Data Elements for Bridge Design, Materials, Construction, Inspection, and Maintenance

Prepared for Mississippi Department of Transportation

State Study No. 295

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16. Abstract

MDOT's bridges are a vital part of infrastructure traveled by the public. Safety, durability, and long life cycles are essential to carrying out MDOT's mission. Federal asset management and performance measure rulemakings are required. The need to address data elements associated with bridges to optimize bridge life cycles, design, materials, construction, inspection, and maintenance were addressed through literature search, national survey of other state DOT practices, review of MDOT's current data elements, and recommendation for additions and filling data gaps. The research findings led to improved understanding of data elements managed by MDOT and enhancing overall knowledge-base and as-built information, clearer definition of staff associated with the various bridge data elements, and through documenting bridge data elements improved consistency, access, staff productivity, communication, data collection, workflows and procedures, and quality is realized.

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The following MDOT employees contributed their time and assisted with the development of the research study through participation on the Technical Advisory Committee:

Paul T. Dees, Lon Burt, and Spencer Yates - MDOT Bridge Design Division

Richard Withers - MDOT Bridge Inspection Program Manager

Adam Browne - MDOT Materials Division

Mike Stroud – MDOT Geotechnical Group

Mike Cresap – MDOT Information Systems

The contribution put forth by everyone involved with the research study is greatly appreciated.

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Executive Summary

MDOT's bridges are a vital part of infrastructure traveled by the public. Safety, durability, and long life cycles are essential to carrying out MDOT's mission. Federal asset management and performance measure rulemakings are now required. The need to address bridge data elements and overall management and organization of MDOT associated with bridges to optimize bridge life cycles, design, materials, construction, inspection, and maintenance is a vital component to MDOT's operations.

Data elements for bridge design, materials, construction, inspection, and maintenance were addressed through literature search, national survey of other state DOT practices, review of MDOT's current data elements, meetings with MDOT's Technical Advisory Committee, Central Office staff, and Districts 1, 2, 3, 5, 6, and 7, and recommendation for additions and filling data gaps.

Improvements made consist of:

1) Improved understanding of bridge data elements managed by MDOT.
2) Improved connectivity and relationships to existing body of knowledge specific to bridge data elements. MDOT completed a study in April 2019 regarding Best Practices in Estimating Camber of Bulb T and Florida Girders (State Study 288).
3) Improved access to as-built and historic bridge data element information.
4) Added clarity to the MDOT staff associated with the various bridge data elements.
5) Through documenting the various bridge data elements, software used, and organization of MDOT staff associated with bridge data elements improved consistency, access, staff productivity, communication, data collection, workflows and procedures, and quality is realized.

Background

MDOT's bridges are a vital part of infrastructure traveled by the public. Safety, durability, and long life cycles are essential to carrying out MDOT's mission. Federal asset management and performance measure rulemakings have also been required in the last few years. Many bridges have been posted for lower weight limits or closed, which impacts the motoring public.

MDOT seeks to discover what data elements are needed to optimize bridge life cycles, design, construction, and maintenance. Some elements are already in AASHTOWare; however, there may be gaps that need to be addressed. This study will identify gaps and capture what each element means (i.e. metadata) and how each will be used. Some examples of these data elements include the actual concrete strength of prestressed concrete (PSC) beams and cast in place (CIP) bridge decks that might help the Bridge Division to more accurately design and even anticipate certain variables in construction as well as assist in more accurate load ratings of bridges. For example, if the actual concrete strength of a PSC beam were known for a particular bridge, and that bridge was about to be posted based on the data in the plans, the bridge might not be posted based on the "actual" data that was recorded. Other examples, with similar knowledge benefits, might include elements such as actual soil strengths, drilled shaft concrete strengths, and PSC beam camber values.

Anticipated benefits include more consistent and meaningful data elements resulting in more efficient bridge designs and ratings, construction, and maintenance. Capturing these elements and their metadata will immediately yield knowledge capture benefits, which will aid the passing of institutional knowledge and on-boarding new employees. Not only will this benefit both Bridge Design and Bridge Ratings, but other MDOT staff associated with bridge data elements such as Districts, Geotechnical Construction, Materials, Maintenance, and Inspection.

The Technical Advisory Committee (TAC) consisted of representatives from MDOT's Bridge Design Division, Materials Division, Geotechnical Group, and Research Division. Central Office staff included representatives from Construction, Materials, Planning, and Information Systems.

Research Approach

The research study consisted of various tasks that addressed the research topic, including close collaboration and input by MDOT's Bridge Design, Central Office Staff from (Construction, Materials, and Geotechnical) Research Divisions, District Staff, and the Technical Advisory Committee. A kick-off meeting was held at MDOT to discuss the research plan, coordinate information that MDOT would provide throughout the research, and verify contact information. A Technical Advisory Committee (TAC) meeting took place on October 9, 2019 along with a follow up TAC meeting together with Central Office staff on February 6, 2020 to further discuss the research progress and go over research findings summarized to date. Meetings with District 6 and District 2 took place on November 25, 2019 and March 16, 2020 respectively. A virtual meeting was held on October 8, 2021 with Districts 1, 3, 5, and 7.

A literature search was performed to collect all relevant publications and reviewed with MDOT for applicability to the research project.

MDOT's current bridge data elements were reviewed along with MDOT staff associated with bridge design, materials, construction, inspection, and maintenance. MDOT's overall organization of bridge data elements and software were reviewed.

An AASHTO Research Advisory Committee (RAC) Survey was sent out to other State DOT agencies to gain insight to how bridge data elements are being managed and utilized throughout the United States. The AASHTO RAC to the AASHTO Special Committee on Research and Innovation (R&I) supports the activities of R&I and is committed to being a proactive committee promoting quality and excellence in research and in the application of research findings to improve state transportation systems. Each AASHTO Member Department is represented on RAC.

Research Findings and Applications

Literature Review

An extensive literature review was conducted on eighty-two publications to capture a broad-range of topics related to the research study. Various publications were reviewed to ascertain what research has been previously performed related to bridge data elements and/or which literature documents address bridge data elements and/or contained additional information related to the research study.

The list of the publications reviewed and literature review document is included in Appendix A-1 along with highlighted information that is of particular interest to the research topic.

The literature review generated the following list of topics that are co-related to the research topic. The number shown to the right of each topic inside the brackets lists the number of times in the various literature review documents that the topic appeared. The literature review confirmed that there are numerous co-related topics associated with managing bridge data elements within a State DOT owner agency. The challenge for State DOT agencies is to fully understand and document all aspects associated with data elements part of their overall Asset Management and/or Bridge Data Elements Program. Depending on how the State DOT owner agencies are organized, the following co-related topics are either inclusive of Bridge Data Elements or related to Bridge Data Elements to a certain extent.

Bridge data elements either fall under one or several of these co-related topics within a State DOT owner agency or one or several of these co-related topics fall under Bridge Data Elements.

- Data (historic, collection, inspection, paper vs. electronic) [27]
- Preservation, Bridge preservation [21]
- Performance (targets, goals, measures, management, program, reporting, index, gaps) [16]
- Management [16]
- Maintenance [15]
- Condition, conditions, bridge conditions [12]
- Asset [12]
- Testing (pile installation, drilled shaft integrity, software, certifications, chloride content, soil corrosion, elastomeric bearing pad, beta, regression, load) [10]
- Bridge management [9]
- Plan (short-term, long-term, TIP, TAMP, maintenance, data-collection, bridge preservation) [9]
- Repair(s) [8]
- Planning [8]

- Software [8]
- Asset Management [8]
- Cost (life-cycle, historic) [7]
- Material(s) [7]
- Inspection [7]
- Service Life [7]
- Element(s) [5]
- Rehabilitation [5]
- Life cycle [5]
- Topic(s) [5]
- Research [5]
- Benefits [4]
- Decision making [4]
- Specifications [4]
- Penalties [4]
- Practices, best practices [4]
- Construction [4]
- Monitoring [4]
- Records, bridge records [4]
- Deterioration models [4]
- MAP-21 [4]
- Database [4]
- Non-Destructive (testing, evaluation) [4]
- Risk [4]
- Walls, retaining walls [4]
- Durability [4]
- Bridge Management Systems (BMS) [3]
- Web (integration, services) [3]
- Highway Code of Federal Regulations (CFR) [3]
- Overlays [3]
- Implementation [3]
- Knowledge-base [3]
- Training [3]
- Culverts [2]
- Bridge Information Modeling (BrIM), Building Information Modeling (BIM) [2]
- Financial [2]
- Investment [2]
- Load rating [2]
- Procedures [2]
- Prioritization [2]
- Environmental (sustainability) [2]

- Bridge files [2]
- Geotechnical [2]
- Material property data [1]
- Serviceability [1]
- Education [1]
- Fiber reinforcing [1]
- Self-Consolidating concrete (SCC) [1]
- Ultra-High Performance Concrete (UHPC) [1]
- Programming [1]
- Subsurface borings [1]
- Workflow [1]
- Case studies [1]
- Transportation Asset Management Plan (TAMP) [1]
- Compliance [1]
- Topic(s) [1]
- Unmanned aerial vehicle (UAV) [1]
- LIDAR or imaging sensors scanning [1]
- Technologies [1]

National Survey and Other State DOT Current Practices

An AASHTO RAC Survey was sent out on March 3, 2021 with responses received by March 31, 2021. Fourteen AASHTO State Members responded with the questions and synthesis of the responses shown below. All responses are located in Appendices B-1. AASHTO's Special Committee on Research and Innovation website has a complete list of other RAC Survey results at the following website address: https://research.transportation.org/rac-survey-results/.

1. Bridge Data Elements:
   In addition to the Bridge Data Elements associated with Bridge Element Level Condition Inspections, what are the other Bridge Data Elements utilized/managed by your Bridge Division/staff?

   Six AASHTO State DOTs responded that they utilize/manage AASHTO defined National Bridge Elements (NBEs) and/or Bridge Management Elements (BMEs). Seven respondents collect Agency Bridge Elements in addition to the AASHTO defined elements associated with Bridge Inspections/Bridge Inventory or bridge management information with one DOT adding that they store bridge inspection files within the AASHTO BrM software database and store archived design and construction records on archived network drives. One DOT uses an agency-wide document management system with bridge drawings stored and managed by their Bridge Bureau on agency-shared drives.

2. Documentation:

Do you currently have a user manual, procedures, or flowchart that lists/describes the various bridge data elements and State DOT staff associated with the varies Bridge Data Elements? If yes, could you provide a copy of the documentation or link to it?

Three AASHTO State DOTs responded that they do not have current documentation outlining the various bridge data elements along with the various State DOT staff who are associated with the various bridge data elements. The remaining respondents primarily use a combination of DOT Bridge Inspection Manuals and the AASHTO Manual for Bridge Inspection supplemented with tables provided by FHWA.

3. Software:

What software is used to manage and access the various bridge data elements?

