3. LIFE CYCLE PLANNING

Asset management is a series of processes intended to achieve and maintain a state of good repair over the life cycle of an asset. One key process is life cycle planning (LCP), the process of developing a strategy for managing an asset class to achieve a target level of performance while minimizing life cycle costs. LCP is a network level analysis intended to help lower costs and improve condition. Using bridge and pavement management systems, Iowa DOT can estimate the cost of managing its bridges and pavements and determine the optimal mix of treatments to perform to achieve condition goals at lower life cycle costs.

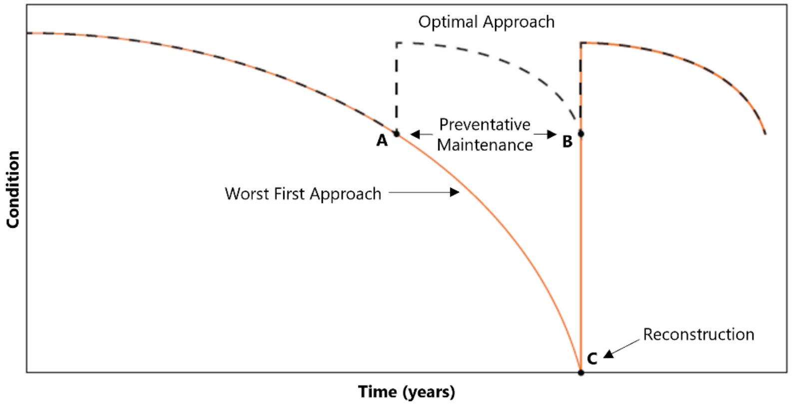
Introduction

This chapter presents Iowa DOT's LCP approach for bridges and pavements. LCP is defined in 23 CFR 515.5 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 condition."

Life cycle costs are the costs of managing an asset from inception through disposal. Many agencies, including Iowa DOT, historically used a "worst-first" approach to bridge and pavement management. This approach focuses on replacing the poorest bridges and pavements first. A more cost-effective approach considers treatments that slow down deterioration and prolong asset life. This strategy is typically less expensive than letting an asset deteriorate to the point of needing replacement.

Figure 3.1 illustrates the two approaches. The solid line represents an asset that is built and deteriorates to point C before any work is performed. Once work is performed, in this case reconstruction, the condition returns to its original level. The dashed line shows preventative maintenance work being done at point A. The asset's condition improves and then eventually deteriorates to point B, which occurs in the same timeframe at point C but represents much better condition. The cost of performing work at points A and B can be significantly lower than waiting until point C.

Figure 3.1: LCP approach of preventative maintenance vs. worst-first approach



Generally, an effective life cycle plan emphasizes performing timely maintenance activities to keep an asset in good condition while avoiding, where possible, assets deteriorating to poor condition. Once an asset deteriorates to poor condition, treatment options are more expensive. The benefit of an effective LCP strategy over a worst-first strategy is that it has the potential to reduce long-term costs to both the transportation agency and road users. Treating assets long before they reach a poor condition shortens the impact to the motoring public, yields a higher level of pavement or bridge condition over time, and improves the image of the state. LCP also provides the information needed to determine how best to prioritize asset investments when funding levels are insufficient to meet all the transportation system's needs. This is critical because, as discussed in Chapter 4, there are anticipated funding shortfalls over the next 10-20 years that would prevent maintaining the desired condition levels for bridges and pavements statewide.

Federal Requirements

FHWA requires that state DOTs establish a process for conducting LCP at the network level for NHS pavements and bridges. The following elements must be included in an LCP process.

- Identification of deterioration models
- Potential work types, including treatment options and unit costs
- A strategy for minimizing life cycle costs and achieving performance targets
- Asset performance targets

In addition, LCP should include future changes in traffic demand and information on current and future environmental conditions, including extreme weather events, climate change and seismic activity. In 2021, the Infrastructure Investment and Jobs Act added the specific requirement that life cycle cost analysis consider extreme weather and resilience.

3.1 Bridge

Data Collection

Bridge inventory and condition data is collected as part of a field inspection that is performed every 12, 24, or 48 months, depending on the designated inspection frequency, in accordance with FHWA's National Bridge Inspection Standards (NBIS). Each inspection is documented in the Structure Inventory and Inspection Management System (SIIMS) database. The documentation for an inspection includes photos, sketches, inspector's notes, condition ratings for specific elements, National Bridge Inventory (NBI) data, and recommendations for maintenance. The inspection documents are collected and reviewed by qualified bridge inspectors.

Along with the required NBI data, additional information is collected to enhance and support bridge management. Many individual bridge items and their corresponding conditions and configurations are documented during the biennial inspections for bridges on the NHS. These elements include the National Bridge Elements (NBE), Bridge Management Elements (BME), and Agency Developed Elements (ADE). Iowa DOT also collects additional data items during every inspection.

NHS bridges, including locally owned NHS bridges, make up the bridge asset class. For bridges, the asset sub-groups include mostly concrete bridges and steel bridges, along with other types.

A culvert is considered to be an NBI bridge if the culvert or multiple culverts is greater than 20 feet in length and the clear distance between openings for multiple culverts is less than half the width of the opening along the roadway. The bridge asset subgroup of culverts is excluded from LCP because no material adverse effect on the development of sound investment strategies will occur by eliminating these assets.

This lack of impact is due to the extremely long life along with the long-term stability of these assets. Maintenance considerations only begin to occur around 75 years of service. Additionally, there is only one condition rating for culverts, making it difficult to determine the specific factors contributing to the rating and therefore the optimal way to treat it. Of the 475 culverts on the NHS in Iowa, only one is not in good or fair condition. Relatively few culverts are worked on each year, and they do not have a significant impact on the budget.

The SIIMS database is used by all bridge owners in Iowa. The NBE and NBI data collected in this system are imported into the AASHTOWare Bridge Management System (BrM). The BrM will be used in the future to model deterioration and forecast budget needs based on NBE and NBI data collected for NHS bridges.

Treatments

Bridges are designed to last over 50 years and to withstand a variety of different distresses over their life. However, the individual components of a bridge deteriorate at different rates over time and require treatment – in some cases multiple times over the life of the bridge – to maintain a bridge in good overall condition.

An example of routine maintenance is joint replacement. If joints are allowed to fail, then water and road salts may seep into the bridge deck, superstructure, and substructure, shortening the life of these components.

A bridge deck is exposed to truck traffic, road salt, and other distresses. Bridge decks typically last 20 to 30 years before they require maintenance, and they are often patched multiple times over their life. A deck overlay is a common maintenance practice. If a deck is not rehabilitated in a timely fashion, then the only feasible treatment may be to replace the deck or the entire bridge.

Treatments performed on a bridge's superstructure and substructure vary depending on the bridge's materials. Steel bridges require periodic repainting to avoid corrosion. Weathering steel does not require paint but may need to be washed on a regular basis. Concrete girders and other structural members may require periodic patching. The beam ends near joints are the structural members most prone to deterioration, and these may require periodic repair.

