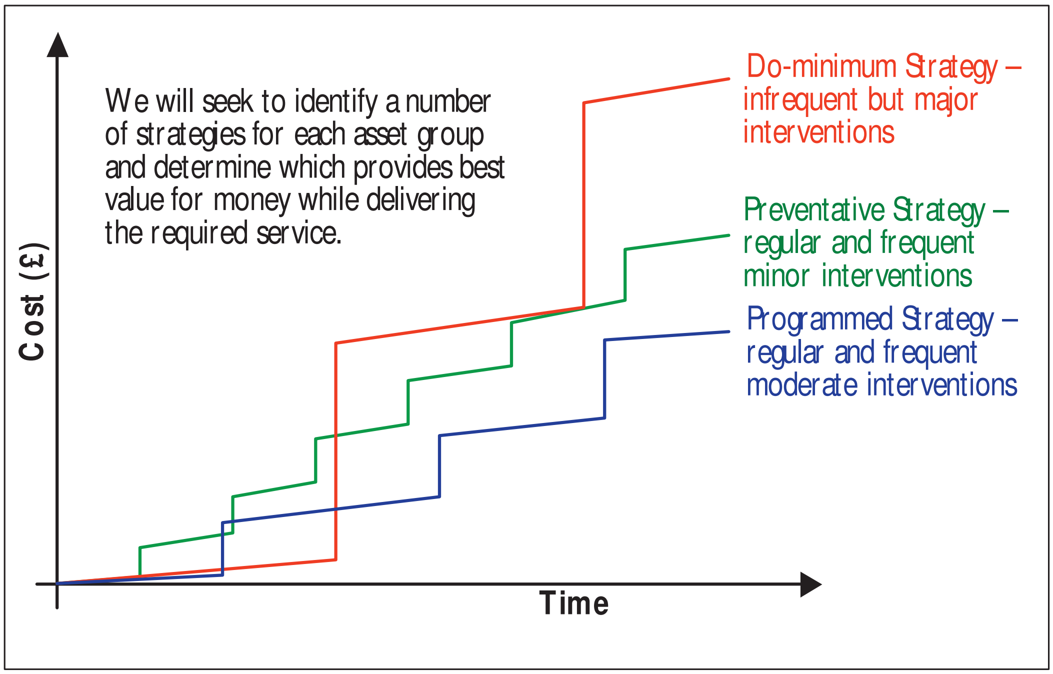


Figure 15. Comparison of life cycle cost for three alternative maintenance strategies (source: Road Asset Management Plan, Transport Scotland, 2007)

When different maintenance and rehabilitation strategies (including preventive maintenance) are considered, the LCCA approach will help determine which one is the most cost effective over the long term.

Interpretation of WSDOT Practice. *Partial* At the network level, WSDOT primary objective for pavement management is “managing to the lowest life cycle cost.” (*Strategies Regarding Preservation of the State Road Network* 2010). WSDOT first incorporated the use of LCCA in the early 1990s to help estimate the total pavement network needs in a cost-effective manner. Improvements to the pavement management process have been made over the years to help determine sub-optimal treatment strategies as the available funds have decreased.

WSDOT Network-level LCCA

Most pavement management systems estimate the future funding needs by accumulating the costs of all the pavement preservation, rehabilitation, and reconstruction costs associated with all the pavement sections that deteriorate to a critical or trigger level.

What makes WSDOT’s method stand out from the practices of other states is that WSDOT’s funding needs are determined using pavement preservation strategies that are known to produce the lowest life cycle cost and which satisfy the performance criteria.

Figure 16 provides two interrelated graphs that describe WSDOT’s approach to achieving the lowest life cycle cost (LLCC) for all the pavement sections within the state’s highway network. The top graph depicts a typical pavement deterioration curve within a condition index of 0 to 100. From in-house LCCA studies and its application of the pavement management program over the years, WSDOT has determined that the optimum time to apply a pavement preservation treatment is when the critical pavement condition index (i.e., lowest index of either cracking, rutting, or roughness) for a given pavement section drops to a level of between 45 and 50. If a treatment is applied when the condition is below 45, WSDOT’s experience has shown that the cost of the preservation treatment will be higher because of the effect of the poor pavement condition on the cost of the treatment. Similarly, WSDOT’s experience has indicated that a preservation treatment when the condition index is higher than 50 will result in higher LLC because of wasted service life. This approach to planning the application of a pavement preservation treatment when the condition index is in the 45 to 50 range means that LLCC is built into WSDOT’s pavement management process.

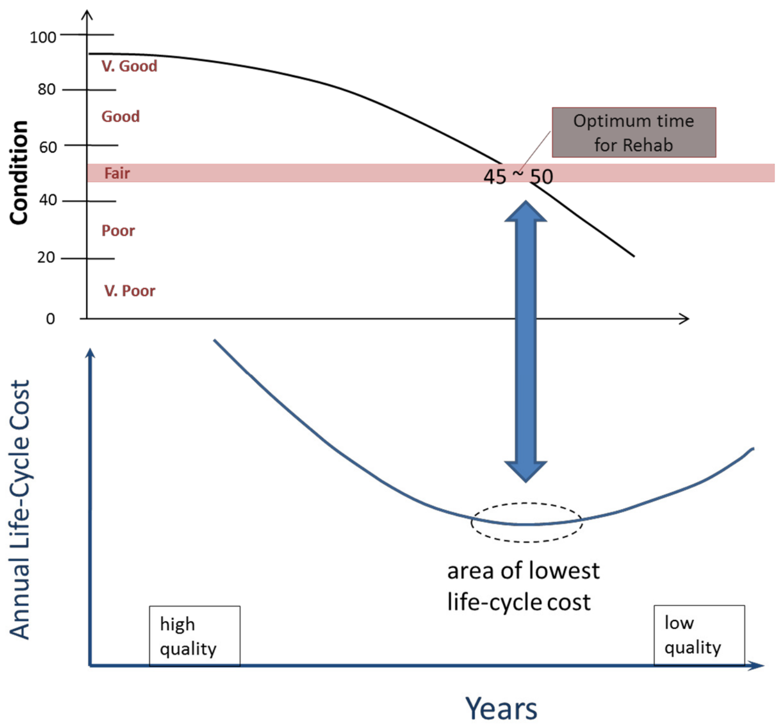


Figure 16. Charts illustrating WSDOT's approach to using LCCA to determine a cost-effective treatment strategy (Source: WSDOT Pavement Asset Management document, 2014).

WSDOT's approach does not consider pavement preservation treatments that are applied early in the life of the pavement (i.e., when the age is less than 5 years or when the pavement condition index has a value that is greater than 60). This means that it is possible that WSDOT's pavement preservation alternatives (all of which occur later in the life of the pavement) may not result in the lowest life cycle cost. There are pavement preservation treatments such as microsurfacings, fog seals and rejuvenating fog seals, thin-bonded HMA overlays, and chip seals in the case of HMA pavements that, when applied earlier in the pavement life, can result in extended pavement lives and lower overall life cycle costs. These treatments would need to be analyzed in Washington State conditions to determine whether they would improve pavement life here.

Practice 3. Integrating maintenance and preservation

From the consultants' experience in working with state DOTs, not a single state was identified which includes maintenance and operations cost in pavement life cycle cost analysis. In the consultants' judgment, this is because the costs are relatively low and are often not tracked in a manner than allow for their incorporation in network level life cycle cost analysis.

Interpretation of WSDOT Practice*. No.* WSDOT has not incorporated maintenance and operations costs into its life cycle cost analysis, but has been working towards doing so. The Department has done a pilot project to include maintenance costs in the Olympic region. The primary reason that these maintenance costs have not been included is that they are difficult to track. WSDOT is in the process of implementing a new Highway Activity Tracking System (HATS), which will ultimately make it possible for routine maintenance costs to be included in the analysis process.

Recommendation for improvement

Pavement recommendation 2. Pavement life cycle cost analysis could be improved by considering earlier treatment timing for asphalt and chip seal pavements and by incorporating operating and routine maintenance costs into the analysis.

Practice 4. Backlog estimation and scenarios

For managing a pavement network at the lowest possible life cycle cost under financial and other constraints, the agency must use prediction models and prioritization tools to determine which projects, when funded, result in a sustainable strategy from a network standpoint. The tools should be capable of analyzing a variety of scenarios that involve consideration of trade-offs, such as fluctuations in funding, risk levels associated with rapid rate of pavement deterioration that can present potentially unsafe conditions for the road users, criticality of a route, and so on.

Backlog of unfunded needs refers to the funding needed to address all of the pavement preservation and major rehabilitation needs for roads that have reached a certain condition threshold.

Interpretation of WSDOT Practice. *Yes.* In addition to the pavement condition indices for cracking, rutting, and roughness, WSDOT uses three other performance measures to communicate network level performance: remaining service life, asset sustainability ratio, and deferred preservation liability (i.e. backlog).

- *Remaining Service Life (RSL).* This represents the cumulative measure of the years of service left in the pavement network. A RSL of 45 to 55 is considered a generally healthy estimate by WSDOT. From 2003 to 2012, there has been a loss of approximately 18 percent in the RSL and, at forecasted funding levels, WSDOT estimates a large drop in remaining service life in the next decade (see figure 17).

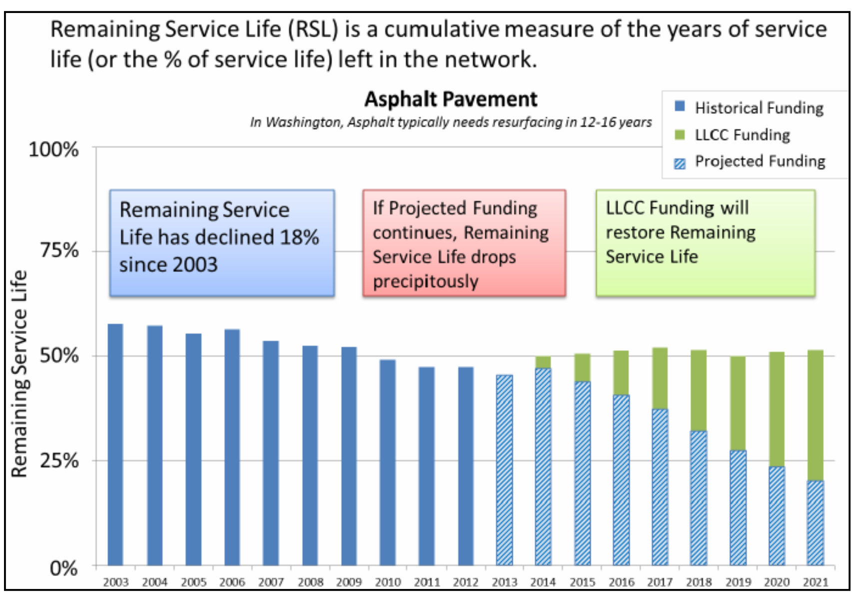


Figure 17. Historical and projected Remaining service life for WSDOT's asphalt pavement network [source: WSDOT].

- *Asset Sustainability Ratio (ASR).* This metric measures the annual sustainability of investments made in pavement preservation. It is the ratio of lane-mile-years replenished (LMY) to LMY consumed. WSDOT's goal is to achieve an ASR of 0.9. Figure 18 illustrates the historical and forecasted ASR values.

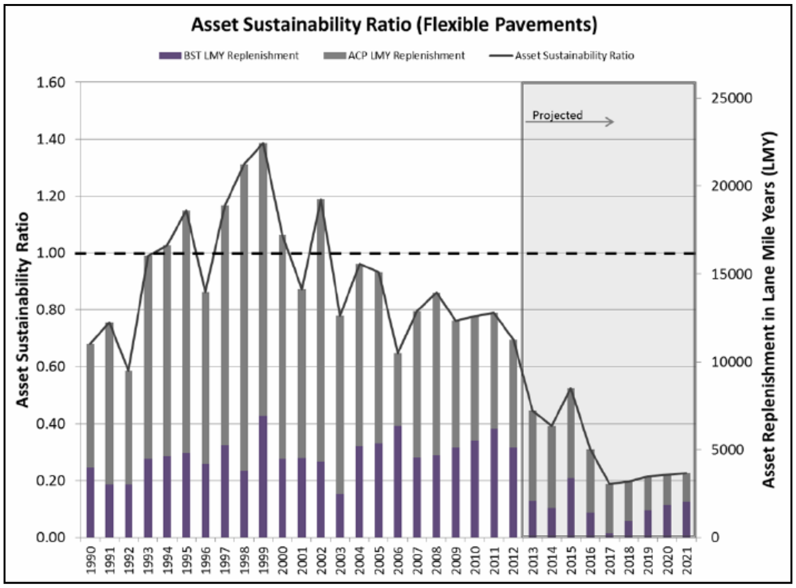
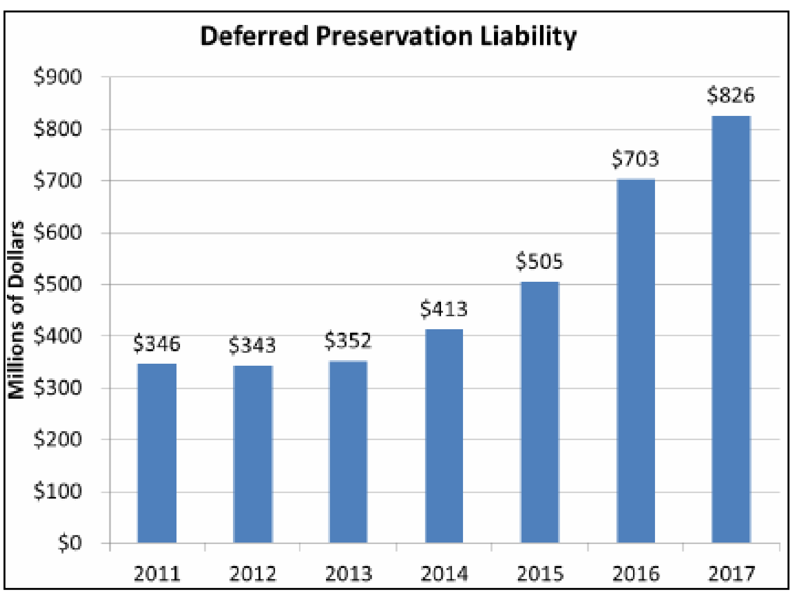


Figure 18. Historical and projected ASR's for WSDOT's asphalt pavement network [source: WSDOT].



Deferred Preservation Liability. WSDOT backlog or deferred preservation liability calculation is based on treatment costs and timing and the due year used to start accumulating liability (which is assumed to be two years before the actual due year being reported).

Figure 19 shows the estimated deferred preservation liability from 2011 to 2017. An increase in backlog is expected starting in 2015, which is an anticipated result of projected decreases in pavement preservation funding.

Figure 19. Historical and projected DPL for WSDOT's pavement network [source: WSDOT].

Research Question 3.

How accurate is the information that is used to develop long-term estimates of maintenance and preservation needs?

For pavements, the project team conducted a review and assessment of existing WSDOT practices and protocols to answer the following questions:

- *Automated pavement data collection equipment calibration.* Are appropriate quality control and quality assurance protocols used to ensure accuracy in the functioning of the various automated data collection equipment used to gather information on pavement inventory and conditions?
- *Pavement surface condition.* Does the pavement condition survey procedure produce consistent estimates of distresses and distress indices?

Automated pavement data collection equipment calibration

WSDOT uses two types of specialized vehicles to collect pavement data (see figure 20): (a) a pavement condition survey van, and (b) a friction testing truck and trailer.

Figure 20. Data collection equipment used by WSDOT

Interpretation of WSDOT practice. The calibration efforts undertaken by WSDOT are, based on the experience of the consultants, consistent with the practices of most state Departments of Transportation.

WSDOT CALIBRATION TESTS

- Distance Measuring Interval Calibration. A one-mile test section is used to periodically check the DMI measurements of the data collection vehicle
- Bounce Test. Test performed prior to the data collection season to ensure that the accelerometers are functioning as intended.
- Block &Water Trough Tests. Tests performed prior to the data collection season if sensors are damaged or replaced
- Weekly Tests. Calibration sections on asphalt and concrete pavements surveyed every week to check for potential sensor problems
- Comparison with a SurPro Profiler. Validate the IRI data collected with the measurements from a SurPro
- Friction Tester Verification. Certified on a two-year cycle
- Post Data Collection Checks: Ensure completeness and accuracy of the data collected

Pavement surface condition data review

WSDOT uses three pavement condition measures to develop its long-term needs projections: pavement surface condition (a cracking index); pavement profile condition (a roughness index); and pavement rutting condition (a rutting index).

Of the three condition ratings, only the pavement surface condition rating involves review by WSDOT pavement surveyors. The pavement data collection van is used to collect high resolution downward and right of way imagery that are then visually inspected in the office by WSDOT pavement condition surveyors to develop condition ratings.

Roughness, rutting, and faulting on concrete pavements data are generated automatically using the standardized computations performed using the transverse and longitudinal profiles collected using the van. The information collected by the pavement condition survey van is incorporated into the WSPMS without further review by WSDOT personnel.

WSDOT provided a list of pavements sections that are routinely used to calibrate the consistency of ratings between its pavement condition surveyors. Using this list a total of eight 1-mile sections (four asphalt and four concrete) were selected for the independent engineer (IE) from the project team to survey and compare the results to those from the WSDOT surveyors. The independent evaluator conducted the pavement ratings by examining the same electronic images and using the same software tools as the WSDOT surveyors.

The pavement surface condition (PSC) ratings for the pavement sections computed using the surveys performed by the WSDOT surveyors and the independent engineer do not give any evidence to suspect or doubt the overall accuracy of WSDOT's survey procedure. The types, severities, and quantities of distresses identified by the independent engineer and the WSDOT surveyors were also comparable.

Table 10.Comparison of PSC ratings

Concrete Sections				
S. No.	IE PSC	WSDOT PSC	Absolute Difference	Percent Difference
1	87.7	87.2	0.4	0.5
2	74.5	69.2	5.3	7.1
3	73.0	73.1	-0.1	-0.1
4	55.4	51.7	3.7	6.7
Asphalt Sections				
S. No.	IE PSC	WSDOT PSC	Absolute Difference	Percent Difference
1	49.6	49.8	-0.2	-0.4
2	53.4	62.5	-9.1	-17.0
3	55.5	50.3	5.2	9.4
4	92.8	82.1	10.7	11.5

Interpretation of WSDOT practice. The consistency between the independent rating and those of the WSDOT surveyors coupled with the quality of WSDOT reference guides indicates that WSDOT has a consistent and repeatable methodology to determine pavement surface condition ratings.

Research Question 4.

How does WSDOT quantify risks to its need and cost estimates?

Risks

Systemic risks

- Market fluctuations affecting cost of labor, materials, or equipment.
- Budget (or other agency) restrictions preventing allocation of sufficient funding for pavement preservation activities.
- Insufficient or inaccurate data, limiting agency's capability to manage assets effectively.

Site-specific risks

- Sudden condition-related failure, particularly when agency lacks information about impending failure (e.g., blow ups on concrete pavements due to weather-related issues, roadway collapse due to sudden failure of underlying drainage structures).
- Natural hazards and climate change impacts such as earthquakes, floods, severe storms, etc.
- Man-made hazards such as drastic increases in truck loading (increase in legal load or overload limits) that can accelerate pavement deterioration, drastic increases in traffic volumes due to increased economic activity in certain areas, etc.

Table 11 provides an overall summary of WSDOT's practices in quantifying risk in pavement long-term needs and cost estimates.

Table 11. Summary of WSDOT practices in quantifying risks in needs and cost estimates

Ingredient	WSDOT Status	Gap exists	Gap size
1. Systemic risks			
Forecasting market conditions	Yes	No	n/a
Performance-and fiscally-constrained scenarios	Yes	No	n/a
2. Site-specific risks			
Quantifying needs - condition-caused failure	None	No	n/a
Quantifying needs - risk of natural hazards	None	No	n/a
Quantifying needs - risk of man-made hazards	None	No	n/a
3. Integration of risk into priority-setting	Yes	No	n/a

WSDOT status: Ability of WSDOT to consistently and efficiently repeat this function each year or each cycle as required

Gap exists: Improvement needed in order to comply fully with best practices

Gap size: Relative effort to expand, automate, and document the capability for repeatable use

WSDOT considers systemic risk in its long-term estimates of pavement needs. The Department does not consider site-specific risks in its long-term estimates, which is appropriate. Site specific risks are localized and, in the rare circumstances where catastrophic failure occurs, have little to no impact on network level conditions.

WSDOT is exceptional among state Departments of Transportation in its integration of risk into its project prioritization process.

The sections below describe in more detail WSDOT's practices in quantifying risks in needs and cost estimates. In each practice area, the italics *yes* or *none* correspond to the summary of the comparison of WSDOT practices shown in table 11.

Practice 1. Systemic risk

Forecasting market conditions

Market fluctuations impact state Department of Transportation expenses and revenues.