All AASHTO State DOT respondents utilize software to manage and access bridge data elements. InspectX by Bridge Intelligence is used by two AASHTO DOTs. AssetWise Asset Reliability Inspections from Bentley Systems is used by seven respondents to manage structure information with one DOT developing a web-based tool called Combined Inspection System (CombIS) that integrates with AssetWise Asset Reliability Inspections software.

Four DOTs use combinations of internal spreadsheets, SQL servers/databases, or system shared drives to store element level information with access to internal transportation management systems. One of the four DOTs uses AASHTOWare BrDR to link their data. One DOT uses an internal inspection software called WIGINS that is linked to an internal asset management system (Agile Assets' BMS). A DOT noted storing project plans, bridge plans, and bridge inspection files on their archived plan website along with various manuals and design resources also being available through their website. Another DOT uses an internal transportation management system to store element level information.

4. Management:

Do you have a Data Governance structure or Data Assets Oversight Group who makes decisions regarding bridge data assets and/or the Department's overall data assets?

Four AASHTO DOT respondents have either a Data Governance structure or Data Assets Oversight Group, one DOT is in the process, and nine DOTs do not. Several of the DOTs who answered "no" commented that decisions are made within the respective structures management unit, bridge program, or division of bridge engineering and infrastructure management concerning bridge data with input and/or support by other DOT groups or teams. Another DOT respondent who answered “no” handles bridge element decisions within their heavy bridge maintenance section under their maintenance division.

5. Additional Information:
   In addition to the various data elements associated with inspection of bridges, what are the other data elements that are associated with managing your bridge inventory and which Divisions, Branches, or Units are responsible for the other bridge data elements? Examples include:

- Geotechnical/subsurface information
- Hydraulics & scour data
- Costs
- Design data
- Load rating information
- Bridge project records
- Precast manufacture data
    - Camber information
    - Concrete compressive strength cylinder break data
- Construction information
    - As-built data
    - Pile driving records or pile test data
    - Material certs
    - Shop drawings
- Maintenance data
- Repair data
- GIS data

One AASHTO DOT respondent has in addition to the national bridge elements (NBE), agency defined elements (ADE) are collected and managed by an internal Bridge Management System (BMS) Team. Another DOT archives all project records and files managed by their Bridge Management Section and their IT and/or Planning departments are responsible for GIS applications.

Review of MDOT Current Bridge Data Elements

One of the primary research tasks was to review MDOT’s current bridge data elements, organization and management of bridge data elements, staff associated with bridge data elements, and software utilized.

One common question that came up initially when meeting with various MDOT staff is what are the various bridge data elements and where do they exist within MDOT. Some other questions were, who is responsible for collecting and maintaining the various bridge data elements, who has access, and is there any documentation within MDOT associated with the various data elements for bridge design, materials, construction, inspection, and maintenance. These initial questions through meetings and discussions with MDOT staff assisted with clarifying aspects of the research that needed to be addressed.

The review of MDOT's current bridge data elements began with a collection of the existing documentation MDOT has published available to the public primarily through MDOT's website along with reviewing how MDOT is currently organized. MDOT, like other State DOT Agencies, has a core group of staff at the Central Office level who support the current six (6) District offices located throughout the State of Mississippi. The Districts are primarily responsible for Project Delivery and Construction, Bridge Inspections, and bridge maintenance. Several Districts share the responsibility of materials with Central Office Materials Division.

In addition to MDOT's Districts and Divisions, MDOT has supporting groups, and various functions that are integral to managing MDOT's overall Transportation Program including bridges. The focus of the research is specific to bridges, but, in addition to bridges, MDOT has other assets that are managed within MDOT's overall Transportation Asset Management Program that include culverts, retaining walls, MSE walls, noise walls/sound walls, pavement, high-mast light poles, and signs. The planning and programming of these various assets with MDOT's Transportation Program has similarities and are a vital part of MDOT's operations.

Figure 1 depicts MDOT's organization and entities associated with the various data elements for bridge design, materials, construction, inspection, and maintenance.

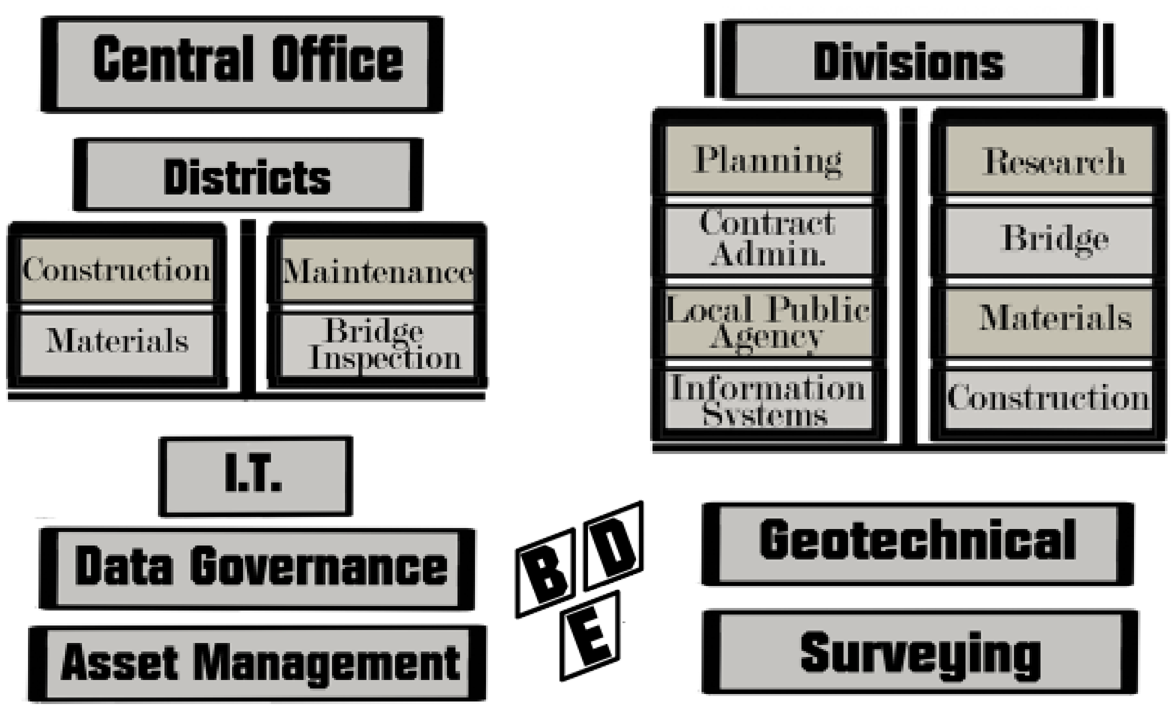


Figure 1 - MDOT Organization and Entities Associated with Data Elements

Another approach used during the research was to understand what data element needs MDOT's various Divisions (e.g. Bridge Design, Construction, Materials, Planning, Contract Administration, Local Public Agency, and Information Systems), Districts (Construction, Materials, Bridge Inspection, and Maintenance), and Geotechnical and Surveying Groups required for performing their functions within MDOT. Needs that developed included load ratings, bridge design, bridge inspections, bridge hydraulics and scour, reporting bridge element level conditions and performance measures/data, bridge inventory data, short-term and long-term bridge planning, incorporating bridge elements into MDOT's Transportation Asset Management Plan (TAMP), maintaining bridge records part of bridge asset management, material testing and material records, cost data, funding information, camber data for precast/prestressed girders, as-built bridge data and bridge construction documentation and daily reports, existing bridge plans, GIS, bridge repairs, and bridge maintenance/preservation information.

Table 1 lists the various bridge data elements and MDOT staff associated with the various data elements for bridge design, materials, construction, inspection, and maintenance.

Table 1 – Data Elements and MDOT Staff Associated with Data Elements

Data Elements	MDOT staff associated with BDE
bridge design	Bridge Division
materials	Central Office, Districts
geotechnical/subsurface	Geotechnical Group
hydraulics & scour	Bridge Division
costs	Contract Administration Division, Districts
load ratings	Bridge Division
project records/documents	All MDOT staff
construction	
specifications	Construction & Materials Divisions (Central Office)
product inspections	Materials Division (Districts)
prestressed concrete girders	Materials Division (Districts)
camber data	Materials Division (Districts)
prestressed concrete piles	Materials Division (Districts)
steel piles	Materials Division (Districts)
daily reports	Districts
material certifications	Materials Division (Districts)
pile testing data	Districts
pile driving records	Districts
geotechnical data	Districts, Geotechnical Group
material testing	Districts
as-built drawings	Districts
shop drawings	Bridge Division, Materials Division (Districts)
working drawings	Bridge Division, Materials Division (Districts)
bridge inspection/element level condition data	Bridge Division, Districts (Bridge Inspection Personnel)
chloride content/corrosion data	Bridge Division, Districts
non-destructive evaluation (NDE)	Bridge Division, Districts
structural health monitoring/instrumentation	Bridge Division, Districts
UAV/drones	Bridge Division, Districts
scour data	Bridge Division, Districts
maintenance	Districts
bridge repairs	Bridge Division, Districts
GIS data	Information Systems Division

Central Office and District staff use various forms to collect project information and/or as-built data. Project data is stored at the District level and uploaded to various MDOT Software Applications (e.g. ProjectWise, AssetWise/InspectTech, AASHTOWare/Site Manager, AMMO, Bridge Division Server, or Oracle Database). ProjectWise is used by MDOT to manage projects and includes project information.

MDOT's current bridge inspection software is InspecTech. Bridge Inspections are performed by District Bridge Inspection staff. Bridge data elements and quantity data is collected during the bridge inspections in compliance with National Bridge Inspection Standards (NBIS). MDOT's State Bridge Inspection Program Manager Richard Withers is located in Central Office. InspecTech software is used to collect bridge element level inspection data. The data is collected in the field on paper and transferred into InspectTech. MDOT integrated AssetWise in June 2019, which integrates bridge inspection information collected through InspecTech. District Bridge Inspectors also use an application located on the bridge server for taking stream/groundline soundings during bridge inspections. This app/form is then input into InspectTech.

One commonly used application for maintenance management is MDOT's accountability in MDOT Maintenance Operations, commonly referred to as AMMO. AMMOT is primarily used for daily operations, support of maintenance and business processes, and reporting. A bridge maintenance work order and Inspection of Prestressed Concrete Bridge Members form is used by District staff and uploaded to AMMO. District staff also collects a daily pour log. Districts use AMMO software to create work orders for bridge maintenance and bridge preservation activities and District maintenance analysist assists with pavement and bridge asset information contained in AMMO software. Each bridge asset is assigned an asset identification number. Districts perform interim bridge inspections associated with generating major bridge repair work orders and documents the information in InspectTech bridge inspection software (e.g. hydro-demolition of existing bridge deck with new overlay). There is a difference between typical bridge maintenance activities and bridge repairs. Bridge repairs are usually coordinated with the Bridge Division and are typically performed by Contractors and not District personnel. InspectTech bridge inspection software maintains records of the bridge repairs. Costs for the repairs are not maintained in InspectTech. District staff does maintain maintenance costs, but by the task/number maintained in the AAMO software rather than by bridge. All bridge maintenance activities and bridge repairs are stored in AMMO. Site Manager and AMMO are currently not in NBIS element level/specific data format.