Various preservation and maintenance activities are undertaken to help maintain a bridge's condition. Many decks have overlays or sealers applied, which helps keep chloride out and maintain the deck in better condition. Iowa DOT also has a robust bridge painting program. Washing and cleaning bridges can be helpful for removing contaminants and slowing deterioration, but this can be challenging to implement in a systemic fashion due to a lack of staff and the inefficiencies of hiring contractors for this type of work. Also, traffic control can become a major issue for preservation treatments, particularly in urban areas, which adds to the project's expense and decreases acceptance of the work due to potential operational issues.

As a bridge ages the maintenance and rehabilitation costs incurred in keeping the bridge in service tend to increase. At some point it becomes more cost effective to replace a bridge than to continue to rehabilitate it. Also, it is generally more cost effective to replace smaller structures such as culverts, rather than to rehabilitate them.

Where there are functional issues with a bridge, such as limitations in the bridge's clearances, load carrying capacity, or traffic capacity, replacement is often the most cost-effective alternative.

Iowa DOT's typical bridge treatments and costs are listed in Table 3.1. These treatments and costs are entered into the NBI Optimizer described in the next section, and used to generate recommendations for treatments. Treatment costs are reviewed and updated annually.

Table 3.1: Bridge treatments and unit costs

Work Type	Treatment Family	Project Treatment	Typical Unit Cost
Preservation	Paint steel	Routine painting of steel girders	$12/sq. ft.
Preservation	Wash weathering steel	Wash weathering steel girders on a regular basis	$10,000/bridge
Preservation	Epoxy injection	Inject epoxy into delaminated areas under deck overlays	$18/sq. ft.
Maintenance	Strip seal joint repair	Replace glands	$240/ft.
Maintenance	Expansion joint replacement	Install new expansion joints	$3,000/ft.
Maintenance	Deck patching	Repair delaminated and spalled areas of a deck	$110/sq. ft.
Maintenance	Prestressed girder repair	Repair girder ends under joints	$2,000/beam end
Rehabilitation	Deck overlay	Dense concrete overlay	$50/sq. ft.
Rehabilitation	Deck overlay	Epoxy polymer overlay	$33/sq. ft.
Rehabilitation	Deck replacement	Replace bridge deck	$115/sq. ft.
Reconstruction	Bridge replacement	Replace bridge	$375/sq. ft. of existing bridge deck area
Reconstruction	Culvert replacement	Replace culvert	$850/CY/ft. of culvert length*
Construction	New bridge	New bridge	$200/sq. ft.
Construction	New culvert	New culvert	$900/CY/ft. of culvert length*

**Cost depends upon culvert configuration. E.g., for a new culvert, if a single barrel culvert takes one cubic yard of concrete per foot of length, the cost is $900 per foot of culvert length; if it is a triple barrel culvert that takes three cubic yards of concrete per foot, the cost is $2,700 per foot of length.*

Modeling Approach

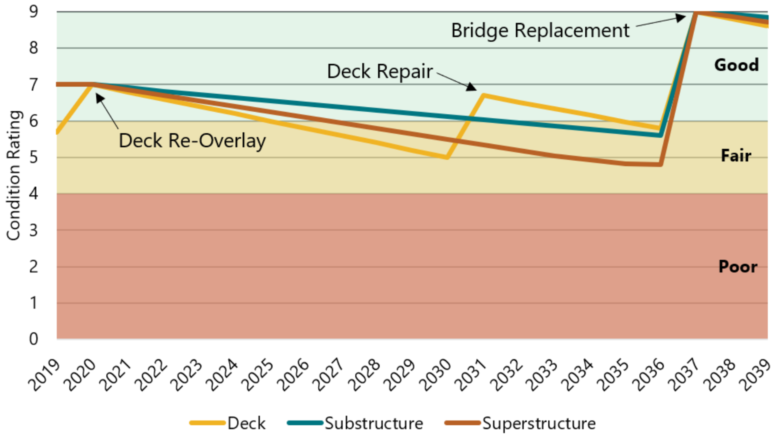
Iowa DOT models deterioration and forecasts future conditions using a tool called NBI Optimizer, developed by Infrastructure Data Solutions (IDS). The NBI Optimizer predicts future conditions of each bridge in the network, simulates the application of bridge treatments, and prioritizes treatments subject to a budget constraint or condition target.

Performing an analysis in the NBI Optimizer requires data on existing conditions, a set of feasible treatments, business rules concerning what treatments are feasible under what conditions, and models for predicting deterioration.

Most of the treatments listed in Table 3.1 are included in the system. For each of these the system further specifies for which types of bridges the treatment may be performed, under what circumstances the treatment is feasible, and the impact of the treatment. The treatment assumptions and other details of the system that are provided for in the configuration of the NBI Optimizer are detailed in the 2014 report "Risk-Based Prioritization and Multi-Objective Optimization for Long-Term Network-Level Preservation Planning of Bridges in Iowa" prepared by IDS for Iowa DOT.

The NBI Optimizer uses historic NBI data to create multivariate inductive deterioration models for approximately 3,200 bridge structures (culverts and border bridges excluded) on the state highway system. The deterioration models incorporate consideration of a range of variables, such as age, traffic volume, design load, and deck type. The deterioration models also evolve over time as additional years of NBI data are added to the system. The tool includes separate deterioration models for deck, superstructure, and substructure ratings for 13 different groups of Iowa DOT bridges. Each deterioration model predicts condition ratings as a function of age. Figure 3.2 shows an example scenario recommended by the deterioration modeling for a 50-year-old bridge that was built in 1969. As bridges age, it is difficult to repair and maintain superstructures and substructures and replacement becomes the preferred option if funding is available.

Figure 3.2: Example recommended treatments from bridge modeling system for a 50-year-old bridge



Note that certain bridges are excluded from the NBI Optimizer analysis, and their needs are handled outside the system. These include locally owned NHS bridges as well as complex structures that are not easily modeled, including selected "major bridges" with unique design characteristics. There are 34 such "major bridges," 18 of which are on the NHS. For each of these bridges, Iowa DOT establishes specific maintenance and preservation activities; these bridges are typically maintained in a higher condition due to their importance and expense. These bridges include the large Mississippi and Missouri River bridges on Iowa's eastern and western borders, which are managed through coordination with the neighboring states. Five-year project needs are evaluated annually with each border state. If one of these bridges is nearing replacement, the planning effort will begin ten years before the replacement is needed. Culverts are also handled separately outside of the NBI Optimizer, for reasons previously discussed.

Future modeling will also be accomplished using the AASHTO BrM system. Iowa DOT is in development of rules and scenarios using NBE and NBI data.

Strategy

Developing the life cycle strategy for a bridge network involves determining what work should be performed on a given bridge, and how to prioritize the work between bridges given a constrained budget. The prioritization approach must consider both life cycle cost considerations and the criticality of addressing a bridge's needs.

For instance, a deck overlay may have high priority given that an overlay, if performed in time, can reduce the life cycle cost of maintaining the bridge. However, rehabilitating or replacing a bridge in poor condition may merit high priority as well, if the bridge is at risk of closure in the event needed work is deferred.

The NBI Optimizer applies the treatments and business rules described previously to determine what work is recommended for a given bridge. To prioritize work between bridges the system calculates a measure called Risk Index (RI). This index is the product of two separate values: a condition index and a risk factor. In the system, bridges are prioritized for treatment based on the change in RI resulting from the work recommended for the bridge.

