

# **USING A LIFE CYCLE PLANNING PROCESS TO SUPPORT ASSET MANAGEMENT**

**Final Document**

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U.S. Department  
of Transportation  
**Federal Highway  
Administration**

**November 2017**



## PURPOSE AND OVERVIEW

The performance-based program introduced in the Moving Ahead for Progress in the 21<sup>st</sup> Century Act (MAP-21) and extended under the Fixing America's Surface Transportation (FAST) Act intended to "...provide a means to the most efficient investment of Federal transportation funds by refocusing on national transportation goals, increasing the accountability and transparency of the Federal-aid highway program, and improving project decision making..." 23 U.S.C. 150(a). The Asset Management Rule<sup>1</sup> emphasizes the importance of life cycle planning (LCP) in its definition for asset management, as shown below:

A strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based on quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the life cycle of the assets at a minimum practical cost.<sup>2</sup>

This definition reflects the definition of asset management established in 23 U.S.C. 101(a)(2).

In addition, the minimum standards for developing and operating bridge and pavement management systems require documented procedures for "determining the benefit-cost over the life cycle of assets to evaluate alternative strategies (including no action decisions), for managing the condition of National Highway System (NHS) pavement and bridge assets."<sup>3</sup>

Because of the importance of considering the whole life of an asset in developing cost-effective investment strategies, the Asset Management Rule (Rule) establishes an LCP approach to managing transportation assets and developing performance- and risk-based asset management plans.

LCP should be considered an approach to managing transportation assets over their whole life, covering the time each asset goes into service after construction to the time it is retired or disposed of. The Rule defines LCP as "a process to estimate the cost of managing an asset class, or asset sub-group, over its whole life with consideration for minimizing cost while preserving or improving the condition."<sup>4</sup> Several specific requirements related to LCP are included in the Rule, as documented below.

*A State DOT shall establish a process for conducting LCP for an asset class or asset sub-group at the network level (network to be defined by the State DOT). As a State DOT develops its LCP process, the State DOT should include future changes in demand; information on current and future environmental conditions*

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<sup>1</sup> The FHWA published the rule on October 26, 2016. The rule is effective on October 2, 2017. See 81 Federal Register 73196 (October 24, 2016).

<sup>2</sup> 23 CFR 515.5.

<sup>3</sup> 23 CFR 515.17.

<sup>4</sup> 23 CFR 515.5.

*including extreme weather events; climate change and seismic activity; and other factors that could impact whole life costs of assets.*

*At a minimum, the LCP process shall include the following:*

1. *The State DOT targets for asset condition for each asset class or asset sub-group;*
2. *Identification of deterioration models for each asset class or asset sub-group, provided that identification of deterioration models for assets other than NHS pavements and bridges is optional;*
3. *Potential work types across the whole life of each asset class or asset sub-group with their relative unit cost; and*
4. *A strategy for managing each asset class or asset sub-group by minimizing its life cycle costs, while achieving the State DOT targets for asset condition for NHS pavements and bridges under 23 U.S.C. 150(d).<sup>5</sup>*

State DOTs are granted flexibility to tailor their life cycle planning to their unique needs. For instance, State DOTs may propose excluding one or more asset sub-groups from its life cycle planning if the State DOT can demonstrate to FHWA that exclusion of the asset sub-group would have no material adverse effect on the development of sound investment strategies due to the limited number of assets in the asset sub-group, the low level of cost associated with managing the assets in that asset sub-group, or other justifiable reasons.<sup>6</sup> A State DOT's Statewide Transportation Improvement Program (STIP) may provide background information to support LCP, but it cannot be used as a substitute for carrying out the required analyses, or be used to override the results of the required independent analyses of relevant data when developing investment strategies.

This document provides guidance on developing an initial LCP process that satisfies the requirements in the Rule and leads to the identification of an effective investment strategy for managing transportation assets, as defined in item (4) of the requirements. While the Rule requires all four of the minimum requirements, this document does not specifically provide guidance on meeting the first three items listed as minimum requirements. As agencies mature in their use of an LCP process, it is anticipated that they will be able to employ more sophisticated analysis tools and techniques.

This guidance is focusses specifically on performing LCP analysis, and does not address requirements for pavement or bridge management systems. The intent of this guidance is to assist State DOTs with the development of their TAMP. However, the concepts can be applied to any transportation agency responsible for managing pavements, bridges, or other infrastructure assets. State DOTs are encouraged to engage partner agencies (including Metropolitan Planning Organizations (MPOs), local agencies, and Toll Authorities, for example) in the LCP process and encourage their use of LCP practices for managing their networks.

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<sup>5</sup> 23 CFR 515.7.

<sup>6</sup> 23 CFR 515.7.

## Life cycle Planning Objectives

A strong LCP process enables an agency to:

- Establish a long-term focus for improving and preserving the system.
- Develop maintenance strategies that consider long-term investment needs.
- Determine the funding needed to achieve the desired state of good repair (SOGR).
- Determine the conditions that can be achieved for different levels of funding.
- Reduce the annual cost of system preservation without impacting asset conditions.
- Provide objective data to support investment decisions.
- Eliminate existing performance gaps.
- Demonstrate good stewardship to internal and external stakeholders.

## Links to Other Asset Management Concepts

Through the process of developing a Transportation Asset Management Plan (TAMP), State DOTs identify an investment strategy that reflects their plans for managing highway assets over the next 10 years. The LCP guides the development of this investment strategy by using asset condition data, deterioration rates, and treatment options to determine the most cost-effective approach to achieve the desired SOGR and sustain the agency's investment in transportation assets. In the same way that planned investments in the maintenance of a car are important to ensure it remains operational for as long as possible, LCP is key to achieving the lowest practical cost for improving and preserving pavements, bridges, and other transportation assets.

## Use of Life cycle Planning Results

The results of an LCP process can be used to better understand the impact of various treatment strategies on asset performance. Using available tools, such as pavement and bridge management systems, an agency can examine a range of LCP scenarios for key assets covering the period from initial construction through maintenance, preservation, repair, rehabilitation, and reconstruction.

The results of the LCP process are also an essential element considered during the financial planning process associated with the development of a TAMP. The LCP scenarios generated through the LCP process are key to determining a realistic network-level investment strategy for asset maintenance, preservation, repair, rehabilitation, and replacement to achieve and sustain the desired SOGR at a minimum practical cost. Through an iterative process that considers available funding, desired SOGR, existing performance gaps, risks, and the conditions that can be achieved for each LCP scenario, an agency can select the investment strategy that best balances these competing factors. While this guidance addresses the LCP process, other guide documents are available for establishing risk management and financial planning processes.

## KEY CONCEPTS

### What Life cycle Planning Is and Is Not

Consider the LCP a network-level analysis that encompasses many aspects of an engineering economic analysis, including the following:

- The availability of different treatment options that are being evaluated over an analysis period, each of which may vary based on costs, applicable conditions, and useful life.
- The opportunity cost associated with choosing one alternative over another, including noneconomic factors. For example, the opportunity cost may be represented by the benefit associated with increased performance over the life of the treatment.
- The funding and other constraints that limit alternatives that can be selected.
- An analysis period that is often set at a fixed number of years.
- The consideration of the time value of money.

Do not confuse LCP for a TAMP with a life cycle cost analysis (LCCA) at the project level. Agencies use the project-level LCCA when comparing two or more design alternatives for a single project. An LCCA considers all agency expenditures and user costs throughout the life of an alternative. Agency costs include initial construction costs as well as costs associated with maintenance, repair, preservation, and rehabilitation activities that will be needed over an analysis period. In addition to agency costs, best practice LCAs include consideration of user costs that result from work zone activities, such as vehicle operating costs and delay costs. The activity costs associated with both agency and user costs are calculated over the life of each alternative and discounted to convert anticipated future costs to a present dollar value, allowing the total life cycle costs of each alternative to be compared directly. The FHWA provides guidance in conducting a project-level LCCA and has developed software tools State DOTs can use to conduct the analysis<sup>7</sup>. The analysis requires detailed information about alternate design approaches (including different design types and materials), treatment strategies, treatment costs, expected treatment lives, traffic counts, traffic distribution patterns by hour, construction periods, detours during construction, and so on, for a single construction project.