Site Manager and AMMO are utilized by MDOT District construction and materials staff to upload bridge assets/data element information. District Materials provides inspection and/or certification of bridge data elements consisting of girders, piles, concrete pour reports, and documents inspections and/or certifications on various forms that are uploaded to MDOT's Site Manager software. District materials staff uploads materials information to Site Manager also and uses a QC/QA spreadsheet to record concrete strength, slump, and air. This information resides in SiteManager and/or on file at the MDOT Field Office at the Concrete Girder Manufactures/Producer's Yard.

There is a spreadsheet in Site Manager used by District Project Engineers to record material information for cast-in-place decks and other cast-in-place bridge elements. Information entered into Site Manager is by project number rather than by bridge identification number.

Project office records (e.g. pile driving records, test pile information) is recorded by District Project Engineers and is passed onto the Bridge Division and is stored in either ProjectWise or the Bridge server.

Site Manager is used to store project daily reports, quantities, and project testing data prepared by MDOT Construction staff. Project records include material certifications. A FMS number is assigned to projects from which project records are filed under. Precast bridge elements consisting of bridge beams/girders, concrete piles, and steel piles are inspected by District Quality Assurance (QA) staff. Data is uploaded to Site Manager.

Geotechnical boring materials data for bridges are handled out of the central office materials lab. Test pile data is recorded by the Project Office staff located in the Districts. Pile records are uploaded to ProjectWise. MDOT's Geotechnical Group collects pile driving analysis (PDA) data.

District construction staff record as-built bridge drawings and upload them to MDOT's Site Manager software and send as-built bridge drawings to central records managed by MDOT's Information Systems Divisions (via MDOT's At-Work Intranet).

As-built drawings for construction contracts are scanned into Projectwise by Roadway Design Division after being submitted by the Project Engineer. Records such as pay item calculations and project diaries are housed in Site Manager. Existing bridge drawings/plans and bridge location maps are stored on the Bridge Division Server.

Unmanned Ariel Vehicles (UAV)/drones are being used to monitor areas after post-storm events and assist with hydraulic data. Unmanned Ariel Vehicles (UAV)/drones are also being used to monitor slides, collect project hydraulics information, and review environmental commitments on various projects.

MDOT's Information Systems Division manages GIS information related to bridge assets.

MDOT's Survey Group provides construction staking information on projects and MDOT has a Pay Item for this work. Elevations and/or construction staking information associated with MDOT's bridge assets/data elements are recorded on project drawings in the form of as-built information.

MDOT's Contract Administration Division checks the pay item calculations and project diaries when submitted with the final documentation.

The following bridge data element information gets coordinated between the Bridge Design Division and Districts: precast/prestressed concrete beam strengths, cast-in-place concrete deck strengths, pile driving records, project letting information, and bridge paint information.

At the time of the research, Site Manager was scheduled to be replaced with AASHTOWare, but no firm schedule commitment dates were provided.

The following Figure 2 represents the various software used by MDOT associated with bridge data elements.

Figure 2 – Software used by MDOT Associated with Data Elements

Recommendations for Additions & Filling Data Gaps

The majority of data elements that are collected and managed specific to bridge design, materials, construction, inspection, and maintenance fall under the element level as defined in publications for national bridge inspection standards. The original Report No. FHWA-PD-96-001 published by the U.S. Department of Transportation Federal Highway Administration was titled "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges." As outlined in the Introduction of the report, this Guide has been prepared for use by the States, Federal, and other agencies in recording and coding the data elements that will comprise the National Bridge Inventory data base. By having a complete and thorough inventory, an accurate report can be made to the Congress on the number and state of the Nation's bridges. The Guide also provides the data necessary for the Federal Highway

Administration (FHWA) and the Military Traffic Management Command to identify and classify the Strategic Highway Corridor Network and its connectors for defense purposes.

The coded items in this Guide are considered to be an integral part of the data base that can be used to meet several Federal reporting requirements, as well as part of the States' needs. These requirements are set forth in the National Bridge Inspection Standards (23 CFR 650.3) which are included as Appendix C. A complete, thorough, accurate, and compatible data base is the foundation of an effective bridge management system. Reports submitted in connection with the Highway Bridge Replacement and Rehabilitation Program and the National Bridge Inspection Program also are related to this Guide.

The AASHTO Manual for Condition Evaluation of Bridges discusses the various items of information that are to be recorded as part of original bridge reports. That manual and the Bridge Inspector's Training Manual/90, with supplements, discuss inspection procedures and the preparation of detailed reports about the structure components. These reports will be the basis for recording values for many of the data elements shown in the Guide, particularly those having to do with the condition or the appraisal ratings.

Some bridge owners are collecting bridge condition ratings for items included in this Guide (Items 58-Deck, 59-Superstructure, 60-Substructure, and 62-Culverts) using the American Association of Highway and Transportation Officials' (AASHTO) Guide for Commonly Recognized (CoRe) Structural Elements. CoRe element inspection ratings provide detailed condition assessments that can serve as input into a comprehensive bridge management system (BMS). The FHWA has provided bridge owners with a computer program for translating bridge condition data in the CoRe element format to National Bridge Inventory (NBI) condition ratings for the purpose of NBI data submittal to FHWA. The purpose of the program is to permit bridge inspectors to record condition information in a format that satisfies both BMS and NBI data collection requirements.

The Structure Inventory and Appraisal (SI&A) Sheet and the sufficiency rating formula, with examples, are included as Appendices A and B, respectively. The SI&A sheet is intended to be a tabulation of the pertinent elements of information about an individual structure. Its use is optional, subject to the statements in the preceding paragraph of this Introduction. It is important to note that the SI&A Sheet is not an inspection form but merely a summary sheet of bridge data required by the FHWA to effectively monitor and manage a National bridge program.

States, Federal, and other agencies are encouraged to use the codes and instructions in this Guide. However, its direct use is optional; each agency may use its own code scheme provided that the data are directly translatable into the Guide format. When data is requested by FHWA, the format will be based on the codes and instructions in the Guide. An agency choosing to use its own codes shall provide translation or conversion of its own codes into those used in the

Guide. In other words, agencies are responsible for having the capability to obtain, store, and report certain information about bridges whether or not this Guide or the SI&A Sheet is used. Any requests by the FHWA for submittal of data will be based on the definitions, explanations, and codes supplied in the Guide, the AASHTO Manual for Condition Evaluation of Bridges, and the Bridge Inspector's Training Manual/90 plus supplements.

The values provided in the tables or otherwise listed in this Guide are for rating purposes only. Current design standards must be used for structure design or rehabilitation. All possible combinations of actual site characteristics are not provided in this Guide. If a special situation not listed in the Guide is encountered, the evaluation criteria closest to the actual site situation should be used.

The implementation of this Guide may require some restructuring of an agency's data base and support software. If so, it is suggested that the agency consider the additional enhancements that would be necessary to support a bridge management system.

Appendix D is a Commentary that compares, item by item, the 1988 Guide to this Guide. The Commentary will provide a ready reference for item changes.

A few definitions of terms relevant to the research taken from the Guide include:

> **Bridge**. The National Bridge Inspection Standards published in the Code of Federal Regulations (23 CFR 650.3) give the following definition:
>
> A structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 feet between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening.
>
> **Commonly Recognized (CoRe) Structural Elements**. A group of structural elements endorsed by AASHTO as means of providing a uniform basis for data collection for any bridge management system, to enable the sharing of data between States, and to allow for a uniform translation of data to NBI Items 58, 59, 60, and 62.
>
> **Bridge Management System (BMS)**. A system designed to optimize the use of available resources for the inspection, maintenance, rehabilitation, and replacement of bridges.

AASHTO's <u>The Manual for Bridge Evaluation</u> emphasizes the importance of maintaining Bridge Records and Bridge Management Systems. Section 2: Bridge Files (Records) states: "Bridge Owners should maintain a complete, accurate, and current record of each bridge under their jurisdiction. Complete information, in good usable form, is vital to the effective management of bridges. Furthermore, such information provides a record that may be important for repair, rehabilitation, or replacement.

A bridge record contains the cumulative information about an individual bridge. It should provide a full history of the structure, including details of any damage and all strengthening and repairs made to the bridge. The bridge record should report data on the capacity of the structure, including the computations substantiating reduced load limits, if applicable.

A bridge file describes all of the bridges under the jurisdiction of the Bridge Owner. It contains on bridge record for each bridge and other general information that applies to more than one bridge.

Items that should be assembled as part of the bridge record are discussed in Article 2.2. Information about a bridge may be subdivided into three categories: base data that is normally not subject to change, data that is updated by field inspection, and data that is derived from the base and inspection data. General requirements for these three categories of bridge data are presented in Articles 2.3, 2.4, and 2.5, respectively.

Some or all of the information pertaining to a bridge may be stored in electronic format as part of a bridge management system. When both electronic and paper formats are used for saving data, they should be cross-referenced to ensure that all relevant data are available to the inspector or evaluator."

Further, AASHTO's The Manual for Bridge Evaluation Section 3: Bridge Management Systems states: "Transportation agencies must balance limited resources against increasing bridge needs of an aging highway system. The best action for each bridge, considered alone, is not necessarily the best action for the bridge system when faced with funding constraints. The best action to take on a bridge cannot be determined without first determining the implications from a system-wide perspective. Bridge engineers, administrators, and public officials have acknowledged the need for new analytical methods and procedures to assess the current and future conditions of bridges and to determine the best possible allocation of funds within a system of bridges among various types of bridge maintenance, repair, rehabilitation, and replacement choices. The advent of Bridge Management Systems (BMS) is a response to this need.

Bridge Management Systems require the data and results from condition evaluation. The aim of this Section is to provide an overview of BMS and discuss their essential features."

In 2005, AASHTO Highways Subcommittee on Bridges and Structures adopted *The Manual for Bridge Evaluation, First Edition (MBE)*. The MBE combines *The Manual for Condition Evaluation of Bridges, Second Edition*, and its 2001 and 2003 *Interim Revisions with the Guide Manual for Condition Evaluation and Load and Resistance Factor Rating of Highway Bridges, First Edition*, and its 2005 Interim Revisions. Revisions based on approved agenda items from annual AASHTO Subcommittee meetings in 2007 and 2008 are also incorporated into the MBE.