When performing an analysis in the system the user specifies an overall budget or condition target, as well as budgets by treatment type. The user also specifies whether the objective of the analysis is to minimize risk or maximize condition. The system then simulates bridge conditions and selects treatments for each bridge to maximize the objective function subject to the budget constraints.

During the configuration of the NBI Optimizer, Iowa DOT implemented a risk-based prioritization scheme based on the existing Iowa DOT Priority Ranking method, as well as a comprehensive database of preservation methods commonly used by Iowa DOT. The preservation methods database included the range of work types, formulae for calculating costs and benefits, and a set of applicable constraints for each preservation method based on policies and work practices.

During the initial configuration of the NBI Optimizer, Iowa DOT evaluated a range of different scenarios for different groups of bridges and different budgets. For each scenario Iowa DOT staff evaluated what treatments were recommended and the overall performance yielded in terms of condition and risk. Based on this initial analysis documented in the 2014 report, Iowa DOT finalized the treatments and business rules in the system, as well as the percentage of the total budget that can be used for each type of treatment. This effort yielded an initial, optimized, risk-based 20-year preservation plan for the state-owned bridge inventory. The plan reflected Iowa DOT's life cycle strategy for its bridges considering life cycle cost considerations, the agency's desired condition outcomes, and available resources.

For subsequent analyses, including those utilized to develop this TAMP, Iowa DOT has run additional scenarios in the NBI Optimizer using the life cycle strategies established through the initial configuration of the system. It is possible to define different sets of treatments and/or treatment constraints for different scenarios. Iowa DOT has tested scenarios in the past using a different mix of treatments to see what the impact on condition would be over time – for example, using more deck overlays rather than replacements. This type of scenario analysis has helped refine the parameters used for annual modeling scenarios. In practice, Iowa DOT currently uses the same basic life cycle strategy for each investment scenario tested. The scenarios thus vary based on overall budget, but not other parameters. By comparing scenario outcomes, bridge managers can evaluate the impacts of a given scenario on bridge condition and the level of risk, and use this information to help make the case for needed investments.

Output from the NBI Optimizer analysis is shared annually with the Iowa Transportation Commission to illustrate the impact of various funding levels on the system-level bridge condition. This helps inform the decision-making process for allocating funding for bridge asset management activities.

Implementing LCP Strategy

The NBI Optimizer output results in valuable modeling scenarios and helps provide confirmation regarding the overall mix of life cycle strategies being used as well as the overall budget necessary to maintain a specific condition. However, it cannot be used to directly select which bridges to program work for. There are additional considerations that must be factored into programming decisions, including traffic considerations, associated work on a corridor, and geographic distribution of resources, just to name a few.

At a high level, Iowa DOT uses a three-pronged bridge asset management strategy to maintain the system's bridges in a state of good repair. This strategy includes the following actions.

- Increasing bridge stewardship with an emphasis on more bridge replacements
- Investing in service-life design materials and details so that the bridges built today last longer than those built under earlier design standards
- Investment in bridge preservation so that bridges in the current inventory last longer

To determine how to implement the LCP strategy across the system's bridges, several steps are routinely taken. Iowa DOT's Bridge Maintenance and Inspection Unit recommends bridge maintenance activities based on the results of the bridge inspections described previously. This information is then forwarded to a bridge maintenance and inspection engineer, who is responsible for making rehabilitation and reconstruction recommendations and developing cost estimates.

The Bridges and Structures Bureau (BSB) compiles the rehabilitation and reconstruction recommendations and prioritizes them based on their urgency. Urgency is evaluated on a scale of one to four, where one means "implement a project as soon as practical," and four means "hold as a future candidate for the Five-Year Program."

Each year, BSB discusses the priorities with each District. At this annual meeting, BSB reviews all newly recommended projects from the past year to determine if they should be candidates for the Five-Year Program. If more than one work type is proposed for a given structure, each recommendation is given an importance rating of high, medium, or low.

After meetings with Districts, BSB reviews all priority one candidates to determine if the current Five-Year Program needs to be adjusted to accommodate project scheduling changes. BSB also determines which projects can be developed for construction in the final year of the upcoming Five-Year Program.

If costs of priority one candidates exceed available budgets, BSB prioritizes them using a process that considers the Bridge Condition Index (BCI), project cost, development time, and public needs. If all priority one candidates are programmed, priority two and three candidates are then considered. This process continues until funding is exhausted.

In addition to focusing on the condition of Iowa’s bridges, Iowa DOT replaces a few bridges each year to accommodate capacity needs, and major urban Interstate reconstruction projects often include replacing bridges that might not have been candidates otherwise.

To help affirm optimization criteria, the output of NBI Optimizer scenarios has been compared to the bridges selected for programming. This is done by comparing the percentages of the overall budget being spent on different types of treatments, as well as by reviewing how many of the bridges selected for programming are also selected for work in by the software. There is typically strong alignment between the modeling scenarios and the bridge component of the Five-Year Program; where there is less alignment, the NBI Optimizer results are used to review projects that may not have been identified through the typical prioritization process.

Based on the results of the NBI Optimizer analysis and process outlined above, Iowa DOT typically allocates 70 to 74 percent of bridge funding for replacements, 9 to 23 percent for rehabilitation, and 7 to 17 percent for maintenance. Preservation activities are not included in these funding breakouts as they are typically funded from a bridge maintenance program.

Local Collaboration

Iowa DOT works in partnership with local agencies to promote good bridge management practices for locally owned bridges, including the locally owned bridges on the NHS. Iowa DOT provides the SIIMS software to local agencies as a tool to help manage local bridges. This software is used to capture the inspection data local agencies are required to provide as part of the annual NBI submittal to FHWA, as well as providing document storage, dashboards, and reports to help local agencies manage their bridges. Iowa DOT also provides other tools and resources to local agencies through support of the Iowa Highway Research Board and Iowa State University’s Institute for Transportation Bridge Engineering Center.

Iowa DOT provides manuals and instructional memorandums to assist local agencies in bridge inspection, maintenance, and load rating. These manuals and memorandums provide the necessary information all local agencies need to manage their bridge inventories.

Another resource for local agencies is the InfoBridge website provided by FHWA. This website can be used to quickly access and filter data from the NBI, and includes options to view performance history, performance forecasts, and various analytics.

Iowa DOT coordinates with Metropolitan Planning Organizations (MPOs) in the establishment of bridge performance targets for the NHS, which includes bridges that are owned by local jurisdictions. Targets are discussed further in Chapter 4.

Consideration of Extreme Weather and Resilience

Extreme weather and resilience are important considerations for bridge life cycle planning. Extreme rain events and areal flooding are likely the greatest risks to Iowa’s bridges from natural disasters. Iowa DOT has improved infrastructure resiliency by constructing scour countermeasures, paved shoulders, upstream dikes, storm sewer improvements, and the placement of protective measures to prevent road embankment and pavement damage when a roadway overtops during a flood event, which helps in reopening the roadway more quickly. Work has also been done to harden structures against corrosion, which helps extend their service life. For the past several decades, Iowa DOT has been using bridge materials that are more resistant to corrosion (e.g., epoxy polymer-coated steel and stainless steel). Managing the risk of bridge corrosion helps extend the life of the asset, saving money over time.

