AASHTO Manual for Bridge Evaluation: Section 3, Bridge Management Systems
A Practical Tour

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Abstract

There have been many developments in Bridge Management Systems (BMSs) over the past ten years. The American Association of State Highway Transportation Officials (AASHTO) Subcommittee on Bridges and Structures (SCOBS) is updating the Manual for Bridge Evaluation (MBE) Section 3 – Bridge Management Systems. This paper features some of the changes to the section, including examples how the Michigan Department of Transportation (Michigan DOT) is implementing their Bridge Management System (BMS).

Keywords: Bridge Management Systems, BMS, AASHTO, Michigan Department of Transportation, MDOT, MBE

INTRODUCTION - DEFINING A BRIDGE MANAGEMENT SYSTEM

There have been many developments in Bridge Management Systems (BMSs) over the past ten years. The American Association of State Highway Transportation Officials (AASHTO) Subcommittee on Bridges and Structures (SCOBS) is updating the Manual for Bridge Evaluation (MBE) Section 3 – Bridge Management Systems. The updated section, referred to in this paper as *MBE Section 3* will be balloted at the 2017 AASHTO SCOBS annual meeting. Figure 1 shows the table of content for the section. This paper features some of the proposed updates to the section, including examples how the Michigan Department of Transportation (MDOT) is implementing their Bridge Management System (BMS).

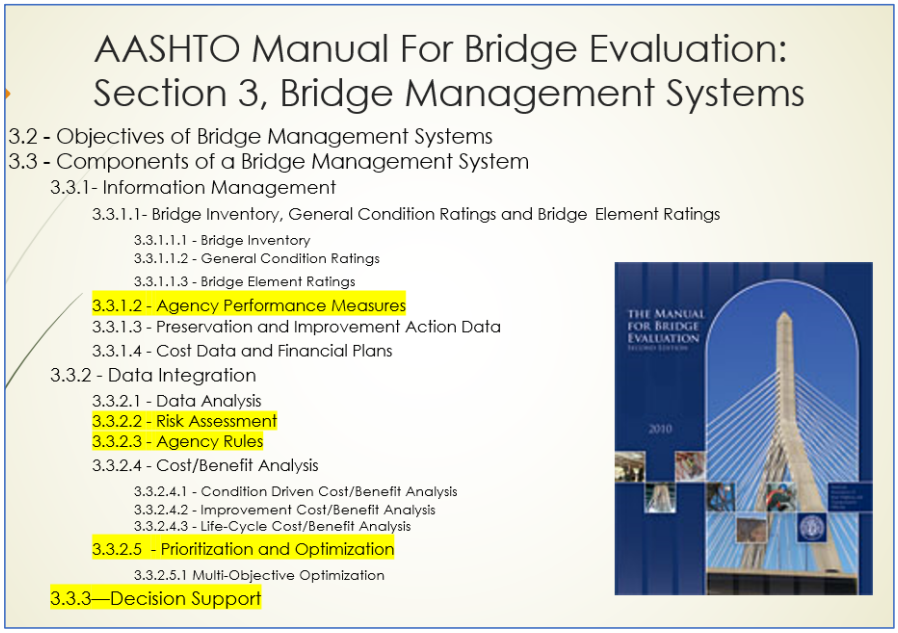

FIGURE 1 Table of Contents for the Draft AASHTO Manual for Bridge Evaluation: Section 3, Bridge Management Systems

MBE Section 3 references the AASHTO Standing Committee on Highways, Planning Subcommittee on Asset Management;

> "Transportation asset management is a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their lifecycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based upon quality information and well defined objectives (*1*)."

The MBE Section 3 discusses the purpose of a BMS;

> "The section describes how a bridge management system fits into overall transportation asset management as follows. A Bridge Management System (BMS) is a tool or collection of tools integrated through a process whose goal is to assist an agency to meet strategic objectives by connecting inventory management and project selection to agency strategic goals through a data driven process. A BMS should meet the needs of both upper management, where it is a strategic planning tool, and technical decision makers, where it is an engineering tool. BMS helps engineers and decision-makers determine the best fiscally constrained action to take on maintenance programs and short, medium, and long-term capital improvement programs. Its purpose is to determine the optimum use of funding by enabling decision-makers to understand the consequences of their actions and strategies. A BMS assists the bridge owner in expending the appropriate level of resources to maintain the inventory in an acceptable state of good repair. It also provides essential information to help transportation agencies enhance safety, perform risk assessments, extend the service life of bridges, and serve commerce and the motoring public (*2*)."