On the expense side, major issues for pavement management include:

- Supply and demand of raw materials for pavement construction, that include asphalt, cement, fly ash, aggregates, reinforcing steel, etc.
- Fluctuations in costs associated with construction: these include material transportation and actual pavement construction costs, scope changes during construction, etc.
- Quality of resources: this includes raw materials that are used in the pavement, skilled labor, etc.

Major revenue issues include:

- Vehicle fuel efficiency has improved over the past decade which has been required by the federal Corporate Average Fuel Economy (CAFÉ) program. The improvement in fuel efficiency results in reduced funding from motor vehicle fuel taxes.
- Vehicle-Miles Traveled (VMT), which is affected by population growth and changes in economic activity, effects motor vehicle fuel tax receipts.

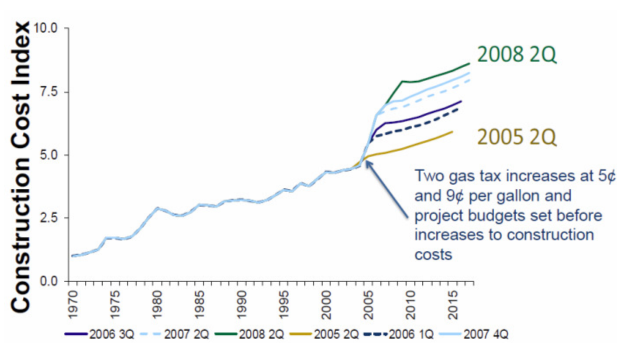


Figure 21. Recent Inflation Trends (Milton 2013)

Interpretation of WSDOT practice. ***Yes.*** On the expense side, WSDOT routinely tracks fluctuations in the costs associated with its resources (see figure 21). WSDOT has also developed spreadsheet tools to assist in price adjustment calculations associated with pavement materials.[3]

[3] http://www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment/Information.htm#GSP04054

On the revenue side, WSDOT's has developed VMT projection models, which helps WSDOT track VMT trends and study the impact of changes in VMT to its revenue projections.[4] The forecasted trends suggest that that the vehicle miles traveled has flattened in recent years and slower growth is projected for future VMT.

The Transportation Revenue Forecast Council issues updates of long-term motor vehicle fuel tax and other transportation revenues quarterly, which take into account changes in VMT and the impact of CAFÉ standards.

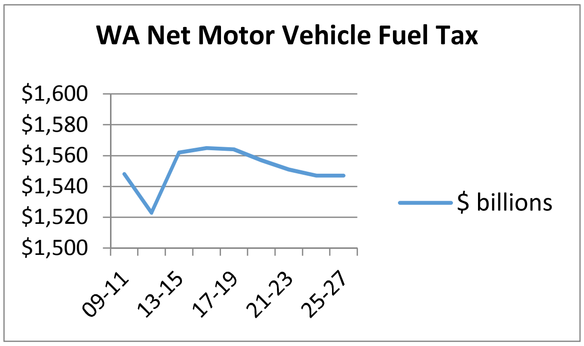


Figure 22 shows the projected decline in net motor vehicle fuel tax.

Figure 22.Net motor vehicle fuel tax projection (Transportation Revenue Forecast Council, Feb. 2014)

Performance constrained scenarios

For long-term maintenance and preservation needs estimates to incorporate market fluctuation impacts, the pavement management system should be capable of analyzing "what-if" scenarios like:

- What if funding levels are reduced by 50 percent or 75 percent?
- What if interstate pavements are prioritized over principal arterials?
- What if chip seal needs are funded before addressing other needs?

Interpretation of WSDOT practice. *Yes.* The WSPMS Forecaster helps WSDOT answer "what-if" questions such as those posed above. WSDOT tracks the investments made in pavement preservation efforts and the impact on overall network conditions routinely.

Figure 23 demonstrates the effectiveness of WSDOT pavement management practices as conditions have remained the same or slightly improved as funding has decreased. This is because of:

- Improvements in treatment timing and application.
- Conversion of asphalt pavements to chip seal.
- Extension of concrete pavement life from dowel bar retrofits, surface grinding, and asphalt overlays which has deferred the need for more costly reconstruction of concrete pavements.

[4] WSDOT (2010). Vehicle Miles Traveled (VMT) Statewide Forecast Model.

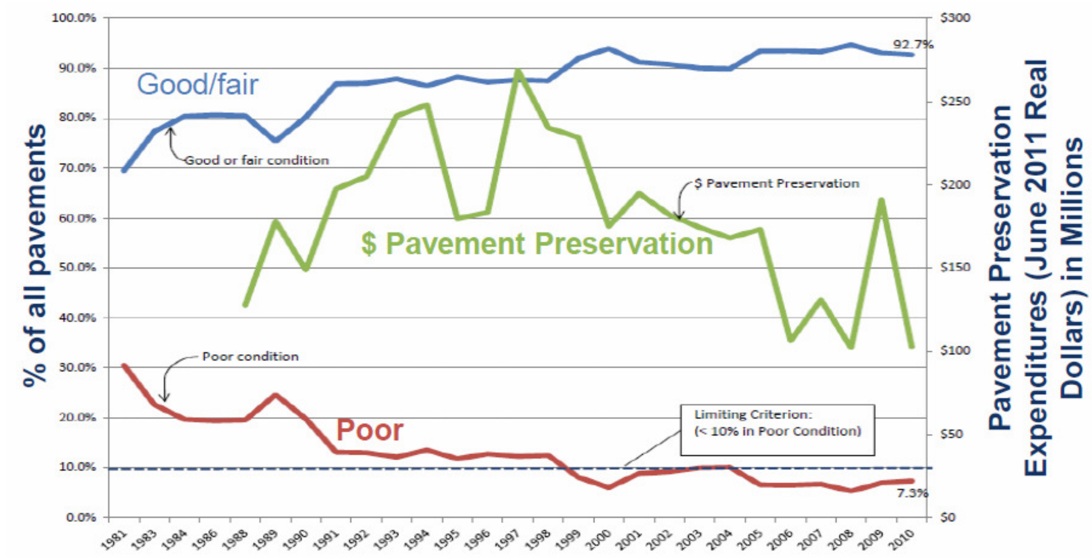


Figure 23. Pavement Performance and Investment Trends: 1980 - 2010 (Milton 2013)

Practice 2. Site-specific risk

Quantifying needs – condition-caused failure, natural and man-made hazards

State Departments of Transportation manage condition-caused failure, natural and man-made hazards but do not quantify these risks in long-term pavement need estimates. This is because the risk of catastrophic pavement failure is low and localized and the cost of repairing the damage and restoring the pavement would be a negligible component of the network budget

Interpretation of WSDOT practice. *None.* WSDOT manages site-specific risk, but does not quantify those risks in its long-term pavement needs estimates.

- *Condition-caused failure.* Condition-caused failure is managed by addressing distress, maintaining sections currently due for rehabilitation, and holding past-due sections together with interim treatments.
- *Natural hazards.* The primary natural hazards are earthquakes, flooding, unstable slopes, and avalanches. WSDOT conducted a study on assessing the vulnerability of its transportation assets to climate change-related impacts.[5]
- *Man-made hazards.* WSDOT develops estimates of long-term traffic projections using statistical analysis of historical data. A traffic forecasting guide, which documents the overall process used, has been published by WSDOT.[6] These projections are used when evaluating pavement structure requirements for new pavements. Asphalt pavements constitute the vast majority of roadways in Washington State. Significant increases in truck traffic and/or repeated overload weights can cause severe cracking and/or rutting along the wheel paths (see figures 24a and 24b below).

---

[5] WSDOT. (2011). Climate Impacts Vulnerability Assessment.

[6] WSDOT. (1991) WSDOT Traffic Forecasting Guide Volume 1 – Introduction to the Forecasting Process and Volume 2 – Forecasting Instructions. http://www.wsdot.wa.gov/Research/Reports/200/219.1.htm

Figure 24a. Severe cracking along the wheel path due to heavy loads on SR-532 near I-5; Figure 24b. Rutting due to heavy loading on I-90 in Spokane (Weigh Station) [source: WSDOT]

WSDOT has studied the impact of increased traffic loading conditions on the condition of its pavements. Traffic forecast models help mitigate the risks associated with systematic increase in traffic volumes.

Site-specific risks are not expected to occur uniformly over the entire network and therefore WSDOT handles these risks on a case-by-case basis. Since instantaneous failure does not usually occur on pavements, these risks can be prioritized and managed on an as-needed basis.

WSDOT handling of site-specific risks is in conformance with industry standards. The consultants do not recommend that WSDOT try to incorporate such risks in its long-term pavement needs estimates.

Practice 3. Integration of risk into priority setting

Very few highway agencies consider risk through a formalized framework within their pavement management system. Poor pavement conditions are generally considered to pose higher risks (to both users and the agency); however, it need not be the only factor influencing the level of risk. There are other factors that contribute to the overall level of risk, including: traffic levels, truck traffic, criticality of route (interstates vs. other local routes), etc.

WSDOT - Risk in priority setting

WSDOT is one of the few agencies in the U.S. that is formally considering risk during the project prioritization process. Risk is considered as one of the performance measures within the Forecaster tool. WSDOT recently developed a risk register to account for the additional risk associated with deteriorated pavement.

Interpretation of WSDOT practice.
Yes. Figure 25 shows the pavement risk register in the forecaster tool.

	Consequence				
Likelihood	(6) Major Collector	(7) Minor Arterial	(8) Other Principal Arterial	(9) Principal Arterial	(10) Interstate
Very Rare (2) [Very Good]	Low (12)	Low (14)	Low (16)	Low (18)	Low (20)
Rare (4) [Good]	Low (24)	Low (28)	Low (32)	Low (36)	Moderate (40)
Seldom (6) [Fair]	Low (36)	Moderate (42)	Moderate (48)	Moderate (54)	High (60)
Common (8) [Deficient]	Moderate (48)	Moderate (56)	High (64)	High (72)	Extreme (80)
Frequent (10) [Failed]	High (60)	High (70)	Extreme (80)	Extreme (90)	Extreme (100)

Figure 25. Risk register used by WSDOT's Forecaster tool [source: WSDOT]

This was primarily designed as a counter-balance against pavement conditions being the dominant parameter driving project selection. Two roads may exhibit similar performance levels from a pavement condition standpoint but one may pose a higher risk (to the agency and the users) when compared to the other due to traffic volumes, route priority, etc. Using the lowest cost fix to achieve the targeted network level-of-service may not be the most optimal solution since higher-risk needs (which are often costlier) may be ignored. Although not explicitly documented, the risks considered during the development of the risk register are:

- Reduction in speed limit due to roadway condition
- Increased risk of accident because of roadway condition
- Increased risk of roadway reconstruction (typically asphalt pavements), or immediate capital needs (for concrete pavements)

The risk rating or impact is a mathematical product of the likelihood and consequence ratings shown in figure 25. The following categories are used to define level of Impact: 0 – 39: Low, 40 – 59: Moderate, 60 – 79: High, and 80 – 100: Extreme. The overall risk within the pavement network is defined as the weighted average rating (weighted by lane-mile or VMT) of the individual risks. A sample screenshot from WSDOT's Forecaster tool is shown in figure 26.

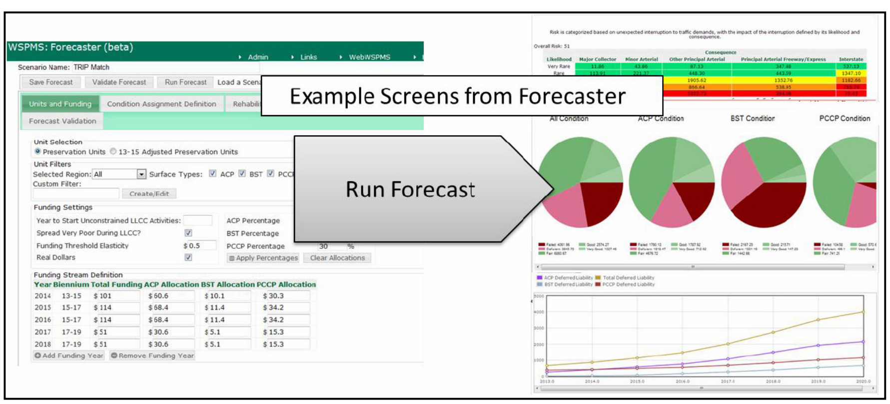


Figure 26. Sample screenshot from WSDOT's Forecaster tool [source: WSDOT]

Bridges

Summary Research Questions Responses & Recommendations for Improvement

Research Question 1. The methods and systems WSDOT uses to develop long-term estimates of bridge maintenance and preservation needs **are not completely consistent** with industry practices and other appropriate standards.

> *Bridge recommendation 1. WSDOT should improve its bridge analysis methods, decision support tools, documentation and staff training in order to provide systematic, complete, and consistently developed estimates of bridge needs. WSDOT should implement best practices including deterioration models from element condition data, unit costs from statistical analysis of capital and maintenance work accomplishment data, effectiveness metrics from statistical analysis of work accomplishment and inspection data, and life cycle cost analysis.*

Research Question 2. WSDOT **does not incorporate life cycle cost analysis** in its bridge management process.

> *Bridge recommendation 2. WSDOT should establish a routine framework where calculations of life cycle cost are expected as a justification for bridge maintenance budgets or bridge needs estimates. WSDOT should compute, and document, the performance levels and policies that minimize life cycle costs, and should compute its backlog as the additional near-term cost required in order to attain optimal long-term performance.*

Research Question 3. The information that WSDOT uses to develop long-term estimates of bridge maintenance and preservation needs **is accurate**.

Research Question 4. WSDOT **quantifies** the effect on bridge preservation and maintenance needs **of systemic risks and site-specific risks from structural deficiency and natural hazards. It does not consider risk from man-made hazards**. WSDOT **does not** consider **risk in bridge project priority setting** which is an exceptional practice in some states.

> *Bridge recommendation 3. WSDOT should develop a bridge risk register and quantitative tools for risk assessment and risk management to enable it to consider risk in priority setting.*

WSDOT bridges

WSDOT manages 3,794 bridge structures.

- *Vehicular bridges over 20 feet*. WSDOT manages 3,082 vehicular bridges over 20 feet, which are subject to federal bridge regulations.
- *Vehicular bridges under 20 feet*. Three hundred and eighty-seven (387) of WSDOT's bridge structures are vehicular bridges under 20 feet. These bridges are not subject to federal bridge regulations.
- *Culverts over 20 feet*. One hundred and twenty-eight (128) of WSDOT's bridge structures are culverts over 20 feet in length.
- *Other structures*. Other structures include pedestrian structures (75), ferry terminal structures (68), tunnels and lids (42), boarder bridges managed by other states (6), railroad bridges (5), and the Washington State Convention Center, which is built over 1-5.

Figure 27 shows the distribution of bridge structures:

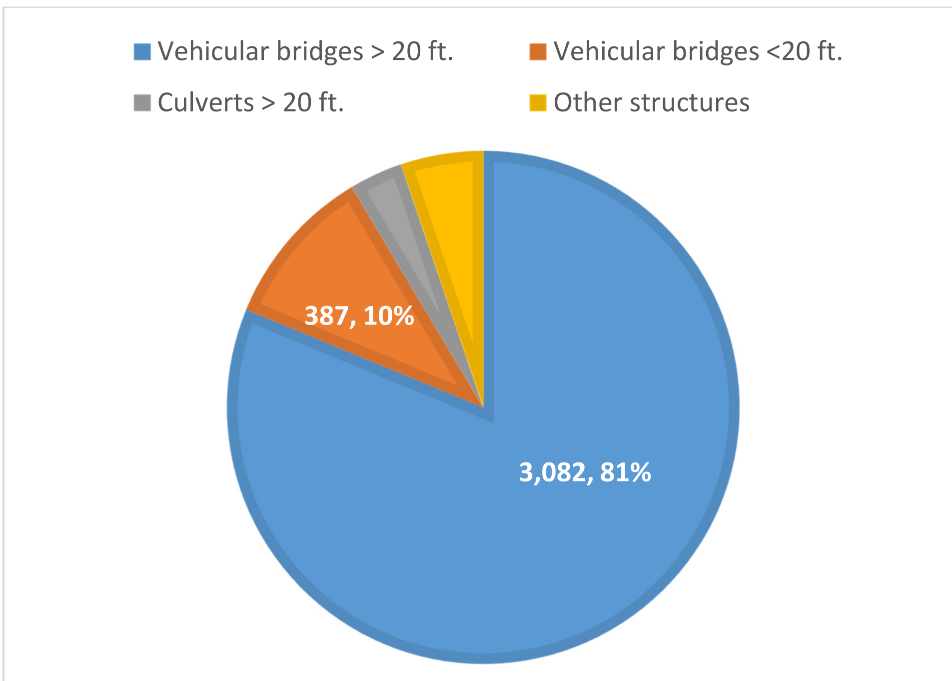


Figure 27. Bridge structures. (Source WSDOT Gray Notebook June 2013)

Bridge performance goals

The preservation goal for bridges in the June 2013 Gray Notebook is to have 97 percent or more of WSDOT bridges in fair or better condition. As shown in figure 28, in FY 2013, 96 percent of WSDOT bridges are in fair or better condition. The Gray Notebook does not provide a projection of bridge conditions through 2018 as it does for pavement conditions.

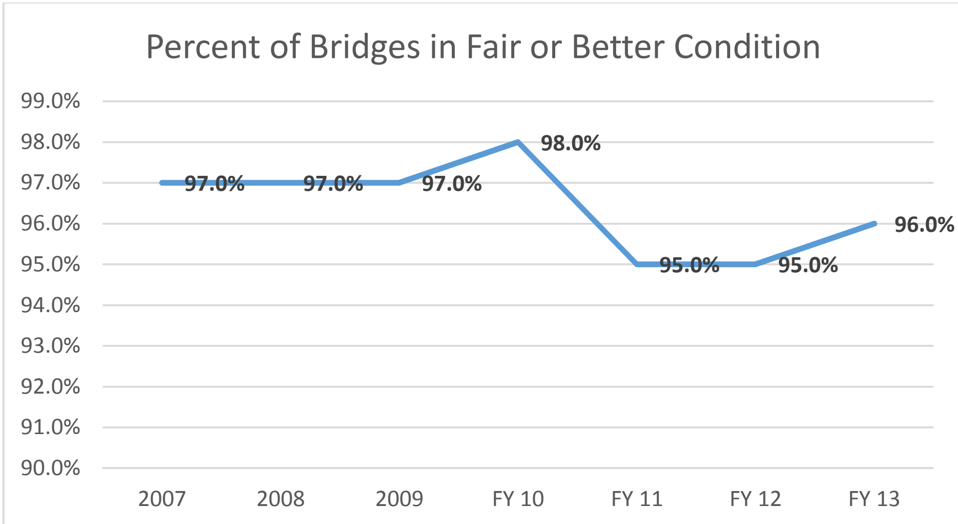


Figure 28. Percent of bridges in fair or better condition. (Sources WSDOT Gray Notebook, June 2009-2013 bridge reports)

Bridge preservation funding

2013-15 biennium 16-Year Capital Plan

The 2013-15 biennium 16-year capital plan projects a decline in funding for bridge preservation, from $280.3 million in the 2013-15 biennium to a low of $51.3 million in the 2021-23 biennium. The average biennium funding for bridge preservation is $97.8 million from the 2015-17 biennium through the 2027-29 biennium.

Table 12 shows the 2013-15 biennium 16-year capital plan for bridge preservation.

Table 12. 2013-15 16-year capital plan for pavement and bridge preservation. (Source Legislative Evaluation and Accountability Program 2014-2 Program P)

($ in millions)	**13-15**	**15-17**	**17-19**	**19-21**	**21-23**	**Three Biennia 23-29**
Hood Canal Bridge	0.3	0.1				
Bridge Preservation - Repair	135.6	73.3	35.0	34.4	29.7	183.7
Bridge Preservation - Scour	0.7	2.2	0.5	0.2	0.2	
Bridge Preservation - Seismic Retrofit	41.9	4.3		3.0	5.6	112.2
Bridge Preservation - Replacement	101.8	10.9	26.4	36.6	15.8	110.8
Total Bridge Preservation	**280.3**	**90.8**	**61.9**	**74.2**	**51.3**	**406.7**

Unfunded System Investments

In the 2014 legislative session, the Legislature considered additional funding for transportation. To inform that exercise, WSDOT prepared a list of its priorities for new revenue referred to as the Orange List.[7] As shown in Table 13, the list included funding to provide a 10-year preservation investment to achieve a bridge condition in excess of 97 percent fair and good or 99 percent in the optimal higher investment level.

Table 13. WSDOT Priorities for New Revenue – 2013

WSDOT 2014 Orange List	**Recommended Priority Investment Level ($ millions)**	**Optional Higher Investment Level ($ millions)**
Bridge Preservation	$384 *10-year investment 97% fair and good*	$504 *10-year investment 99% fair and good*

Research Question 1.