Iowa DOT completed a study to assess the exposure conditions of transportation infrastructure under climate change and extreme weather events as part of the FHWA Climate Change Resilience Pilot Program. The pilot focused on the Cedar River and South Skunk River Basins and developed an innovative methodology for generating stream flow scenarios. The project was the only one of the pilots to link climate projections of precipitation with future streamflow projections to enable vulnerability assessment under climate change scenarios. Multiple bridge and highway assets in the river basins have proven to be vulnerable and will only become more vulnerable in the future as the frequency of precipitation and flooding events continues to increase. To help improve long-term resilience of Iowa's bridges and associated pavements, design guidelines to incorporate future hydrological conditions into project development have been drafted and are under review. These guidelines would utilize the procedures for incorporating climate change in the design of infrastructure that are outlined in NCHRP Project 15-61, "Applying Climate Change Information to Hydrologic and Coastal Design of Transportation Infrastructure" (2019). Incorporating these considerations would help ensure that, where appropriate, new bridges are built by considering anticipated future hydrological conditions rather than just being based on historical conditions.

In addition to integrating resilience considerations into bridge design in systemic manner, individual projects have also had significant resilience components integrated into their design due to their critical location and/or vulnerability. An example of this is the recent project on the IA 2 corridor in Fremont County. The area saw significant flooding in 2019 that closed this vital route connecting Iowa and Nebraska across the Missouri River. Closures of IA 2 and other routes in southwest Iowa lasted for weeks or months, resulting in significant impacts for transportation in the region.

While temporary solutions were put into place within a few months, it was necessarily to quickly develop and design long-term, resilient solutions to help mitigate the likelihood of future flooding impacts on the corridor. The long-term solutions were three-fold; the first two components have been completed while the third is underway.

1. Relocate a federal levee and construct two new bridges immediately adjacent to the river bridge, dubbed the "overflow bridges," to allow floodwaters to run under IA 2.
2. Raise the grade of IA 2 four feet and construct four bridges to allow for water flow.
3. Collaborate in the construction of a protective dike around the I-29/IA 2 interchange to protect both the roadways and nearby businesses.

3.2 Pavement

Data Collection

Pavement condition data is collected on the Interstate System each year. The rest of the non-Interstate NHS and Primary Highway System has data collected on a biennial cycle with data on about half of the system being collected each year. Inspection vehicles equipped with sensors collect data on pavement smoothness and pavement surface defects. These defects include items like cracking, faulting, rutting, spalling, and patching.

In addition, Iowa DOT periodically conducts the following more detailed condition assessments.

- Assessment of structural capacity using a falling weight deflectometer: 5-year cycle and upon request
- Assessment of pavement subsurface using ground-penetrating radar: 5-year cycle and upon request
- Assessment of pavement friction: 5-year cycle

The collected data is reviewed according to Iowa DOT’s Pavement Condition Management Data Quality Plan to ensure both data quality and completeness. After this review, the data is included in the pavement management information system (PMIS), which is the database for pavement data. Past years of pavement data are also saved in PMIS so pavement conditions can be tracked over time. Additional data about the history of the pavement and traffic are also stored in the system. The pavement history includes the construction date, pavement thickness, pavement width, and quality of aggregate used in the pavement. The data is assigned to individual pavement management sections that are referenced by mile posts and can be located by a linear referencing system. This allows the data to be used by geographic information systems (GIS). This methodology provides for the best available data to be used in the LCP analysis.

Interstates, Non-Interstate NHS, non-NHS, and local NHS pavements compose the pavement asset classes. With respect to asset subgroups, the pavement management system (PMS) performs analyses for the pavement types of Asphalt, Composite, and Jointed Concrete; however, the federal performance reporting requirements combines the pavement subgroups of Asphalt and Composite pavements. No pavement asset subgroup is excluded from LCP.

Treatments

Pavements deteriorate under loading from traffic, especially heavy trucks, and due to exposure to routine weather such as freeze-thaw cycles or extreme weather events such as flooding, unusual heat waves, or harsh winters. Pavements are all designed to withstand their expected conditions, but the actual conditions vary by location. There can also be some variation in the materials and techniques used in construction. These variations mean not all pavements display the same types of distresses as they age.

Common distresses include rutting, raveling, joint faulting, joint deterioration, cracking, and roughness. Depending on the age of the pavement and the types of distresses that can be seen or measured, different treatments have varying effectiveness for extending the life of the pavement.

Consistent with the principles of asset management, a wide range of work types are used to maintain pavements. These work types differ based on the pavement condition. Generally, this work is divided into five categories: construction, reconstruction, rehabilitation, preservation, and maintenance.

Construction involves building a new roadway section or a significant reconfiguration of an existing roadway. Construction projects may be identified in long-range planning documents, and are ultimately programmed in the Five-Year Program and the Statewide Transportation Improvement Program (STIP). These projects typically involve issues that extend beyond the pavement condition, such as safety, capacity, freight, operations, and other considerations. Since these projects involve many different configurations and environments, there is not a standard per-mile cost for construction. Each project will undergo individual scoping and planning to determine its cost and benefits.

Treatments for the other work types are shown in Table 3.2. The table does not cover all possible treatments for each work type, but it does cover those most commonly used and their approximate cost per lane mile. The treatment family is a grouping used in the pavement management software that helps identify the work type. The project treatment(s) are the alternatives that may be selected from a treatment family. Costs are reviewed and updated regularly, and the typical costs reflect the average project costs for each lane mile of the treatment. Actual costs of an individual project will differ from those shown in the table, but these costs are considered typical and used in the benefit/cost analysis of the pavement management software.

Table 3.2: Pavement treatments and unit costs

Work Type	Treatment Family	Project Treatment	Typical Cost per Lane Mile
Construction	Construction	New Hot Mix Asphalt (HMA) or Portland Cement Concrete (PCC) pavement	Project specific
Reconstruction	Reconstruction	New HMA or PCC pavement	$875,000 Interstate $700,000 Non-Interstate
Rehabilitation	Major structural rehabilitation (more than 4.5 inches of structure needed)	Crack and seat with HMA overlay, HMA overlay, or PCC overlay	$500,000 Interstate $441,000 Non-Interstate
Rehabilitation	Minor structural rehabilitation (3.0 to 4.5 inches of structure needed)	HMA overlay or PCC overlay	$380,000 Interstate $305,000 Non-Interstate
Rehabilitation	Functional rehabilitation (less than 3.0 inches of structure needed)	HMA overlay	$350,000 Interstate $231,000 Non-Interstate
Rehabilitation	Cold-in-place recycling	Cold-in-place recycling	$260,000
Preservation	Diamond grinding I & II	Diamond grinding I & II	$77,000
Preservation	Thin surface treatments	Thin lift HMA, microsurfacing, and chip seal	$33,000
Maintenance	Maintenance	Patching, crack filling and sealing, slurry leveling, and joint replacement	Variable – based on project quantity and density

Modeling Approach

Pavement management is a process that utilizes data describing the current condition of pavements, estimated benefits from pavement treatments, computer modeling to forecast future pavement conditions, and budget constraints to assist in determining how to best manage pavement assets over time. Done well, pavement management is using data to assist in determining the right treatment at the right time on the right pavement so that the most value is received from the funds invested in the road network.