The MBE Section 3 discusses BMS data base requirements;

> "A BMS requires comprehensive, connected and well organized relational databases that are capable of supporting the various analyses involved in bridge management and reporting this information in a way that can be readily understood by various stakeholders (*2*)."

The Michigan DOT has a corporate relational database for storing all bridge data. It is built upon the AASHTOWare Pontis (now Bridge Management) database with state specific tables added to it. Michigan has their own web-based system, called MiBridge, for collection and reporting of all bridge data.

Network Level Bridge Management System

The Michigan DOT has two levels of BMS; network level and project level. Network level BMS includes data collection and analysis for the state's population of highway bridges. This includes many of the methods described by MBE Section 3, including development of strategic goals, performance measures and objectives, and regular reporting. They have had strategic goals for their population of bridges for the last 20 years. Like the Federal Highway Administration's (FHWA) new national performance measures, the Michigan DOT uses the National Bridge Inventory (NBI) General Condition Ratings (GCRs) as performance measures for their freeway and non-freeway bridges, with one of the goals being to meet and maintain 95% of trunkline freeway bridges in good or fair condition. Dashboards have been created to show the public how the state is doing as shown in Figure 2, and Michigan tracks condition trends of their good, fair, and poor bridges as shown in Figure 3.

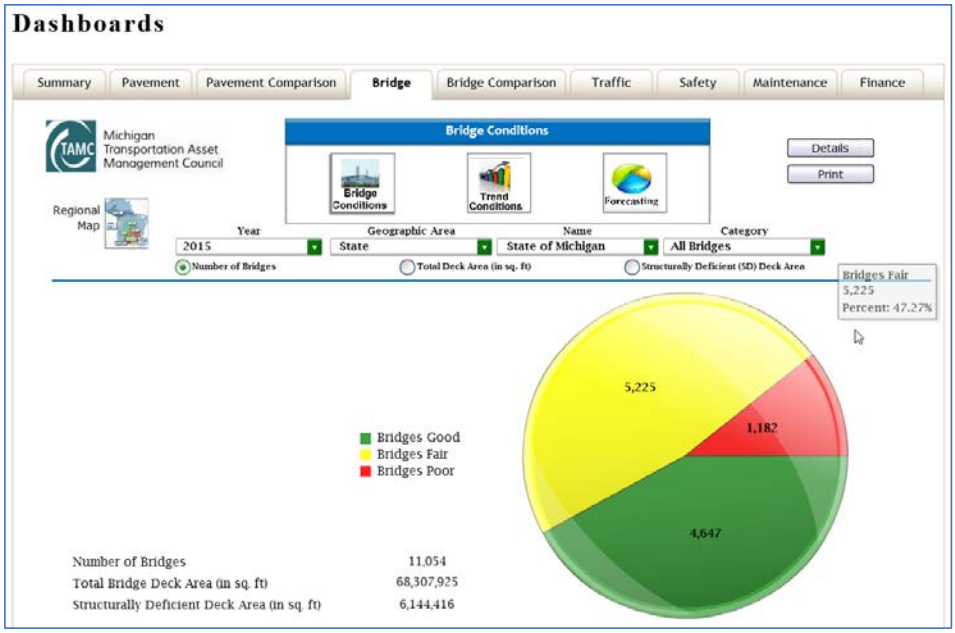

FIGURE 2 Michigan Transportation Asset Management Council Bridge Dashboard.