Are the methods and systems WSDOT uses to develop long-term (10-year) estimates of maintenance and preservation needs consistent with industry practices and other appropriate standards?

WSDOT's practices were determined from interviews and reviews of: *WSDOT Bridge Painting Needs* (WSDOT 2011), *Maintenance Accountability Process (MAP) Manual* (WSDOT 2012), *The WSDOT Bridge Inspection Manual (2012),* and other WSDOT technical documents.

Bridge management system

Similar to the way in which WSDOT uses the WSPMS to conduct the transportation needs assessment steps for pavements, most state Departments of Transportation use bridge management systems to perform these same needs assessment steps for bridges.

A bridge management system is:

- A *set of* procedures, data, and analysis tools.
- Used *to support agency decision making* in the planning of future preservation, maintenance improvements, and replacements of existing structures.
- Intended to *achieve a desired level of service in the most cost-effective manner.*

The most common bridge management software package in current use is AASHTO's Pontis, which is licensed by 40 states. Some states have developed their own custom bridge management systems and some use spreadsheet tools rather than a software package.

[7] WSDOT, Priorities for New Revenue – 2013

A 2010 survey by FHWA of state Departments of Transportation,[8] found that states vary in the degree to which they utilize the capabilities of bridge management systems. All of the states that responded to the survey capture and store bridge inspection and condition data in their bridge management system; 86 percent capture and store bridge planned project information; 63 percent use the system to predict deterioration; and 38 percent include life cycle cost analysis in their bridge management decision-making.[9]

Although states vary in their use of bridge management system capabilities,[10] there are industry standards established by FHWA and AASHTO for how and for which tasks such systems should be used. The FHWA 2010 survey identified a number of issues that FHWA is working on to encourage the adoption of these standards by states, including: greater use of life cycle cost analysis; use of analytical software products, methods, or tools to predict deterioration; and documentation of bridge management practices. FHWA describes its goal as:

> *Emphasizing the use of a bridge management system to assist bridge owners in being able to do the right activity, to the right bridge, at the right time and at the right cost is paramount to preserving our transportation infrastructure in general and our highway bridges in particular*. http://www.fhwa.dot.gov/Bridge/management/index.cfm.)

Interpretation of WSDOT practice. Until 2009, WSDOT conducted its bridge management process by licensing an AASHTO bridge management software package, Bridgit. AASHTO discontinued its support for Bridgit in 2009 which was in use by two states, Washington and Maine.

WSDOT's Washington State Bridge Inventory System (WSBIS) aggregates the state's bridge inventory and condition data and is used to fulfill the reporting requirements of the National Bridge Inspection Standards. The data is stored in the Bridge Reporting

WSDOT BRIDGE PRESERVATION PROGRAM CANDIDATE SELECTION AND PRIORITZTION METHODS

Bridge replacement - rehabilitation program

- Evaluation. Review bridges on priority array list with a sufficiency rating < 50 and structurally deficient/ review type of deficiency/determine if on a T-1 or T-2 freight route
- Prioritization. Formula ADT/sufficiency rating x load factor x freight route factor

Special bridge repairs

- Evaluation process – review items on repair list beyond maintenance, review BMS elements in condition state 3 or 4, determine if any floating bridge anchor cables
- Prioritization. Compare items such as loading carrying capacity of bridge and bridge importance.

Moveable bridge program

- Evaluation. Consultant review every five years/ plan for each structure
- Prioritization. Based on system reliability & user needs. Reliability is "based on the collective judgment of the staff, consultants and region staff".

[8] http://www.fhwa.dot.gov/bridge/management/bms.pdf

[9] In the time since the 2010 survey the use of life cycle cost analysis has increased substantially, because of a requirement for life cycle cost analysis in Transportation Asset Management Plans mandated by MAP-21. FHWA has not updated its survey.

[10] For example, Pontis was developed to meet the needs of all the states and has a wide range of features as a result. Each state implements only the features related to its own needs, and no state has implemented them all. Agencies typically develop their own tools to supplement those provided by Pontis, if needed. In a few cases, where states were not able to implement an off-the-shelf solution, they have developed their own complete bridge management software packages.

Database, which draws information from separate databases holding state owned and local agency owned structures.[11]

From this inventory data, WSDOT undertakes a biennial process that relies heavily on professional judgment to develop project lists, prioritize needs, and estimate future performance.

> *If a repair is deemed necessary (following inspection), then engineers review the repair options and put together a scope of work. If the repair is within the parameters of maintenance activities, then the maintenance program will repair the damage. For each bridge, the preservation need is prioritized and ranked against all bridge needs statewide according to the degree of risk and damage. This prioritization process occurs every two years. (WSDOT 2007-2026 Highway System Plan, p. 14)*

The evaluation and prioritization processes for steel bridge painting, bridge decks, special bridge repairs, moveable bridge and the bridge replacement-rehabilitation programs are summarized in the boxes. In addition to these programs, WSDOT has a prioritization process for its scour and seismic programs.

WSDOT BRIDGE PRESERVATION PROGRAM CANDIDATE SELECTION AND PRIORITZTION METHODS

Steel bridge painting program

- Evaluation process – review BMS paint element data, weathering steel element data, identify bridges with > 2% paint area in condition 3, identify weather steel elements with >5% in condition 3
- Prioritization process – Oregon border bridge funding, rank based on quantity of paint element in condition state 3/total steel surface area, consider bridge importance, insert weathering steel bridges into list

Bridge deck program

- Evaluation process – review concrete deck and overlay element data, identify bridges with >2% concrete deck element quantity and concrete overlays >5% in condition 2 and 3, concrete overlays with ruts >1/2 inch
- Prioritization. Rank based on sum of BMS element quantities in condition 2 and 3, top 10 based on quantity of patch, T1 & T2 freight routes then remaining.

[11] Washington Bridge Inspection Manual, November 2012, pg. 1-3.

AASHTO and FHWA Guides and WSDOT Processes

From a review of AASHTO and FHWA guides, the consultants identified 17 steps in the bridge needs estimation process which have been categorized into four processes.

Table 15 compares WSDOT's systems and methods with the AASHTO and FHWA practices.

AASHTO and FHWA Guide Processes

- Bridge inventory and condition data
- Estimation of current needs
- Bridge deterioration
- Prioritization

Table 15. Comparison of WSDOT systems and methods for estimating long-term bridge needs and AASHTO and FWHA Guides

	WSDOT Status	Gap exists	Gap size
Bridge inventory and condition data			
Bridge inventory data	Yes	No	n/a
Bridge condition data	Yes	No	n/a
Element condition data	Advanced	No	n/a
Estimation of current needs			
Bridge-level capital project cost data	Yes	No	n/a
Bridge-level maintenance activity cost data	Yes	No	n/a
Projection of inflation	Yes	No	n/a
Estimation of future needs and performance			
Network-level deterioration models	Partial	Yes	Medium
Treatment unit costs in outcome units	Partial	Yes	Medium
Effectiveness of treatments	Partial	Yes	Medium
Identification of current needs	Partial	Yes	Medium
Network-level needs caused by deterioration	Partial	Yes	High
Prioritization			
Generation of program alternatives	Partial	Yes	Medium
Discount rate set by policy	Yes	No	n/a
Calculation of life cycle cost	None	Yes	Medium
Objective program-wide prioritization	Partial	Yes	Medium
Quantified fiscal constraints/alternatives	None	Yes	Low
Fiscally-constrained condition targets	None	Yes	High

WSDOT status: Ability of WSDOT to consistently and efficiently repeat this function each year or each cycle as required

Gap exists: Improvement needed in order to produce accurate estimate of 10-year needs

Gap size: Relative effort to expand, automate, and document the capability for repeatable use

The findings on WSDOT's bridge condition estimating practices conform to industry practices and other appropriate standards is summarized in figure 29.

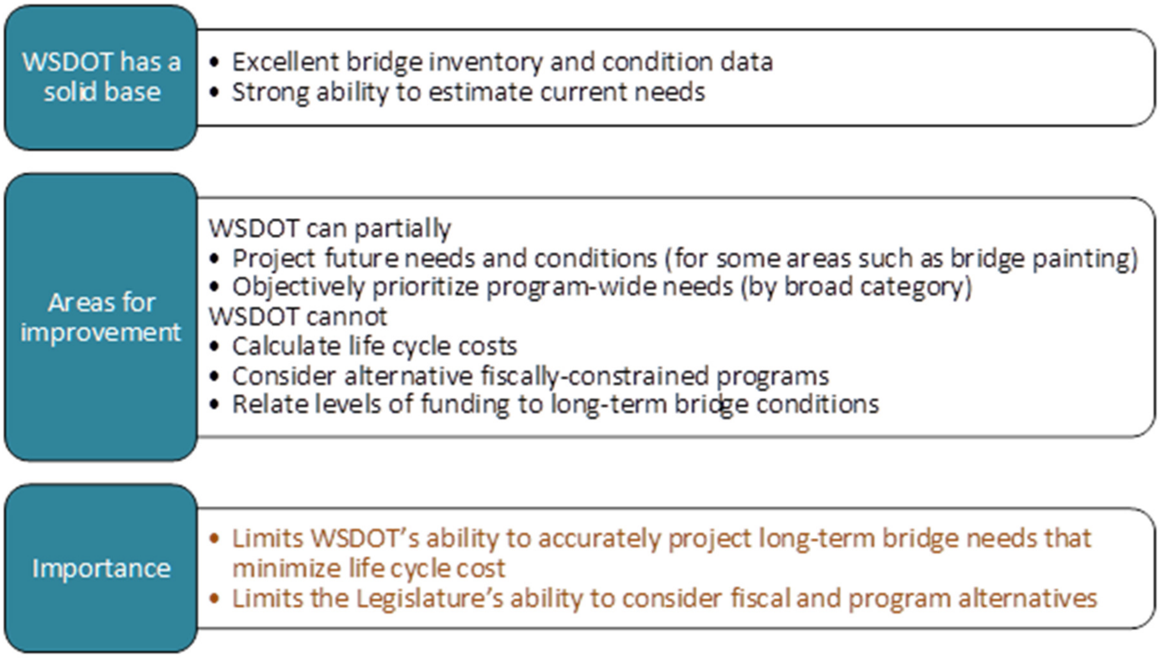


Figure 29. Summary of bridge Research Question 1 findings.

WSDOT is compliant with industry norms in its inventory and condition data. With a few exceptions it is also compliant in the development of current needs based on past inspection data. This provides WSDOT with a strong foundation for projecting long-term needs.

WSDOT's capabilities are limited in assessing needs over a long-term (10-year) period. The ability to consider needs over a 10-year period is important - it allows state Departments of Transportation to provide accurate projections of the impact of funding and program decisions on the future condition of state bridges and it allows legislatures and other decision-makers to consider data-driven alternatives. Key areas in which WSDOT does not meet industry practices and other standards include:

- WSDOT does not have the deterioration models used by most states for forecasting future needs. The lack of these models limits the ability of WSDOT to forecast: 1) the future cost of needs resulting from deterioration; and 2) the future condition of the inventory that results from the combined effects of deterioration and on-going investments in preservation and maintenance.
- WSDOT uses professional judgment to project changes in the condition of bridges at the network level at various funding levels. The use of judgment for this type of network-level forecast is not common practice and is not supported by industry guidebooks. Network-level projections should be based on validated, quantitative analysis of bridge deterioration and the effectiveness of alternative treatments. The projections should be able to consider network-level investment alternatives; to optimize the allocation of resources; to estimate the cost of a given set of performance targets; and to estimate the performance and backlog which might result from a given investment level.

- WSDOT does not have an institutional framework in which bridge needs can be systematically, completely, and consistently developed and reported to the Legislature and other stakeholders.

The sections below describe in more detail how WSDOT compares with industry practices in the AASHTO and FHWA bridge management guides. In each practice area, the italics *yes, no*, or *partial* correspond to the summary of the comparison of WSDOT practices shown in table 15.

Practice 1. Bridge inventory and condition data

WSDOT's bridge inventory, condition and element condition data are discussed at length in Question 3.

Interpretation of WSDOT practice. *Yes.* WSDOT is compliant with federal requirements for bridge inventory, inspection and condition data. WSDOT was one of the early agencies to implement a system of bridge element inspection similar to the AASHTO CoRe elements. The WSDOT process is comprehensive in surveying all of the structural elements that can generate preservation and maintenance needs.

The Department's element catalog was especially innovative in covering bridge sidewalks and pedestrian railings; expansion joint components; floating bridge components; seismic restrainers; deck overlays; and protective coatings on steel elements. More recent versions of the AASHTO Element Manual have followed Washington's lead in adding deck surfaces, steel coatings, and other protective elements.

WSDOT bridge inspectors use this element level condition data when making work recommendations, especially for priority one maintenance items. Some of the elements, particularly deck overlays and paint system elements, are used to assist the inspector's judgment in identifying current preservation needs, and to document these needs.

Practice 2. Estimation of current need

Bridge-level capital project cost data

Most transportation agencies maintain a database of capital projects which they can use to track project status and to view the work history on a given bridge. At least half of the states are able to extract contract pay item data, such as quantities and costs. These are usually expressed in units of resources (labor, materials, equipment) or in units of output (e.g. square feet of concrete patched). Another common feature is tracking of agency time and materials used on contract work (for example, construction supervision).

This information is important for needs estimation because it feeds into a process of cost estimation for preservation needs.

Interpretation of WSDOT practice. *Yes.* WSDOT maintains a database of past and current capital projects, from which it is possible to readily extract cost data by bridge and type of work. The data include indirect costs of traffic control and mobilization, which are contractor responsibilities. The Department also compiles

INVENTORY, CONDITION, ELEMENT DATA

Inventory

- FHWA National Bridge Inspection Standards define inventory requirements
- Many states include non-bridge structures (i.e. sign structures, sign panels, high-mast light poles etc.) in their bridge system databases

Condition

- FHWA National Bridge Inventory Coding Guide includes four condition data items (deck, superstructure, substructure, and culvert)

Element

- AASHTO Guide for Commonly Recognized (CoRe) Structure Elements
- MAP-21 mandates expansion of National Bridge Inventory to include element data – FHWA in rule-making process

tabulations of bid data, which include resource unit costs. Figure 30 shows an example of the type of cost tracking performed by the WSDOT Construction Office.

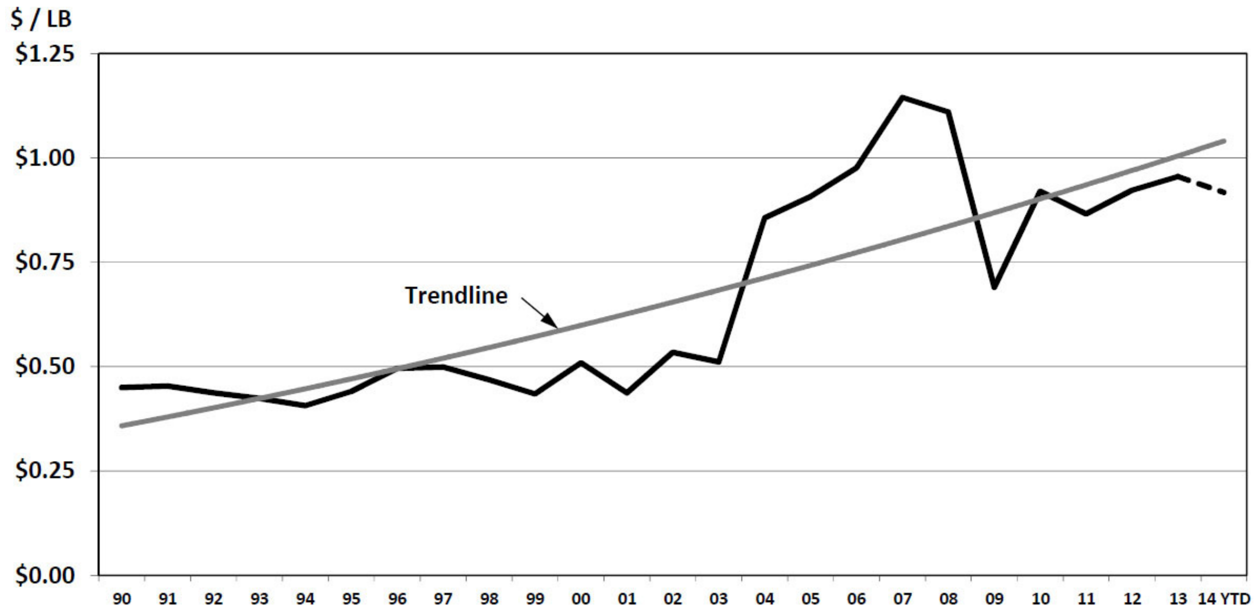


Figure 30. Example of resource cost tracking – cost per pound of steel reinforcing bar (source: WSDOT Construction Office)

Bridge-level maintenance activity cost data

Most state Departments of Transportation have Maintenance Management Systems which are used at least to track the work of agency forces in terms of labor, materials, and equipment; and often include tracking of contract maintenance as well. This information is important for needs estimation because it feeds into a process of cost estimation for maintenance needs.

Interpretation of WSDOT practice. *Yes.* WSDOT practices are consistent with the industry state of the practice. WSDOT maintains a database of maintenance activities, in which it is generally possible to identify the specific bridges and type of work. All work is performed in-house so the system is oriented toward the compilation of resource data - labor, materials, equipment, and services. Cost data can be derived from this information using current rates.

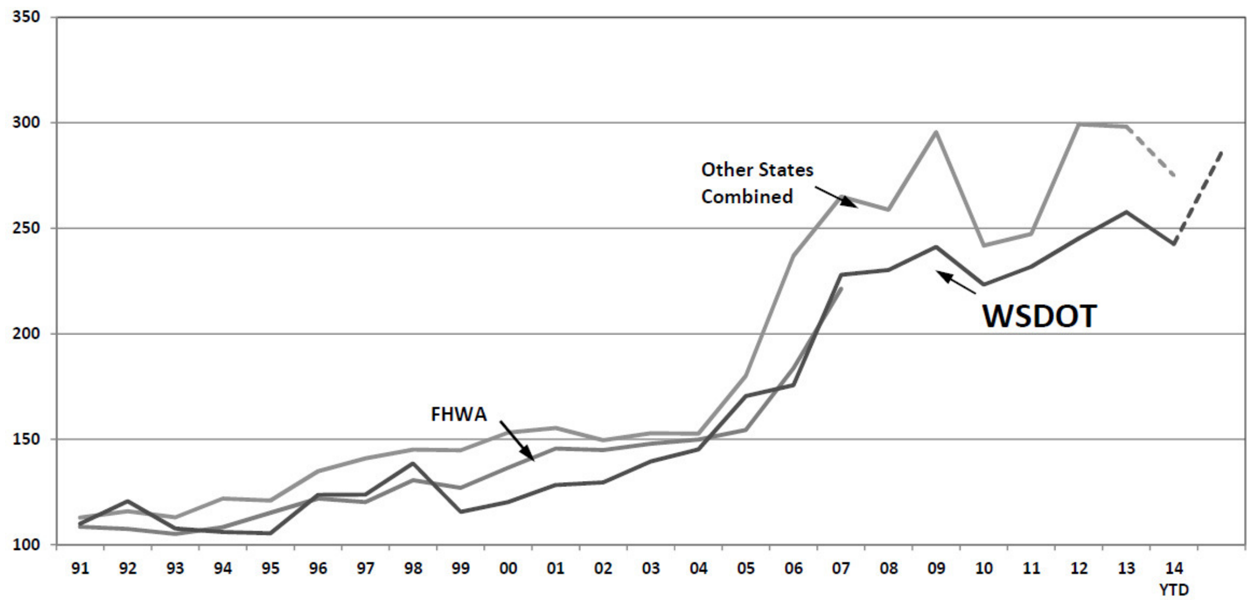
WSDOT routinely tracks the accomplishment of certain types of maintenance tasks using its Maintenance Accountability Process (WSDOT 2012). Statistics on work output are tracked online for bridge deck repair, structural bridge repair, and bridge cleaning.[12] This information does not include costs. The Department is in the process of implementing its Maintenance Productivity Enhancement Tool (MPET) which will track labor, equipment, and materials more comprehensively.

Projection of inflation

It is important to add inflation to ten-year needs estimates in order to provide an unbiased estimate of the resources that will be required to satisfy the performance objectives in future years.

[12] http://www.wsdot.wa.gov/maintenance/accountability/

Interpretation of WSDOT practice. *Yes.* WSDOT routinely tracks the inflation of its cost factors and has a mature capability to forecast future inflation. Figure 31 shows the historical growth of construction costs in Washington.



WSDOT base 1990 = 110.
FHWA and other states base 1987 = 100.
Other states: California , Colorado, Oregon, South Dakota & Utah.

Note: 2003 and 2004 WSDOT CCI data points adjusted to correct for spiking bid prices on structural steel.