Iowa DOT uses optimization and visualization tools to help manage state-owned highways. These tools, or pavement management systems (PMS), include the Deighton Total Infrastructure Management System (dTIMS) and an Iowa DOT developed Iowa Pavement Stewardship Tool (IPST). These tools assist in developing pavement selections and treatments based on data that will allow Iowa DOT to manage pavements over their whole life. More detailed documentation of the PMS is available in the technical document "Iowa Pavement Management System."

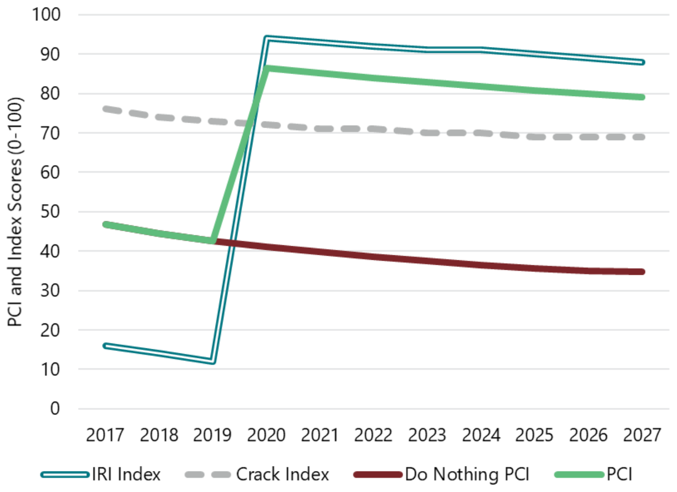
Data

To best manage the pavement network, it is divided into sections based on construction history. The limits of a pavement management section correspond with the limits of a homogenous as-built pavement cross section. As the construction year, surface type, base type, or thickness changes along a route, a new pavement management section is created. This has resulted in the number of pavement management sections growing over time while the average length of sections decreases. Iowa DOT currently maintains over 4,100 pavement management sections with an average length of 2.7 miles per section. A significant number of these segments – 40% – are less than a mile. This is much shorter than a typical project and means many projects include multiple pavement management sections, which can add complications to project development.

Deterioration Modeling

Every year, Iowa DOT pavement engineers use algorithms to develop deterioration models for each pavement section based on the condition data from that section. These performance models predict the anticipated future condition of each pavement section if no work is performed. The PMS use these deterioration models to forecast future conditions of each section and select appropriate treatments for the current and future years of an analysis scenario, which is typically 10-20 years. Figure 3.3 is an example deterioration curve from dTIMS where a diamond grind treatment is applied to an existing PCC pavement. Models are developed for each section, each distress, and each treatment. Models are updated annually, and the model error is tracked as a quality control measure.

Figure 3.3: Example PMS deterioration curve for a PCC pavement with diamond grinding applied in 2019



Decision Trees

Performing analyses in the PMS requires data on past and existing conditions, a set of feasible treatments, business rules concerning what treatments are feasible under what conditions, and models for predicting deterioration. The treatments and supporting business rules are specified through decision trees for each treatment type. Example decision trees for thin surface treatments and functional rehabilitations are shown in Figures 3.4 and 3.5.

Figure 3.4: Thin surface treatment decision tree from PMS

Cost	$30,000 / lane mile
IRI	If IRI > 80, 78% improvement, otherwise unchanged
Friction	50
Rutting	If rutting > 0.25, 50% improvement, otherwise unchanged
Fault Average	
Crack Ratio	Reset to zero
Structural Cracking	Reset to zero
Structure Need	
Joint Spalling	
Pavement Type	
Age	Reset Thin surface pavement age, Structural Cracking, Crack Ratio, and Friction to zero

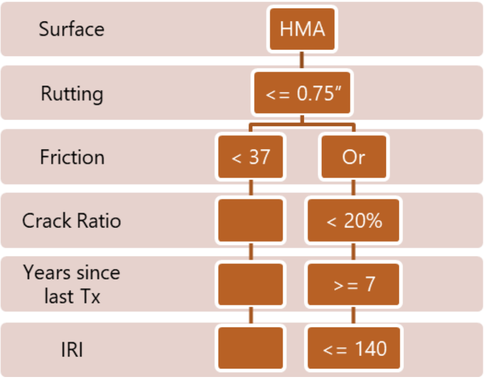
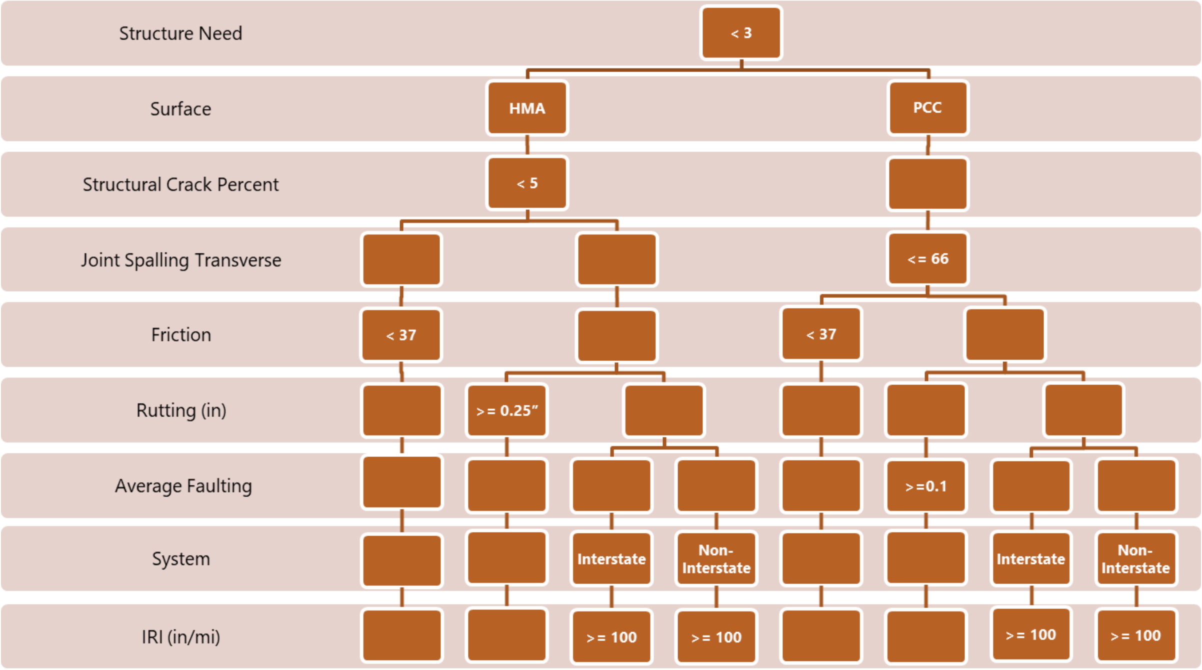


Figure 3.5: Functional rehabilitation decision tree from PMS



Optimization Tools

dTIMS

Iowa DOT utilizes a pure optimization tool, Deighton Total Infrastructure Management System (dTIMS), to establish a long-range plan of investments that yields the highest overall network Pavement Condition Index (PCI) over the analysis period. Among the advantages of dTIMS is the ability to analyze the network over long periods of more than 20 years. Each PMIS section is considered for investment if it meets the decision tree criteria. The tool outputs a recommended schedule of treatments within the budget constraints. Figure 3.6 shows the distribution of project lengths from the output, along with the output of the Grouped Benefit Cost (GBC) tool, discussed next. As shown in the figure, 41% of the recommended projects are under three lane miles. Likewise, in Figure 3.7, 67% of the projects cost less than $2 million. In practice, it is not practical to develop and administer a large number of small projects, so districts will typically combine smaller adjacent segments into a cohesive project. Typically, Iowa's six districts each develop around 4-8 projects annually, depending on the budget.