The LCP is performed at the network level, where the needs of all roads and bridges in a system or a subset of the system are considered over an analysis period. It is not practical to conduct an LCCA at the network level because feasible projects and treatments have not been scoped and no preliminary engineering has been done to collect the detailed data necessary for a full LCCA. Therefore, the type of network-level LCP addressed in this document takes advantage of existing pavement and bridge management system capabilities, applying an engineering-economic analysis approach to evaluate and compare the cost-effectiveness of asset strategies to preserve desired asset conditions or improve asset conditions over the long term. Although the network-level analysis may be less detailed than the more commonly used project-level analysis, both applications use engineering economic analysis principles to identify alternatives that represent the lowest practical life cycle cost over the analysis period to achieve the desired objectives.

<sup>7</sup> To learn more about available resources on LCCA or to obtain a copy of FHWA's Real Cost analysis tool, see FHWA's website: <https://www.fhwa.dot.gov/infrastructure/asstmgmt/lcca.cfm>

Pavement and bridge management systems provide a way to compare the long-term impacts associated with different combinations of projects and treatments for an entire network at a selected level of funding. A network could include all NHS routes within a State or both NHS and non-NHS routes, for example. State DOTs have flexibility in how they define the network for LCP purposes. State DOTs also have flexibility in selecting the asset classes that will be analyzed using LCP at the network level, but LCP is required for two asset classes: 1) NHS pavements and 2) bridges on the NHS. An asset class may be further divided into asset sub-groups (such as asphalt, concrete, and composite pavements or concrete, steel, and truss bridges) to better reflect differences in performance and treatment strategies. While the TAMP covers a minimum of 10 years, pavement and bridge management systems may evaluate impacts over a longer analysis period to capture future benefits associated with managing the whole life of the network assets.

## Important Terminology

There are several terms that are used throughout this guidance that are explained here to avoid confusion, as noted below:

- **Treatment Options** – Treatment options are typically defined in a management system with rules that describe when and where the treatments are considered viable. For example, a treatment may be an option for roads with a specific functional classification but may not be appropriate for roads belonging to a different functional classification. Treatment rules are used to evaluate the feasibility of a treatment at any stage of the asset life cycle, so the rules will cover the entire range of possible asset conditions.
- **LCP Strategies** (or LCP asset strategies) – An LCP strategy is a collection of treatments that represent the entire life of an asset class or sub-group. For example, one LCP strategy might include a set of treatment rules that reflect a “worst-first” philosophy that includes rehabilitation and reconstruction treatments once an asset has deteriorated. Since the worst-first strategy is not cost-effective, it is typically used only for comparison purposes to illustrate the amount of deterioration that can occur if no preservation treatments are used. A more cost-effective LCP strategy might reflect a “preservation” philosophy that is designed to include low-cost treatments to keep good roads in Good condition longer with rehabilitation and reconstruction options for more deteriorated assets. Agencies may define different LCP strategies to represent different levels of preservation aggressiveness. For instance, an agency may have three bridge deck strategies: one that includes the application of rigid overlays with the first overlay installed at the onset of deck deterioration, another that includes the application of thin overlays, and a third that includes patching only until partial deck reconstruction is required. The intent in developing multiple LCP strategies is to compare whether one results in better long-term conditions than another with the same level of funding.
- **LCP Scenarios** – An LCP scenario applies a strategy to a particular funding level to determine a particular funding approach. An agency may evaluate several LCP scenarios to support its financial planning process. For instance, one LCP scenario might evaluate the funding needed to maintain current conditions or asset value. Another LCP scenario might identify the funding needed to achieve a desired SOGR.
- **Investment Strategy** – During the financial planning process, an agency evaluates the expected funding levels, the existing performance gaps, risks, and desired SOGR for each

asset to develop an investment strategy that defines how the funding will be spent, what level of performance will be achieved, and what level of risk will be accepted. At a minimum, the TAMP should include a 10-year investment strategy that identifies a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions to achieve and sustain the desired SOGR at the minimum practical cost.

- **Performance Gap** – A performance gap exists when there is a difference between current or projected conditions and the desired SOGR. A performance gap analysis is conducted to estimate the annual funding needed to achieve and sustain the desired SOGR.
- **Iterative Process** – An iterative process includes a cycle of repeated operations to determine a desired result. The development of the investment strategy in the TAMP is an example of an iterative process because the risk management and financial planning processes drive the development of multiple LCP scenarios showing how funding can be put to use. Other agency plans, such as safety or freight plans may also drive the development of LCP scenarios, triggering the iterative process. For instance, a new freight plan might require an agency to upgrade 30 percent of its NHS network to accommodate the heavy loads within 5 years. This would impact the level of funding available during financial planning and require adjustments to the LCP scenarios.

### The Life cycle Planning Approach to Managing Assets

The LCP requires a long-term approach to managing transportation assets so that decision makers can plan in advance for the investments that will be needed to achieve and sustain a desired SOGR. It considers a whole-life approach to managing assets, taking into account treatment needs from initial construction to replacement or disposal. The common stages of an asset life cycle are shown in figure 1.

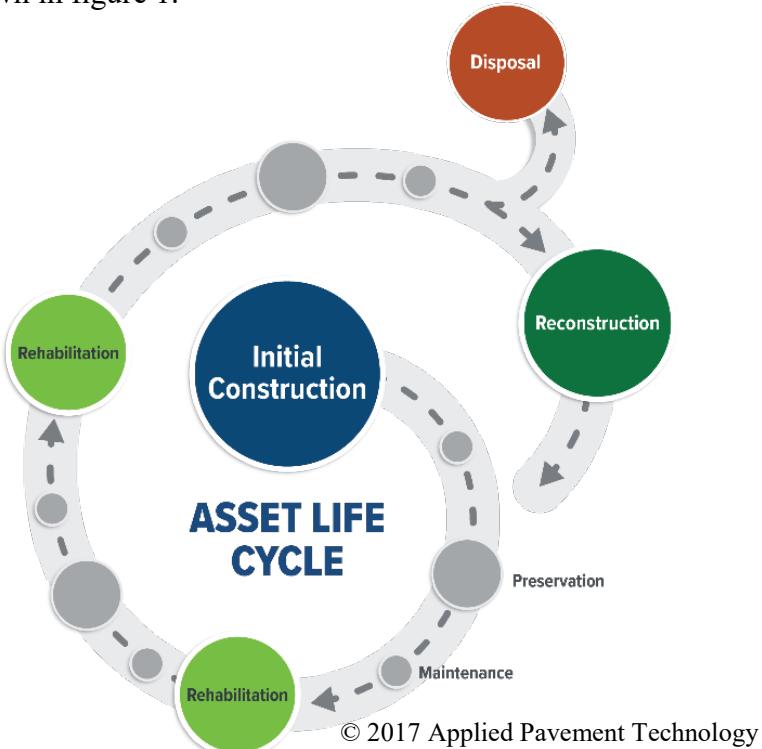


Figure 1. Stages of an asset life cycle.

At each stage of an asset's life, different treatment options are appropriate, each with a different life expectancy and cost. The LCP uses available tools, such as pavement and bridge management systems, to analyze different asset strategies within LCP scenarios to support the financial planning process.