The importance of the adoption of the MBE is that element level condition data is now required to be collected and reported. Section 3.3.1.1.1-Bridge Inventory of the MBE states: "The National Bridge Inventory (NBI) is data collected by each state Department of Transportation (DOT) and reported to the Federal Highway Administration (FHWA). The data includes inventory, appraisal, and condition information for the nation's highway bridges. NBI data includes component and element level condition data. Bridge owners may also have agency specific bridge inventory data that they use in their BMS." Further, Section 3.3.1.1.3-Bridge Element Ratings states: "To meet the data needs of a modern BMS, AASHTO developed an element level condition assessment system. Bridge elements comprised of National Bridge Elements (NBEs), Bridge Management Elements (BMEs), and Agency-Defined Elements (ADEs) are defined in the AASHTO Manual for Bridge Element Inspection (MBEI). The goal of bridge element data is to completely capture the condition of bridges in a simple and effective way that can be standardized across the nation while providing the flexibility to be adapted to both large and small agency settings. Element descriptions consider material composition and where applicable, the presence of protective systems. The condition of each element is reported according to the quantity or percentage of the element rated in four Condition States (CS): CS 1-Good, CS2-Fair, CS3-Poor, and CS4-Severe. The MBEI defines the condition states in objective engineering terms that are intended to provide consistent ratings nationwide. All National Bridge Elements and a select number of Bridge Management Elements on the National Highway System (NHS) are reported to the FHWA to develop bridge condition reports to the United States Congress. Using element level data, DOTs and local bridge owners can better evaluate individual components of a structure, determine and prioritize preservation needs, and estimate cost for projects."

Also, Section 4.2.6-Collection of Element Level Data of the MBE states: "Federal regulations (MAP-21) require element level data to be collected and transmitted to the FHWA for highway bridges on the National Highway System (NHS). In addition to federal mandated minimum requirements, Bridge Owners may record additional element level data for bridges on the HNS to suit individual needs. Collection of element level data for bridges off the NHS is at the Bridge Owner's discretion. Develop and implement procedures to collect element level data for bridges on the NHS in accordance with the AASHTO *Manual for Bridge Element Inspection*. Develop and implement standardized Element Level inspections of HNS bridges, following procedures identified in the AASHTO *Manual for Bridge Element Inspection*."

MDOT is in compliance with the National Bridge Inspection standard requirements and is collecting, recording, and submitting the necessary bridge information outlined in the National Bridge Inspection Standards.

The research did not find any data gaps in the data elements currently collected and managed by MDOT associated with bridge design, materials, construction, inspection, and maintenance. Therefore, no recommendations are given.

In the future, if MDOT does find new or supplemental Agency-Specific data elements of interest, then MDOT can supplement the National Bridge Elements (NBE) with Agency Defined Elements (ADE) accordingly.

Definition of Metadata for Added Elements

Metadata can be defined as all of the data used to describe an asset. Since the research did not find any gaps in MDOT's current data elements for bridge design, materials, construction, inspection, and maintenance, there are no added data elements; therefore no metadata for added elements.

Conclusions

1. The literature review revealed numerous co-related topics that are associated with data elements for bridge design, materials, construction, inspection, and maintenance. This research topic is very broad and includes many aspects associated with bridge data elements that span across multiple organization entities within a State DOT agency. This creates both a challenge and opportunity for MDOT and other State DOT agencies to document how their organizations are currently operating related to bridge data elements and how bridge data elements are managed.
2. The AASHTO RAC National Survey provided insight that other State DOT agencies are:
    a. Documenting and managing data elements mainly as defined in the National Bridge Elements (NBEs) or in addition to NBEs, agency defined bridge elements (ADEs) are collected and managed. All bridge data element information is stored through a combination of software applications, database, or agency-wide document management systems.
    b. Utilizing agency specific software, spreadsheets, databases, website, or system shared drives, internal transportation management systems, and AASHTOWare.
    c. Nine of the AASHTO members do not have a data governance or data asset oversight group; four have, and one DOT is in the process of establishing a data governance or data asset oversight group. Collectively the various State DOT agencies are collaborating among their management teams together with their bridge program leaders for bridge data element decisions.
3. MDOT is currently managing their data elements for bridge design, materials, construction, inspection, and maintenance throughout their respective Divisions and Districts including support from the Geotechnical and Survey Groups. The collection and documentation of the data elements get uploaded to several different applications that have their own access and functionality.
4. There are day-to-day activities and responsibilities within MDOT by each of the respective Divisions, Districts, and Groups personnel associated with Bridge Data Elements that is a very important component to the MDOT Managing their overall Transportation Program. Close collaboration between these staff is a vital role and will continue to be a vital role in the future. Therefore, a clear understanding and documentation of the various data elements for bridge design, materials, construction, inspection, and maintenance should be a top priority.
5. Based on the research findings and recommendations, the following benefits are realized:
    a. More consistent and meaningful data elements will result in more efficient bridge designs and ratings, construction, maintenance, bridge inspections, and materials.

b. Capturing these elements and their metadata will immediately yield knowledge capture benefits, which will aid the passing of institutional knowledge and on-boarding new employees.
c. Improved understanding of bridge data elements managed by MDOT.
d. Improved connectivity and relationships to existing body of knowledge specific to bridge data elements. MDOT completed a study in April 2019 regarding Best Practices in Estimating Camber of Bulb T and Florida Girders (State Study 288).
e. Improved access to as-built and historic bridge data element information.
f. Added clarity to the MDOT staff associated with the various bridge data elements.
g. Through documenting the various bridge data elements, software used, and organization of MDOT staff associated with bridge data elements, improved consistency, access, staff productivity, communication, data collection, workflows and procedures, and quality is realized.

Recommendations

The following recommendations are provided for consideration by MDOT.

1. Streamline access to bridge data elements by providing access for District staff to bridge data elements in ProjectWise and/or other software.
2. Ppload prestressed girder and pile manufacture product records into MDOT's Site Manager or other software.
3. Look for ways to streamline access to historic bridge data element information and workflows.
4. Eliminate historic project records and new project records located on multiple software platforms.
5. Provide access to ProjectWise for all MDOT staff.
6. Create a user manual/reference guide for MDOT staff associated with bridge data elements.
7. Instead of entering bridge data element information into Site Manager and/or other MDOT databases by project number, enter the associate bridge data element information according to each Bridge Identification Number (BIN).
8. Link all materials data/information associated with bridge assets into one report.
9. Link all bridge cost information to each bridge asset.
10. Have a single report associated for each bridge asset that includes all bridge records including data elements.
11. Include the bridge identification number (BIN) on all bridge records/reports/forms/inspection data and AMMO maintenance activities.
12. Bridge Division to assign bridge identification number and include with all project plans/drawings.
13. In addition to national bridge elements (NBE), make a list of additional agency defined elements (ADE).
14. Document institutional knowledge within MDOT related to Bridge Data Elements.

Implementation Plan

MDOT will implement recommendations to streamline data elements for bridge design, materials, construction, inspection, and maintenance. This could result in specification updates, addition of data elements to bridge inspection criteria and/or project records, and possibly data to feed performance prediction models. Training and knowledge-base transfer of data element information could also be integrated into MDOT's Operating Procedures.

References

AASHTO The Manual for Bridge Evaluation

AASHTO Transportation Asset Management Guide

AASHTO Maintenance Manual for Roadways and Bridges

AASHTO LRFD Bridge Design Specifications

AASHTO Committee on Bridges and Structures, T-9 Bridge Preservation, T-18 Bridge Management Evaluation & Rehabilitation, and T-19 Software & Technology

Bridges for Service Life Beyond 100 Years (SHRP 2 Report S2-R19A-RW-1)

Design Guide for Bridges for Service Life (SHRP 2 Report S2-R19A-RW-2)

FHWA Bridge Preservation Guide, August 2011, FHWA-HIF-11042

FHWA Bridge Preservation Guide, Spring 2018, FHWA-HIF-18-022

FHWA Life Cycle Planning-An Overview

FHWA Service Life Design for Bridges (R19A) MDOT Bridge Safety Inspection Policy and Procedure Manual

Moving Ahead for Progress in the 21st Century Act (MAP-21), A Summary of Highway Provisions

MDOT Bridge Design Manual

MDOT Bridge Design Memorandum

MDOT Bridge Safety Inspection Policy and Procedure Manual

MDOT Construction Manual

MDOT Materials Division Inspection, Testing, and Certification Manual

MDOT Project Development Manual for Local Public Agencies

Mississippi Standard Specifications for Road and Bridge Construction

Mississippi Transportation Asset Management Plan, August 2019

NCHRP 12-108, Guide Specification for Service Life Design of Highway Bridges

NCHRP, Bridge Life-Cycle Cost Analysis, Report 483

NCHRP Synthesis 439, Use of Transportation Asset Management Principles in State Highway Agencies, A Synthesis of Highway Practice

NCHRP Synthesis 508, Data Management and Governance Practices, A Synthesis of Highway Practice

Transportation Research Board, AHD30 Structures Maintenance Committee, AHD35 Bridge Management Committee, and AHD37 Bridge Preservation Committee

U.S. Department of Transportation Federal Highway Administration, Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges, Report No. FHWA-PD-96-001, Office of Engineering Bridge Division, December 1995.

Appendices

A. Literature Review

    A-1 Literature Review Document

B. AASHTO RAC Survey

    B-1 Survey Results

Appendix A

Literature Review

A-1

Literature Review Document

List of literature review documents (as of 2-27-20) with summary of aspects relative to the MDOT Data Elements research study.

1. Durability of Lightweight Concrete Bridges
   Reid W. Castrodale, PhD, PE and Kenneth S. Harmon, PE
   PCI-FHWA National Bridge Conference, Proceedings Paper 48/October 5-7, 2008
   Provides overview to lightweight concrete and lightweight aggregates characteristics that make it a durability option for concrete bridges.
2. Sand Lightweight Concrete For Prestressed Concrete Girders in Three Washington State Bridges
   Reid W. Castrodale, PhD, PE and David D. Chapman, PE
   2016 PCI-FHWA National Bridge Conference
   Covers three projects constructed in Washington State that used high-strength sand lightweight concrete for precast/prestressed concrete girders. Material property data was collected and presented along with reasons why high-strength sand lightweight concrete was used.
3. Bridge Preservation
   David A. Tomley, PE and Andrea Moore
   Presentation given at PCI Gulf South Transportation Committee meeting with MDOT, Jackson MS, November 6, 2019
   Highlighted the benefits to implementing bridge preservation strategies backed by a financial analysis to justify future and/or initial expenditures. Bridge preservation strategies can lead to reduced annual bridge costs and/or reduced bridge funding requirements/backlog. Other topics of corrosion mitigation, abrasion resistance, service-life, life-cycle planning/analysis/costs, bridge maintenance, bridge repairs, and new bridge construction were covered.
4. Mississippi Department of Transportation Public Accountability Transportation Hub (PATH)
   https://path.mdot.ms.gov/
   Website that provides an interactive visual analysis of historical and current conditions of roads and bridges throughout the state of Mississippi.
5. AASHTO LRFD Bridge Design Specifications
   Section 2.5.2-Serviceability & Section 2.5.2.1-Durability & Section 2.5.2.1.1-Materials including Commentary C2.5.2.1.1

C2.5.2.1.1

The intent of this Article is to recognize the significance of corrosion and deterioration of structural materials to the long-term performance of a bridge. Other provisions regarding durability can be found in Article 5.12.