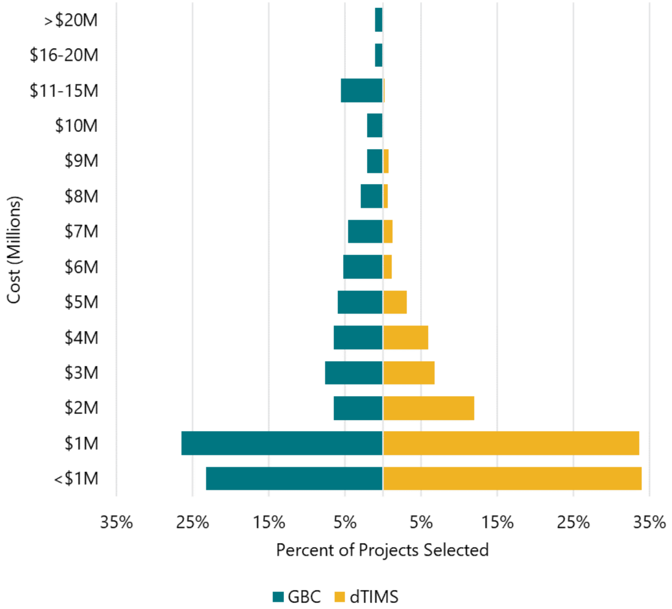
Grouped Benefit Cost (GBC)

To provide districts with project recommendations that are of a size and cost more likely to be implemented, a stand-alone engine was developed as part of the IPST. The engine uses the same decision trees, costs, and business logic as dTIMS. The primary difference between GBC and dTIMS is the project candidates are longer and coincide with the as-built limits of the last rehabilitation project constructed. In other words, the 4,100 PMIS segments used in dTIMS are grouped into roughly 1,740 longer segments. The other key difference is the GBC selects projects that yield the highest benefit/cost (B/C) instead of the highest PCI. Benefit is defined as the improvement in performance (measured by change in the area under the PCI curve multiplied by lane miles) from applying a treatment over the life of that treatment.

While these two objectives (B/C and PCI) are related, they are not the same. The GBC achieves this objective by simply ranking the B/C of each candidate and selecting the highest available B/C projects until the budget is depleted. While not a true optimization tool (i.e., more than one solution exists to achieve the objective), it results in a very similar network-level PCI as dTIMS. Figure 3.6 shows the GBC project length distributions and Figure 3.7 shows the GBC project cost distributions, with both also showing dTIMS output for comparison.

Figure 3.6: Distribution of project length in dTIMS and GBC

Figure 3.7: Distribution of project cost in dTIMS and GBC

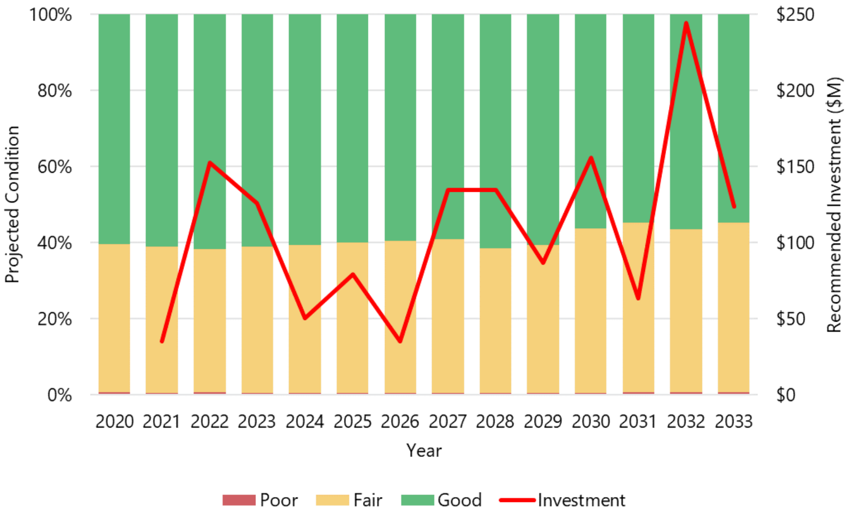


Condition Reporting

The deterioration models are developed using data that is aggregated to the limits of the pavement management sections. FHWA requires monitoring good, fair, and poor condition based on 1/10th mile aggregations, thus introducing variability that needs to be considered. To account for this variability, the models are mathematically adjusted by maintaining the same curve while shifting the intercept value to correspond to the observed values at the 1/10th mile level.

Each 1/10th mile segment on the network is forecasted over ten years using the models assigned to the section. The good, fair, and poor condition levels can then be shown for any budget scenario considered in the LCP over the 10-year run. Figure 3.8 shows the predicted condition on the Interstate System based on the status quo budget, or the amount of funding currently anticipated to be available over time. Condition projections are discussed further in Chapter 4.

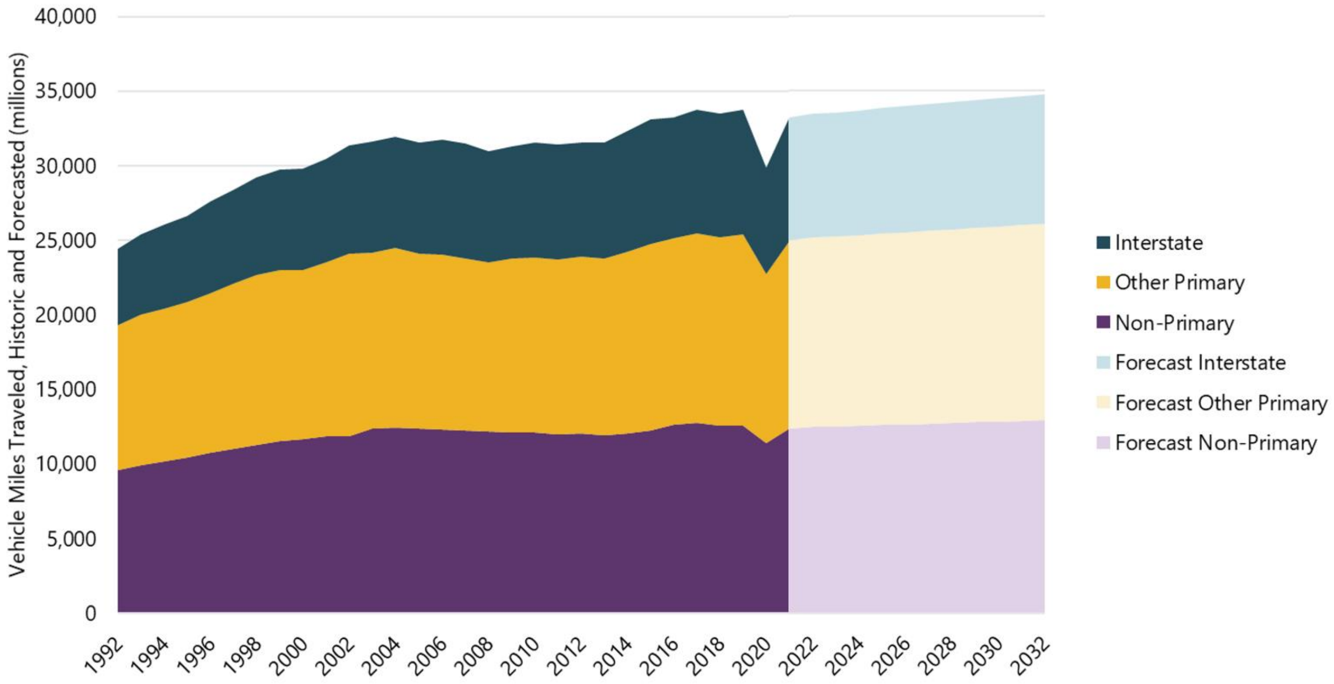
Figure 3.8: Predicted good, fair, and poor condition of the Interstate System, status quo budget