WSDOT 2014 data through March.
FHWA index discontinued in 2007.
Other states data is the average California through 2009, Oregon through 2010, Colorado data through 2011 and South Dakota and Utah 2012 data and Utah 2013 data.

Figure 31. WSDOT Construction Cost Indices, May 2014

Practice 3. Estimation of future needs and performance

Network-level deterioration models

Deterioration models forecast future bridge conditions at a level of detail useful for various asset management purposes including needs estimation (Thompson and Hyman 1992, Gordon et al 2011). A 2010 FHWA survey found that 63 percent of the states surveyed have quantitative models to predict deterioration at the element level – a separate model for each type of bridge element.

Use of Element Data in Deterioration Models

The most common form of deterioration model operates with bridge element condition data. The model:

- Forecasts the probability of each possible condition at the end of a one-year period, based on conditions at the beginning of the period.
- Agrees well with subsequent bridge inspection data (Sobanjo and Thompson 2011) and is sufficiently detailed for network-level needs estimation.

WSDOT has bridge element inspection data, but has not

Interpretation of WSDOT practice. *Partial.* WSDOT has prepared a needs analysis for steel coating systems, which includes estimates of paint and steel deterioration rates (WSDOT 2011). These estimates, prepared from a combination of data analysis and judgment, are in the form of typical lifespans of coatings and of steel elements whose coatings have failed.

WSDOT has developed rules of thumb for the increase in deck deterioration that occurs during the period after an inspector discovers deck distress until a repair action can be completed.

WSDOT describes its use of these analyses as ad hoc in nature, primarily used at the project level (rather than for the inventory as a whole), not repeated on a regular cycle, and rarely documented. Most of the element types in the WSDOT inventory have not been analyzed in this way. A more comprehensive and systematic process would be required in order to estimate long-term preservation and maintenance needs.

Most state Departments of Transportation have developed a set of bridge deterioration models. These states are able to forecast upcoming needs caused by deterioration within a 10-30 year period for the entire network, are able to forecast network conditions at the end of the period, and are able to perform life cycle cost analysis. WSDOT has not developed such models.

Treatment unit costs in outcome units

In bridge management analyses, unit costs are used with current condition and with forecasts of future condition to convert condition information into predicted future costs. This is essential for life cycle cost analysis (see Question 2) and also for consistent network-wide estimation of preservation and maintenance needs. For both of these uses, the same computation must be performed for every bridge in the inventory for every year of the analysis, unit costs must be updated for inflation, and the unit costs must be expressed in outcome units — i.e. the same units that are used in element inspection, in order to relate them directly to inspection data. Two ways to do this are:

1. *Statistical analysis* of capital and maintenance work accomplishment data, in combination with bridge element condition and quantity data, to derive typical unit costs.
2. *Expert judgment*. Agencies that either do not have suitable work accomplishment data, or have not yet analyzed their data, often use an expert judgment elicitation process to develop approximate unit costs to use when estimating future bridge needs. This is a viable alternative and can be accurate if based on validated project cost estimation procedures.

Interpretation of WSDOT practice. *Partial.* WSDOT project cost estimates are performed by examining and averaging groups of similar projects, or by building up from resource unit costs. The same approach is used to prepare project-level and treatment-level needs estimates. This labor-intensive method is best practice for project design, has worked reasonably well for estimating current needs, but would be prohibitively time-consuming if used to generate future needs that have not already been identified and investigated.

Unlike most states, WSDOT has calculated the painted surface area on each bridge, and stores this information in its bridge database. Condition of coating elements is also tracked in the same square foot units. This best practice is very useful for estimation of needs. The Department developed painting unit costs from this information for its painting needs report (WSDOT 2011).

Using a combination of data analysis and judgment, WSDOT has also developed ad hoc unit costs for bridge deck surfaces, modular expansion joints, and floating bridge anchor cables. According to WSDOT, these models are not documented and therefore cannot be repeated in a consistent way.

This type of analysis has not been performed for other bridge elements. WSDOT has a sufficiently large and complete database of work accomplishments to generate these models for all of its bridge elements.

Effectiveness of treatments

Effectiveness metrics are used in order to forecast the performance of the bridge inventory at the network level if a proposed program of projects is implemented.

Interpretation of WSDOT practice. *Partial.* WSDOT has been tracking before-and-after data for paint and for certain types of deck overlays and patches. A future analysis of these data will provide reliable treatment effectiveness models for these elements. A methodology for evaluating the effectiveness of steel bridge washing has been developed in a research study (Berman et al 2013a) but has not yet been tested using WSDOT data. The effectiveness of certain common fatigue cracking counter-measures has also been investigated in laboratory research (Roeder 2001).

WSDOT indicates that it has not performed this type of analysis for a needs estimate. WSDOT indicates that the Orange List performance prediction was based on judgment and not based on any validated, quantitative analysis of deterioration or the effectiveness of treatments. The use of judgment for this type of network-level forecast is not common practice and is not supported by industry guidebooks.

Identification of current needs

Every state DOT has some type of capability to estimate bridge needs based on current inspection data including current conditions. Bridge management systems perform this task automatically, and most agencies supplement their bridge management system analysis with their own judgment and knowledge of program plans, environmental issues, and other site-specific information affecting the feasibility of projects. Spreadsheet analyses are also common.

Interpretation of WSDOT practice. *Partial.* WSDOT is in a small minority of states that do not have a bridge management system capability to generate current candidate needs automatically. Providing such estimates manually is not state of the practice because it is labor intensive, cannot be easily replicated, and is not able to produce alternative scenarios that would allow policy makers to optimize investments in bridges. WSDOT maintains a listing of near-term needs for several common preservation activities, such as repainting (WSDOT 2011). The Department can generate a list of high-priority maintenance needs, some of which is guided by research-based decision rules (Berman et al 2013b). It also maintains lists of structurally deficient and functionally obsolete bridges to consider for future rehabilitation or replacement on particular freight routes.

Effectiveness of Treatments

Metrics used to forecast network level bridge performance if a proposed program of project is implemented.

- Developed from a combination of work accomplishment and inspection data.
- Enables comparison of before-and-after element condition for each preservation or maintenance action.
- Derive metrics of treatment effectiveness.

WSDOT has not performed this type of analysis

Orange list performance outcome based on professional judgment not analysis

WSDOT indicates that the development of such needs is incomplete. The Department intends to develop lists of certain needs and has not yet been able to do so (for example, timber deck replacements, secondary maintenance tasks, the cost of a desired spot painting program, repairs on movable bridge components).

Network-level needs caused by deterioration

Bridge management systems have the capability to forecast element deterioration and generate future needs from this information. Usually this analysis is performed at the project level but aggregated to the network level before being used. Project level needs estimates in these systems are probabilistic, so they do not give precise information about individual bridges, but they do add up to reasonably reliable estimates of future needs at the network level. The information provided in such an estimate will provide the anticipated level of funding needed, but does not identify specific projects or treatments

The deterioration aspect of needs estimation is essential for an accurate result. As will be discussed in detail in Question 2, a bridge program that minimizes life cycle cost follows a consistent policy that keeps the inventory as a whole in a consistent optimal condition from year to year. This means that for every bridge that deteriorates between one inspection and the next, that bridge or another bridge must be improved in condition by preservation action. In the later years of a ten-year period, nearly all of the needs are driven by deterioration. It would be very inaccurate to omit these needs, and few agencies do.

Interpretation of WSDOT practice. *Partial.* WSDOT indicates that it does not have network level bridge deterioration models, and therefore does not have the capability to estimate future deterioration-caused needs in a consistent manner for all elements in the inventory. It does, however, consider deterioration in a quantitative way for a subset of future needs, specifically painting and near-term (1-2 years) deck deterioration. As a result, the assessment is that WSDOT has a partial capability in this area.

Practice 4. Prioritization

Generation of program alternatives

Because of uncertain funding constraints, uncertainties in deterioration and costs, and site characteristics, it is useful to be able to consider multiple approaches to the preservation of each bridge or each element. For example, on a given bridge the Department may consider either replacement or rehabilitation, and may consider whether a functional improvement (such as widening) should be added to a rehabilitation project. It would be prohibitively time-consuming to do this manually for forecasting future needs for all bridges in the inventory. As a result, an automated process of some sort is necessary. One state (Florida) has developed a spreadsheet model that can automatically generate scope and timing alternatives for any of its bridges. Most states use Pontis or a custom-developed automated analysis for this purpose.

Interpretation of WSDOT practice. *Partial.* WSDOT routinely considers alternatives for larger projects as a part of preliminary design, but does not do this for smaller projects nor for needs that are being considered for 5-10 years in the future. WSDOT indicates that the process the Department uses for certain types of needs, such as painting and bridge deck overlays, could not be repeated multiple times for different scenarios, because of the large amount of staff time this would take. The Department says it recognizes the need to automate this function but has not done so because of other competing priorities.

Discount rate set by policy

Life cycle cost analysis requires the use of a discount rate to quantify the value of postponing future costs. Transportation agencies typically use a discount rate higher than the US Treasury bond rate. As of this writing, the OMB Circular A-94 rate for 30-year Treasury bonds is 1.9 percent, but discount rates used by state Departments of Transportation are more commonly in the 2-5 percent range.

Interpretation of WSDOT practice. *Yes.* Like most states, WSDOT has a de facto policy on the discount rate to be used in financial analysis. In cooperation with the State Treasurer's Office, WSDOT uses a 4 percent discount rate. This rate could also be used for bridges if WSDOT implements bridge life cycle cost analysis.

Calculation of life cycle cost

Life cycle cost analysis is an essential tool in bridge management and is discussed in more detail in Research Question 2. It is used to evaluate the possibility of incurring a small expense for preventive maintenance, as a way of postponing a much bigger expense of rehabilitation or replacement. The discount rate is an adjustment factor applied to future cash flows to reflect the benefit of postponing expenses.

Interpretation of WSDOT practice. *None.* The Department does not have an automated or documented capability to calculate bridge life cycle costs.

Objective program-wide prioritization

One of the major differences between project level analysis and network level analysis is that the former tries to find the best action at a given time for a given bridge, while the latter tries to find the best allocation of limited funding across all bridges in the inventory over multiple years (Thompson and Hyman 1992).

Interpretation of WSDOT practice. *Partial*. The WSDOT Bridge and Structures Office has an established protocol for prioritizing candidate bridge investments of all types. This provides general guidance on the weighting of project characteristics by defining project categories.

None of these criteria include life cycle cost, none consider fiscal constraints, and none provide an objective basis for deciding whether a project is needed within ten years or within some longer time frame. As a result, the methods described in WSDOT documents, while reasonable and suitable for project level decision making, are not sufficient for a 10-year

Objective Program-wide Prioritization

Differences between project and network level analysis:

- Project level analysis focuses on one bridge and cannot compare needs with funding constraints.
- Project level analysis does not consider that work may be deferred into the future due to funding constraints or in comparison to other projects.
- A policy that minimizes life cycle costs for one bridge in isolation may not be a policy that minimizes life cycle cost for the inventory as a whole.
- Important needs, such as seismic retrofits, are difficult to evaluate for cost-effectiveness without considering related needs on many other bridges.

WSDOT does not have the ability to do objective program-wide prioritization.

network level needs estimate.

Quantified fiscal constraints/alternatives

Fiscal constraints play an unavoidable role in the quantification of multi-year needs (Gordon et al 2011). In any given year of a ten-year program, the total magnitude of preservation needs caused by deterioration is strongly affected by the level of investment in maintenance and preservation in the years previous.

Question 2 describes the methods used in bridge management systems to compute needs based on life cycle cost analysis. These methods depend on an assumption that funding is sufficient to sustain the inventory. Beyond that level, funding constraints determine how long it will take, if ever, to bring network conditions to a cost-minimizing level.

Interpretation of WSDOT practice. *None*. WSDOT's projection of changes in bridge condition ratings at various funding levels is an estimate based on professional judgment and is not based on any validated, quantitative analysis of deterioration or effectiveness of treatments. The use of judgment for this type of network-level forecast is not common practice and is not supported by industry guidebooks.

Fiscally-constrained condition targets

Bridge management systems have the capability to assemble needs into programs, select a project for each bridge based on life cycle cost, prioritize the project list within funding constraints, and then estimate the resulting performance of the bridge inventory as a result of the program.

Interpretation of WSDOT practice. *None.* The criteria for WSDOT's Orange List for bridges are not clearly defined, but WSDOT indicates that the projects are mostly based on current conditions and mostly do not account for new needs that will arise from future deterioration. Since WSDOT lacks deterioration models as discussed above, predictions of future bridge inventory condition, such as those in the Orange List, cannot be substantiated.

Recommendation for Improvement

WSDOT has the bridge inventory, bridge condition, element condition, bridge-level capital project cost data, and bridge-level maintenance activity cost data from which it can develop improved analysis methods and decision-support tools.

Bridge recommendation 1. WSDOT should improve its bridge analysis methods, decision support tools, documentation and staff training in order to provide systematic, complete, and consistently developed estimates of bridge needs. WSDOT should implement best practices including deterioration models from element condition data, unit costs from statistical analysis of capital and maintenance work accomplishment data, effectiveness metrics from statistical analysis of work accomplishment and inspection data, and life cycle cost analysis.

Research Question 2.

Are practices in place to minimize life cycle preservation and maintenance costs?

Guidelines provided by AASHTO and FHWA establish five bridge life cycle cost analysis capabilities.

Table 16 summarizes the comparison of WSDOT's bridge life cycle cost practices with industry practices.

AASHTO and FHWA Life Cycle Cost Capabilities

1. Asset level life cycle cost – computation of the long-term cost associated with each bridge
2. Project-level treatment criteria – decision rules to plan future actions on individual assets, intended to minimize life cycle cost but without regard to fiscal constraints or optimal timing
3. Computation of network level life cycle cost – total cost that is economically sustainable and developing and evaluating alternative policies and multi-year programs to find solutions with the lowest long-term network costs
4. Integrating maintenance and preservation – policies that consider both preservation and maintenance in order to make best use of each approach in minimizing life cycle cost
5. Backlog estimation and scenarios – procedures to compute the additional multi-year investment required in order to attain long-term optimal condition and to consider alternative fiscal constraints and performance targets to find realistic policies and multi-year programs that minimize long term costs.

Table16. Comparison of WSDOT bridge life cycle cost practices with industry practices.

Ingredient	WSDOT Status	Gap exists	Gap size
1. Asset life cycle cost	None	Yes	Medium
2. Project-level treatment criteria	Partial	Yes	Low
3. Network level life cycle cost	None	Yes	Medium
4. Integrating maintenance and preservation	Partial	Yes	Medium
5. Backlog estimation and scenarios	Partial	Yes	Medium

WSDOT status: Ability of WSDOT to consistently and efficiently repeat this function each year or each cycle as required

Gap exists: Improvement needed in order to produce an accurate estimate of 10-year needs

Gap size: Relative effort to expand, automate, and document the capability for repeatable use

WSDOT does not have practices in place to routinely estimate or to minimize bridge life cycle preservation and maintenance costs. WSDOT:

- Uses preservation and maintenance strategies at the project level that are based on staff understanding of best practice rather than on a WSDOT calculation of life cycle cost.
- Has not documented the tradeoff between routine bridge maintenance and longer-term preservation expenditures.
- Has prepared estimates that are not clearly defined, and do not consider sustainable fiscal scenarios or life cycle costs for addressing bridge preservation and maintenance backlogs.

The sections below provide more detail on each life cycle cost practice area. In each practice area, the italics *partial* or *none* correspond to the summary of the comparison of WSDOT practices shown in table 16.

Practice 1. Asset life cycle cost

Conducting bridge asset level life cycle cost analysis includes consideration of alternatives over the projected life span (75-200 years) of the bridge. The life of a bridge can be represented by a series of future activities laid out over time in a Life Cycle Activity Profile (see figure 32). The life cycle costs, including user costs, are compared across alternatives which may include a planned scope, modifications to project scope or schedule, and doing nothing. Each of these alternatives leads to a different future sequence of preservation, maintenance, rehabilitation, and replacement work and a different life cycle cost.

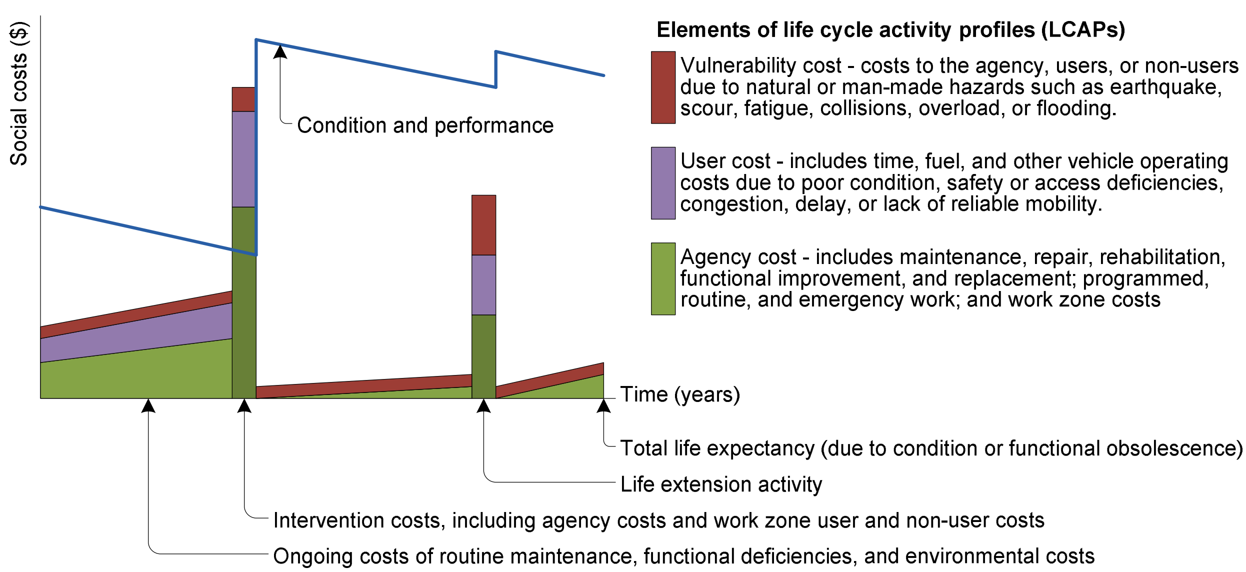


Figure 32. Typical ingredients in a life cycle activity profile (LCAP)

Interpretation of WSDOT practice. *None.* WSDOT does not currently conduct life cycle cost analysis on its bridges and lacks the software or other tools to conduct such analysis.

Practice 2. Project-level LCCA

All state Departments of Transportation have processes of keeping up-to-date with industry research, methods and products in order to find preservation and maintenance strategies which can minimize the life cycle costs of individual structures. Most DOTs also conduct their own research and experiments in order to determine which treatments work best under local conditions.

These criteria are often applied by bridge inspectors when recommending treatments for specific structures based on the conditions they see in the field. The same decision rules are used in life cycle cost analysis in order to create life cycle activity profiles, where the forecast condition of a bridge in the future is used in order to identify future projects and their costs.

Interpretation of WSDOT practice. Partial. There is no documented analysis to show whether the lifespans of paint and steel and bridge decks (see box) used in WSDOT analyses agree with lifespans that could be derived from historical WSDOT inspection data. There is no process to extend a similar analysis over all the diverse bridge elements in the Washington inventory. Since the method is very labor-intensive, there is no practical way to analyze alternative program scenarios or to model the effect of uncertainty. The methods WSDOT is currently using are effective for project-level decision making on certain bridges, but would be unsuitable for a ten-year network-wide assessment of preservation and maintenance needs.

WSDOT Bridge Project-level LCCA

WSDOT analyses rely on industry publications and best practices, using preservation activities shown by other agencies to minimize life cycle costs. Used by WSDOT for:

- Painting program – the typical lifespans of paint and steel used in the analysis serve the purpose of a very simple deterioration model. Life cycle costs have not been computed.
- Bridge deck preservation and maintenance - WSDOT has developed, over many years of research, a very effective set of bridge deck preservation and maintenance policies which have reduced the need for expensive bridge deck replacement projects. WSDOT does not have a documented calculation of life cycle cost to show whether this policy minimizes life cycle costs, or whether it could be adjusted to reduce life cycle costs.

WSDOT is not able to compute life cycle costs.

Practice 3. Network level life cycle cost

Treatments that are appropriate and effective for a specific condition found on a given bridge are not necessarily treatments that the agency can afford to perform statewide. Similarly strategies that minimize project life cycle costs are not necessarily the same strategies that minimize network life cycle costs.

If the life cycle cost analysis uses consistent models of deterioration, costs, and effectiveness, and if it is constrained to be economically sustainable, then over the long time period of the analysis any investment strategy will converge to a steady long-term network condition (Thompson and Hyman 1992). The strategy with the lowest life cycle cost converges on the optimal condition of the network.