One objective of the LCP process is to determine the best LCP scenario to close existing performance gaps between the current and desired SOGR. Another objective is to determine the LCP scenario that yields the lowest cost to maintain the network, or a subset of the network, over the life of the asset class. By following an LCP process, agencies have found that asset strategies employing low-cost treatments that extend service life, preserve desired asset conditions longer, and postpone the need for rehabilitation can be effective at reducing a performance gap. For example, the LCP process used by one State DOT determined that its pavement and bridge conditions would fall below the agency's desired SOGR unless they adopted a strategy that increased the use of preservation treatments. Over a 6-year period, the strategy was expected to preserve pavement and bridge conditions above the desired SOGR and allow the agency to reallocate \$300 million towards other preservation needs by deferring the need for more costly rehabilitation activities.

An LCP approach to asset management can be applied to any highway asset that relies on maintenance and preservation activities to cost-effectively extend its service life. Routine condition surveys provide information on current asset conditions and time-series data can be used to develop forecasting models that predict when maintenance, preservation, repair, rehabilitation, or reconstruction activities will be needed, in accordance with agency-designed treatment rules or guidelines. Some assets, such as ITS devices and traffic signals, may be more suited to a cyclic maintenance strategy than a condition-based strategy, which would be influenced by historical performance or the service life estimated by the manufacturer. Other highway assets, such as raised pavement markings, may be managed using a more reactive maintenance strategy that drives replacement when markings are damaged. However, even some major assets, such as bridges, may use a combination of condition-based and interval-based (or cyclical) treatments, as shown in the example provided in table 1. In general, high-value assets or assets representing a significant level of investment are probably more commonly managed using the LCP process for the majority of treatments applied over the life of an asset.

The LCP process allows agencies to consider a wide variety of risks in their planning, including changes in demand and environmental conditions (such as extreme weather events and seismic activity). For instance, the FHWA guidance on risk management references an example from the Mississippi DOT in which extreme drought conditions in the southeastern part of the State resulted in early pavement failures that led to increased repair costs and reduced pavement conditions<sup>8</sup>. Since accelerated rates of deterioration have to be taken into account and more substantial treatment options will have to be included in the strategy considered for that portion of the network, this type of situation has a direct impact on the LCP scenarios that are developed.

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<sup>8</sup> Mississippi Department of Transportation, news release, Nov. 29, 2016.

Table 1. Wisconsin DOT bridge preservation guidance.<sup>9</sup>

<b>Bridge Component</b>	<b>Bridge Preservation Type</b>	<b>Activity Description</b>	<b>Preventive Maintenance Type</b>	<b>Action Frequency (years)</b>
All	Preventive Maintenance	Sweeping, power washing, cleaning	Cyclical	1-2
Deck	Preventive Maintenance	Deck washing	Cyclical or Condition Based	1
Deck	Preventive Maintenance	Deck sweeping	Cyclical or Condition Based	1
Deck	Preventive Maintenance	Deck sealing/crack sealing	Cyclical or Condition Based	4-5
Deck	Preventive Maintenance	Thin polymer (epoxy) overlays	Cyclical or Condition Based	8-12
Deck	Preventive Maintenance	Drainage cleaning/repair	Cyclical or Condition Based	As needed
Deck	Preventive Maintenance	Joint cleaning	Cyclical or Condition Based	As needed
Deck	Preventive Maintenance	Deck Patching	Condition Based	1-2
Deck	Preventive Maintenance	Chloride extraction	Condition Based	1-2
Deck	Preventive Maintenance	Asphalt overlay with membrane	Condition Based	6-12
Deck	Preventive Maintenance	Polymer modified asphalt overlay	Condition Based	12-15
Deck	Preventive Maintenance	Joint seal replacement	Condition Based	10
Deck	Preventive Maintenance	Drainage cleaning/repair	Condition Based	1
Deck	Repair or Rehab Element	Rigid concrete overlays	Condition Based	As needed
Deck	Repair or Rehab Element	Structural Reinforced concrete overlay	Condition Based	As needed
Deck	Repair or Rehab Element	Deck joint replacement	Condition Based	As needed
Deck	Repair or Rehab Element	Eliminate joints	Condition Based	As needed
Super	Preventive Maintenance	Bridge approach restoration	Cyclical	2
Super	Preventive Maintenance	Seat and beam ends washing	Cyclical	2
Super	Repair or Rehab Element	Bridge rail restoration	Condition Based	As needed
Super	Repair or Rehab Element	Retrofit rail	Condition Based	As needed
Super	Repair or Rehab Element	Painting	Condition Based	As needed
Super	Repair or Rehab Element	Bearing restoration (replacement, cleaning, resetting)	Condition Based	As needed
Super	Repair or Rehab Element	Superstructure restoration	Condition Based	As needed
Super	Repair or Rehab Element	Pin and hanger replacement	Condition Based	As needed
Super	Repair or Rehab Element	Retrofit fracture critical members	Condition Based	As needed
Sub	Preventive Maintenance	Substructure Restoration	Condition Based	As needed
Sub	Preventive Maintenance	Scour Counter Measure	Condition Based	As needed
Sub	Preventive Maintenance	Channel Restoration	Condition Based	As needed

### Information Needed to Conduct Life cycle Planning

In addition to the availability of analysis tools (such as pavement and bridge management systems), LCP relies on the availability of the following types of reliable data:

- Asset condition information.
- Asset condition deterioration models. The deterioration rates reflected in the models may be impacted by many factors, including changes in environmental conditions, which could lead to more frequent interventions and earlier replacement.

<sup>9</sup> Wisconsin DOT Bridge Preservation Policy Guide, Version 1.02, 2016.

- Asset maintenance and rehabilitation intervals or treatment rules that describe when and where a treatment is considered viable. The intervals between treatments may be shortened or lengthened based on traffic use, design and construction practices, or as weather conditions shift in the future.
- Treatment costs.
- Expected condition improvements, new deterioration rates, or new service-life estimates for each treatment.
- Expected changes in system demand that may impact deterioration rates or treatment options.
- Assets or areas at risk due to current or future environmental conditions.
- Expected budget levels.
- Inflation and discount rates.
- System hierarchies (e.g., high-priority routes versus low-priority routes).
- Constraints or other conditions that influence investments, such as a requirement that no more than 5 percent of the interstate miles can be in Poor condition.
- Information regarding desired SOGR and/or existing performance gaps to address.

A data gap analysis may be useful to help evaluate the appropriateness and completeness of the data for conducting LCP. Because of the importance of this data to asset management, establishing data governance plans for managing and updating the data should be in place.

## Forming the LCP Team

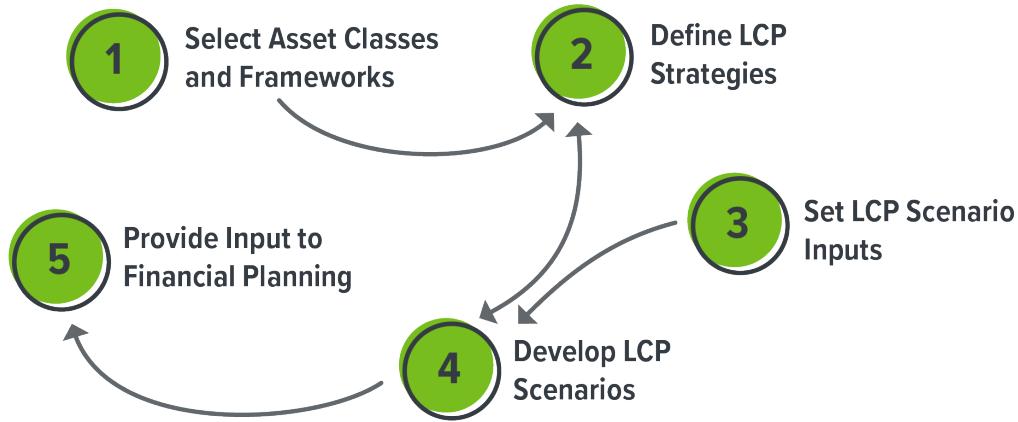
The most effective LCP processes benefit from the contributions of a cross-functional team of individuals with experience in managing and operating assets, setting and monitoring performance targets, conducting planning and programming activities, and mitigating risks. The LCP team should include the types of individuals shown in table 2.