Other than the deterioration of the concrete deck itself, the single most prevalent bridge maintenance problem is the disintegration of beam ends, bearings, pedestals, piers, and abutments due to percolation of waterborne road salts through the deck joints. Experience appears to indicate that a structurally continuous deck provides the best protection for components below the deck. The potential consequences of the use of road salts on structures with unfilled steel decks and unprestressed wood decks should be taken into account.

These Specifications permit the use of discontinuous decks in the absence of substantial use of road salts. Transverse saw-cut relief joints in cast-in-place concrete decks have been found to be of no practical value where composite action is present. Economy, due to structural continuity and the absence of expansion joints, will usually favor the application of continuous decks, regardless of location.

Section 2.5.2.3-Maintainability

2.5.2.3—Maintainability

Structural systems whose maintenance is expected to be difficult should be avoided. Where the climatic and/or traffic environment is such that a bridge deck may need to be replaced before the required service life, provisions shall be shown on the contract documents for:

- a contemporary or future protective overlay,
- a future deck replacement, or
- supplemental structural resistance.

Areas around bearing seats and under deck joints should be designed to facilitate jacking, cleaning, repair, and replacement of bearings and joints.

Jacking points shall be indicated on the plans, and the structure shall be designed for jacking forces specified in Article 3.4.3. Inaccessible cavities and corners should be avoided. Cavities that may invite human or animal inhabitants shall either be avoided or made secure.

C2.5.2.3

Maintenance of traffic during replacement should be provided either by partial width staging of replacement or by the utilization of an adjacent parallel structure.

Measures for increasing the durability of concrete and wood decks include epoxy coating of reinforcing bars, post-tensioning ducts, and prestressing strands in the deck. Microsilica and/or calcium nitrite additives in the deck concrete, waterproofing membranes, and overlays may be used to protect black steel. See Article 5.14.2.3.10e for additional requirements regarding overlays.

Section 2.6.2-Site Data

"A site-specific data collection plan shall include consideration of:

- Collection of aerial and/or ground survey data for appropriate distances upstream and downstream from the bridge for the main stream channel and its floodplain;
- Estimation of roughness elements for the stream and the floodplain within the reach of the stream under study;

- Sampling of streambed material to a depth sufficient to ascertain material characteristics for scour analysis;
- Subsurface borings;
- Factors affective water stages, including high water from streams, reservoirs, detention basins, tides, and flood control structures and operating procedures;
- Existing studies and reports, including those conducted in accordance with the provisions of the National Flood Insurance Program or other flood control programs;
- Available historical information on the behavior of the steam and the performance of the structure during past floods, including observed scour, bank erosion, and structural damage due to debris or ice flows; and
- Possible geomorphic changes in channel flow.

Section 5.12-Durability

5.12—DURABILITY

5.12.1—General

Concrete structures shall be designed to provide protection of the reinforcing and prestressing steel against corrosion throughout the life of the structure.

Special requirements that may be needed to provide durability shall be indicated in the contract documents. Portions of the structure shall be identified where:

- Air-entrainment of the concrete is required,
- Epoxy-coated or galvanized reinforcement is required,
- Special concrete additives are required,
- The concrete is expected to be exposed to salt water or to sulfate soils or water, and
- Special curing procedures are required.

Protective measures for durability shall satisfy the requirements specified in Article 2.5.2.1.

C5.12.1

Design considerations for durability include concrete quality, protective coatings, minimum cover, distribution and size of reinforcement, details, and crack widths. Further guidance can be found in ACI Committee Report 222 (ACI, 1987) and Posten et al. (1987).

The principal aim of these Specifications, with regard to durability is the prevention of corrosion of the reinforcing steel. There are provisions in *AASHTO LRFD Bridge Construction Specifications* for air-entrainment of concrete and some special construction procedures for concrete exposed to sulfates or salt water. For unusual conditions, the contract documents should augment the provisions for durability.

The critical factors contributing to the durability of concrete structures are:

- Adequate cover over reinforcement,
- Nonreactive aggregate-cement combinations,
- Thorough consolidation of concrete,
- Adequate cement content,
- Low *W/C* ratio, and
- Thorough curing, preferably with water.

The use of air-entrainment is generally recommended when 20 or more cycles of freezing and thawing per year are expected at the location and exposure. Decks and rails are most vulnerable, whereas buried footings are seldom damaged by freeze-thaw action.

Sulfate soils or water, sometimes called alkali, contain high levels of sulfates of sodium, potassium, calcium, or magnesia. Salt water, water soluble sulfate in soil above 0.1 percent or sulfates in water above 150 ppm justify use of the special construction procedures called for in *AASHTO LRFD Bridge Construction Specifications*. These include avoidance of

5.12.3—Concrete Cover

Revise table 1 of this Article as follows:

Table 5.12.3-1—Cover for Unprotected Main Reinforcing Steel (in.)

Situation	Cover (in.)
Direct exposure to salt water	4.0
Cast against earth	3.0
Coastal	3.0
Exposure to deicing salts	2.5
Deck surfaces subject to tire stud or chain wear	2.5
Exterior other than above	2.0
Interior other than above • Up to No. 11 bar • No. 14 and No. 18 bars	 1.5 2.0
Bottom of cast-in-place slabs • Up to No. 11 bar • No. 14 and No. 18 bars	 1.0 2.0
Precast soffit form panels	0.8
Precast reinforced piles • Noncorrosive environments • Corrosive environments	 2.0 3.0
Precast prestressed piles	2.0
Cast-in-place piles • Noncorrosive environments • Corrosive environments o General o Protected • Shells • Auger-cast, tremie concrete, or slurry construction	 2.0 3.0 3.0 2.0 3.0
Precast concrete box culverts • Top slabs used as a driving surface • Top slabs with less than 2 ft of fill not used as a driving surface • All other members	 2.5 2.0 1.0

construction joints between the levels of low water and the upper limit of wave action. For sulfate contents above 0.2 percent in soil or 1,500 ppm in water, special concrete mixes may be justified. Further guidance may be found in ACI 201 or the *Concrete Manual* (1981).

5.12.2—Alkali-Silica Reactive Aggregates

The provisions of *AASHTO LRFD Bridge Construction Specifications* Article 8.3.4 shall apply.

5.12.3—Concrete Cover

Cover for unprotected prestressing and reinforcing steel shall not be less than that specified in Table 5.12.3-1 and modified for *W/C* ratio, unless otherwise specified either herein or in Article 5.12.4.

Concrete cover and placing tolerances shall be shown in the contract documents.

Cover for pretensioned prestressing strand, anchorage hardware, and mechanical connections for reinforcing bars or post-tensioned prestressing strands shall be the same as for reinforcing steel.

Cover for metal ducts for post-tensioned tendons shall not be less than:

- That specified for main reinforcing steel,
- One-half the diameter of the duct, or
- That specified in Table 5.12.3-1.

For decks exposed to tire studs or chain wear, additional cover shall be used to compensate for the expected loss in depth due to abrasion, as specified in Article 2.5.2.4.

Modification factors for *W/C* ratio shall be the following:

- For $W/C \leq 0.40$ 0.8
- For $W/C \geq 0.50$ 1.2

Minimum cover to main bars, including bars protected by epoxy coating, shall be 1.0 in.

Cover to ties and stirrups may be 0.5 in. less than the values specified in Table 5.12.3-1 for main bars but shall not be less than 1.0 in.

C5.12.3

The concrete cover modification factor used in conjunction with Table 5.12.3-1 recognizes the decreased permeability resulting from a lower *W/C* ratio.

Minimum cover is necessary for durability and prevention of splitting due to bond stresses and to provide for placing tolerance.

Table 5.12.3-1—Cover for Unprotected Main Reinforcing Steel (in.)

Situation	Cover (in.)
Direct exposure to salt water	4.0
Cast against earth	3.0
Coastal	3.0
Exposure to deicing salts	2.5
Deck surfaces subject to tire stud or chain wear	2.5
Exterior other than above	2.0
Interior other than above • Up to No. 11 bar • No. 14 and No. 18 bars	 1.5 2.0
Bottom of cast-in-place slabs • Up to No. 11 bar • No. 14 and No. 18 bars	 1.0 2.0
Precast soffit form panels	0.8
Precast reinforced piles • Noncorrosive environments • Corrosive environments	 2.0 3.0
Precast prestressed piles	2.0
Cast-in-place piles • Noncorrosive environments • Corrosive environments - General - Protected • Shells • Auger-cast, tremie concrete, or slurry construction	 2.0 3.0 3.0 2.0 3.0

5.12.4—Protective Coatings

Protection against chloride-induced corrosion may be provided by epoxy coating or galvanizing of reinforcing steel, post-tensioning duct, and anchorage hardware and by epoxy coating of prestressing strand. Cover to epoxy-coated steel may be as shown for interior exposure in Table 5.12.3-1.

C5.12.4

Specifications for acceptable epoxy coatings are included in the materials section of *AASHTO LRFD Bridge Construction Specifications*.

5.12.5—Protection for Prestressing Tendons

Ducts for internal post-tensioned tendons, designed to provide bonded resistance, shall be grouted after stressing. Other tendons shall be permanently protected against corrosion and the details of protection shall be indicated in the contract documents.

C5.12.5

In certain cases, such as the tieing together of longitudinal precast elements by transverse post-tensioning, the integrity of the structure does not depend on the bonded resistance of the tendons, but rather on the confinement provided by the prestressing elements. The unbonded tendons can be more readily inspected and replaced, one at a time, if so required.

External tendons have been successfully protected by cement grout in polyethylene or metal tubing. Tendons have also been protected by heavy grease or other anticorrosion medium where future replacement is envisioned. Tendon anchorage regions should be protected by encapsulation or other effective means. This is critical in unbonded tendons because any failure of the anchorage can release the entire tendon.

Section 5.14.2.3.10e-Overlays

5.14.2.3.10e—Overlays

Overlays shall be considered for all bridge decks exposed to freeze thaw cycles and application of deicing chemicals. The governing authority should consider providing additional protection against penetration of chlorides. For all types of segmental bridges (precast and cast-in-place), it is recommended that this additional protection be provided by the addition of a minimum of 1.5 in. of concrete cover, added as an overlay or alternatively a waterproof membrane with bituminous overlay. The governing authority may require specific materials and placement techniques stipulated by local practices.

C5.14.2.3.10e

Overlays are encouraged instead of the inclusion of additional monolithic concrete because an overlay will add protection at the critical segment joint. Delamination of overlays is generally due to poor installation practices or material selection and can be resolved. It is not recommended that the additional cover be obtained by merely increasing concrete covers. The added cover will not add protection across the segment joint which is the area of most concern due to the ability of the water to migrate to the tendon and reinforcement.

Careful attention to detail is required when using overlays to assure the proper railing heights are obtained. All railings next to deck areas to be overlayed should be detailed from the top of the overlay.

The need to remove and replace the overlay can be based on measurement of chloride penetration into the overlay. Use of high performance concrete is an effective means of minimizing chloride penetration into concrete.

Bridges located in other corrosive environments, such as coastal bridges over salt water, should be evaluated for the need for additional protection.