LCCA Economic Sustainability Requirements

Sustainable objective. All bridges safely in service, or explicitly allows certain bridges to be closed

No bridges fall through the cracks. Criteria for minimum acceptable bridge and no unintended bridge closures

Consistent analysis. Calculate life cycle cost in a consistent manner for all bridges across the network

Sustainable outcomes. Analysis must estimate future conditions to ensure that the network remains in acceptable condition indefinitely.

Affordability. Likely that the total annual cost of the chosen strategy is fiscally sustainable.

Controllability. Compare planned performance against actual and adjust the planning assumptions to improve realism going forward.

This has several implications:

- *If conditions are currently worse* than optimal, a larger investment will be required initially in order to attain the optimal condition. The total excess cost, above and beyond the optimal cost, could be termed the backlog.
- *If conditions are currently better than optimal*, a lower initial investment is part of the long-term cost-minimizing solution. Costs will be lower initially, then increase to the optimal level. The backlog can be negative in this case.
- *If the agency strays from the optimal strategy* by under-investing or deferring preservation and maintenance, any money saved will be more than offset by the higher costs of returning to optimal condition.
- *If an agency is following its optimal strategy* and the inventory is at optimal condition, there is no backlog.

Interpretation of WSDOT practice. *None.* WSDOT indicates that it does not have a model or software system to compute life cycle costs, and so it lacks the ability to generate alternatives and optimize them. As a result, there is no way of knowing whether life cycle costs are minimized at the network level.

Practice 4. Integrating maintenance and preservation

Life cycle cost analysis is most useful for extending bridge service life and postponing replacement. But it can also be used in designing maintenance policies and for analyzing the tradeoff between preservation and maintenance. A disciplined maintenance policy, such as bridge washing, can slow the rate of deterioration and promote a less frequent need for preservation work. Similarly, well-timed preservation work can help a maintenance policy to be more effective as well as extending the life of a structure. These treatment classes work together to minimize life cycle cost.

Figure 33. Bridge deck repair (source: WSDOT Bridge Office)

Interpretation of WSDOT practice. *Partial.* WSDOT has maintenance practices in place that are intended to minimize life cycle costs, including:

- Bridge washing for fracture critical bridges, to be fully implemented by 2017.
- Bridge deck maintenance
- Annual cleaning of expansion joints, which is partially implemented at this time.

Other routine maintenance treatments whose effect on deterioration is unknown include bearing lubrication, deck sealing (either crack sealing, full-surface sealing, or chip sealing), zone painting, and concrete spall repairs.

Lacking a model to compute life cycle costs, WSDOT does not have a means to quantify the optimal allocation of funding between maintenance (operations funding) and preservation (capital funding). It is possible that costs could be reduced in the long term by placing more relative emphasis on one category or the other, but WSDOT does not have quantitative evidence to support any such decision.

Practice 5. Backlog estimation and scenarios

For managing a bridge network at the lowest possible life cycle cost under financial and other constraints, the agency must use prediction models and prioritization tools to determine which projects, when funded, result in a sustainable network strategy. The tools should be capable of analyzing a variety of scenarios that tie performance outcomes with fiscal alternatives.

Backlog is the extra cost that an agency would incur in order to bring the inventory to its long-term optimal condition. Optimal condition is the set of network-wide conditions that the agency can sustain, at a constant funding level, over the long term, at minimum life cycle cost. Determining this backlog requires models of deterioration, cost, and effectiveness.

Interpretation of WSDOT practice. *Partial.* WSDOT does not have the ability to analyze alternative scenarios for bridge preservation and maintenance that tie funding levels to performance outcomes. This limits WSDOT's ability to manage the bridge network at the lowest possible life cycle cost given its financial and other constraints.

WSDOT has developed estimates of unfunded bridge preservation and maintenance work that are referred to as a backlog. The estimates are based on a listing of treatments that are believed to be desirable under best practice, and are a mixture of needs that can be safely delayed and others that cannot be delayed without increasing costs. The backlog estimates are not based on a life cycle cost analysis of optimal conditions and so they cannot be substantiated as a cost-minimizing solution at the systemwide level.

Recommendation for Improvement

Bridge recommendation 2. WSDOT should establish a routine framework where calculations of life cycle cost are expected as a justification for bridge maintenance budgets or bridge needs estimates. WSDOT should compute, and document, the performance levels and policies that minimize life cycle costs, and should compute its backlog as the additional near-term cost required in order to attain optimal long-term performance.

Research Question 3.

How accurate is the information that is used to develop long-term estimates of maintenance and preservation needs?

To answer this question for bridges, the consultants reviewed the 2008-13 FHWA Quality Assurance Review reports. These reviews, which measure and track the quality of every state's bridge inspection program, cover the National Bridge Inspection Standards, data items unique to each state, and the condition of structural elements gathered under AASHTO guidelines.

FHWA's "Metrics for the Oversight of the National Bridge Inspection Program" commonly called the "23 metrics" (FHWA 2013) documents the Quality Assurance Review.

Table 17 summarizes WSDOT's compliance with the 23 metrics.

Interpretation of WSDOT practice. With the exception of portions of fracture critical bridges, the quality of bridge inventory and condition data within the National Bridge Inspection Standards as audited and monitored by the FHWA Quality Assurance Review Process is excellent for needs assessment purposes. For fracture critical bridges, WSDOT is currently implementing a best practice of bridge washing that will, by January 2017, improve the quality of data on these 187 bridges for needs assessment purposes.

The sections below describe each metric in more detail.

FHWA 23 METRICS

1. Bridge inspection organization
2. Qualifications, program manger
3. Qualifications, team leader
4. Qualifications, load rating engineer
5. Qualifications, inspection diver
6. Routine frequency – lower risk bridges
7. Routine frequency – higher risk bridges
8. Underwater frequency – lower risk
9. Underwater frequency – higher risk
10. Fracture critical inspection frequency
11. Inspection frequency criteria
12. Quality of inspections
13. Load rating
14. Posting or restricting bridges
15. Bridge files
16. Fracture critical member procedure
17. Underwater procedure
18. Scour critical procedure
19. Complex bridge procedure
20. Quality control/quality assurance procedure
21. Critical finding procedure
22. Maintain bridge inventory
23. Timing updating of data

Table. 17. WSDOT 23 Metrics - FWHA Quality Assurance Reviews 2008-2013

	WSDOT Status	Gap exists
#1 - Bridge inspection organization	Yes	No
#2 - Qualifications, program manager	Yes	No
#3 - Qualifications, team leader	Yes	No
#4 - Qualifications - load rating engineer	Yes	No
#5 - Qualifications - inspection diver	Yes	No
#6 - Routine frequency - lower risk bridges	Yes	No
#7 - Routine frequency - higher risk bridges	Yes	No
#8 - Underwater frequency - lower risk	Yes	No
#9 - Underwater frequency - higher risk	Yes	No
#10 - Fracture critical inspection frequency	Partial	Yes
#11 - Inspection frequency criteria	Yes	No
#12 - Quality of inspections	Yes	No
#13 - Load rating	Yes	No
#14 - Posting or restricting bridges	Yes	No
#15 - Bridge files	Yes	No
#16 - Fracture critical member procedure	Yes	No
#17 - Underwater procedure	Yes	No
#18 - Scour critical procedure	Yes	No
#19 - Complex bridge procedure	Yes	No
#20 - QC/QA procedure	Yes	No
#21 - Critical finding procedure	Yes	No
#22 - Maintain bridge inventory	Yes	No
#23 - Timely updating of data	Yes	No

WSDOT status: Ability of WSDOT to consistently and efficiently repeat this function each year or each cycle as required

Gap exists: Improvement needed in order to produce accurate 10-year estimate
Note: The numbered metrics are mandatory federal criteria

Metric #1: Bridge inspection organization

An organization is in place to inspect, or cause to inspect, all highway bridges on public roads. Organizational roles and responsibilities are clearly defined and documented for each of the following aspects of the National Bridge Inspection Standards (NBIS): policies and procedures, QC/QA, preparation and maintenance of a bridge inventory, bridge inspections, reports, and load ratings.

Functions delegated to other agencies are clearly defined and the necessary authority is established to take needed action to ensure NBIS compliance.

A program manager is assigned the responsibility for the NBIS.

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #2: Qualifications of personnel – Program Manager

The Program Manager is either a registered professional engineer or has ten-years of bridge inspection experience. The Program Manager has successfully completed FHWA approved comprehensive bridge inspection training. The Program Manager has completed periodic bridge inspection refresher training according to State policy.

WSDOT has been in full compliance with this metric for each of the past five years. In general, WSDOT exceeds federal requirements in its personnel qualifications and training in all positions. Earlier issues with recertification of certain positions have been effectively resolved.

Metric #3: Qualifications of personnel – Team Leader(s)

Each Team Leader must have at least one of the following qualifications:

- *Professional Engineer registration*
- *Five-years of bridge inspection experience*
- *National Institute for Certification in Engineering Technology (NICET) Level III or IV Bridge Safety Inspector certification*
- *Bachelor degree in engineering from Accreditation Board for Engineering and Technology (ABET) accredited college or university, a passing score on the Fundamentals of Engineering Exam, and two-years of bridge inspection experience.*
- *Associate Degree in engineering from ABET accredited college or university and four-years of bridge inspection experience.*

In addition to the above qualifications, Team Leaders must have the following training:

- *Successful completion of FHWA approved comprehensive bridge inspection training.*
- *Completion of periodic bridge inspection refresher training according to State policy.*

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #4: Qualifications of personnel – Load Rating Engineer

The individual charged with overall responsibility for load rating bridges, the Load Rating Engineer, is a registered professional engineer.

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #5: Qualifications of personnel – Underwater Bridge Inspection Diver

Underwater bridge inspection divers are qualified by having successfully completed at least one of the following training courses:

- *FHWA approved comprehensive bridge inspection training course*
- *FHWA approved underwater bridge inspection diver training course*

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #6: Inspection frequency – Routine – Lower risk bridges

Routine inspections are performed at regular intervals not to exceed 24-months, or not to exceed 48-months when adhering to FHWA approved criteria. Lower risk bridges are defined for this metric as those *with superstructure and substructure, or culvert, condition ratings of fair or better, and not requiring load restriction.*

The 24 month standard inspection interval is established nationwide to provide a uniform level of deterioration-related risk. States may request exemption from the 24 month inspection requirement on a case by case basis.

If an agency does not allocate sufficient resources for the specified inspection interval, this exposes it to several risks:

- Structural failure caused by an undiscovered problem, which can cause partial or complete structural collapse and the resulting loss of life, injuries, property damage, environmental harm, traffic congestion, civil liability, and recovery costs.
- Loss of public confidence in the safety and reliability of the transportation system and confidence in its leadership.
- Potential federal sanctions which can include loss of funding.

Inspection schedule compliance was a problem for WSDOT in the past, but over the past five years the Department has been making consistent progress in the timeliness of its routine inspections. WSDOT has fully implemented earlier Plans of Corrective Action and has tightened the tolerances in its inspection interval to reduce condition-related risk. In the 2013 FHWA Quality assurance report, 100 percent of the surveyed bridges were in compliance for routine inspections.

Metric #7: Inspection frequency – Routine – Higher risk bridges

Routine inspections are performed at regular intervals not to exceed 24-months. Higher risk bridges are defined for this metric as those with a superstructure or substructure, or culvert, condition rating of poor or worse, or require load restriction.

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #8: Inspection frequency – Underwater – Lower risk bridges

Underwater inspections are performed at regular intervals not to exceed 60-months, or not to exceed 72 months when adhering to FHWA approved underwater criteria. Lower risk bridges are defined for this metric as those with a substructure or culvert condition rating of fair or better, and evaluated as not scour critical.

Underwater inspections are generally necessary for bridges whose foundations are located in bodies of water. Such bridges can experience damage to substructure units or foundations, and undermining of the soil around the foundation — known as scour — which might not be visible to an inspector in a normal inspection. Specially trained and equipped divers enter the water to examine the underwater elements and surrounding material.

A scour critical bridge is a bridge with a foundation element that has been determined to be unstable for the observed or evaluated scour condition. It is a bridge where there is a reasonable possibility that undermining of the foundation by water movement may damage or destroy the structure. As of June 2013 WSDOT had 270 scour critical bridges.[13]

---

[13] http://wsdot.wa.gov/publications/fulltext/graynotebook/Jun13.pdf, page 11.

Scour is the most common cause of bridge failure nationally and in Washington State, which has lost 43 bridges to this hazard. In addition to the required underwater inspections, most states, including Washington, employ automated monitoring equipment to warn of underwater loss of material supporting bridge foundations, at locations believed to be especially sensitive (Hunt 2009). Scour can be a significant source of bridge preservation and maintenance needs.

WSDOT has been in compliance with this metric for each of the past five years. FHWA's 2013 Quality Assurance Review identified certain issues with the format and cross-referencing of paper and electronic records of underwater inspections. None of these issues would have any effect on the accuracy of needs estimates. WSDOT is implementing improvements in its office procedures to correct the deficiencies.

Metric #9: Inspection frequency – Underwater – Higher risk bridges

Underwater inspections are performed at regular intervals not to exceed 60-months. Higher risk bridges are defined for this metric as those with a substructure or culvert condition rating of poor or worse, or evaluated as scour critical.

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #10: Inspection frequency – Fracture Critical Member

Fracture-critical members are inspected at regular intervals not to exceed 24-months.

The federal National Bridge Inspection Standards define a fracture critical member as "a steel member in tension, or with a tension element, whose failure would probably cause a portion of, or the entire bridge, to collapse." As of June 2013, WSDOT owned 187 bridges with fracture critical members.[14]

Several parts of steel trusses and certain steel arches are fracture critical, especially the horizontal members at the bottom of each truss. Because of their location and horizontal orientation, these members are also places that naturally gather heavy deposits of organic matter from plants and animals, and debris thrown by vehicles from the roadway surface. These deposits retain water and chemicals, causing corrosion, and have the potential to conceal fatigue cracks in the steel.

Fatigue cracks, which become increasingly common as steel bridges age, are difficult to see in the early stages when mitigation actions are most likely to be economical and effective.

Fracture Critical Bridges

Dec. 2013 FHWA - Fracture critical inspection data incomplete, did not adhere to required 24 month inspection interval

- Caused by inability of inspectors to see potential crack areas

Jan. 2014 – WSDOT Plan of Corrective Action – bridge washing program for fracture critical bridges to enable inspection

- Combine washing with spot painting of areas – *best practice to minimize life cycle cost for fractural critical members*

[14] http://wsdot.wa.gov/publications/fulltext/graynotebook/Jun13.pdf, page 7.

The AASHTO Manual for Bridge Evaluation requires that the area examined for cracks be sufficiently clean and free of debris to provide a clear view. However, this requires special equipment and a crew that would not be available to bridge inspectors in the normal course of their work (Connor et al 2005).

In a December 18, 2013 letter to Secretary Peterson, FHWA noted that Washington's fracture critical inspection data were incomplete, failing to adhere to the 24 month inspection interval.

The failure to complete the required fracture critical inspections would cause a systematic error in bridge preservation needs estimates in the following ways:

- If significant fatigue cracking were found, in some cases it would be necessary to increase the routine fracture critical inspection frequency, because fatigue cracks can develop and spread very quickly. This would increase the cost of bridge inspection.
- As a response to a finding of fatigue cracks, WSDOT would be obliged to conduct a set of mitigation measures to arrest the cracks and prevent them from growing. In some cases rehabilitation actions such as the replacement of structural members may be necessary. These actions are expensive and could require maintenance expenditure or an emergency allocation of capital funding.
- If fatigue cracking is found to reduce the load carrying capacity of the bridge, temporary expenditure of operational and enforcement resources may be necessary to redirect heavy traffic, and the structure would likely be programmed for major rehabilitation or replacement.
- The existence of undiscovered fatigue cracks, or the lack of data on fatigue cracks, increases the risk of structural collapse and the resulting loss of life, injuries, property damage, environmental harm, traffic congestion, civil liability, and recovery costs.
- Prolonged failure to comply with metric #10 can expose WSDOT to federal sanctions including loss of funding.

On January 30, 2014, WSDOT submitted a Plan of Corrective Action, known as PCA #7, to remedy the non-compliance finding on metric #10. This requires the Department to execute a bridge washing program on bridges containing fracture critical members.

WSDOT is coordinating its fracture critical inspections with the bridge washing schedule, and also plans to follow up after the inspection with a spot painting program to protect the cleaned structural members from subsequent corrosion. This is a best practice strategy to minimize life cycle costs.

Metric #11: Inspection frequency – Frequency criteria

Criteria are established to determine level of inspection, and frequency for all of the following inspection types where appropriate:

- *Routine inspections – for less than 24-month intervals*
- *Fracture critical member inspections – for less than 24-month intervals*
- *Underwater inspections – for less than 60-month intervals*
- *Damage inspections*
- *In-depth inspections*
- *Special inspections*

The 2013 FHWA Quality Assurance Review found that the random sample of bridges evaluated were in 100 percent compliance with inspection frequency criteria. Previous years had compliance ratings of less than 100 percent, but this has been consistently improving over the past five years.

Metric #12: Inspection procedures – Quality Inspections

Each bridge is inspected in accordance with the nationally recognized procedures in the AASHTO Manual for Bridge Evaluation contributing to quality assessments, ratings, and documentation, as measured by the following criteria:

- *Condition codes within generally acceptable tolerances,*
- *All notable bridge deficiencies identified, and*
- *Condition codes supported by narrative that appropriately justifies and documents the rating or condition state assignment.*

A qualified team leader is at the bridge at all times during each initial, routine, in-depth, fracture critical member and underwater inspection.

The 2013 FHWA Quality Assurance Review concluded that WSDOT is in compliance with this metric, and that the quality of the most important National Bridge Inventory appraisal and condition data had improved substantially, relative to previous years. The review included a number of recommendations for process improvements, but the error rate is too small to have any significant effect on needs estimates.

The 2013 FHWA Quality Assurance Review noted that element level condition data do not have an established set of error tolerances. It also noted other process improvements for the gathering of element level condition data. If WSDOT moves toward more use of element level analysis for its future needs estimates, these recommendations will take on increased importance.

Metric #13: Inspection procedures – Load Rating

Bridges are rated for their safe load carrying capacity in accordance with the AASHTO Manual for Bridge Evaluation for all State legal vehicles and routine permit loads. Load ratings are accurate for current conditions.

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #14: Inspection procedures – Post or Restrict

Bridges are posted or restricted in accordance with the AASHTO Manual for Bridge Evaluation or in accordance with State law, when the maximum unrestricted legal loads or State routine permit loads exceed that allowed under the operating rating or equivalent rating factor. Posting deficiencies are promptly resolved.

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #15: Inspection procedures – Bridge Files

Bridge files are prepared as described in the AASHTO Manual for Bridge Evaluation to maintain and record the following:

- *Significant bridge file components*

- *Results of bridge inspections together with notations of any action taken to address the findings of such inspections*
- *Relevant maintenance and inspection data to allow assessment of current bridge condition*
- *Findings and results of bridge inspections*

FHWA's 2013 Quality Assurance Review identified certain issues with the format and cross-referencing of paper and electronic records of underwater inspections. None of these issues would have any effect on the accuracy of needs estimates. WSDOT is implementing improvements in its office procedures to correct the deficiencies

Metric #16: Inspection procedures – Fracture Critical Members

Bridges with fracture critical members have written inspection procedures which clearly identify the location of all fracture critical members, specify the frequency of inspection, describe any specific risk factors unique to the bridge, and clearly detail inspection methods and equipment to be employed. Fracture critical members are inspected according to those procedures.

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #17: Inspection procedures – Underwater

Bridges requiring underwater inspections have written inspection procedures which clearly identify the location of all underwater elements, specify the frequency of inspection, describe any specific risk factors, and clearly detail inspection methods and equipment to be employed. Underwater elements are inspected according to those procedures.

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #18: Inspection procedures – Scour Critical Bridges

Bridges over water have a documented evaluation of scour vulnerability. Bridges that are scour critical have a scour Plan of Action prepared to monitor known and potential deficiencies and to address scour critical findings. Bridges that are scour critical are monitored in accordance with the Plan of Action.

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #19: Inspection procedures – Complex Bridges

Complex bridges have the following identified:

- *Specialized inspection procedures which clearly identify the complex features, specify the frequency of inspection of those features, describe any specific risk factors unique to the bridge, and clearly detail inspection methods and equipment to be employed.*
- *Additional inspector training and experience required to inspect complex bridges.*

Complex bridges are inspected according to those procedures.

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #20: Inspection procedures – Quality Control/Quality Assurance

Systematic quality control (QC) and quality assurance (QA) procedures are used to maintain a high degree of accuracy and consistency in the inspection program. QC/QA procedures include periodic field *review of inspection teams, periodic refresher training requirements, and independent review of inspection reports and computations.*

WSDOT is now in full compliance with this metric. Compliance issues were noted in earlier reviews but these would have no impact on needs estimates.