Table 2. LCP team members and their roles.

Discipline	Role or Contribution
Executive Leadership	Setting the direction and providing input to the development of LCP scenarios.
Division Heads from Planning, Maintenance, Structures, Pavements, and Other Asset Areas	Developing and evaluating the feasibility of different LCP scenarios.
Asset Managers	Operating asset management software programs to develop prediction models, to evaluate the impacts of different asset strategies, and to develop LCP scenarios.
Risk Managers	Identifying areas or assets that are at risk, including potential environmental risks.
District or Region Personnel Responsible for Project and Treatment Selection	Providing feedback regarding feasible treatment options to use in developing asset strategies.
Metropolitan or Regional Planning Organizations	Contributing to the development of LCP strategies and encouraging the use of LCP by local agencies.

## THE STEPS IN THE LCP PROCESS

The LCP process shown in figure 2 can be adapted to fit the particular needs and resources of any agency, as discussed in this section of the document.



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Figure 2. A 5-step LCP process to be followed for each asset.

**Step 1: Select the asset classes and networks to be analyzed** – Consider assets that have the greatest value, represent a significant annual investment to maintain, or are considered to be at risk due to current or future environmental conditions. An agency may define its own networks for LCP and may elect to analyze portions of its system separately. For instance, an agency may have the need to develop an LCP scenario for its NHS system separately from the rest of its system. The objective is to define networks that match how you manage your system, so if your desired SOGR differs for different parts of the system, separate networks should be created.

**Step 2: Define LCP strategies** – Each LCP strategy should include a variety of treatment options that consider condition and asset performance needs over the life of an asset, treatment costs, environmental risks, desired SOGR, other agency priorities, and performance gaps that could best be addressed by improving existing assets or adding new assets.

**Step 3: Set LCP scenario inputs** – Establish the analysis period to be used, desired SOGR, risks, performance gaps, anticipated funding levels (which may come from financial planning), and any constraints or requirements (such as minimum pavement and/or bridge conditions) that must be taken into consideration in evaluating LCP scenarios.

**Step 4: Develop the LCP scenarios** – Using the asset strategies developed in step 2 and the inputs from step 3, develop LCP scenarios. Because of the iterative nature of the analysis, the development of LCP scenarios may lead back to step 2 and the development of new asset strategies.

**Step 5: Provide input to financial planning** – Use the information from step 4 to provide input to the financial planning process.

For many agencies, the most difficult aspect of the LCP process is quantifying the condition improvement benefits that occur from restorative treatments. Historical performance trends, often documented in a pavement or bridge management system, can provide this information for those asset groups. However, agencies typically don't have this type of information for other assets that they manage. In the absence of this data, agencies could begin the LCP process using average replacement cycles recommended by the asset manufacturer and estimates or assumptions about the number of assets addressed with different levels of repair each year. Over time, these assumptions and estimates can be replaced with historical data. Agencies will also want to consider any effects caused by changes in environmental conditions on replacement cycle frequency and costs.

## USING THE LIFE CYCLE PLANNING PROCESS

The previous section introduced a 5-step process for conducting LCP. This section of the guidance expands on the level of detail provided for each of the steps in the process.

### **Understanding the 5-Step LCP Process**

The 5-step LCP process shown in figure 2 is intended to enable transportation agencies to develop LCP scenarios that are considered during the financial planning process to develop the TAMP investment strategies. Each step in the process can be adapted to the data and analysis tools, as described below.

#### Step 1: Select the Asset Classes and Networks to be Analyzed

The first step in the process is to select the asset classes that will be analyzed using the LCP process. State DOTs must conduct LCP on two asset classes in their TAMP: NHS pavements and bridge assets on the NHS.<sup>10</sup> The same LCP concepts applied to NHS pavements and bridges can be used to analyze other asset groups that an agency has elected to include in its TAMP.

For each asset class, the agency has to define the network to be included in the asset strategies. For example, if a State DOT is including only interstates and noninterstate NHS routes in its TAMP, the network analysis can be limited to include only that portion of its total network.

#### Step 2: Define LCP Strategies

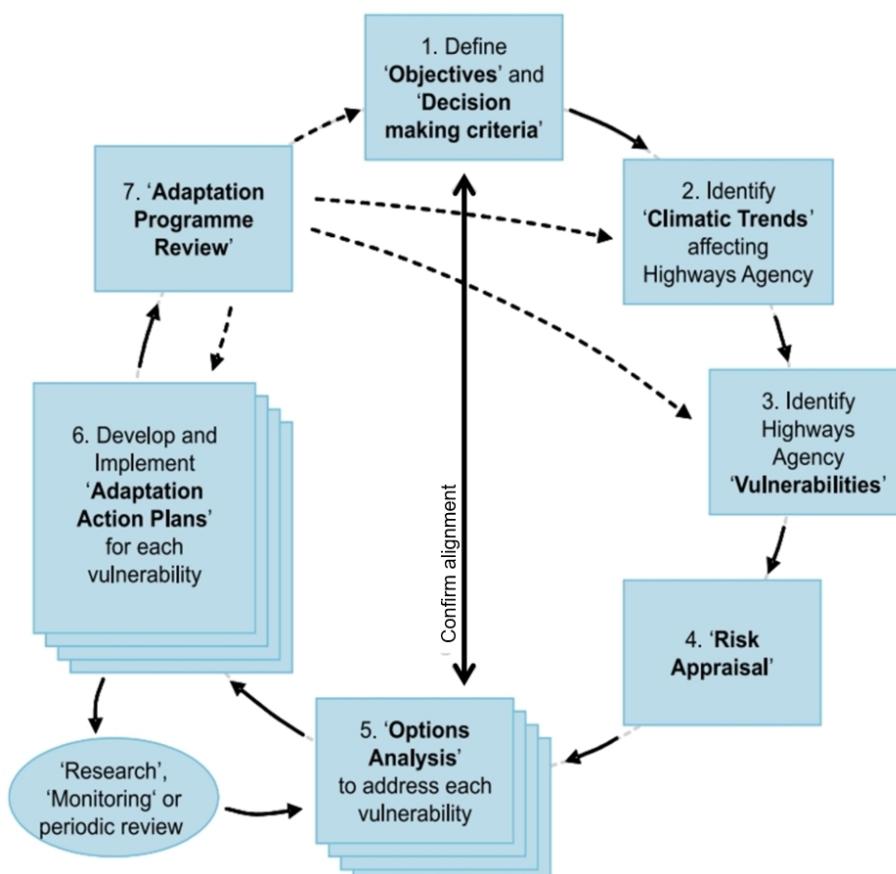
The assets and networks defined in step 1 are then analyzed using tools such as pavement and bridge management systems. This step in the process involves setting up LCP strategies for each asset class using the management system features to establish treatment rules, treatment cycles, and treatment intervals. Each asset strategy should consider rates of deterioration, treatment costs, and condition improvement benefits, as well as the factors that influence treatment type, timing, and priority. When available, treatment histories can be useful in determining treatment intervals for developing treatment rules. If histories are not available, expert judgement or industry standards may be used.

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<sup>10</sup> 23 CFR 515.17

An agency may set up several different LCP strategies for a given asset class, each reflecting different approaches to manage the network. For instance, an LCP strategy that relies extensively on rehabilitation and reconstruction treatments would generate different long-term performance results than another strategy that includes the more aggressive use of preservation treatments to defer the need for most costly repairs. Risks may also drive asset strategies. For instance, a culvert strategy might be created to replace culverts to better address potential flooding issues in high-risk areas, while a more traditional preservation-focused strategy is established for low-risk areas.

The alternate strategies considered in the LCP process should represent a range of solutions for managing the network and reducing agency risks and performance gaps. These strategies may differ from traditional practices by introducing new treatments or a more aggressive focus on preservation actions, for example. Strategies can also be set up to represent potential changes to future schedules for maintenance, preservation, and rehabilitation that might result from variations in climatic conditions, such as changes in freeze-thaw cycles or extreme temperatures. A process for considering the influences due to climate conditions on maintenance, preservation, and rehabilitation schedules is reflected in figure 3.