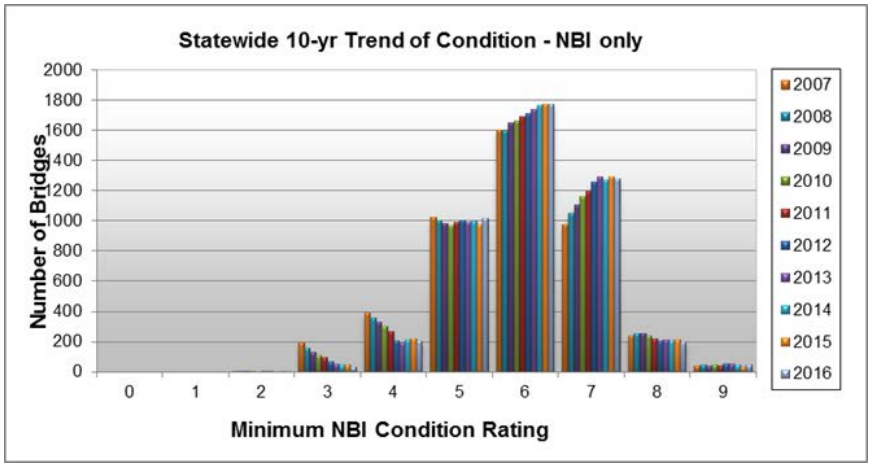

FIGURE 3 Condition Trends for Michigan Highway Bridges.

To achieve their goals, the Michigan DOT uses a strategy based upon allocating funds to their seven regions for capital preventive maintenance, rehabilitation, and replacement projects per the candidates in each region. Data analysis using current and forecasted condition is done to determine the right mix of fixes to be used to most efficiently manage the network of bridges. To perform this analysis, they identified Agency Rules to reflect current practice and developed tools to show the deterioration rate of their bridges, track costs (direct and indirect) of bridge projects, and account for construction inflation. Michigan tracks the condition bridges are in when a project is initiated and the resulting condition after the project is completed.

The MBE Section 3 discusses Agency Rules as follow;

> "In order for a BMS to make bridge level decisions consistent with agency practice, agency rules need to be developed. The intent of the rules is to translate agency practices and their effects on bridge, program and network level recommendations into the system's modeling approach. These rules should be intuitive and reflect agency business practice and policy (*3*)."

> "Rules may be applied at the bridge, program, or network level…. Program level rules may reflect varying performance measure goals or funding constraints while network rules cover standard agency practice (*2*)."

The Michigan DOT forecasts bridge condition using their Bridge Condition Forecasting System (BCFS). Agency rules are set for what GCR would cause a bridge to be selected for either preventive maintenance, rehabilitation, and replacement projects and what GCR the completed project will improve the structure to. Results of a BCFS model are shown in Figure 4. In the figure, forecasted bridge condition is shown through 2025 for MDOT's freeway and non-freeway bridges. By comparing near- and long-term bridge condition for different strategies, an optimal balance of preventive maintenance, rehabilitation and replacement can be identified.

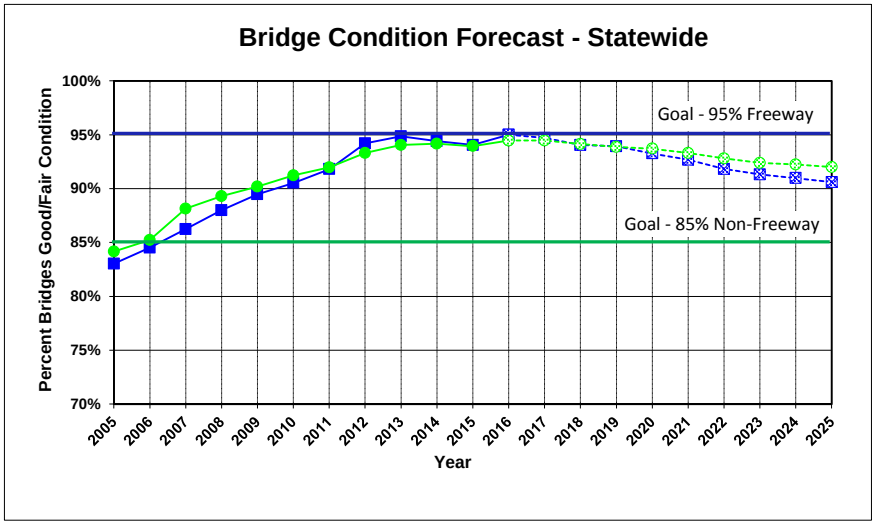

FIGURE 4 Forecasting Bridge Condition using MDOT's Bridge Condition Forecasting System (BCFS)