Metric #21: Inspection procedures – Critical Findings

A procedure is established to assure that critical findings are addressed in a timely manner. The FHWA is periodically notified of the actions taken to resolve or monitor critical findings.

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #22: Inventory – Prepare and Maintain the Bridge Inventory

An inventory of all bridges subject to the National Bridge Inspection Standards is prepared and maintained. Data collected are in accordance with what is required for the NBIS Structure Inventory and Appraisal sheet. Data are recorded according to FHW procedures and available for collection by FHWA as requested.

WSDOT has been in full compliance with this metric for each of the past five years.

Metric #23: Inventory – Timely Updating of Data

Structure Inventory and Appraisal data are submitted to the FHWA National Bridge Inventory as requested using FHWA established procedures. These data are entered in the State's inventory within 90 days of the date for State owned bridges and within 180 days of the date for all other bridges for the following events:

- *Routine, in-depth, fracture critical member, underwater, damage and special inspections*
- *Existing bridge modifications that alter previously recorded data and for new bridges*
- *Load restriction or closure status*

WSDOT is in full compliance in the 2013 report. The previous year had slightly lower compliance, so this was an improvement.

Research Question 4.

How does WSDOT quantify risks to its need and cost estimates?

Risks

Systemic risks

- Market fluctuations affecting cost of labor, materials, or equipment.
- Budget (or other agency) restrictions preventing allocation of sufficient funding for bridge preservation activities.
- Insufficient or inaccurate data, limiting agency's capability to manage assets effectively.

Site-specific risks

- Sudden condition-related failure, particularly when agency lacks information about impending failure
- Natural hazards and climate change impacts such as earthquakes, floods, and scour
- Man-made hazards such as collisions and truck overloads

Table 18 provides an overall summary of WSDOT's practices in quantifying risk in bridge long-term needs and cost estimates.

Table 18. Summary of WSDOT practices in quantifying risks in needs and costs estimates

Ingredient	WSDOT Status	Gap exists	Gap size
1. Systemic risks			
Forecasting market conditions	Yes	No	n/a
Performance-and fiscally-constrained scenarios	None	Yes	Medium
2. Site-specific risks			
Quantifying needs - condition-caused failure	Yes	No	n/a
Quantifying needs - risk of natural hazards	Yes	No	n/a
Quantifying needs - risk of man-made hazards	None	Yes	Low
3. Integration of risk into priority-setting	None	Yes	Medium

WSDOT status: Ability of WSDOT to consistently and efficiently repeat this function each year or each cycle as required

Gap exists: Improvement needed in order to comply fully with best practices

Gap size: Relative effort to expand, automate, and document the capability for repeatable use

Practice 1. Systemic risks

Forecasting market conditions

Market fluctuations impact state Departments of Transportation expenses and revenues.

On the expense side, major issues for bridge management include:

- Supply of resources, particularly raw materials such as steel and concrete, but also specialized manufactured goods such as modular expansion joints (figure 34).
- Demand for these same resources, especially the competing needs of other transportation agencies around the world.
- The costs of transporting materials, which are especially sensitive to the price of oil.
- Quality of resources, especially the availability of a sufficiently skilled labor force, which affects the productivity of the Department's work and its ability to meet performance objectives at planned budget and staffing levels.

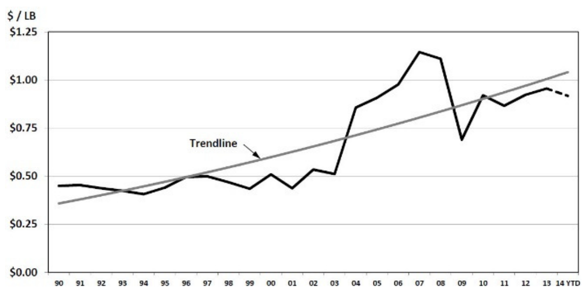


Figure 34. Example of resource cost tracking – cost per pound of steel reinforcing bar (source: WSDOT Construction Office)

Major revenue issues are the same as those for pavement, including:

- Vehicle fuel efficiency has improved over the past decade which has been required by the federal Corporate Average Fuel Economy (CAFÉ) program. The improvement in fuel efficiency results in reduced funding from motor vehicle fuel taxes.
- Vehicle-Miles Traveled (VMT), which is affected by population growth and changes in economic activity, effects motor vehicle fuel tax receipts.

Interpretation of WSDOT practice. *Yes.* WSDOT routinely tracks fluctuations in the costs associated with its resources. The Department has developed VMT projection models and considers those projections and the impact of the CAFÉ standards in its motor vehicle fuel forecasts.

Performance constrained scenarios

For long-term maintenance and preservation needs estimates to incorporate market fluctuation impacts, the bridge office should be capable of analyzing "what-if" scenarios like:

- What if funding levels are reduced by 50 percent or 75 percent?
- What if bridges on T-1 and T-2 freight routes are prioritized over other bridges?
- What if fracture critical bridges are prioritized over other bridges?

Interpretation of WSDOT practice. *None.* During interviews with the WSDOT Office of Bridges and Structures and with the Office of Capital Program Development and Management, the subject of uncertainty in cost and revenue was explored. For both types of uncertainty, WSDOT officials state that it would be technically feasible to develop consistent scenarios of performance, cost, and funding, if given the necessary data and tools. However, according to WSDOT, development of a performance-constrained bridge preservation and maintenance needs estimate has not been an institutional requirement expected of the Department, and so it has not been done.

Practice 2. Site-specific risk

Site-specific risks include condition-caused failure, natural hazards, and man-made hazards.

Condition-caused failure

In common industry practice, a bridge is considered failed if it becomes necessary to close the structure in order to maintain public safety. In a managed bridge inventory the owner monitors bridge deterioration and takes steps to rehabilitate or replace a bridge before its safety becomes a concern. It is frequently the case, and is considered good practice, that a bridge that is slated for replacement for functional reasons (such as traffic volume) is allowed to deteriorate with minimal maintenance until the time of its scheduled replacement, provided that it remains safe.

Interpretation of WSDOT practice. *Yes.* Washington has 138 structurally deficient bridges, ranking it 22nd in the nation in structurally-deficient bridges by deck area, according to 2012 FHWA data.[15] Structurally deficient bridges are not necessarily unsafe, and all unsafe bridges are closed, by WSDOT policy. A bridge can remain in a structurally deficient state for many years before its load-carrying capacity is affected. However, the exact amount of life remaining is impossible to predict, and expensive emergency repairs may become necessary occasionally to keep the structure open. Therefore these bridges are a source of uncertainty in needs estimates. WSDOT includes an allowance in its needs assessment and budgeting for risk mitigation actions for structurally deficient bridges.

Question 3 described an ongoing issue with the inspection of fracture-critical bridges, which may cause an understatement of fatigue-related needs.

WSDOT does not attempt to forecast emergency repairs due to advanced deterioration or fatigue, but does make an assumption that future emergency repair costs will be similar to past costs. This is common practice. WSDOT also has the capability to create listings of structurally deficient and fracture critical bridges. It is able to prioritize these by condition but not by failure risk. This also is common practice.

[15] http://wsdot.wa.gov/publications/fulltext/graynotebook/Jun13.pdf, page 5.

Natural hazards

There are three major natural hazards that affect long-term bridge estimates and needs: scour, earthquakes, and fires.

Interpretation of WSDOT practice.

Yes.

- *Scour.* In maintenance budgeting, scour-related maintenance needs are typically assumed to be similar to previous years. WSDOT has also identified a set of preservation projects based on underwater inspection, where more significant work is needed. The Department does not attempt to forecast future scour preservation needs that have not already been identified in current inspections. This is common practice.
- *Earthquakes.* The listing of long-range bridge seismic retrofit needs includes 629 bridges and $1.4 billion in estimated need. WSDOT has a process to prioritize these bridges within the seismic category, based on structure configuration, lifeline routes, traffic volume, and peak ground acceleration (a measure of expected earthquake strength). The seismic priority-setting criteria do not indicate a method for prioritizing seismic retrofits against non-seismic programs, nor for allocating funding between seismic and non-seismic needs, nor for determining which needs have to be met within ten years.
- *Fire.* Fire is another hazard responsible for bridge failures, having destroyed 9 bridges in the WSDOT list[16]. WSDOT does not have a preservation program or needs estimate specifically for fires, but it does have maintenance procedures for clearing flammable brush and other material from bridge sites. As with other maintenance activities, the budgeting process is biennial and assumes that each year's needs will be similar to preceding years. This is common practice.

Although WSDOT's processes for estimating risk mitigation fit with common practice, it should be noted that common practice does not consider uncertainty in these estimates, and does not estimate an allowance for emergency work if an extreme event takes place. The state of the practice is not as advanced with risk mitigation costs as it is with other types of preservation and maintenance costs.

Man-made hazards

In the 2012 Gray Notebook WSDOT reported that over its history the state has had four bridges destroyed by collisions and three by overloads.[17] The ability to maintain vertical and horizontal clearance measurements, and load-carrying capacity for standard truck configurations, is mandated in the National Bridge Inspection Standards and is available in every state, including Washington. Every state also has the capability to produce lists of bridges with substandard values for these measures, and to use the information to guide truck drivers.

What is not as universal is the ability to put this information to work for proactive risk management. AASHTO's Pontis bridge management system and North Carolina's and Florida's custom-developed systems have the ability to prioritize these types of functional deficiencies according to the inconvenience they cause to road users.

---

[16] http://wsdot.wa.gov/publications/fulltext/graynotebook/Jun12.pdf, page 13.
[17] http://wsdot.wa.gov/publications/fulltext/graynotebook/Jun12.pdf, page 13.

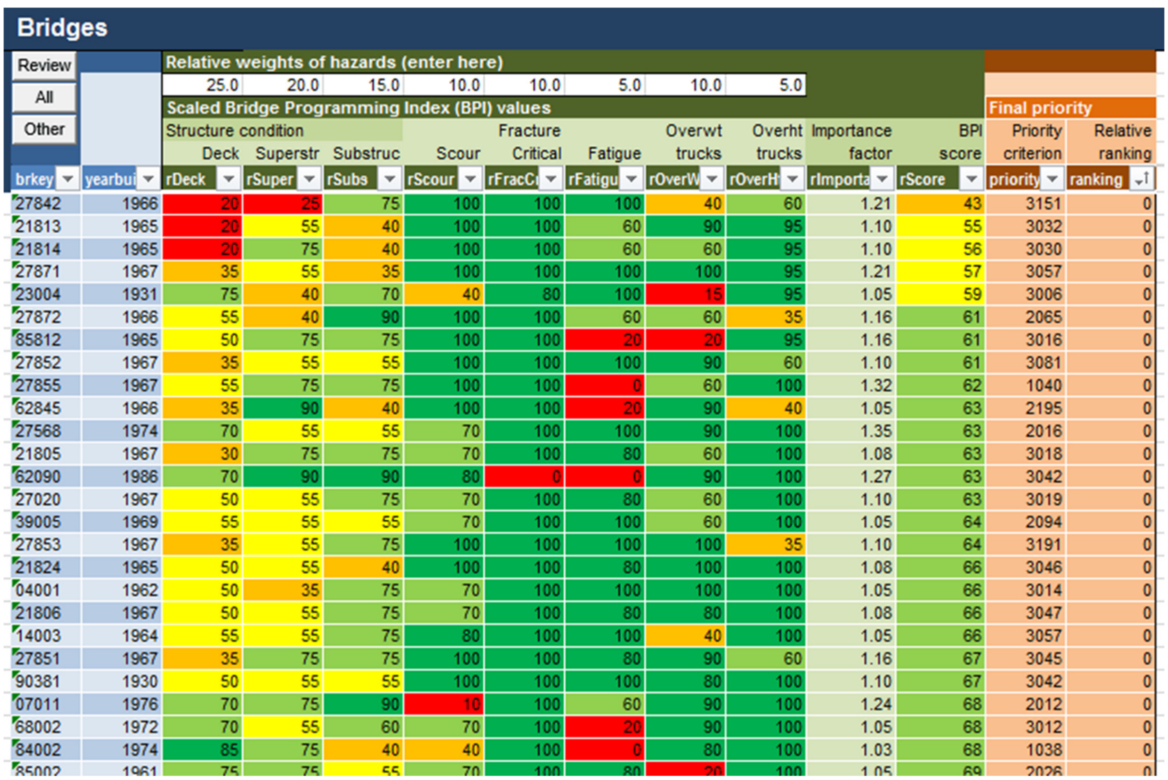
Such models can be used to estimate bridge strengthening or raising needs, and also play a role in prioritization. It is unusual for a bridge to be replaced strictly because of the risk of collisions and overloads, but the presence of this risk elevates the priority of a bridge that also has other types of condition deficiencies or vulnerabilities. This affects the magnitude of ten-year needs estimates because it determines the number of bridges to be improved or replaced within the ten-year time frame, as opposed to being postponed beyond ten years.

The total needs computed in this way are typically very large, because many bridges have minor deficiencies in clearances or load-carrying capacity. The prioritization function is therefore necessary in order to reduce the list to a realistic size.

Interpretation of WSDOT practice. *None.* WSDOT indicates that it does not have capability to estimate bridge strengthening or raising needs at the network level and does not consider risk mitigation for man-made hazards in its long-term estimates.

Integration of risk into priority setting

A few exceptional state Departments of Transportation (Pennsylvania, Minnesota (Figure 35), and Florida) have developed a risk-based priority setting process that incorporates all of the condition-based, natural, and man-made hazards considered significant in each state.



Bridges

Review | All | Other

		Relative weights of hazards (enter here)										Final priority	
		25.0	20.0	15.0	10.0	10.0	5.0	10.0	5.0				
		Scaled Bridge Programming Index (BPI) values											
		Structure condition Deck	Superstr	Substruc	Scour	Fracture Critical	Fatigue	Overwt trucks	Overht trucks	Importance factor	BPI score	Priority criterion	Relative ranking
brkey	yearbui	rDeck	rSuper	rSubs	rScour	rFracCr	rFatigu	rOverW	rOverH	rImporta	rScore	priority	ranking
27842	1966	20	25	75	100	100	100	40	60	1.21	43	3151	0
21813	1965	20	55	40	100	100	60	90	95	1.10	55	3032	0
21814	1965	20	75	40	100	100	60	60	95	1.10	56	3030	0
27871	1967	35	55	35	100	100	100	100	95	1.21	57	3057	0
23004	1931	75	40	70	40	80	100	15	95	1.05	59	3006	0
27872	1966	55	40	90	100	100	60	60	35	1.16	61	2065	0
85812	1965	50	75	75	100	100	20	20	95	1.16	61	3016	0
27852	1967	35	55	55	100	100	100	90	60	1.10	61	3081	0
27855	1967	55	75	75	100	100	0	60	100	1.32	62	1040	0
62845	1966	35	90	40	100	100	20	90	40	1.05	63	2195	0
27568	1974	70	55	55	70	100	100	90	100	1.35	63	2016	0
21805	1967	30	75	75	70	100	80	60	100	1.08	63	3018	0
62090	1986	70	90	90	80	0	0	90	100	1.27	63	3042	0
27020	1967	50	55	75	70	100	80	60	100	1.10	63	3019	0
39005	1969	55	55	55	70	100	100	60	100	1.05	64	2094	0
27853	1967	35	55	75	100	100	100	100	35	1.10	64	3191	0
21824	1965	50	55	40	100	100	80	100	100	1.08	66	3046	0
04001	1962	50	35	75	70	100	100	100	100	1.05	66	3014	0
21806	1967	50	55	75	70	100	80	80	100	1.08	66	3047	0
14003	1964	55	55	75	80	100	100	40	100	1.05	66	3057	0
27851	1967	35	75	75	100	100	80	90	60	1.16	67	3045	0
90381	1930	50	55	55	100	100	100	80	100	1.10	67	3042	0
07011	1976	70	75	90	10	100	60	90	100	1.24	68	2012	0
68002	1972	70	55	60	70	100	20	90	100	1.05	68	3012	0
84002	1974	85	75	40	40	100	0	80	100	1.03	68	1038	0
85002	1961	75	75	55	70	100	80	20	100	1.05	69	2026	0

Figure 35. Example of risk-based bridge prioritization in Minnesota DOT

Prioritization of risk mitigation measures influences the ten-year needs estimate because it affects the number of bridges that will be allowed to remain in poor or vulnerable condition (rather than being mitigated or replaced). Without an objective way of prioritizing, the allocation of resources among risk categories can only be arbitrary or subjective.

Interpretation of WSDOT practice. WSDOT does not have a method to consider risk in priority setting for bridges. WSDOT would benefit from an objective process to determine how much of each category of needs should be met within ten years, consistent with other Department priorities within reasonable fiscal constraints. This is not yet common practice, but it is best practice (Gordon et al 2011, Sobanjo and Thompson 2013, Committee 2012).

Recommendation for Improvement

Bridge recommendation 3. WSDOT should develop a bridge risk register and quantitative tools for risk assessment and risk management to enable it to consider risk in priority setting.

Legislative Reporting

Summary Research Question Response & Recommendation for Improvement

WSDOT is not required to routinely provide information to the Legislature on long-term bridge and pavement preservation needs. Such information is provided to the Legislature on a periodic basis in the Gray Notebook and in response to specific legislative mandates.

Some exceptional states regularly report long term pavement and bridge maintenance and preservation needs to the Legislature.

> *Legislative reporting recommendation. The Legislature should consider requiring that WSDOT provide it reports on long-term bridge and highway preservation needs as part of the budget process and/or in the biennial Transportation Attainment Report.*

WSDOT communication of long-term bridge and pavement preservation needs

WSDOT provides information to the Legislature on long-term bridge and pavement preservation needs through annual Gray Notebook reports and periodic special reports.

Gray Notebook and performance reporting

The Gray Notebook is WSDOT's main performance assessment, reporting, and communication tool, providing quarterly reports on agency and transportation system performance. As noted on the WSDOT website, "the purpose of the Gray Notebook is to keep WSDOT accountable to the Governor, the Legislature, Washington state citizens, and transportation organizations."[18]

Each issue of the Gray Notebook includes a report on WSDOT's goals, performance and trends, which tracks two preservation measures: the percentage of state highways pavement in fair or better condition by vehicle miles traveled; and the percentage of state bridges in fair or better condition by bridge deck area.[19]

---

[18] http://www.wsdot.wa.gov/Accountability/PerformanceReporting/default.htm

[19] It should be noted that these measures are weighted by deck area and are affected by two very large bridges: 520 and Alaskan Way. When these projects are completed, statewide conditions will improve, even if WSDOT does nothing else to fix any other bridges. In some states where there are separate authorities responsible for large bridges, these bridges are excluded from state-owned bridge performance reporting.

Bridge report – long term need and backlog

An annual bridge report is included in the second quarter Gray Notebook each year. The last two bridge reports have included 10-year need projections. These projections are based on a list of current known deficiencies in bridges and, with the exception of steel painting, do not include a network analysis of needs based on projected deterioration of the bridges over the 10-year period.

The June 2013 Gray Notebook included a discussion of the anticipated decline in bridge preservation funding and of the backlog of steel painting and concrete overlay projects. The 2012 Gray Notebook included information on due and past due steel painting and concrete overlay projects. The 2011 Gray Notebook included information on due and past due concrete overlay projects.

Pavement report – long-term need and backlog

An annual pavement condition report is included in the 4th quarter Gray Notebook. The last two pavement reports have information on deferred preservation liability.

The December 2012 Grey Notebook included a projection of the future preservation liability for five years. The December 2013 Gray Notebook included a discussion of the anticipated decline in pavement preservation funding.

Periodic reports to the Legislature

2010 – WSDOT Strategies Regarding Preservation of the State Road Network

In 2009, the State Legislature directed WSDOT in SB 6381 to conduct an analysis of state highway pavement replacement needs for the next ten years including, but not limited to, the current backlog of asphalt and concrete pavement preservation projects and the level of investment needed to reduce or eliminate the backlog and resume the lowest life cycle cost.

The report, *WSDOT Strategies Regarding Preservation of the State Road Network*, provided backlog and funding needs for chip seal, HMA, and concrete pavements.

- *Chip seal*. The report notes that the department does not have and does not plan to have a backlog of chip seal pavements, which are the highest priority for preservation funding.
- *HMA.* An analysis of three funding alternatives is provided in the report: to eliminate the 2011 backlog of 1,330 lane-miles that are due or overdue for treatment in 10 years; to maintain the current backlog; and to allow the backlog to grow at current funding levels. Funding was projected at $925 million available over the 10 year period (2011-2020) with $1,079 million more needed to eliminate the asphalt pavement backlog and $834 million more needed to maintain the 2011 backlog.
- *Concrete.* Concrete funding was projected to require a ten-year total of $887.6 million (2011-2020) for rehabilitation and reconstruction of concrete pavements.