6. Best Practices for Estimating Camber of Bulb T and Florida Girders, April 1, 2019
   David A. Tomley, P.E., MSCE
   Mississippi Department of Transportation State Study No. 288 (FHWA/MDOT-RD-19-288)
   MDOT has experienced under-camber prestressed concrete girders recently on several projects that have led to construction delays and/or increased construction costs. The need to address current practices for estimating beam camber were addressed through; literature search, survey of other State DOT current practices, historic material and beam camber data provided by the Mississippi Concrete Girder Manufacturers, and camber estimate calculations for items that influence beam camber. The research findings included improvements to; better understanding of beam camber, material property versus strength expectation, ride smoothness, increased Industry awareness, advancing MDOT’s current practices, enhancing MDOT’s database of

historic material and beam camber information, reducing design and/or functional modifications to MDOT projects, minimizing added project and infrastructure costs, and reducing delays during construction.

7. Best Practices for Estimating Camber of Bulb T and Florida Girders Technical Brief, April 2019
8. Mississippi Department of Transportation Bridge Safety Inspection Policy and Procedure Manual
   Chapter 3-Bridge Inspection File (Records)
   3.1 Purpose of Bridge Records
   “As bridge inspection files are updated, the existing information is archived and retained to establish a history for each bridge. Each district shall maintain a complete, accurate, and up-to-date record for each bridge under their jurisdiction. These records are needed to:
   - Document the condition and functionality of infrastructure, including the need and justification for bridge restrictions, for public safety.
   - Document improvements and maintenance repairs performed.

All bridge records, at a minimum, should meet the requirements of Section 2.1 of the AASHTO MBE, which states the following:

> Bridge Owners should maintain a complete, accurate and current record of each bridge under their jurisdiction. Complete information, in good usable form, is vital to the effective management of bridges. Furthermore, such information provides a record that may be important for repair, rehabilitation, or replacement.
>
> A bridge record contains the cumulative information about an individual bridge. It should provide a full history of the structure, including details of any damage and all strengthening and repairs made to the bridge. The bridge record should report data on the capacity of the structure, including the computations substantiating reduced load limits, if applicable.
>
> A bridge file describes all of the bridges under the jurisdiction of the Bridge Owner. It contains one bridge record for each bridge and other general information which applies to more than one bridge.

3.2 Components of Bridge Records

18. Repair plans

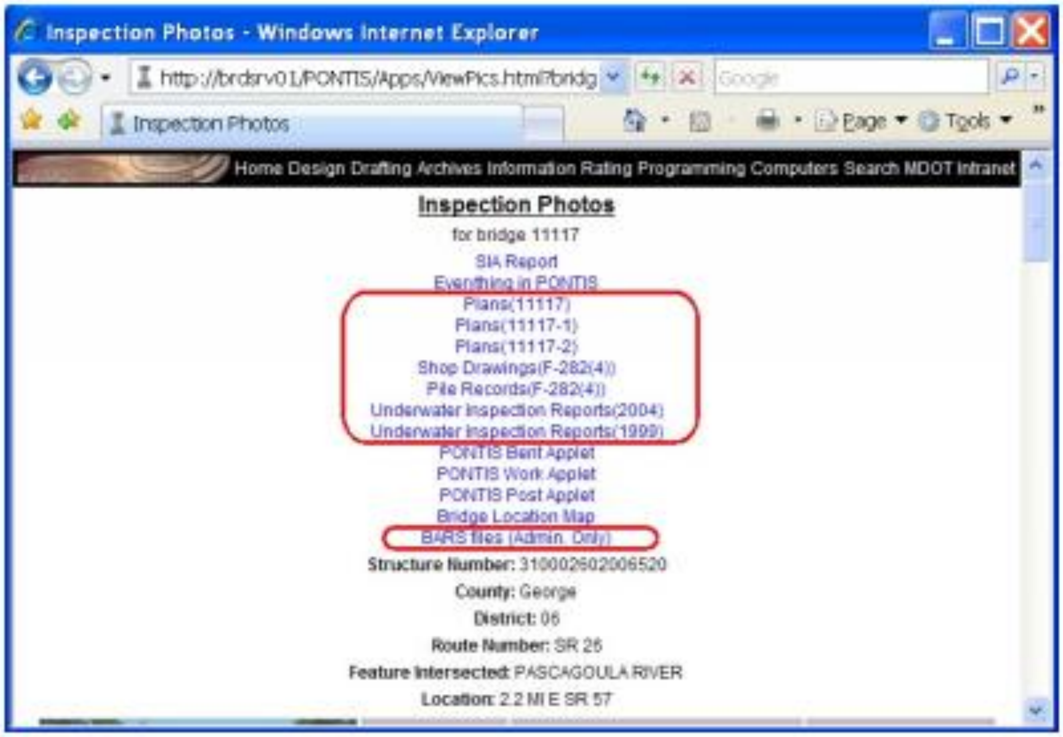


Figure 4 – MDOT Bridge Intranet Site

4.1 MDOT Load Rating and Posting Policy
"For each load rating analysis, a summary sheet, full documentation of the load rating computations, and any supporting information shall be provided and maintained in the bridge record for the life of the structure".

9. U.S. Department of Transportation Federal Highway Administration Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges, Report No. FHWA-PD-96-001, December 1995.
10. AASHTO, The Manual for Bridge Evaluation, Third Edition 2018
    Section 2: Bridge Files (Records)

2.2.1—Plans

2.2.1.1—Construction Plans

Each bridge record should include one full-size or clear and readable reduced-size set of all drawings used to construct or repair the bridge.

2.2.1.2—Shop and Working Drawings

Each bridge record should include one set of all shop and working drawings approved for the construction or repair of the bridge.

2.2.1.3—As-Built Drawings

Each bridge record should include one set of final drawings showing the "as-built" condition of the bridge, complete with signature of the individual responsible for recording the as-built conditions.

2.2.2—Specifications

Each bridge record should contain one complete copy of the technical specifications under which the bridge was built. Where a general technical specification was used, only the special technical provisions need be incorporated in the bridge record. The edition and date of the general technical specification should be noted in the bridge record.

2.2.3—Correspondence

Include all pertinent letters, memoranda, notices of project completion, daily logs during construction, telephone memos, and all other related information directly concerning the bridge in chronological order in the bridge record.

2.2.4—Photographs

Each bridge record should contain at least two photographs, one showing a top view of the roadway across and one a side elevation view of the bridge. Other photos necessary to show major defects or other important features, such as utilities on the bridge, should also be included.

2.2.5—Materials and Tests

2.2.5.1—Material Certification

All pertinent certificates for the type, grade, and quality of materials incorporated in the construction of the bridge, such as steel mill certificates, concrete delivery slips, and other Manufacturers' certifications, should be included in the bridge record. Material certifications should be retained in accordance with the policies of the Bridge Owner and the applicable statute of limitations.

2.2.5.2—Material Test Data

Reports of nondestructive and laboratory tests of materials incorporated in the bridge, during construction or subsequently, should be included in the bridge record.

2.2.6—Maintenance and Repair History

Each bridge record should include a chronological record documenting the maintenance and repairs that have occurred since the initial construction of the bridge. Include details such as date, description of project, contractor, cost, contract number, and related data for in-house projects.

2.2.7—Coating History

Each bridge record should document the surface protective coatings used, including surface preparation, application methods, dry-film thickness and types of paint, concrete and timber sealants, and other protective membranes.

2.2.8—Accident Records

Details of accident or damage occurrences, including date, description of accident, member damage and repairs, and investigative reports should be included in the bridge record.

2.2.9—Posting

Each bridge record should include a summary of all posting actions taken for the bridge, including load capacity calculations, date of posting, and description of signing used.

2.2.10—Permit Loads

A record of the most significant special single-trip permits issued for use of the bridge along with supporting documentation and computations should be included in the bridge record.

2.2.11—Flood Data

For those structures over waterways, a chronological history of major flooding events, including high-water marks at the bridge site and scour activity, should be included in the bridge record where available.

2.2.12—Traffic Data

Each bridge record should include the frequency and type of vehicles using the bridge and their historical variations, when available. Average Daily Traffic (ADT) and Average Daily Truck Traffic (ADTT) are two important parameters in fatigue life and safe load capacity determination that should be routinely monitored for each bridge and each traffic lane on the bridge. Weights of vehicles using the bridge, if available, should also be included in the bridge record.

2.2.13—Inspection History

Each bridge record should include a chronological record of the date and type of all inspections performed on the bridge. The original of the report for each inspection should be included in the bridge record. When available, scour, seismic, and fatigue evaluation studies; fracture-critical information; deck evaluations; and corrosion studies should be part of the bridge record.

2.2.14—Inspection Requirements

To assist in planning and conducting the field inspection of the bridge, a list of specialized tools and equipment as well as descriptions of unique bridge details or features requiring non-routine inspection procedures or access should be provided. Special requirements to ensure the safety of the inspection personnel, the public, or both should be noted, including a traffic management plan.

2.2.15—Structure Inventory and Appraisal Sheets

The bridge record should include a chronological record of Inventory and Appraisal Sheets used by the Bridge Owner. A sample Structure Inventory and Appraisal Sheet is shown in Appendix A4.1.

2.2.16—Inventories and Inspections

The bridge record should include reports and results of all inventories and bridge inspections, such as construction and repair inspections.

2.2.17—Rating Records

The bridge record should include a complete record of the determinations of the bridge's load-carrying capacity.

2.4.2—Revised Inspection Data

The bridge record should reflect the information in the current bridge inspection report. The date that the field investigation was made should be noted. All work that has been done to the bridge since the last inspection should be listed. When maintenance or improvement work has altered the dimensions of the structure, the channel, or both, the new dimensions should be recorded.

2.5—CONDITION AND LOAD RATING DATA

2.5.1—General

This data defines the overall condition and load capacity of the bridge and is based on the Inventory and Inspection data. Article 4.13 provides guidance on data collection requirements for load rating. As a minimum, the following information should be included:

1. *Bridge Condition Rating*. Document the bridge condition inspection results, including observed conditions and recommended maintenance operations or restrictions regarding the deck, superstructure, substructure, and, if applicable, channel.
2. *Load Rating*. A record should be kept of the calculations to determine the safe load capacity of a bridge and, where necessary, the load limits for posting. A general statement of the results of the analysis with note of which members were found to be weak, and any other modifying factors that were assumed in the analysis, should be given. See Section 6 for the load rating procedures.

2.5.2—Revised Condition and Load Rating Data

When maintenance or improvement work or change in strength of members or dead load has altered the condition or capacity of the structure, the safe load capacity should be recalculated.

2.6—LOCAL REQUIREMENTS

Bridge Owners may have unique requirements for collecting and recording bridge data mandated by local conditions, legislative actions, or both. These requirements should be considered in establishing the database and updating procedures for the bridge file.