As shown by both historic and forecasted data, the key to achieving the Michigan DOT's bridge strategy with limited funds is a commitment to preservation. Figure 3 shows that many of ~~their~~Michigan DOT's bridges are rated in fair condition (overall NBI rating for the bridge being rated 5 or 6 on the NBI condition rating scale.) Management will then ~~They~~ dedicate funds to these bridges to correct deficiencies, slow ~~deterioratio~~deterioration,~~n~~ and reduce the number of bridges becoming poor each year. A very simple, but helpful measure the Michigan DOT uses to evaluate their preservation program on a network level is counting the number of bridges that become poor each year as shown in Figure 5. This is done statewide and for each region. A successful preventive maintenance program will result in slowing bridge deterioration. By knowing how many bridges are expected to become poor, Michigan DOT bridge managers then know how many bridges they need to improve just to maintain the current condition state. Additional projects will result in an improvement of bridge condition.

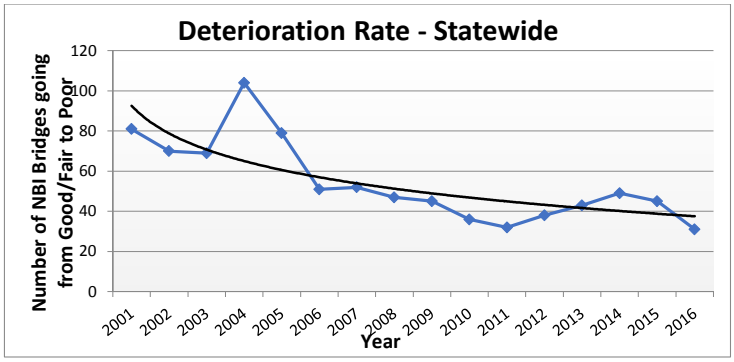

FIGURE 5 MDOT Number of Bridges Going to Poor Each Year.

Project Level Bridge Management

The Michigan DOT has become very good at network level bridge management, and they are now working on enhancing project level management. The draft MBE Section 3 says;

> "~~a~~Advanced BMS analyses requires a more detailed condition assessment to predict and prioritize bridge repair, preservation, or replacement actions (*2*)."

For example, Figure 6 helps visualize the circular cycle of network level bridge management. The entire population of bridges is slowly deteriorating and moving into lower condition states. Projects are done to either slow the deterioration or improve bridge condition. Good bridges are preserved with cyclic maintenance activities. Fair bridges are preserved and improved with preventive maintenance and minor rehabilitation projects. Finally, poor bridges are improved with major rehabilitation and replacement projects.

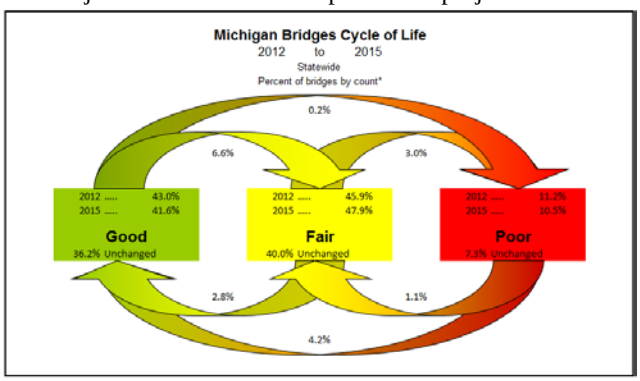

FIGURE 6 Michigan Bridges Cycle of Life.