2012 State of Transportation

The Secretary of Transportation's annual presentation to the Legislature at the start of session included in 2012 a slide showing a steep decline in projected pavement conditions, from a 2011 level of approximately 92 percent of highways in fair to good condition to approximately 65 percent by 2023 with no additional funding.

Other states communication of long-term bridge and pavement preservation needs

The consultants conduced a 50 state web survey to determine whether, and if so how, long-term pavement and/or bridge maintenance needs are regularly reported to state legislatures. Seven states (California, Colorado, Michigan, Nebraska, Nevada, New Jersey, and Texas) were found to have regular reports. In six of these states, the reports are required by statute and in one, Michigan, the reports are part of an annual capital programming process and are also included in on-going performance measure reporting. [20]

Table 19 summarizes the reports provided to the Legislature in the seven states that provide regular reporting on long-term pavement and/or bridge preservation and maintenance needs

Table 19. Summary of on-going state department of transportation legislative reports on long-term preservation needs

State Report	Frequency	Projection Period	Shows Total Need	Compares Total Need to Available/ Other Funding Levels	Ties to Performance Goals
California					
• 5 Year Maintenance Plan	Biennial	10 years	Yes	Yes	Yes
• State Highway Operation & Protection Plan		10 years	Yes	Yes	No
Colorado					
• Transportation Deficit Report	Annual	10 years	Yes	Yes	Yes
Michigan					
• Five-Year Transportation Plan	Annual	10 years	Yes	Yes	Yes
• Transportation Systems Performance Measures	Annual/ monthly	10 years	No	No	Yes
Nebraska					
• Needs Assessment Report	Annual	20 years	Yes	No	No
Nevada					
• State Highway Preservation Report	Annual	12 years	Yes	Yes	Yes
New Jersey	Annual	10 years			
• 10 Year Statewide Capital Investment Strategy			Yes	Yes	Yes
Texas					
• Statewide Transportation Report	Annual	20 years		Yes for pavement	Yes for pavement

[20] Arizona, Minnesota, South Dakota, and Wyoming provide long-term estimates of preservation and maintenance needs for bridges and/or pavement in their state long-range transportation plans or, in the case of Minnesota, in a companion 20-Year State Highway Investment Plan. Other state legislatures have received special reports that define long-term bridge and pavement needs including Idaho, Kansas, Montana, and Pennsylvania. Florida, Maryland, Tennessee, and Virginia have attainment or other reports in which they demonstrate that their goals for bridge and pavement preservation and maintenance are being met.

California

Section 164.4 of the California State Streets and Highway Code requires the California Department of Transportation (Caltrans) to prepare a five-year maintenance plan to address maintenance needs of the state highway system. The plan must be updated every two years and must include needs for pavement, bridge, and drainage maintenance.

- Only maintenance activities that, if the activities were not performed, could result in increased State Highway Operation and Protection Program (SHOPP) (i.e. capital) costs in the future.
- Recommended strategies, specific activities, and funding to reduce or prevent backlog during the five years of the maintenance plan.
- Specific goals and quantifiable accomplishments.
- Cost control and efficiency strategies.
- Cost estimates for the five years of the maintenance plan.
- SHOPP cost avoidance from implementation of the maintenance plan.
- A budget model that allows achieving the requirements of this legislation.

Section 164.6 of the California State Streets and Highway Code requires Caltrans to prepare a cost estimate of rehabilitation needs to achieve specific milestones and quantifiable accomplishments, such as miles of highways to be repaved and number of bridges to be retrofitted. The 2013 Ten-Year Street Highway Operation and Protection Plan (SHOPP) identifies both a goal-constrained ten-year need and a financially-constrained ten-year need. Projects in the SHOPP are limited to capital improvements relative to maintenance, safety, and rehabilitation of the state highways and bridges and capital improvements that do not add new traffic lanes to the system.

For pavements, the 2013 Five-Year Maintenance Plan set goals for 2013 to: 1) reduce the backlog of pavement needing preventive/corrective maintenance to 5,000 lane miles or 10% of inventory; and 2) reduce the deterioration rate of pavement becoming distressed to 500 lane miles or 1% of inventory. Three funding scenarios (baseline, reduce backlog over 10 years, eliminate backlog over five years) developed were developed, with a recommendation to maintain current funding levels which would allow these goals to be met.

For bridges, the 2013 report noted that the goal for 2011 was to reduce the backlog to 10 percent of inventory, which was achieved plus an additional 10 percent. The 2013 goal is the same, with a recommendation to maintain the current funding level.

LEVEL OF INVESTMENT 3—ELIMINATE BACKLOG (FIVE YEARS)

With an increase of $631.1 million a year beginning in FY2014/15 to bring the total annual funding level to more than $1 billion, within a five-year period the goal for pavement and bridge maintenance work would be achieved, as listed in Table 4 below. The pavement backlog will decrease from 8,410 lane miles (17 percent) to 4,160 lane miles (8 percent) in five years, and the bridge backlog will decrease from 2,170 bridges (17 percent) to 1,030 bridges (8 percent) in five years. At the projected drainage assessment rate of 12,000 assessments a year, there still would be 59,000 culverts remaining in the inventory to be assessed at the end of the five years, with an estimated 2,760 culverts needing repair work each year. However, the current backlog for drainage repairs will be eliminated from 14,733 (7 percent) to 0 (0 percent) in five years. Future SHOPP needs would be significantly less than either of the previously identified levels of investment.

Table 4. LEVEL OF INVESTMENT 3–ELIMINATE BACKLOG (FIVE YEARS)

Program	Annual PYs	Annual Cost ($000,000)	Annual Accomplishments	Average Annual Change in Backlog	Future SHOPP Cost Avoidance ($000,000)
Pavement*	625	520.0	5,000 lane-miles	850 decrease	2,080
Bridge†	329	178.2	861 bridges	228 decrease	1,953
Drainage‡	900	345.0	6,294 culverts 12,000 assessments	3,534 decrease	730
Total	1,854	1,043.2	---	---	4,763

*Pavement costs include personal services and Major Maintenance contracts. Annual costs include $455 million in Major Maintenance contracts and $65 million in personnel services for contract delivery support. The 2005, 2007, 2009, and 2011 Maintenance Plans did not include State maintenance forces for pavement work. The State force work included is limited to spot locations of damage, such as pothole repair and crack sealing.

†Bridge costs include State force repair crews, materials, equipment rental, contract dollars, and support. Funding includes $111.2 million in Major Maintenance contracts and $67.0 million in support of contract delivery, paint, and inspection.

‡Drainage costs include $12.5 million for State maintenance forces for assessments, maintenance, repairs, and associated equipment and materials, $3.5 million for the drainage program, $256 million in Major Maintenance contracts, and $73 million in Major Maintenance contracts and support costs.

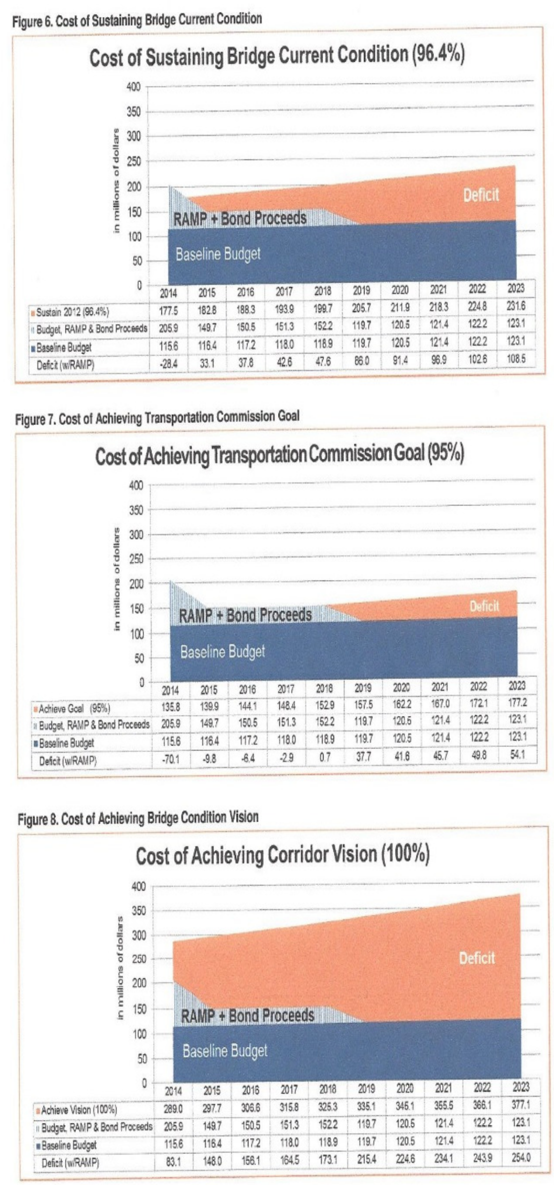
Figure 36. Excerpt from California Five-Year Maintenance Plan

Colorado

Colorado state statute §43-4-813, C.R.S. 2009 requires the Colorado Department of Transportation an annual Transportation Deficit Report. This requirement was part of the passage of the Colorado FASTER – Funding Advancement for Surface Transportation and Economic Recovery Act which also created a Bridge Enterprise Fund to fund reconstruction of structurally deficient bridges. FASTER addresses goals of repairing deficient highways and bridges and sustaining existing transportation system performance levels. The annual Transportation Deficit Report is to include:

- Estimated costs (and resulting deficits) of sustaining the current condition over the next 10 years;
- Estimated costs (and deficits) of achieving the goal of the Transportation Commission (TC) within the next 10 years as stipulated in Transportation Commission Policy Directive 14
- Estimated costs (and deficits) of achieving the Accomplish Vision Scenario within the next 10 years as stipulated in the 2035 Statewide Transportation Plan;
- Annual increase and rate of increase of this cost; and
- Factors contributing to the costs including the rate and distribution of population growth, vehicle size and weight, land-use policies, and work patterns, as well as techniques and tools for mitigating these factors.

The 2013 Transportation Deficit Report, showed deficits in three funding scenarios for pavement and bridges. For pavement, the 10-year deficit was $1.1 billion to sustain current conditions, $2.3 billion to meet performance goals, and $3.8 billion to meet the vision goal. For bridges, the deficits were $62 million to sustain current conditions, $140 million to meet goals, and $190 million for the vision level.



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Sustain 2012 (96.4%)	177.5	182.8	188.3	193.9	199.7	205.7	211.9	218.3	224.8	231.6
Budget, RAMP & Bond Proceeds	205.9	149.7	150.5	151.3	152.2	119.7	120.5	121.4	122.2	123.1
Baseline Budget	115.6	116.4	117.2	118.0	118.9	119.7	120.5	121.4	122.2	123.1
Deficit (w/RAMP)	-28.4	33.1	37.8	42.6	47.6	86.0	91.4	96.9	102.6	108.5

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Achieve Goal (95%)	135.8	139.9	144.1	148.4	152.9	157.5	162.2	167.0	172.1	177.2
Budget, RAMP & Bond Proceeds	205.9	149.7	150.5	151.3	152.2	119.7	120.5	121.4	122.2	123.1
Baseline Budget	115.6	116.4	117.2	118.0	118.9	119.7	120.5	121.4	122.2	123.1
Deficit (w/RAMP)	-70.1	-9.8	-6.4	-2.9	0.7	37.7	41.6	45.7	49.8	54.1

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Achieve Vision (100%)	289.0	297.7	306.6	315.8	325.3	335.1	345.1	355.5	366.1	377.1
Budget, RAMP & Bond Proceeds	205.9	149.7	150.5	151.3	152.2	119.7	120.5	121.4	122.2	123.1
Baseline Budget	115.6	116.4	117.2	118.0	118.9	119.7	120.5	121.4	122.2	123.1
Deficit (w/RAMP)	83.1	148.0	156.1	164.5	173.1	215.4	224.6	234.1	243.9	254.0

Figure 37. Excerpt from Colorado Transportation Deficit Report

Michigan

Michigan does not have statutory required report, but the legislature receives information on the long-term system needs from an annual Five-Year Transportation Program that is submitted to the legislature. Michigan also includes long-term projections of need in its on-line performance measurement system.

- *Five-Year Transportation Program.* The highway portion of the Five-Year Transportation Program is updated annually. It includes, in addition to proposed projects, a discussion of pavement and bridge performance measurement and 10-year condition projections. It also provides assessment of condition at alternative funding levels.

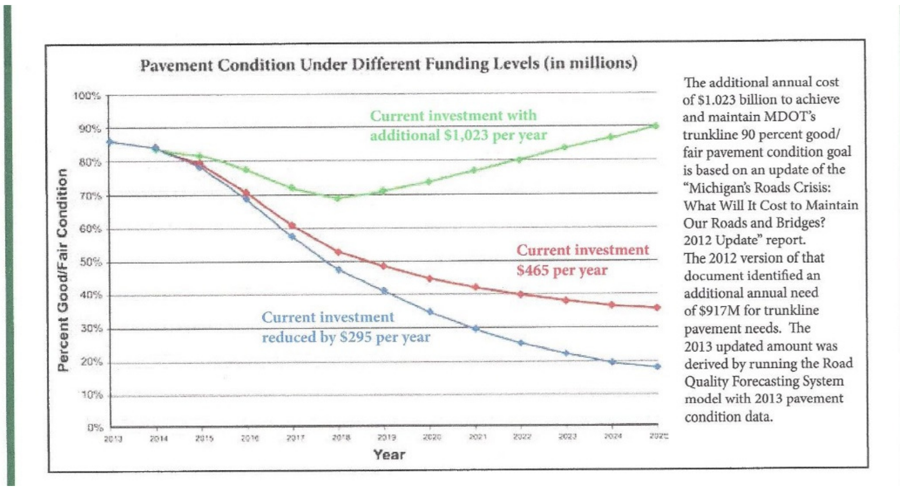


Figure 38. Except from Michigan State Department of Transportation Five Year Transportation Plan

- *Transportation System Performance Measures.* Michigan is the only state that we found that includes projected condition in its performance measure reporting. The reports, which can be found on the Michigan Department of Transportation web site include 10-year pavement and bridge conditions projection at existing funding levels. The performance measures report does not provide information on what happens at alternative funding levels, which is found in the Five-Year Transportation program.

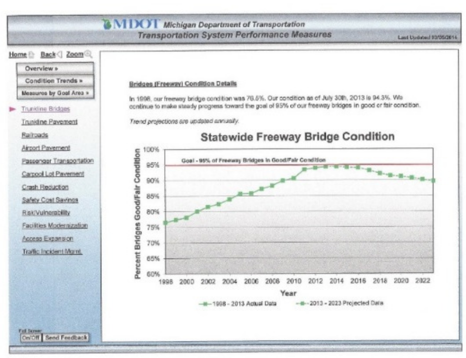


Figure 39. Excerpt from Michigan Transportation System Measures

Nebraska

Nebraska Code § 39-1365.02 requires an annual report on the needs of the state highway system and the department's planning procedures. Such report shall include:

- The criteria by which highway needs are determined;
- The standards established for each classification of highways;
- An assessment of current and projected needs of the state highway system, such needs to be defined by category of improvement required to bring each segment up to standards. Projected fund availability shall not be a consideration by which needs are determined;
- Criteria and data, including factors enumerated in section 39-1365.01, upon which decisions may be made on possible special priority highways for commercial growth; and
- A review of the department's procedure for selection of projects for the annual construction program, the five-year planning program, and extended planning programs.

The 2013 Needs Assessment Report divides the needs into four categories: pavement restoration; rural geometrics and bridges; urban geometrics and bridges; and railroad crossings. Needs, which include improvement projects such as widening of state highways, are projected from 2015-2035. No information is provided on projected available funding nor on performance of the system in response to these investment.

The Nebraska Department of Transportation's Annual Report includes a report on asset management, which provides performance reports for pavement and bridge condition.

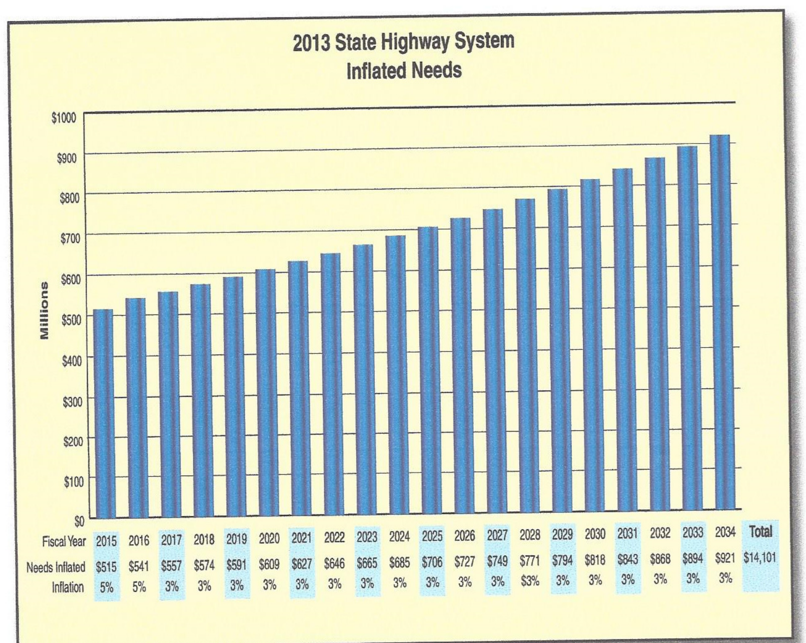


Figure 40. Excerpt from the Nebraska 2013 Needs Assessment

Nevada

Nevada Revised Statute 408.230 requires the Nevada Department of Transportation to report to the legislature by Feb 1 of odd-numbered years on the progress being made in the Department's 12-year plan for re-surfacing state highways.

The State Highway Preservation Report includes pavement preservation and bridge preservation. For each, the report includes the backlog of preservation work and an analysis of present versus needed funding.

TABLE 7: Pavement Backlog, Costs, and Funding

State-Maintained System - 2013 – 2025 (in millions of dollars)

With Present Funding

		Pavement Preservation Costs * (Normal Annual Deterioration Costs)			Pavement Preservation Funds ** (Funds Planned for Preservation Work)				
Fiscal Year	Backlog of Pavement Work	Overlay & Major Rehabilitation	Preventive & Corrective Maintenance	Total	State Overlay & Major Rehabilitation	Federal Overlay & Major Rehabilitation	State Pavement Maintenance		Total
2013	$1,919.7	$222.6	$12.7	$235.3	$46.0	$53.8	$12.7		$112.5
2014	$2,042.4	$209.5	$13.1	$222.5	$56.0	$78.0	$13.1		$147.1
2015	$2,117.9	$227.8	$13.5	$241.2	$52.0	$74.0	$13.5		$139.5
2016	$2,219.6	$233.3	$13.9	$247.2	$53.4	$71.4	$13.9		$138.6
2017	$2,328.2	$240.3	$14.3	$254.6	$55.5	$74.2	$14.3		$144.0
2018	$2,438.9	$247.6	$14.7	$262.3	$57.7	$77.2	$14.7		$149.6
2019	$2,551.5	$255.0	$15.2	$270.1	$60.0	$80.3	$15.2		$155.5
2020	$2,666.2	$262.6	$15.6	$278.2	$62.5	$83.5	$15.6		$161.5
2021	$2,782.9	$270.5	$16.1	$286.6	$64.9	$86.8	$16.1		$167.8
2022	$2,901.6	$278.6	$16.6	$295.2	$67.5	$90.3	$16.6		$174.4
2023	$3,022.4	$287.0	$17.1	$304.0	$70.2	$93.9	$17.1		$181.2
2024	$3,145.3	$295.6	$17.6	$313.2	$73.1	$97.6	$17.6		$188.3
2025	$3,270.1								

With Needed Additional Funding

		Pavement Preservation Costs * (Normal Annual Deterioration Costs)			Pavement Preservation Funds ** (Funds Planned & Needed for Preservation Work)				
					Existing			Needed	
Fiscal Year	Backlog of Pavement Work	Overlay & Major Rehabilitation	Preventive & Corrective Maintenance	Total	State Overlay & Major Rehabilitation	Federal Overlay & Major Rehabilitation	State Pavement Maintenance	Additional Overlay & Major Rehabilitation	Total
2013	$1,919.7	$222.6	$12.7	$235.3	$46.0	$53.8	$12.7	$217.6	$330.1
2014	$1,824.8	$209.5	$13.1	$222.5	$56.0	$78.0	$13.1	$226.3	$373.4
2015	$1,673.9	$227.8	$13.5	$241.2	$52.0	$74.0	$13.5	$235.4	$374.9
2016	$1,540.3	$233.3	$13.9	$247.2	$53.4	$71.4	$13.9	$244.8	$383.4
2017	$1,404.1	$240.3	$14.3	$254.6	$55.5	$74.2	$14.3	$254.6	$398.6
2018	$1,260.1	$247.6	$14.7	$262.3	$57.7	$77.2	$14.7	$264.8	$414.4
2019	$1,107.9	$255.0	$15.2	$270.1	$60.0	$80.3	$15.2	$275.4	$430.9
2020	$947.2	$262.6	$15.6	$278.2	$62.5	$83.5	$15.6	$286.4	$447.9
2021	$777.5	$270.5	$16.1	$286.6	$64.9	$86.8	$16.1	$297.8	$465.7
2022	$598.4	$278.6	$16.6	$295.2	$67.5	$90.3	$16.6	$309.8	$484.2
2023	$409.5	$287.0	$17.1	$304.0	$70.2	$93.9	$17.1	$322.2	$503.4
2024	$210.1	$295.6	$17.6	$313.2	$73.1	$97.6	$17.6	$335.0	$523.3
2025	$0.0								

*Inflation assumed at 3.00% per annum **Revenue growth rate assumed is 4.00% per annum.