3.1—INTRODUCTION

Transportation agencies must balance limited resources against increasing bridge needs of an aging highway system. The best action for each bridge, considered alone, is not necessarily the best action for the bridge system when faced with funding constraints. The best action to take on a bridge cannot be determined without first determining the implications from a system-wide perspective. Bridge engineers, administrators, and public officials have acknowledged the need for new analytical methods and procedures to assess the current and future conditions of bridges and to determine the best possible allocation of funds within a system of bridges among various types of bridge maintenance, repair, rehabilitation, and replacement choices. The advent of Bridge Management Systems (BMS) is a response to this need.

Bridge Management Systems require the data and results from condition evaluation. The aim of this Section is to provide an overview of BMS and discuss their essential features.

3.2—OBJECTIVES OF BRIDGE MANAGEMENT SYSTEMS

The goal of BMS is to determine and implement an infrastructure preservation and improvement strategy that best integrates capital and maintenance activities so as to maximize the net benefit to society. BMS helps engineers and decision-makers determine the best action to take on long- and short-term capital improvement and maintenance programs in the face of fiscal constraints. It enables the optimum or near-optimum use of funding by enabling decision-makers to understand the essential trade-offs concerning large numbers of bridges. It also provides essential information to help transportation agencies enhance safety, extend the service life of bridges, and serve commerce and the motoring public.

3.3—COMPONENTS OF A BRIDGE MANAGEMENT SYSTEM

In any BMS there are three main components:

- Database
- Data Analysis
- Decision Support

3.3.1—Database

A BMS requires a comprehensive database or a system of databases that is capable of supporting the various analyses involved in bridge management. There are three major types of data required by a BMS:

1. bridge inventory, condition, and rating data;
2. cost data; and
3. preservation and improvement activity data.

Much of this data is not available in the National Bridge Inventory (NBI). The essential data elements for BMS include many NBI data items, but also other information, especially more detailed inventory and condition data on the elements of each structure. Many states obtain additional data through expanded inspection programs to supplement data for bridge management purposes.

3.3.1.1—Commonly Recognized Structural Elements (CoRe)

NBI ratings provide a general idea of the overall condition of each major component of a bridge, but provide no details on the type of deficiencies that may be present or their extent. BMS analyses require more detailed condition assessment of a bridge according to its constituent elements. Projecting overall condition of bridge components such as deck, superstructure, and substructure is useful, but it is not sufficiently detailed to adequately project deterioration. More detailed condition data on elements of each component must be gathered to model deterioration at the element level.

To meet the data needs of BMS, an element level condition assessment system was developed that tracks not only the severity of the problem but also its extent. The element level data collection, though originally developed for Pontis®, is not considered unique to Pontis®. AASHTO and FHWA have defined a group of Commonly Recognized (CoRe) structural elements that are common to bridges nationwide. The CoRe elements provide a uniform basis for detailed element level data collection for any Bridge Management System and for sharing of data among states. A bridge is divided into individual elements or sections of the bridge that are comprised of the same material and can be expected to deteriorate in the same manner. Element descriptions consider material composition and, where applicable, the presence of protective systems. The condition of each element is reported according to a condition state, which is a quantitative measure of deterioration. The condition states are defined in engineering terms and based on a scale from one to five for most elements. The CoRe element definitions are supplemented in some cases with a "Smart Flag" to provide additional information about the condition of an element.

3.3.2—Data Analysis

The purpose of data analysis is to enable better strategies to allocate and use limited resources in an optimum way. The best decision is the one that minimizes costs over the long run while providing the desired level of service. Because decisions made today on bridge maintenance or improvement affect the condition of the bridge system in the future, BMS include mechanisms for predicting the future effects of today's decisions. Two major prediction tools that are important for BMS operation are bridge deterioration models and bridge-related cost models. The deterioration and cost models feed engineering and economic data into the optimization module, where these inputs, along with additional budget and policy data, are analyzed to yield a selection of projects for maximum economic benefit.

Data analysis is composed of three main components:

- Condition data analysis
- Cost data analysis
- Optimization

3.3.2.1—Condition Data Analysis

Long-term planning requires highway agencies to make decisions that are cost-effective over the long run. Assessing future needs based on current condition data is an essential component of BMS data analysis. Element level deterioration models of various formulations have been developed to serve as condition prediction tools.

Deterioration models in most BMS project the future condition of structural and other key elements and the overall condition of each type of bridge, both with and without intervening actions. Deterioration models can be used to estimate the service life of new bridges, the remaining life of in-service bridges, and the extension in service life due to rehabilitation or other maintenance activities.

Deterioration models use several cycles of condition data to identify trends, then extrapolate the trends to predict how an element will deteriorate over time. A minimum of three or four cycles of inspection data is required to develop deterioration models. As an alternative, a highway agency can survey an experienced group of engineers and bridge inspectors and form deterioration models based on expert opinion.

Successful prediction of bridge deterioration depends upon identifying all factors that have a major influence on the elements' condition over time. Element type and material, current condition, age, maintenance history, and environment are examples of the major factors that affect deterioration. Other factors may be prevalent for certain element types or in certain geographic locations. For example, traffic volume and the presence of de-icing salts are known to influence deck deterioration rates. Once the major factors are identified, relevant data can then be collected to form a database for building reliable deterioration models.

3.3.2.2—Cost Data Analysis

To manage the infrastructure efficiently, the cost implications of alternative actions have to be known and considered. Costs to be considered include the direct and indirect costs that will be incurred by the agency and the user. Costs incurred by the public may make up most of the total costs.

3.3.2.2.1—Agency Costs

The cost to a highway agency for a bridge is seldom a one-time cost; rather, it is a long-term, multi-year investment of a series of expenditures for maintenance, rehabilitation, and replacement. Therefore, bridge management should take a long-term view of the economic life of a bridge, reflecting the highway agency's long-term responsibility. Life-cycle costs are normally defined as the sum of future agency costs that occur over a specified period in which each cost has been discounted to its present value. In BMS, life-cycle costs address maintenance, repair, and rehabilitation (MR&R), and improvement costs. Life-cycle costs should be comparable from one structure to another. If life-cycle costs are calculated over an expected life that varies with each type of structure, it is convenient to convert life-cycle costs to equivalent uniform annual costs.

3.3.2.2.2—User Costs

Optimization approaches to BMS recognize that maintenance, repair, and rehabilitation actions are a response to deterioration while improvements such as widening and strengthening respond to user demands. The choice of MR&R actions should be predicated on minimization of agency life-cycle costs while improvements should be based on the benefit to road users of eliminating bridge deficiencies. These benefits include reductions in travel time, accidents, and motor vehicle operating costs that result mainly from reducing load and clearance restrictions.

Consideration of user costs is essential in BMS if functional deficiencies are to be eliminated. If agency costs alone are considered, the alternatives would tend to favor maintenance only to extend life until permanent closure. Two types of costs are incurred by users because of functional deficiencies of a bridge: accident costs and detour costs. Bridges having narrow deck width, low vertical clearance, or poor alignment have a higher occurrence of accidents than bridges without these deficiencies. Bridges with low vertical clearance or insufficient load capacity will force a certain volume of truck traffic to be detoured to alternate routes, resulting in increased vehicle operating costs.

3.3.2.3—Optimization

Optimization has become the preferred method for bridge network management. 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 the selected projects is maximized (agency and user costs 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 BMS software.

The system should consider both constrained and unconstrained budget cases. If unlimited budgets are available, it is possible to determine the optimum period in which selected alternatives should be scheduled. Where adequate funding is not available to maintain a desired level-of-service, the BMS calculates the economic consequences of a lower level-of-service and provides an objective means of setting priorities for bridges so that the impact on agency and user costs is minimized. When a project has to be delayed, the BMS is capable of using the deterioration models and cost models to quantify the bridge level effect, traffic growth, and the impact on road users; and to determine the new optimal set of actions for the bridge at a later period. By exploring period-by-period project deferrals, multi-year programs can be generated.

Modern optimization approaches can take several forms. The differences in optimization approaches tend to be in the specific techniques used and in the way that network-level considerations are reflected in the analysis. Two common approaches are:

1. *Top-Down Approach*, where network-level issues are addressed first, then the results are used to guide project selection and scheduling; and
2. *Bottom-Up Approach*, where an improved form of the project-level analysis is automatically iterated and adjusted until all network-level concerns are satisfied.

3.3.3—Decision Support

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 must never 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.

An optimization performed by a BMS is only as valid as its underlying assumptions. A BMS may never have all the necessary information in its database. Often the missing information is mostly intangibles, such as engineering experience, local needs, and political considerations. A BMS may therefore build in user adjustments at all critical decision areas.

3.4—NATIONAL BRIDGE MANAGEMENT SYSTEMS

Research efforts initiated in North Carolina and a few other states in the 1980s resulted in the emergence of bridge management concepts that were further refined in subsequent FHWA demonstration projects. In 1989, FHWA, in conjunction with six state DOTs, sponsored the development of a network-level bridge management system for use by state and local transportation officials. The effort resulted in the development of the Pontis® computer program. Pontis® has separate sets of models for optimizing bridge preservation and improvement activities, and a project programming model that integrates the results of the preservation and improvement analyses. Pontis® uses a top-down optimization approach in that it optimizes the network needs before arriving at individual project needs. This process is most useful for network budgeting and programming. Recommendations for best action for each bridge are based on network-level considerations.

In 1985 NCHRP Project 12-28 (2) was initiated. The first phase of this project developed the modular elements necessary for a model form of effective bridge management at the network level. In the subsequent phases, a microcomputer-based software package (BRIDGIT™), meeting FHWA and AASHTO guidelines for bridge management systems, was developed to handle the immediate and long-term needs of highway agencies. BRIDGIT™ uses a project-level based optimization strategy to provide network-level recommendations. It recommends specific actions for each bridge, consistent with the overall network strategy. BRIDGIT™ is useful for all areas of bridge management, from programming and budgeting to project selection to bridge maintenance.

A few states have opted to develop their own BMS. The two U.S. national systems, Pontis® and BRIDGIT™, have a generic design that can be adapted to accommodate the individual needs of an agency.

11. Measuring Performance Among State DOTs, Sharing Best Practices Comparative Analysis of Bridge Condition Final Report, NCHRP 20-24(37)E
National Cooperative Highway Research Program
Spy Pond Partners, LLC with Arora and Associates, August 2010

Executive Summary

Comparative Performance Measurement for Bridge Condition

Today's transportation agencies need to find ways to improve service and demonstrate tangible results for their customers while operating under increasingly tight resource constraints. Within an agency, performance measurement provides a valuable tool for strengthening external accountability and achieving alignment and focus around desired end results.

Comparative performance measurement allows agencies to examine their individual performance within a larger context. It motivates organizations to pursue improvements by showing them what their peers have been able to achieve. It facilitates improvement by identifying specific practices of agencies that have achieved good results. Establishing comparable measures can take considerable effort, but pays off when participating organizations learn from practices employed by their peers to improve their own performance. Comparative performance measurement initiatives also have the important effect of shining a spotlight on current approaches to how performance is being measured and how results are being used. Participating agencies have an opportunity to examine the consistency and accuracy of their measurement practices, learn about differences in measurement across agencies, and work towards a greater degree of commonality.