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Figure 3. Influence of environmental conditions on treatment schedules.<sup>11</sup>

<sup>11</sup> Climate Change Adaptation Strategy and Framework. 2009. UK Highways Agency. [http://assets.highways.gov.uk/about-us/climate-change/CCAF\\_Strategy\\_and\\_Vol\\_1\\_Rev\\_B\\_Nov.pdf](http://assets.highways.gov.uk/about-us/climate-change/CCAF_Strategy_and_Vol_1_Rev_B_Nov.pdf)

The LCP process should analyze these alternate strategies for each asset and compare them from a long-term perspective. To compare two or more strategies for the same asset class, the long-term results of each strategy should be generated using the same level of annual funding. The LCP strategies for each asset class that result in the best long-term performance from this analysis represent the most cost-effective asset strategies to be used in step 4.

#### *Differences in Analyzing Pavement and Bridge LCP Asset Strategies*

Pavement and bridge management systems analyze asset strategies using different methodologies.

#### **A. Pavement Management Project and Treatment Recommendation Process**

A pavement management system applies its treatment rules and performance models to the inventory and condition data available for the network being analyzed. The performance models are used to predict pavement conditions to determine treatment needs each year. In a 10-year pavement management analysis, the performance models predict the condition of each pavement section in the network for each year of the analysis. The predicted conditions are matched to treatment rules to determine whether that section has any treatment needs in any, or all, year(s) of the analysis period. If the pavement management system recommends a repair in any year, the treatment rules define the improvement to the condition of the section once the treatment is constructed, the cost of the treatment, and the new rate of deterioration for the section. Over a 10-year period, a series of treatments can be generated for each pavement section based on the treatment rules that have been established. An example of two different treatment strategies for a flexible pavement is provided in figure 4. The treatment rules in a pavement management system are designed to trigger treatments on a cycle similar to the ones shown in the figure, assuming sufficient funding is available to meet all network needs and performance models reflect the assumed rates of deterioration. For example, in the traditional strategy, overlays are assumed to last 10 years. If the actual rates of deterioration are shorter or longer than that, the overlay frequency will differ from the one shown.

When budget information is applied to the analysis, there is likely to be more work needed than funding available. A mature pavement management system conducts some type of cost-effectiveness analysis to determine which treatments in any given year result in the greatest benefit for the available funding. For example, a benefit/cost analysis might be used that compares the additional life associated with a treatment to its cost to determine the combination of projects and treatments for the network that results in the most cost-effective solution for a given level of funding. As agencies gain more experience with this type of analysis, they may want to enhance the number and types of treatments considered in the analysis to further reduce the annual costs of managing its asset classes.



\*In both strategies, crack sealing is performed on a 2–3 year cycle.

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Figure 4. Example of two different treatment strategies for flexible pavement.

## B. Bridge Management Project and Treatment Recommendation Process

A bridge management system consists of a number of modules that are useful in supporting resource allocation decisions for bridge improvement and preservation. Statistical deterioration models and cost models are defined for each bridge element. The deterioration models are expressed in the form of transition probability matrices or probability distribution curves that describe the likelihood of an element changing from one condition state to another over a given time period. The probabilities are estimated when setting up the bridge management system for the first time and are later updated when historical data becomes available.

Each treatment or action input into the system has a unit cost and is associated with one or more benefits, such as improving condition, extending service life, or reducing the risk of failure. Multiple treatments may be assigned at the condition state level for each element. Each treatment is classified into a category, such as major rehabilitation, replacement, preservation, and scour work. One or more bridge strategies may be established based on the agency's objectives, the bridge tier (e.g., local, NHS, non-NHS), and the intended service. A comprehensive engineering economic analysis is conducted to compare alternative strategies and generate a recommended strategy with an annualized cost or present-worth value to maintain each bridge in the inventory.

The recommended treatments for each bridge are grouped into projects, which are then grouped to develop programs. A network-level optimization is used to generate an LCP scenario that maximizes the utility value (which is a function of the bridge condition, present worth cost, and

risk) for a given budget or determines the lowest budget required to meet the minimum performance thresholds established. The resulting LCP scenarios help determine bridge needs and support the financial planning process.

An example of the type of treatments that can be incorporated into a bridge management system for one element or component (such as deck preservation) is presented in table 3. Similar types of rules would be established for other bridge elements so that all the needs can be considered when developing an overall plan for cost-effective management of the bridge.

Table 3. Sample bridge deck preservation treatment rules<sup>12</sup>.

Deck Surface NBI* (0 to 9 scale with 9 being highest)	Deck Surface Deficiencies (%)	Deck NBI* (0 to 9 scale with 9 being highest)	Deck Underside Deficiencies (%)	Repair Options	Next Anticipated Evaluation (Years)
N/A	N/A	N/A	N/A	Capital Scheduled Maintenance Activities	1 to 8
NBI=5, 6, or 7	2 to 5	NBI >5	N/A	Deck Patch/Seal Cracks	3 to 10
NBI=5, 6, or 7	2 to 5	NBI >5	N/A	Epoxy Overlay	10 to 15
NBI=5, 6, or 7	2 to 5	NBI <=5	N/A	Deck Patch	3 to 10
NBI=5, 6, or 7	2 to 5	NBI <=5	N/A	Hold	1 to 8
NBI = 5	5 to 15	N/A	N/A	Hold	1 to 8
NBI = 5	5 to 15	N/A	N/A	Deck Patch	3 to 10
NBI = 4 or 5	15 to 30	NBI = 5 or 6	<10	Deep Concrete Overlay	25 to 30
NBI = 4 or 5	15 to 30	NBI = 3 or 4	10 to 30	Shallow Concrete Overlay	10 to 15
NBI = 4 or 5	15 to 30	NBI = 2 or 3	>30	Hot Mix Asphalt Overlay with waterproofing membrane	8 to 10
NBI<=4	> 30	NBI >=5	<5	Deep Concrete Overlay	20 to 25
NBI<=4	> 30	NBI=3, 4, or 5	5 to 30	Shallow Concrete Overlay	10
NBI<=4	> 30	NBI=3, 4, or 5	5 to 30	Hot Mix Asphalt Overlay with Waterproofing Membrane	5 to 7
NBI<=4	> 30	NBI = 2 or 3	>30	Replace Deck	40+
NBI<=4	> 30	NBI = 2 or 3	>30	Hot Mix Asphalt Cap	1 to 3

\*National Bridge Index

### Step 3: Set LCP Scenario Inputs

The management system analysis uses inputs such as expected funding levels, desired SOGR, and other constraints or requirements to produce LCP scenarios in step 4. These inputs are important since they can significantly influence the LCP scenario that is generated. For instance, an agency with constrained funding may concentrate most of its investment on preserving the condition of high-volume facilities, resulting in little more than a minimum maintenance strategy for the remainder of the system.

<sup>12</sup> Extracted from *Bridge Deck Matrixrev110404.wpd* (Michigan DOT), dated November 4, 2004.

Minimum condition levels for interstate pavements<sup>13</sup> and NHS bridge deck<sup>14</sup> conditions have been established that State DOTs must address. These minimum condition levels, as well as any other statutory requirements that are in place, should be considered as factors that will influence LCP scenarios developed for certain asset classes.

#### Step 4: Develop the LCP Scenarios

Using the LCP asset strategies generated during step 2, and the LCP scenario inputs identified in step 3, the management systems can be used to develop LCP scenarios for each asset for consideration in the financial planning process to achieve the desired SOGR over a 10-year window. Agencies may want to evaluate multiple LCP scenarios for each asset and may want to develop LCP scenarios that consider different parts of the network. For example, if a State DOT differentiates between the use of Federal and State funds on portions of the network, the agency may decide to develop separate LCP scenarios for the portion of the network addressed with Federal funds and the portion addressed with State funds.