Figure 41. Excerpt from the Nevada State Highway Preservation Report 2013

New Jersey

The New Jersey Transportation Trust Fund Authority Act (NJSA 27:1B) creates a finance Authority within, but independent of any supervision or control by, the New Jersey Department of Transportation. A 10 Year Statewide Capital Investment Strategy, which may be updated annually, is a requirement of the Act. The Statewide Capital Investment Strategy is developed by the New Jersey Department of Transportation, NJ Transit, the New Jersey Turnpike Authority and the South Jersey Transportation Authority.

For the New Jersey Department of Transportation, the Strategy includes an analysis of five funding scenarios (continued funding level, 25 percent decrease in funding level, 25 percent increase in funding level, maintain condition level, 50 percent backlog reduction, and 100 percent backlog reduction level) and the resulting performance of state-owned pavements and bridges.

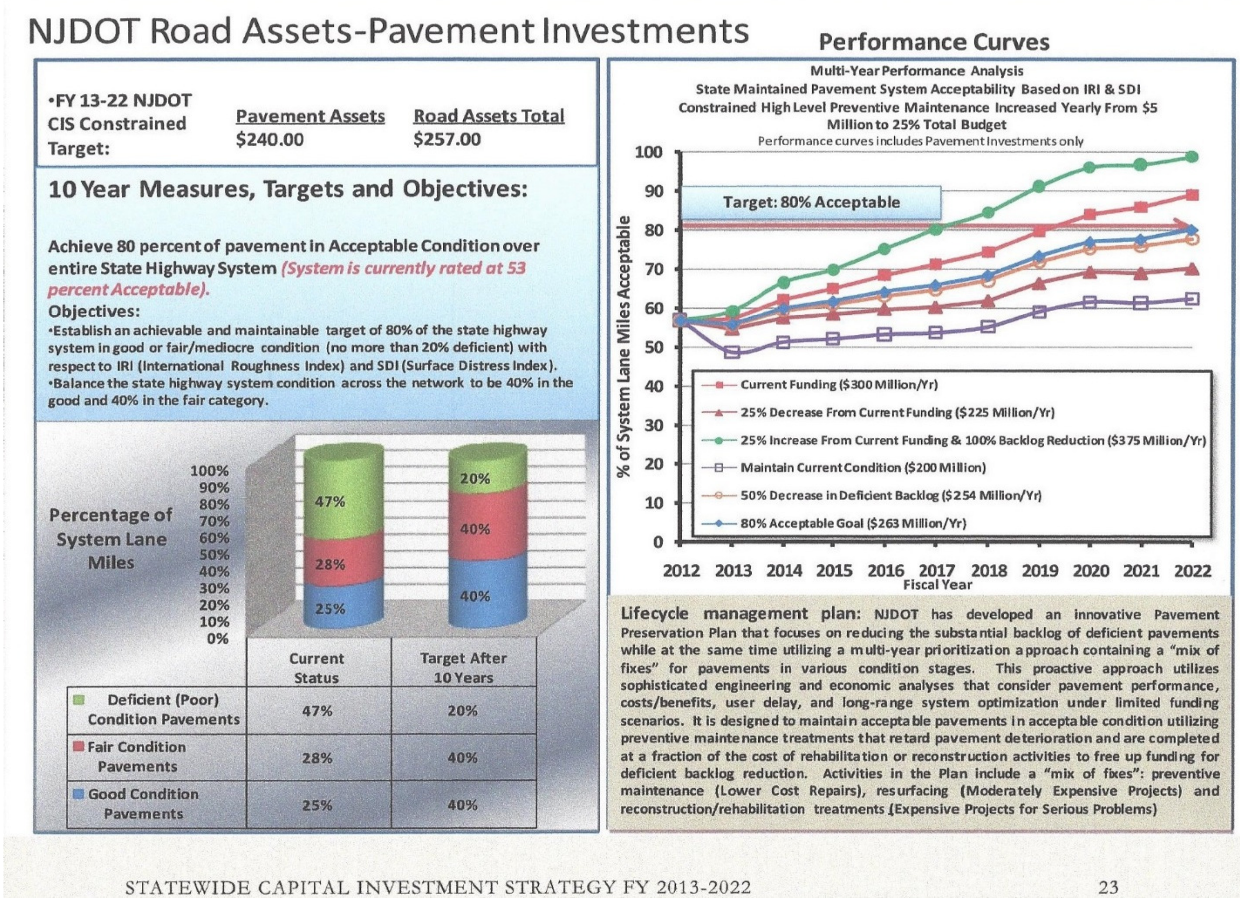


Figure 42. Excerpt from New Jersey Statewide Capital Investment Strategy FY 2013-2022

Texas

Texas Transportation Code §201.809 requires the Texas Department of Transportation to annually provide to the legislature a Statewide Transportation Report on the progress being toward each long-term goal in the statewide transportation plan.

The 2013 report includes a projection of declining pavement conditions by 2035 at current funding levels and a more detailed projected performance of lane-miles in good or better condition by district to 2016. Only current condition information is provided for bridges.

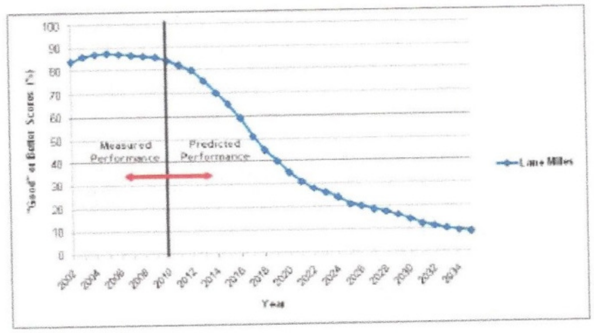


Figure 43. Excerpt from Texas Statewide Transportation Report 2013

Summary of other states' key practices and their applicability to WSDOT

The seven states that regularly report long term pavement and bridge maintenance and preservation needs to the legislature have, in the consultants' judgment, the following key practices.

- Use of pavement and bridge management systems to project network level conditions.
- The long term condition projections relate condition to alternative future funding levels.
- The long term projections are tied to the budget process.
- The long term projections are tied to performance goals and performance measures.

Use of pavement management and bridge management systems to project network level condition

All of the states, except Texas which provides long-term forecasts for pavements but not bridges, project pavement and bridge network level conditions using their pavement and bridge management systems. The Michigan Five-Year Transportation Program includes a discussion of the state's bridge management system and its use in making network level forecasts. "MDOT's Bridge Management System (BMS) is an important part of the overall asset management process. BMS is a strategic approach to linking data, strategies, programs, and projects into a systematic process to ensure achievement of desired results. An important BMS tool used by MDOT to develop preservation policies is the Bridge Condition Forecasting System (BCFS). Working from current bridge conditions, bridge deterioration rates, project costs, expected inflation, and -x strategies, BCFS estimates the future condition of the state trunkline bridge system."[21] The Nevada State Highway Preservation Report includes separate reviews of the state's pavement and bridge management systems.

Applicability to WSDOT. WSDOT has the ability to project pavement network level conditions using the WSPMS. WSDOT does not have the ability to project bridge network level conditions.

Long term projections relate to future funding levels

With the exception of Nebraska, the states show the condition of the pavement and/or bridge system at a variety of funding levels. California's Five-Year Maintenance Plan analyzes three alternative levels of maintenance investment: baseline funding, reduce maintenance backlog over ten years, and eliminate

[21] Michigan Department of Transportation, 2014-18 Five Year Transportation Program, p. 18.

maintenance backlog over five years. The Colorado Transportation Deficit Report shows bridge and pavement funding required to sustain current conditions, achieve the performance goal, and to achieve a visionary goal in the State Transportation Plan.

Applicability to WSDOT. WSDOT has the ability to project pavement network level conditions at alternative funding levels and did so in the 2010 Pavement Report to the Legislature. WSDOT does not have this capability for bridges.

Long term projections are tied to the budget process

The purpose of some of the long term projections are explicitly to make budget recommendations. In California, the Five-Year Maintenance Plan is by statute intended to inform the budget process and the 2013 plan includes a recommendation to maintain the baseline funding level. The Michigan long-term projections are included in the Annual Transportation Program, which is part of the capital budgeting process for the state.

Applicability to WSDOT. WSDOT is not currently required by state statute to provide long-term maintenance and preservation forecasts as part of the state budget process. They could provide these forecasts for pavements and, if they develop an improved bridge management system, for bridges if either required to by statute or as directed by the Office of Financial Management.

Long term projections tied to performance goals and performance measures

The states, in some cases, clearly tie the long-term projections to established performance goals. For example, Michigan's Five Year Transportation Program shows pavement conditions and bridge conditions under alternative funding scenarios and includes a goal. The New Jersey 10-Year Statewide Capital Investment Strategy includes an analysis of five funding scenarios and the resulting performance of state-owned pavements and bridges against a target goal. Michigan is the only state the consultants found that includes long-term projections of bridge and pavement condition in their on-going performance reporting. The long-term projections are based on current funding.

Applicability to WSDOT. WSDOT has pavement and bridge performance goals and, through the Gray Notebook, on-going performance reporting. WSDOT could include long-term projections of bridge and pavement condition in their Gray Notebook reports. The Office of Financial Management's biennial Transportation Attainment Report, which is required by statute, could be modified to include a long-term projection of bridge and pavement conditions at current or alternative funding levels.

Recommendations for Improvement

Legislative reporting recommendation. The Legislature should consider requiring that WSDOT provide it reports on long-term bridge and highway preservation needs as part of the budget process and/or in the biennial Transportation Attainment Report.

To anticipate MAP-21 Transportation Asset Management Plan requirements, the analysis in the legislative report should consider all classes of preservation and maintenance needs over ten years, including new needs expected to arise because of deterioration during this period. It should also account for, and clearly delineate, needs that can be delayed beyond 10 years, and should provide a basis for considering uncertainty in costs and funding.

References

AASHTO. AASHTO Guide for Commonly Recognized (CoRe) Structural Elements with 2002 and 2010 Interim Revisions. American Association of State Highway and Transportation Officials, 1998. Available at https://bookstore.transportation.org/Item_details.aspx?id=1348.

AASHTO. AASHTO Manual for Bridge Element Inspection. American Association of State Highway and Transportation Officials, 2013. Available at https://bookstore.transportation.org/collection_detail.aspx?ID=129.

Arizona Department of Transportation, What Moves You Arizona Long-Range Transportation Plan 2010-2035, November 2011. Available at http://azdot.gov/docs/default-source/planning/lrtp-2011-1129.pdf?sfvrsn=2.

Berman, Jeffrey, Charles Roeder, and Ryan Burgdorfer. Determining the Cost/Benefit of Routine Maintenance Cleaning on Steel Bridges to Prevent Structural Deterioration. Washington State Department of Transportation Report WA-RD 811.1, 2013a. Available at http://www.wsdot.wa.gov/research/reports/fullreports/811.1.pdf.

Berman, Jeffrey W., Charles W. Roeder, Ryan Burgdorfer. Standard Practice for Washing and Cleaning Concrete Bridge Decks and Substructure Bridge Seats Including Bridge Bearings and Expansion Joints to Prevent Structural Deterioration. Washington State Department of Transportation Report WA-RD 811.2, 2013b. Available at http://www.wsdot.wa.gov/research/reports/fullreports/811.2.pdf.

California Department of Transportation, 2013 Five-Year Maintenance Plan, March, 2013. Available at http://www.dot.ca.gov/docs/2013_Fiveyear_Maintenance_Plan.pdf.

California Department of Transportation, Final 2013 Ten-Year State Highway Operation and Protection Program Plan, March 5, 2013. Available at http://www.dot.ca.gov/hq/transprog/SHOPP/prior_shopp_documents/10yr_SHOPP_Plan/2013_Ten_Year_SHOPP_Plan.pdf

Cambridge Systematics, Inc. Pontis 4.3 Technical Manual. American Association of State Highway and Transportation Officials, 2003.

Colorado Department of Transportation, Transportation Deficit Report 2013, April 2013. Available at http://www.coloradodot.info/library/AnnualReports/2013-transportation-deficit-report.

Committee on Increasing National Resilience to Hazards and Disasters, and Committee on Science, Engineering, and Public Policy. Disaster Resilience: a National Imperative. Washington: The National Academies Press, 2012.

Connor, Robert J., Robert Dexter, and Hussam Mahmoud. Inspection and Management of Bridges with Fracture-Critical Details. National Cooperative Highway Research Program Synthesis 354, Transportation Research Board of the National Academies, 2005. Available at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_354.pdf.

FHWA. Bridge Management Questionnaire Report. Federal Highway Administration Office of Asset Management, 2010.
Available at http://www.fhwa.dot.gov/bridge/management/bms.pdf.

FHWA. Bridge Management Practices in Idaho, Michigan, and Virginia. Federal Highway Administration Office of Asset Management, Pavement, and Construction, 2011.
Available at http://www.fhwa.dot.gov/asset/hif12029/hif12029.pdf.

FHWA. Life Cycle Cost Analysis Primer. US Federal Highway Administration, 2002.
Available at http://isddc.dot.gov/OLPFiles/FHWA/010621.pdf.

FHWA. Metrics for the Oversight of the National Bridge Inspection Program. Federal Highway Administration, 2013
Available at http://flh.fhwa.dot.gov/programs/fabs/documents/2013-metrics.pdf.

FHWA. Practical Guide for Quality Management of Pavement Condition Data Collection, 2013.
Available at http://www.fhwa.dot.gov/pavement/management/qm/data_qm_guide.pdf.

FHWA. Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges, US Federal Highway Administration report FHWA-PD-96-001, 1995.
Available at http://www.fhwa.dot.gov/bridge/mtguide.pdf.

Gordon, Mark, George Jason Smith, Paul D. Thompson, Hyun-A Park, Frances Harrison, and Brett Elston. AASHTO Transportation Asset Management Guide, Volume 2: A Focus on Implementation. American Association of State Highway and Transportation Officials. Prepared under NCHRP Project 08-69, 2011.
Available at https://bookstore.transportation.org/item_details.aspx?id=1757.

Hawk, Hugh. BRIDGIT: User-Friendly Approach to Bridge Management. Proceedings of the Eighth International Bridge Management Conference, Denver, 1999.
Available at http://onlinepubs.trb.org/onlinepubs/circulars/circ498/v1_E07.pdf.

Hawk, Hugh. Bridge Life Cycle Cost Analysis. National Cooperative Highway Research Program Report 483, Transportation Research Board of the National Academies, 2003.
Available at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_483a.pdf.

Hunt, Beatrice E. Monitoring Scour Critical Bridges. National Cooperative Highway Research Program Synthesis 396, Transportation Research Board of the National Academies, 2009.
Available at http://wsdot.wa.gov/publications/fulltext/graynotebook/Jun13.pdf.

Markow, Michael J., Managing Selected Transportation Assets: Signals, Lighting, Signs, Pavement Markings, Culverts, and Sidewalks, National Cooperative Highway Research Program Synthesis 371, Transportation Research Board of the National Academies, 2007.
Available at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_371.pdf.

Markow, Michael J., and William A. Hyman. Bridge Management Systems for Transportation Agency Decision Making. National Cooperative Highway Research Program Synthesis 397. Transportation Research Board of the National Academies, 2009.
Available at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_397.pdf.

Michigan Department of Transportation, 2014-18 Five-Year Transportation Program, January 2014. Available at http://www.michigan.gov/documents/mdot/MDOTFinal5YearPlan20114-2018_445737_7.pdf.

Michigan Department of Transportation, 2014 System Performance Measures Report. Available at http://www.michigan.gov/documents/mdot/MDOT-Performance_Measures_Report_289930_7.pdf.

Minnesota Department of Transportation, 20-Year State Highway Investment Plan, 2014. Available at http://www.dot.state.mn.us/planning/mnship/.

Nebraska Department of Roads, 2013 State Highway Needs Assessment, November, 2013. Available at http://www.transportation.nebraska.gov/needs/docs/needs-2013.pdf.

Nevada Department of Transportation, State Highway Preservation Report 2013, February 2013. Available at https://www.nevadadot.com/uploadedFiles/NDOT/About_NDOT/NDOT_Divisions/Planning/2013%20State%20Highway%20Preservation%20Report.pdf.

New Jersey Department of Transportation, NJ Transit, New Jersey Turnpike Authority, South Jersey Transportation Authority, Statewide Capital Investment Strategy FY 2013-22, March 2012. Available at http://www.state.nj.us/transportation/capital/cis/pdf/scis1322.pdf.

Northwest Pavement Management Systems Users Group, Pavement Surface Condition Rating Manual, 1992.

Patidar, Vandana, Samuel Labi, Kumares Sinha, and Paul Thompson. Multi-Objective Optimization for Bridge Management Systems. National Cooperative Highway Research Program Report 590, Transportation Research Board of the National Academies, 2007. Available at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_590.pdf.

Roeder, Charles W., Gregory A MacRae, Athena Y. Kalogiros, and Amy Leland. Fatigue Cracking of Riveted, Coped, Stringer-to-Floorbeam Connections. Washington State Department of Transportation Research Report WA-RD 494.1, 2001. Available at http://www.wsdot.wa.gov/research/reports/fullreports/494.1.pdf.

Shepard, Richard W., & Michael Johnson. "California Bridge Health Index: A Diagnostic Tool to Maximize Bridge Longevity, Investment". *TR News* 215, 2001. Available at: http://onlinepubs.trb.org/Onlinepubs/trnews/trnews215full.pdf.

Sobanjo, John O., and Paul D. Thompson. Enhancement of the FDOT's Project Level and Network Level Bridge Management Analysis Tools: Final Report. Florida Department of Transportation Contract BDK83 977-01, 2011. Available at http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_MNT/FDOT_BDK83_977-01_rpt..pdf.

Sobanjo, John O., and Paul D. Thompson. Development of Risk Models for Florida's Bridge Management System: Final Report. Florida Department of Transportation Contract BDK83 977-11, 2013.

Available at http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_MNT/FDOT-BDK83-977-11-rpt.pdf.

Texas Department of Transportation, Statewide Transportation Report, 2013.
Available at http://ftp.dot.state.tx.us/pub/txdot-info/tpp/statewide_transportation.pdf.

Thompson, Paul D. and William A. Hyman. AASHTO Guide for Bridge Management Systems. American Association of State Highway and Transportation Officials, 1992.
Available at https://bookstore.transportation.org/Item_details.aspx?id=343.

Thompson, Paul D., Fazil T. Najafi, Roberto Soares, and Hong Jae Choung. Florida DOT Pontis User Cost Study: Final Report. Florida Department of Transportation, 1999.
Available at http://www.pdth.com/images/fdotuser.pdf.

WSDOT. WSDOT Bridge Painting Needs. Washington State Department of Transportation Bridge and Structures Office, 2011.

WSDOT. Gray Notebook – June 2011, 2012, 2013 and December 2011, 2012, and 2013.
Available at http://www.wsdot.wa.gov/Accountability/GrayNotebook/gnb_archives.htm.

WSDOT. Maintenance Accountability Process Manual. Washington State Department of Transportation Maintenance Operations, 2012.
Available at http://www.wsdot.wa.gov/Maintenance/Accountability/mapmanual.htm.

WSDOT. Pavement Asset Management, 2014.

WSDOT. Washington's State of Transportation Report to the House and Senate Transportation Committees, 2012.
Available at
https://app.leg.wa.gov/CMD/Handler.ashx?MethodName=getdocumentcontent&documentId=9wNtlG1QWsM&att=false

WSDOT. Supplemental Pavement Rater's Notes, 2013.

WSDOT. WSDOT Strategies Regarding Preservation of the State Road Network, 2010.
Available at http://www.wsdot.wa.gov/NR/rdonlyres/69E02461-0553-4EAE-9DA5-1F85EC93E74F/0/PavementPreservation.pdf.

Washington State Transportation Center (TRAC). The WSDOT Pavement Management System – A 1993 Update, 1993.

Wyoming Department of Transportation, Wyoming Connects, 2012.
http://www.dot.state.wy.us/files/live/sites/wydot/files/shared/Planning/Long%20Range%20Transportation%20Plan%202010.pdf