Using GCRs, the Michigan DOT can categorize projects into work activities, but they are not able to prioritize or optimize individual projects within these categories. To do more refined analysis, Michigan collects the National Bridge Elements (NBEs) and Bridge Management Elements (BMEs) as defined by the AASHTO Manual for Bridge Element Inspection (MBEI). The condition of each element is reported per the quantity or percentage of the element rated in four Condition States (CS); CS 1 - Good, CS 2 - Fair, CS 3 - Poor, and CS 4 - Severe. Michigan also created and is collecting state specific Agency-Defined Elements (ADEs). Using the element condition ratings, they can identify more detailed bridge needs, such as identifying protective systems that could be repaired or replaced before deterioration progresses on the underlying element.

PRIORITIZATION AND OPTIMIZATION

The MBE Section 3 discusses prioritization and optimization;

> "The purpose of optimization at the network level is to select a set of bridge projects in such a way that the total benefit derived from the implementation of all of the selected projects is maximized (costs and risks are minimized). The ability to establish project priorities and optimally allocate limited funds over a predefined planning horizon, both short- and long-run, is a fundamental part of a BMS (*2*)."

> "Bridge owners often need to consider multiple performance criteria and constraints, such as bridge condition, life cycle costs, safety, traffic flow disruption, and vulnerability when making decisions and prioritizing projects. They may need to analyze trade-offs between these performance criteria (*2*)."

The Michigan DOT is working towards using multi-objective optimization to produce a prioritized list of projects that the Region bridge engineer can use when they select projects each year for the Call for Projects. MBE Section 3 discusses the different approaches that can be taken for prioritization and optimization. These include *Top Down*, where network-level performance measures are addressed first, and then the results are used to guide project selection, resource allocation and scheduling. Another method is *Bottom Up*, where by using condition information and inspector recommendations, the most cost effective option is identified for each bridge, and the results of the analysis are summarized back up to the network level. Michigan uses a combination of the two methods. Figure 7 shows a simple flow diagram of the process. The objective is to use bridge elements and the AASHTOWare BrM 5.2.3 software to do the following; For every bridge not already programed, deteriorate the network five years, then using bridge elements and the AASHTOWare BrM software, indicate what the needs are for each bridge, identify what category of work it fits into, estimate the cost for the work, and prioritize the list of possible projects with consideration to fiscal constraints. The Region engineers will use the element work candidates along with inspector recommendations, corridor considerations, and Michigan DOT bridge objectives to help select projects. Some of Michigan's objectives are as follows;

1. Meet and maintain freeway bridge condition goal (95%) good or fair.
2. Reduce scour critical bridges carrying the interstate.
3. Make bridges more resilient to reactive activities resulting from advanced deterioration. (Reduce need to close traffic lanes because of advanced bridge deterioration.)

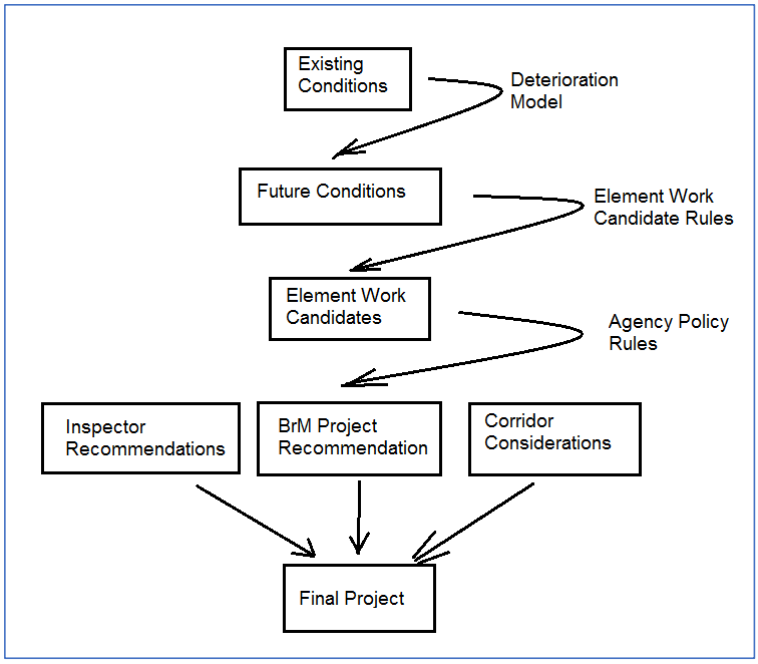

FIGURE 7 MDOT Project Level BMS flow diagram.