Examples of the types of LCP scenarios that might be considered during this step include those listed below. Agencies are not required to generate all of the LCP scenarios listed below, but should at least consider those designed to address elements required by law (such as the funding needed to achieve the desired SOGR). The following LCP scenarios are provided to illustrate the range of funding approaches that might be considered:

- **Minimum maintenance only** – This LCP scenario addresses only localized repairs to address safety, such as pothole patching on pavements and joint repair on bridges. It may be used when an agency has insufficient funds to address all of the network needs. This LCP scenario may be considered a “do nothing” scenario to show how the system would deteriorate without investment.
- **Meet minimum performance requirements** – An agency that is concerned about meeting the minimum pavement or bridge condition requirements may generate an LCP scenario that directs funding to ensure minimum requirements are satisfied in each year of the analysis.
- **Current investment levels** – For comparison purposes, an agency may evaluate an LCP scenario that reflects current levels of investment, so the results can be compared to other investment approaches. When analyzing current investment levels, it may be beneficial to revisit the treatment rules to verify that they include treatment options that span the entire life cycle. In most cases, adding preservation treatments to the asset strategy enables the agency to achieve more cost-effective, long-term performance than in a strategy that includes only rehabilitation or reconstruction. It is often important to be able to show the benefits of a more aggressive preservation strategy to build buy-in among agency personnel.
- **Maintain current conditions or asset value** – The objective of this LCP scenario is to determine the funding needed to maintain the current performance level or asset value for a particular asset. The results are helpful for communicating with agency leadership, elected officials, and other stakeholders regarding funding needs.

<sup>13</sup> 23 USC 119(f)(1), and 23 CFR 490.315

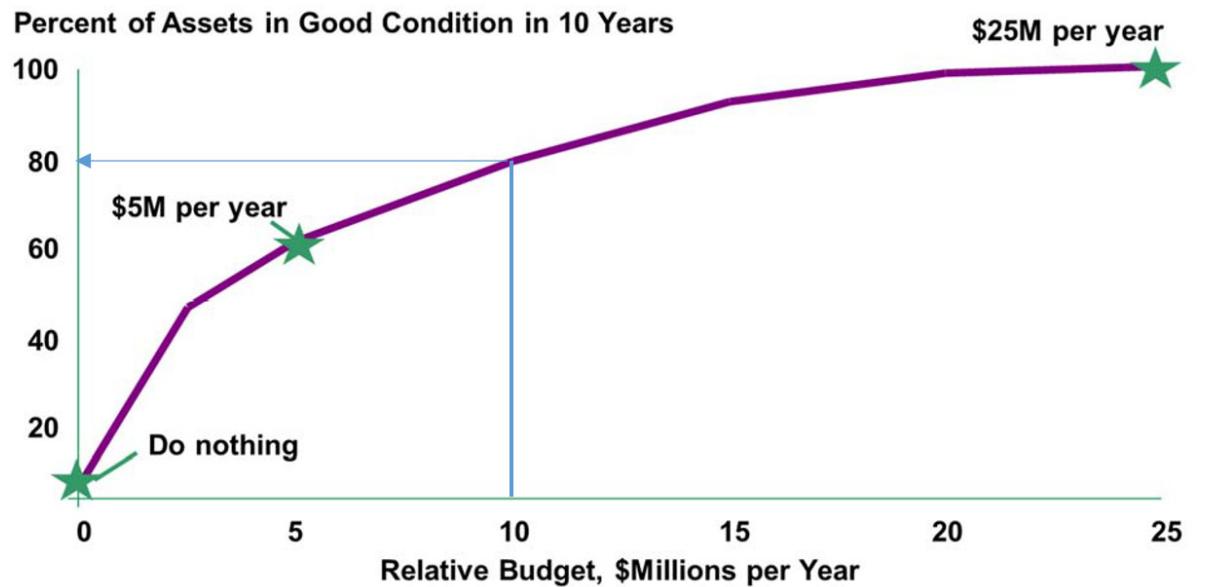
<sup>14</sup> 23 USC 119(f)(2), and 23 CFR 490.411

- **Desired SOGR** – The intent of this LCP scenario is to determine the level of funding required to achieve the desired SOGR for the network. The difference between the level of funding required to achieve the desired SOGR and the actual level of investment outlined in the financial plan represents the funding needed to address the performance gap between current and desired SOGR.
- **Reduced funding scenarios** – Since funding is often not adequate to address all system needs, agencies may be forced to lower the level of service on all, or a portion, of the network. Under this LCP scenario, the impacts of reduced levels of funding are generated for consideration during financial planning. This LCP scenario may be helpful to communicate the impact of budget cuts on future conditions.

The analysis of different LCP scenarios is often an iterative process, using different investment levels and asset strategies to achieve the best possible progress toward the desired SOGR after taking into consideration agency risks, performance gaps, changing environmental conditions, minimum condition requirements, and other constraints. For that reason, the LCP graphic shown in figure 2 includes an arrow from step 4 back to step 2.

#### Step 5: Provide Input to Financial Planning

The LCP scenarios developed during step 4 are considered to be inputs to the financial planning process discussed in a separate guide. By presenting the impacts of the LCP scenarios in a graphic similar to the one shown in figure 5, decision makers can evaluate the trade-offs as they consider investment levels across asset classes and use the information to set the desired long-term SOGR. To guide the financial planning process, agencies may need to provide the results of the LCP scenario beyond the 10-year window required in the TAMP to identify the best long-term solution. When analyzing assets with long service lives, such as bridges, an analysis limited to 10 years can favor replacement and major rehabilitation over preservation because the preservation benefits may not be realized immediately.



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Figure 5. Sample investment level/condition graphic.

In this example, an LCP scenario based on \$5M per year for 10 years results in 60 percent of the network in Good condition, but an LCP scenario based on an annual investment of \$25M per year is needed to bring the entire network into Good condition by the end of the 10-year period. An agency with a desired SOGR for 80 percent of the network to be in Good condition would need to spend \$10M per year for the 10-year period. Having similar graphs for each asset class allows a relatively simple assessment of trade-offs across assets based only on predicted condition. For a more reliable assessment, the revised budget level should be reanalyzed using the management system to verify that the expected conditions can be achieved.

### **Using the Results to Improve Models and Analysis Tools**

The results of the LCP process are an important input to the financial planning process, providing information about the expected performance that can be achieved for different levels of investment and the asset strategies that achieve the best possible progress toward the desired SOGR while taking into account risk, performance gaps, minimum condition requirements, and other constraints.

The mechanics of working through the LCP process for each asset class is an educational experience that exposes vulnerabilities in terms of data and analysis tools. Initially, agencies may rely on sources such as expert judgement, industry standards, or historical trends to provide the data needed to conduct the analysis. As agencies' asset management practices mature, more sophisticated deterioration models can be developed and agency-specific data on treatment performance can be used to develop the asset strategies. Striving to improve the quality of data and the sophistication of analysis tools is important since the better the quality of the data, the better the quality of the analysis results.

The investment strategy that is included in the TAMP may cause an agency to revisit the models in its management systems, its design procedures, treatment options applied, and the links to other agency plans. For instance, if the TAMP investment strategy includes an aggressive and proactive chip seal program for the State's low-volume highway network, the pavement management system treatment rules and performance models should be updated to reflect these changes. Similarly, if data analysis, research findings, or the LCP process indicate differences in the assumed design life of bridges, the information should be used to improve decision trees and programming rules for use in developing LCP scenarios. Additionally, if a highly vulnerable risk area, such as the severe drought example provided earlier, is addressed through the TAMP investment strategy, the agency's risk management plan should be updated to reflect the mitigation plan.