Traffic

An important consideration in the asset management planning process is the amount of traffic that Iowa's roadways serve. Figure 3.9 shows historic vehicle miles traveled (VMT) in Iowa and projected VMT through 2032. These trends further strengthen the need for Iowa DOT to implement asset management. The impact of traffic is incorporated in the deterioration models described previously. Truck traffic is particularly hard on pavements and is the primary cause of deterioration. Iowa DOT projects a 52 percent growth in truck traffic by 2050. As traffic volumes increase, the importance of maintaining existing roadways grows as wear and tear on roadways increases and requires more preservation and maintenance work. As a mitigation for the increasing truck traffic, Iowa DOT evaluates the structural capacity of all pavements at least every five years to determine the need for extra pavement thickness. This evaluation is used as a part of the PMS decision-making process.

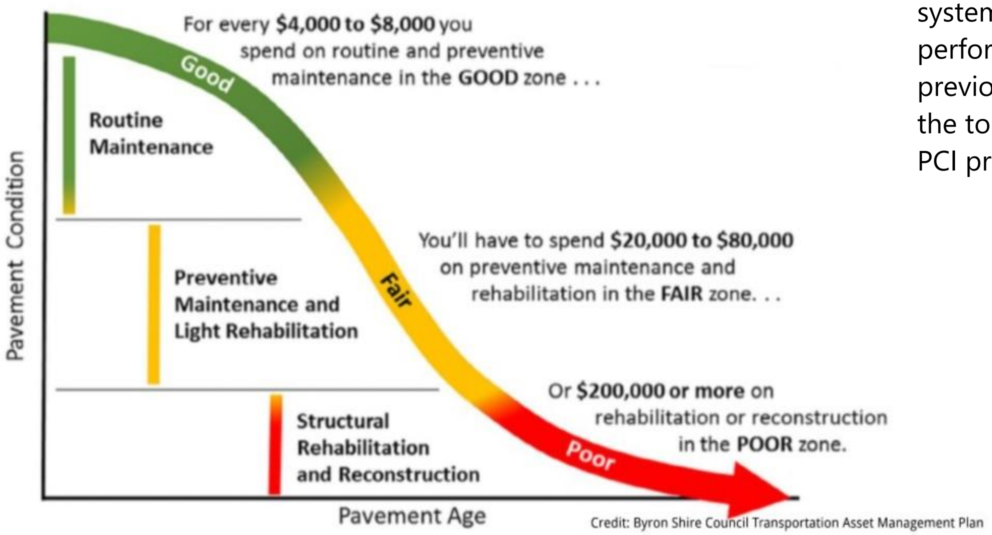
Figure 3.9: Historical and projected traffic volumes



Strategy

Good pavement management selects the right treatment at the right time on the right pavement section. The PMS allows for a systemwide identification of treatment options to help determine the right time for each treatment on each pavement section based on a given funding scenario. In most cases, a treatment is applicable to a given pavement section for multiple years. If the treatment is not applied within that time period, the pavement deteriorates to a point where a more substantial and more expensive treatment is needed. Figure 3.10 shows the value of performing timely pavement maintenance.

Figure 3.10: Pavement deterioration, treatment, and cost curve



Credit: Byron Shire Council Transportation Asset Management Plan

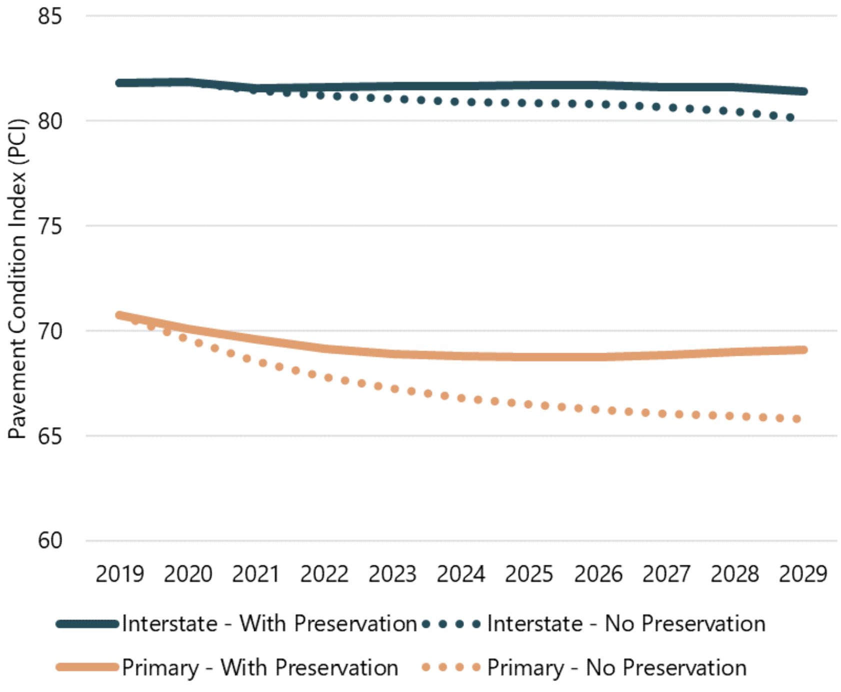
In selecting what treatments to perform, the PMS calculates the cost and benefits of applying each feasible treatment to each pavement section for each year of the analysis. As noted earlier, benefit is defined as the improvement in performance (measured by change in the area under the PCI curve multiplied by lane miles) from applying a treatment over the life of that treatment.