The Michigan DOT takes different approaches for prioritization of replacement projects and rehabilitation/preventive maintenance projects. Prioritization of Michigan DOT replacement projects often includes a risk assessment when the resiliency of the transportation system is at risk of being impacted due to deterioration that cannot be efficiently repaired or when public safety is at risk such as for scour critical bridges. The MBE Section 3 discusses risk assessment;

> "Risk may be understood as the potential for unplanned adverse events to impact one or more transportation facilities in a way that causes unacceptable transportation system performance according to any or all of the agency's performance objectives. In bridge management, the primary concern is disruption of expected or designed service levels, which may cause injuries or property damage, loss of mobility, and immediate expenditures or long-term excess costs (*4*)."

> "Risk assessment evaluates the likelihood and consequence of adverse events. The likelihood of the event includes the probability of the event occurring and may include the vulnerability of the structure to the event. The consequence of the adverse event would quantify the damage to the structure, the impact on the flow of people and goods in the transportation network and the importance (criticality) of the structure (*2*)."

At the Michigan DOT, when an inspector identifies a structural element that has distress that may need high priority repair that could impact traffic, a Request for Action (RFA) is submitted. A team of Michigan DOT bridge engineers meets each month to review and prioritize RFAs based on urgency. For example, a Priority 1 RFA will require the Michigan DOT statewide bridge crew do repairs as soon as possible. For a Priority 2 RFA, a special needs construction contract will be done to complete the repairs. The team considers several factors including location of deterioration, severity of deterioration, structural redundancy, and location of distress in relation to traffic or other loads. Based on these prioritized levels, the structures are temporarily or permanently repaired by internal forces, maintenance contracts or programmed for work within the capital program. Funding is set aside at a statewide level so that action can be taken without delaying or deferring other work within the region's 5-year plan.

Scour risk assessment is performed by the Michigan DOT on an annual basis as part of the Bridge Call for Projects process. Data items that impact scour vulnerability and criticality are queried from the bridge database and imported into a spreadsheet. Data items impacting vulnerability include scour criticality (NBI Item 113), number of substructure units in the water, soil type, and presence of existing scour mitigation. Data items affecting criticality include average daily traffic, detour length, economic importance, and detour length. Many of the items are MDOT-specific and may not be collected by all states. The data items selected, as well as the scoring and weighting of these items were revised at the direction of and approved by the interdisciplinary MDOT Scour Committee. In addition to standard NBI data, the assessment uses data from the Scour Plan of Action (POA) to more accurately determine scour vulnerability. The various data items are scored and weighted to arrive at a final vulnerability and criticality score for each structure. These scores are plotted as shown in Figure 8.

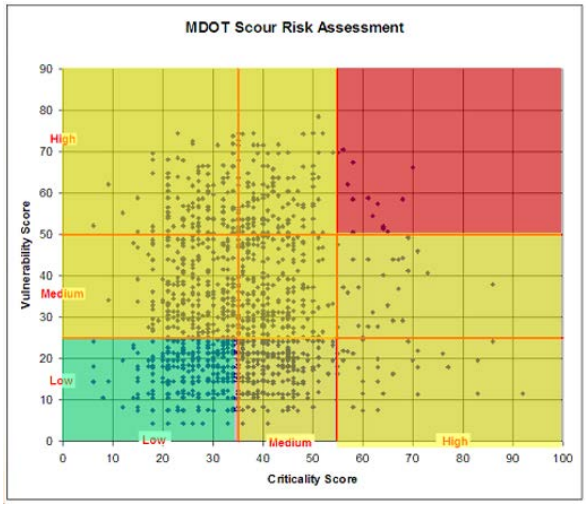

FIGURE 8 MDOT Scour Risk Assessment.

Those bridges with high criticality and high vulnerability, as well as scour critical Interstate bridges, are documented in the Call for Projects submittals and progress is monitored.