### **Addressing Gaps in the LCP Process**

Some of the common gaps in applying a network-level LCP process are described below:

- Incorporating routine maintenance costs into the analysis – Routine maintenance costs may not be explicitly considered in the analysis conducted using the management systems, but the financial planning process may take into account trends in routine maintenance expenses over the years to set maintenance investment levels and adjust asset strategies. Any gaps in addressing routine maintenance costs as part of the LCP process should be documented in the TAMP.
- Setting treatment intervals – It can be difficult to establish reasonable treatment intervals for a number of reasons. For instance, an agency may not have much experience with

some of the treatments being considered in the analysis, instead relying on industry standards or expert judgement to estimate conditions. The variability in network conditions and performance can also make it difficult to set treatment intervals. For instance, the same treatment applied in one geographic region of a state could have very different performance in another geographic region. To overcome this hurdle, it is important for DOT personnel to recognize that, on average, general performance trends are sufficiently representative to be useful for the LCP process. Over time, the results from an engineering economic analysis can be used to develop or validate treatment intervals.

- Analyzing treatment strategies – Pavement and bridge management systems that meet the minimum requirements outlined in the Rule can satisfy the guidance for LCP outlined in this document. However, it is anticipated that as the LCP process becomes more familiar to practitioners, there will be enhancements to the existing systems to support this type of analysis.

Over time, these gaps are expected to be addressed as asset management practices mature nationally and as agencies become more familiar with the LCP process.

## PUTTING LIFE CYCLE PLANNING INTO PRACTICE

There are several examples of applying an LCP process to an asset management program that are showcased in this section of the Guide. The examples illustrate methods of developing the asset strategies to consider, conveying the impact of different LCP scenarios, and incorporating risk into the process. This section also addresses organizational changes that may be needed to support the LCP process

### Developing Asset Strategies

Over the last several years, Washington State DOT has adopted several practices aimed at improving the management of its pavement assets. For instance, the DOT has implemented a strategy for its pavement network that requires the application of at least one maintenance treatment before a new capital rehabilitation project can be programmed for flexible roads. The strategic maintenance project is funded using pavement rehabilitation funds because the DOT's LCP process demonstrated that maintenance activities substantially extend pavement service life, or keep a pavement from failing prematurely, at a lower cost than the traditional resurfacing strategy. The Department estimates that a \$13M investment in strategic maintenance on 3,500 lane miles of flexible pavement over the period from 2009 to 2015 resulted in an annual savings of approximately \$25M by delaying major resurfacing needs by 2 to 4 years<sup>15</sup>.

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<sup>15</sup> Li, J., D. R. Luhr, M. Russell, T. Rydholm, and J. S. Uhlmeyer. 2017. "Cost-Effective Performance Management for Washington State Pavement Assets." *Transportation Research Board Annual Meeting CD-ROM*, January 8-12, 2017, Washington D.C.

The Minnesota DOT used the LCP analysis conducted during the development of its draft TAMP to verify the cost-effectiveness of its current pavement and bridge preservation strategies. The following asset strategies were considered for pavements and bridges<sup>16</sup>:

### Pavement Strategies

- Strategy 1 – Representative of Current Practice: Delay the need for reconstruction by applying a combination of surface treatments, crack sealing, and mill and overlays, depending on the condition of the pavement and the available budget.
- Strategy 2 – Worst-First Strategy: Reconstruct a pavement as it deteriorates to Poor condition without routine preservation activities.
- Strategy 3 – Desired Strategy (reflecting the strategy outlined in the DOT's *Pavement Design Manual*): Apply a major rehabilitation or reconstruction activity at year 50, once the pavement has gone through a few preservation cycles and minor rehabilitation events. The objective for this strategy was to create an end to the more traditional mill and overlay strategy since later applications were not performing as well as early applications.

### Bridge and Large Culvert Strategies

- Strategy 1 – Representative of Current Practice: Perform repair and preventive maintenance (such as painting and patching) on approximately two percent of bridges and large culverts, and wash about 75 percent of bridges annually. Perform limited repair actions on other bridges and large culverts based on funding availability and the judgment of inspectors and bridge engineers.
- Strategy 2 – Worst-First Strategy: Replace entire bridge or large culvert structures as they deteriorate to a Poor condition without any preventive maintenance or repairs.

For both pavements and bridges, the strategies that included preservation activities with rehabilitation were found to be more cost-effective than the worst-first strategies.

This guidance suggests that agencies include alternate strategies in their LCP process that differ from their existing practices to determine whether annualized costs could be reduced. Using the MnDOT case study as an example, a third, more aggressive strategy could be added to the bridge analysis, as described below:

- Aggressive Strategy 3 – Perform repair and preventive maintenance, including painting and overlay application with maintenance, aggressive deck joint repair (address approximately 20 percent of bridges each year), and wash about 75 percent of the bridges annually. Perform routine maintenance annually.

The analysis of the additional strategy would enable an agency to consider implementing an alternate approach to system preservation that may result in better long-term decisions. If the strategy includes treatments or treatment intervals that are new to the agency, assumptions about

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<sup>16</sup> Minnesota DOT. 2014. *Transportation Asset Management Plan – Draft*. Available from: <https://www.dot.state.mn.us/assetmanagement/pdf/tamp/tamp.pdf>

treatment costs and condition improvement benefits may have to be made. Over time, as the treatments are used, these estimates can be replaced with performance data.

### Conveying the Impact of Different Funding Scenarios

During the development of its TAMP, one State DOT evaluated its LCP scenarios using four different funding levels. The four funding scenarios are described below and the resulting performance associated with each is presented in figure 6. The performance estimates were generated through an analysis using pavement management software:

- Funding Scenario 1 – \$75M per year, which represented the expected level of funding.
- Funding Scenario 2 – \$132M per year, which represented the most recent historical average level of funding.
- Funding Scenario 3 – \$323M per year, which represented the funding needed to maintain current pavement conditions.
- Funding Scenario 4 – \$378M per year, which represented the funding needed for 95 percent of all State-maintained highways to reach Fair condition.

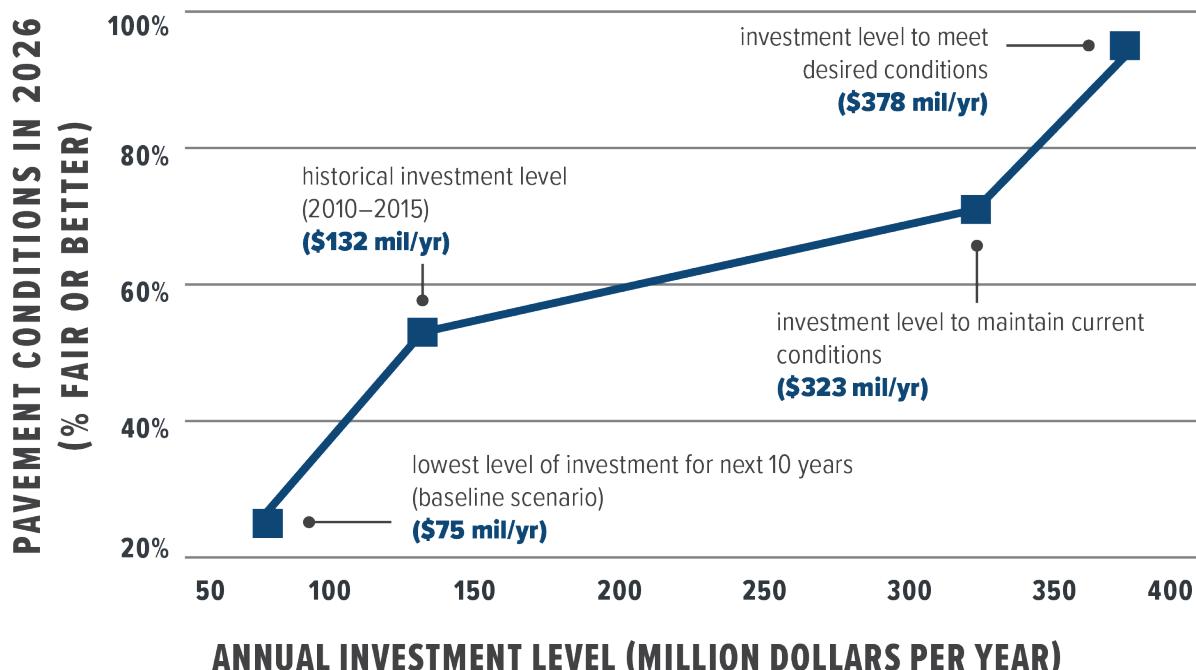


Figure 6. Example showing performance expectations for four funding scenarios for pavement.