The PMS identifies the mix of actions that will result in the greatest benefit for the pavement network with the available budget. In the initial configuration of dTIMS, Iowa DOT configured the system such that, absent a specific funding constraint, the system tends to allocate funding to support the agency's desired life cycle strategies. That is, the system recommends treatments that yield Iowa DOT's desired level of performance for its pavements at minimal life cycle costs. As noted previously, the GBC allocates funding based on the highest B/C. Since the tools use different processes but result in very similar network-level PCI projections, they both help inform the overall LCP strategy.

When the PMS are run, scenarios are defined with a budget specified by year. Separate runs are performed for Interstates and other state-owned roads. For each system, preservation treatments are provided a spending cap to control for factors such as available contractor capacity. No additional constraints are placed on different treatments or systems. For each run, the system recommends work to perform to maximize progress towards achieving the agency's desired condition, subject to the available budget. Note that it is theoretically possible to develop and test different sets of treatments and decision trees for different scenarios. However, in practice Iowa DOT typically uses the same basic life cycle strategy for each investment scenario tested, with the scenarios varying only in available budget. Nonetheless, the specific treatments selected do vary based on the available budget, with greater emphasis on thin overlays and other lower-cost treatments when the budget is tightly constrained. By comparing scenario outcomes, pavement managers can make informed decisions about the long-term costs and benefits of their decisions.

Figure 3.11 shows the results of two analyses run in dTIMS to demonstrate the benefits of prioritizing preservation treatments. For this comparison, the PMS evaluated two scenarios at the same level of annual investment. In the "With Preservation" scenario, the PMS applied the available funding, including $10 million dedicated to preservation treatments. In the "No Preservation" scenario, the system was unable to choose any thin surface treatment or diamond grinding and allowed pavements to deteriorate to the point of needing more costly resurfacing overlays before being selected to receive work. Although neither strategy achieves the agency's pavement objective at the defined budget level, the results show consistently better network pavement conditions using the strategy that includes preservation treatments.

Figure 3.11: Effect of preservation program on pavement condition



Implementing LCP Strategy

Iowa DOT also uses the PMS to inform the process of selecting pavement projects. The PMS recommendations are used by program administrators when developing reconstruction, rehabilitation, and preservation programs. Iowa DOT has separate processes for selecting projects for the Interstate System and the remainder of the Primary Highway System.

Interstate projects are prioritized by Iowa DOT's central office. Capacity projects are guided by the Iowa Interstate Investment Plan (I3P). Interstate stewardship (preservation and maintenance) projects compete against each other for funding, regardless of location. For the Interstate System, PMIS data are part of the annual statewide review where potential pavement replacement and rehabilitation projects are evaluated. Districts also use the PMIS data as a resource in the development of the Interstate preservation and maintenance programs.

The rest of the Primary Highway System is managed collaboratively by the central office and the district offices. Generally, construction and reconstruction projects are identified by districts and prioritized by a team from the central office and districts. Rehabilitation, preservation, and maintenance projects are managed by the districts. In addition to pavement condition data, Iowa DOT also uses information on the condition of bridges and other structures, safety, traffic volume, capacity, and economic benefit when making these decisions.

For non-Interstate routes, the districts use the pavement management recommendations and data in conjunction with site visits, pavement investigations, and local knowledge about roadways to develop the district pavement rehabilitation, preservation, and maintenance programs. The pavement management recommendations do not provide specific maintenance treatments, but the PMS do provide data to the districts about the current condition and history that is used to prioritize maintenance treatments. These maintenance treatments address specific events or pavement defects in order to maintain a functional state of operation.

The rehabilitation and preservation projects developed from these procedures become part of the recommendations given to the Iowa Transportation Commission for funding consideration. If they are approved, they become part of the Five-Year Program; and if they are federally funded, the projects are placed in the Statewide Transportation Improvement Program (STIP). As part of the process, the Iowa Transportation Commission is updated on the current condition and estimated future condition of Iowa DOT's pavements based on various funding scenarios.

PMS and the modeling software are an evolving process. The modeling efforts have limitations. There are time lags between data collection, data availability, and the analysis; the models do not perfectly predict future conditions; treatment costs are estimates; treatment selection lengths may not be practical or economical; and local knowledge of pavements is not represented in the models. In addition, Iowa DOT considers other factors such as traffic, system classification, and a need for funding flexibility when making project selections. Iowa DOT tries to minimize disruption to the traveling public and promotes longer-term fixes at the end of treatment windows when they align with desired asset management and operational goals.

The factors listed above demonstrate that engineering judgement is needed when reviewing the pavement management output and developing projects. Iowa DOT strives to have a practical, low-cost approach to pavement management and continues to work to improve its pavement management systems with better models and better-aligned funding and project recommendations. As an example of this ongoing evolution, Iowa DOT has begun to program $35 million for non-Interstate pavement replacement projects, starting in FY 2027, to slow the rate of growth of the system's average age. This $35 million is just an initial step towards lowering the average age of the system; more effort will be needed to significantly slow the rate of growth. Determining which projects to prioritize for funding will involve tradeoffs, particularly between rural and urban projects. Rural projects typically take less time to be developed, involve more mileage for the cost, and make more of an impact in lowering the age of the system, while urban projects typically require more time to develop, involve less mileage for the cost, and make less of an impact in lowering the age of the system; however, they often serve more users. These and other factors will need to be considered in developing the program of pavement replacement projects.

Local Collaboration

Iowa DOT works in partnership with local agencies to promote good pavement management practices for locally owned pavements, including the locally owned pavements on the NHS. Iowa DOT participates in and is the primary funding source for the Iowa Pavement Management Program (IPMP) at Iowa State University's Center for Transportation Research and Education. IPMP has been supported by Iowa DOT since 1996; its role is to support local agencies in the collection and management of pavement data as well as with modeling and analysis tools.

IPMP focuses on local agency needs and is a technical resource for pavement management. Since 2013, Iowa DOT has expanded pavement data collection efforts to collect pavement condition data on all paved roads in Iowa. Data is currently collected annually for Interstates, every other year for the non-Interstate NHS and the remainder of the Primary Highway System, and every four years for other paved roadways. Data is shared, free of charge, with counties, cities, and planning agencies through IPMP and is available for their use. IPMP hosts a web portal that local agencies can use to view, interact with, and download their data. IPMP also facilitates a pavement management and dTIMS focus group with local agencies that meets quarterly. Additionally, work is underway to update the performance curves for local agencies so they will not depend on pavement age as that information is not always reliable.

Regarding federal performance measures, Iowa DOT coordinates with MPOs in the establishment of pavement performance targets. This includes targets for the non-Interstate NHS system, which includes segments of roadways that are owned by local jurisdictions. Targets are discussed further in Chapter 4.

Consideration of Extreme Weather and Resilience

Extreme weather and resilience are important considerations for pavement life cycle planning. Extreme rain events and areal flooding are likely the greatest risks to Iowa's roadways from natural disasters. Following the 2019 floods that had severe impacts along the Missouri River and Mississippi River, resiliency efforts have included initiation of improved design standards for vulnerable areas. The improved standards include features such as armored shoulders and embankment protections to help stabilize slopes. These types of features may not prevent the roadway from overtopping, but they increase the likelihood that the roadway will be able to be back in service more quickly with lower repair costs. Incorporating these elements and other resilience-related features into project design will help improve the resiliency of the pavement over the life cycle of the asset.

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