As opposed to the replacement prioritization where the focus is on minimizing impacts to the transportation system by reducing risk, the Michigan DOT's bridge preservation program prioritizes lowering life cycle cost by maintaining structures in fair condition (lowest major condition rating of 5 or 6) and preventing the need for full replacement. The goal is to prevent bridges rated fair (NBI 5) from deteriorating to poor (NBI 4) condition by performing rehabilitation or preventive maintenance. Prediction models have been developed to identify those bridges that are likely to become poor the earliest. Due to the recent transition from CoRe elements to NBE elements, the models currently rely on NBI data but the process will soon include element data. Years of NBI data collection have made it possible to create deterioration curves for the deck, superstructure, and substructure ratings and the number of years that a bridge can expect to last with a fair condition (NBI 5) can be estimated. By querying past inspection data, the number of years that a major component rating has been fair (NBI 5) is known and thus the number of years remaining fair can be calculated. As part of the Call for Projects process, a listing of all fair rated bridges~~ fair rated bridges~~, along with their predicted year to become poor, is provided to the Region Bridge Engineers. Those that are due to become poor soon (or even overdue) are given highest priority consideration for PM work.

It is important to remember that individual bridges are often part of a corridor of bridges. To minimize the impact on highway traffic, the Michigan DOT coordinates bridge projects within a corridor in the same construction season. Often it is practical to advance a project on a particular bridge if other bridges within the corridor are in more urgent need of PM work. This not only lessens the negative impact on traffic, but also allows for more efficient work if similar projects on a series of bridges are done at the same time. For corridors of particular importance, the work should be planned with the long-term goal of minimizing the number of times that traffic will be disrupted and anticipated future needs addressed at the same time as current needs. Additionally, the bridge projects should be coordinated with pavement projects in the corridor.

Decision Support

MBE Section 3 concludes by pointing out that bridge management is not strictly a data analysis or analytical process.

> "The function of a BMS is to provide bridge information and data analysis capabilities to improve the decision-making abilities of bridge managers. A BMS should not make decisions. Bridges cannot be managed without the practical, experienced, and knowledgeable input of the engineer/manager. A BMS is never used in practice to find one best policy among the possible choices. Instead, managers should use the BMS as a tool to evaluate various policy initiatives, often referred to as "what if" analysis. The available choices may relate to network-level decisions or project-level decisions (*2*)."

The Michigan DOT very much agrees with this. Every bridge has a unique history, location, and impact within the transportation system and the community that it is found. Often, bridge databases do not contain sufficient information to identify the full impact of planning a project, such as the community activities and festivals that might control the construction schedule, the endangered species that could delay the timing of scour mitigation, or the safety and pavement project that will require a bridge replacement to meet alignment requirements. The central office Bridge Management Section within the Michigan DOT recognizes that the bridge program is one part of the overall transportation program. The goal of the section is to provide tools to make the network level decision making as easy as possible so that the region and design staff resources can focus on the more nuanced and unique project level issues to maintain a safe, efficient and effective transportation network.

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Conclusions

This paper ~~showed~~includes ~~some~~highlights of the updates being proposed to the AASHTO Manual for Bridge Evaluation (MBE) Section 3 - Bridge Management Systems. The updates are being made to ~~include the~~reflect ~~results of~~progress in state-of-the-art practice and results of research in Bridge Management Systems (BMS). This paper demonstrate~~d~~s the ~~practical~~ application of these ~~methods~~practices by the Michigan DOT. ~~Network management was shown~~The Michigan DOT leverages a collection of integrated tools to assist the agency in meeting strategic objectives. This paper includes examples of upper management use as a strategic planning tool including ~~, including~~ performance measurement, the use of dashboards, network level condition forecasting, and tracking bridge deterioration. The paper also includes examples of the Michigan DOT's use of their integrated BMS at the p~~P~~roject level by technical decision makers ~~bridge management was demonstrated including how the Michigan DOT is using~~through element level condition data and agency rules to identify and prioritize bridge projects for preventive maintenance, rehabilitation, and replacement. Through this network and project level approach to bridge management, the Michigan DOT works to enhance safety, extend the service life of bridges, and serve commerce and the motoring public.

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