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For bridges, the information was presented in terms of the percent of bridge deck area in Poor condition over a 12-year period, although the benefits were calculated over a much longer analysis period. Three different funding scenarios were investigated, as described below and shown in figure 7:

- Funding Scenario 1 – Anticipated: \$11.9M per year, which represented the expected level of funding.
- Funding Scenario 2 – Stability: \$23.29M per year, which represented the funding needed to maintain current conditions.
- Funding Scenario 3 – Optimistic: \$28.6M per year, which represented a significant increase in funding to include several bridge replacement projects.

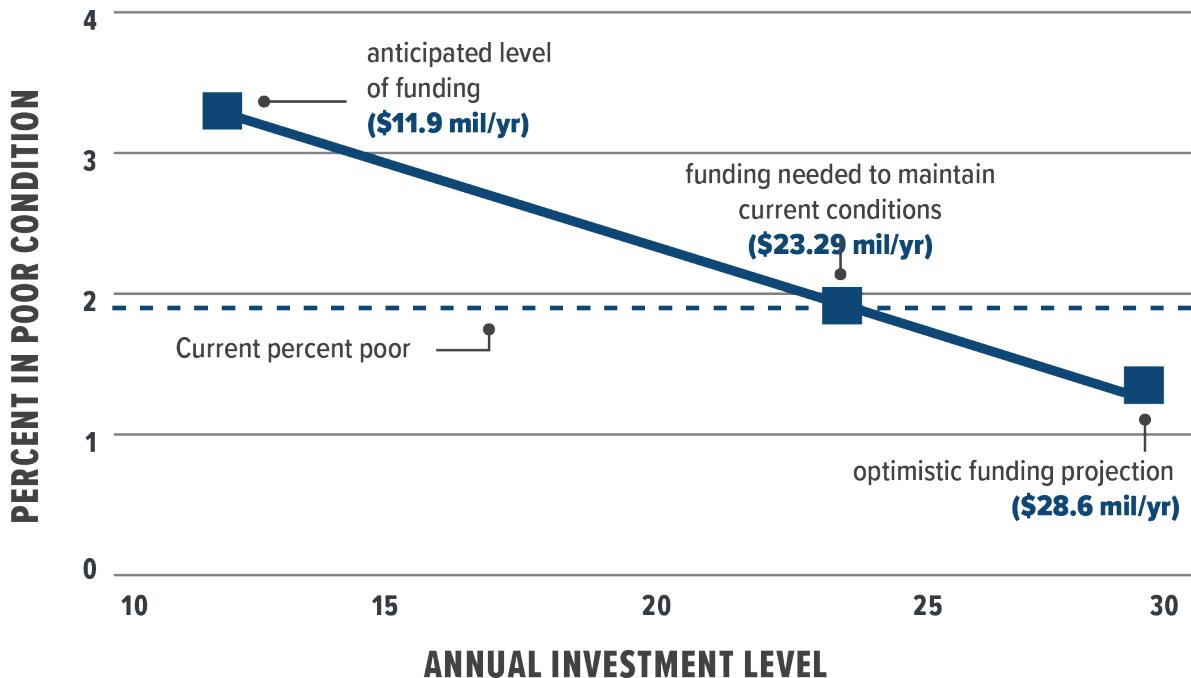


Figure 7. Expected conditions under three different funding scenarios for bridges.

The presentation of the results from the pavement and bridge funding analysis was a key consideration in selecting the asset investment levels that would be incorporated into the TAMP. The information also served as an effective way of communicating the need for additional funding to support system improvement and preservation needs.

## Incorporating Risk into the LCP Process

The FHWA guidance on risk management includes a discussion on identifying and managing high-priority risks, including risks associated with extreme weather events and geologic events. The existence of these types of risks may influence the asset strategies and LCP scenarios that are developed through the LCP process. For instance, if an agency identifies seismic risks to its structures as a high-priority risk that will be addressed through the 10-year investment strategy in the TAMP, significant investment in seismic retrofit projects could be expected to consume resources that otherwise could have been spent to improve or preserve asset conditions.

However, if diverting funds to seismic retrofit would impact the agency's ability to meet the minimum condition requirements for NHS pavements or bridges, the agency may decide to slow the rate at which retrofit projects are constructed or choose to accept the risk without a mitigation strategy, illustrating the iterative and interconnected nature of the LCP, risk management, and financial planning processes.

## Corresponding Business Process Changes to Support Life cycle Planning

The implementation of LCP recommendations often results in changes to the traditional way that transportation agencies conduct business since they can lead to a more aggressive preservation program and earlier use of low-cost treatments. To ensure the success of these changes, transportation agencies may have to consider corresponding changes to existing business processes to ensure quality treatments are constructed in a cost-effective manner. This often requires agencies to reevaluate existing practices to address the following types of issues:

- **Shifting from a worst-first philosophy** – It can be a challenge for agencies to shift from a worst-first strategy that focuses on deficient assets to a more cost-effective strategy that features earlier intervention. This shift requires support from executive leadership and a commitment on the part of field personnel to implement new techniques.
- **Inconsistencies in District work programs** – In decentralized organizations, Districts often have a large amount of independence in selecting projects and treatments. However, this can lead to inconsistencies in the way an agency's assets are managed on a statewide basis and may make it difficult to ensure that targeted conditions will be achieved. Therefore, business processes that support the more consistent use of preservation treatments and more consistent approaches to project identification and prioritization may be warranted.
- **Availability of qualified contractors and strong construction practices** – An aggressive program of preservation treatments requires a strong contractor community with a qualified workforce to construct good-quality preservation treatments. In some agencies, certification programs are in place to ensure that only experienced contractors are used. Agencies should also evaluate their design practices to ensure that preservation treatments are constructed within the “window of opportunity” when the expected life of a treatment can be realized and only minor deterioration is present.

## KEYS TO SUCCESS

Based on the information presented in this chapter, and drawing on lessons learned from successful DOT implementations, the following keys to success are provided:

- **Top level support for a preservation-first strategy** – to help shift from a worst-first mindset.
- **Consideration of innovative treatment strategies, early intervention, and risk** – to ensure that high priorities are addressed on a timely basis.
- **Alignment at all levels of the organization** – to ensure that the recommendations from the management systems that are used to develop the TAMP investment strategies reflect the projects that are programmed and constructed.
- **Availability of contractors, applicability of recommended treatments, and strong construction practices** – to ensure that high-quality treatments are constructed and the maximum possible service life is obtained from each investment.

## AVAILABLE RESOURCES AND REFERENCES

The following resources are available to assist with the development and implementation of life cycle planning processes.

*FHWA Asset Management website (<https://www.fhwa.dot.gov/asset/>)* – The FHWA website provides access to guidance, webinars, domestic and international TAMPs, and other resources on asset management and life cycle planning.

*AASHTO Transportation Asset Management Portal (<https://www.tam-portal.com/>)* – The AASHTO Asset Management Portal contains copies of state TAMPs that include life cycle planning, webinars on various topics (including life cycle planning), and information on upcoming events.

*The Highway Infrastructure Asset Management Guidance. 2013.  
(<http://www.highwayefficiency.org.uk/efficiency-resources/asset-management/highway-infrastructure-asset-management-guidance.html>)* – This document includes a chapter on life cycle planning related to asset management.