This report presents results of the fourth in a series of comparative performance measurement efforts sponsored by the American Association of State Highway and Transportation Officials (AASHTO). The purpose of these efforts is to identify states that have achieved exemplary performance, find out what practices have contributed to their success, and document these practices for the benefit of other states. This effort focuses on bridge condition.

Contribution of This Study

This study was based on an analysis of bridge condition data from the National Bridge Inventory (NBI.) Based on the available data, it identifies states that have achieved a high level of performance relative to other states, with respect to recently reported (2009) bridge condition or with respect to improvements in bridge condition since 1999. It presents bridge management, maintenance, design and construction practices that the representatives of these states feel have contributed to these performance results. While these practices are already fairly well recognized among those in the highway bridge community, linking them to performance results serves to underscore their importance. Given the critical importance of bridges and the high costs of bridge construction and preservation, this study adds an important dimension of state department of transportation (DOT) performance to the comparative performance measurement series. Highlighting these results in the context of comparative performance information provides a compelling basis for executives to quickly identify where they stand, see the potential for further improvement, and scan the key types of practices that can be explored for achieving that improvement.

12. Sofware Engineering Project Management
    Edited by Richard H. Thayer Foreword by Edward Yourdon
    Software Quality Assurance: A Management Perspective
    Robert H. Dunn

To many, quality assurance brings to mind the industrial quality-control model, wherein statistical analysis of measurements made at various production control points are used to prevent out-of-tolerance operations. To others, quality assurance means monitoring the adequacy and timeliness of responses to customer service complaints. Still others view quality assurance strictly in terms of process audits.

Software quality assurance (SQA) is none of these. It may borrow a bit from statistical quality control, may use measurements and analysis, and may rely on certain auditing procedures, but—except when used simply as a synonym for "testing"—SQA most closely follows the model of total quality management (TQM). That is, the quality of software is expected to derive from the quality of the process used to develop or maintain software, and SQA is largely a matter of ensuring that a good process is in place, followed, and continuously improved. The process, of course, includes all phases of testing, but testing is scarcely the only interest of SQA.

A proper process for development and maintenance encompasses management methods, technology, and personnel qualifications. Although involved in the entire process, SQA focuses on

- continuous improvement of the process through audits that attempt to determine where the process breaks down and through analysis of measurements of the process itself;
- defect prevention (feasible task definitions, traceability of requirements to verification steps, early defect detection, and the like);
- analysis of the product, including its effect on users; and
- testing of the final product (validation of the solution).

Note that concern for products is not inimical with emphasis on process. The proof, as always, lies in the pudding.

SQA arose in response to specific classes of problems confronting management. It is possible for a programming shop to experience only one of the classes, but two or more is the rule since the classes are interrelated. They are all familiar:

- Project out of control—uncertain progress and status, unreliable cost estimates, unreliable estimates of completion
- Poor performance—frequent crashes, results not necessarily repeatable, excessive use of such resources as time and memory
- Difficult maintenance—software overly complex, operational code no longer traceable to specific source code or data files and build lists
- Difficulty of use—customers or other users find software does not quite match their expectations or abilities or the environment in which the software is used

We don't have to look far to see why these four classes of problems are intertwined. Unreliable software may result from premature curtailment of testing caused by delayed progress during earlier stages of development. A program that runs too slowly may result from a botched maintenance job caused by the programmers' inability to understand the code they modified. In turn, the confusing code may result from a rushed design traceable to extensive delays in developing a requirements model. Customers may find a product unusable simply because training or user documentation didn't quite match the final product because of a constantly changing requirements model.

What is uncommon is to find problems in performance, maintenance, or use in a product whose development or maintenance was at all times attended by a high degree of project control. From a philosophical point of view, it would seem that project control should be the prime concern of SQA. From a practical point of view, the thought is of little consequence. The devil is in the details, and SQA succeeds by placing emphasis on the suitability of the process, defect prevention activities, analysis, and preparation and support for testing. Project control follows more or less automatically. Figure 1 lists the ways SQA attends to the details.

- Making certain programming staff is adequately trained in new techniques, methods, and tools
- Evaluating the effectiveness of current development methods and tools, or providing the information enabling such evaluation
- Ensuring that project plans—not just for development activities, but also for configuration management, testing, and the like—are drawn as policy or standards dictate
- Using reviews, analysis tools, and tests to find defects at the earliest possible time
- Following up on library control, change control, distribution, and storage to assure management of compliance with plans and relevant policies and standards
- Recording the detection of individual defects and following up to make certain they are corrected, or at least dealt with in a satisfactory manner
- Collecting aggregate defect data and subsequently analyzing the data to determine fault modality and the effectiveness of detection techniques
- Using the analysis of defect data to improve processes
- Generating and analyzing various data for early indication of adverse trends in the project or the evolving product
- Qualifying or validating the final product
- Gathering, analyzing, and evaluating feedback from users
- Evaluating potential software suppliers, including tool vendors, and monitoring their performance
- Objectively evaluating the fidelity with which plans and applicable standards are followed, and determining root causes for deviations
- Making certain staff is empowered to prevent defective code, artifacts of development, and user documentation from being entered into a software release

Figure 1. Constituents of a software quality assurance program.

13. Asset Management Guide for Local Agency Bridges in Michigan
Michigan Transportation Asset Management Council
Prepared by TranSystems Corporation, May 2011

1.4 Definitions / Acronyms

This Guide employs a number of terms commonly used in: the inspection, evaluation, and maintenance of bridges; asset management plans; capital programming and funding; resource management; and the administration of Michigan's Local Bridge Program. Links to references containing definitions of these terms are provided in the right hand column, as are the common acronyms used in the Guide. The user is encouraged to review the cited references in order to better understand and implement the principles and procedures described in the Guide.

In May 2006, AASHTO, the American Association of State Highway Transportation Officials initiated the ***Transportation System Preservation Technical Services Program (TSP·2).*** The program, dedicated to the preservation of infrastructure investment was initiated as a clearinghouse to disseminate information on enhancing the performance and extending the useful life of the highway infrastructure, both pavements and bridges, thru efficient and effective preservation measures. The TSP2 website contains the working definition of *bridge preservation.*

Bridge preservation starts with obtaining timely information on bridge conditions; then, developing and implementing a planned strategy to maintain and extend the useful life of the bridge network. A preservation strategy is composed of various preventive maintenance activities and treatments. Applied at the proper time, preventive maintenance activities extend the service life of the bridge in a cost-effective manner. The definition of critical terms used in the management of bridge assets are discussed in Section 2.2.

Definitions

FHWA Asset Management Overview
http://www.fhwa.dot.gov/asset/if08008/amo_09.cfm

Transportation System Preservation Technical Services Program (TSP·2)
http://www.tsp2.org

Acronyms

AASHTO – American Association of State Highway and Transportation Officials
ADT – Average Daily Traffic
ADTT - Average Daily Truck Traffic
BCFS – Bridge Condition Forecasting System
BIR – Bridge Inspection Report
BMS – Bridge Management System
BSIR – Bridge Safety Inspection Report
CRAM – County Road Association of Michigan
CPM – Capital Preventive Maintenance
FHWA – U. S. Dept of Transportation, Federal Highway Administration
LBAB – Local Bridge Advisory Board
LBF – Local Bridge Fund
LBP – Local Bridge Program
LTAP – Michigan Local Technical Assistance Program
LCCA – Life Cycle Cost Analysis
MDOT – Michigan Department of Transportation
MBIS – Michigan Bridge Inspection System
MBRS – Michigan Bridge Reporting System
MML – Michigan Municipal League
MTF – Michigan Transportation Fund
MPO – Metropolitan Planning Organization
NBI – National Bridge Inventory
NBIS – National Bridge Inspection Standards
NCHRP - National Cooperative Highway Research Program
RBC – Regional Bridge Council
RSL – Remaining Service Life

1.6 Role of the Michigan Transportation Asset Management Council (TAMC)

Created by Act 499 of the Michigan Public Acts of 2002, the TAMC's stated mission is to: *advise the State Transportation Commission on a statewide asset management strategy & the necessary procedures & analytical tools to implement such a strategy on Michigan's highway system in a cost-effective, efficient manner.*

In order to apply the principles of asset management to the process of allocating transportation resources, TAMC developed the following high level strategic process which could be applied to a variety of infrastructure types:

- Assess current condition
- Create a "mix of fixes", estimate costs and funding levels
- Predict future condition, develop performance measures and targets
- Conduct tradeoff analysis, indentify candidate projects
- Set Priorities, develop a multi-year program
- Report results

This Guide is intended to assist local agencies in applying this process to the development of a preservation plan for bridges under their jurisdiction and to provide background material on bridge preservation.

SAFETEA-LU – Safe, Accountable, Flexible, and Efficient Transportation Equity Act Legacy for Users
SI – Structural Improvement
SIA – Structure Inventory and Appraisal
STIP – Statewide Transportation Improvement Program
TAMC – Michigan Transportation Asset Management Council
TEDF – Transportation Economic Development Fund
TIP – Transportation Improvement Program
TMS – Transportation Management System

TAMC Website Link
http://mcgiweb6.mcgi.state.mi.us/mitrp/Council/Default_Council.aspx

2.0 Bridge Asset Management in Michigan

2.1 Bridge Management System

A Bridge Management System (BMS) is defined as a collection of interacting processes designed to assist decision makers in the selection of cost-effective bridge preservation, rehabilitation, and improvement strategies and actions to improve the efficiency and safety of, and protect the investment in a network of bridges (23 CFR 500.107) Code of Federal Regulations.

Michigan has a system-wide process for transportation asset management of highway bridges. For local agencies this process is administered through the local bridge program by the Local Bridge Advisory Board and seven Regional Councils. The Transportation Asset Management Council supports the state's BMS by providing technical assistance and guidance, and by publishing annual asset management reports, communicating infrastructure needs, and implementing asset management principles.

2.2 Bridge Preservation through Preventive Maintenance

The Federal-aid to Highways Program allows States to use Highway Bridge Program (HBP) funds to improve the condition of highway bridges through replacement, rehabilitation, and preservation activities identified using an approved systematic process. Bridge preservation and preventive maintenance are terms that are used interchangeably.

Bridge preservation is defined by FHWA as: *Actions or strategies that prevent, delay, or reduce deterioration of bridges or bridge elements; restore the function of existing bridges; keep bridges in good condition; and extend their useful life. Preservation actions may be preventive or condition-driven.*

Preventive Maintenance is recognized as a cost effective way to preserve the investment in and service life of bridges. AASHTO defines preventive maintenance as: *A planned strategy of cost-effective treatment to an existing roadway system and its appurtenances that preserves the system, retards future deterioration and maintains or improves the functional condition of the system without increasing structural capacity.*

An effective bridge preservation program: 1) employs long-term network strategies and practices that are aimed to preserve the condition of bridges and extends their useful life; 2) has sustained and adequate funding sources; 3) ensure that the appropriate treatments are applied at the appropriate time.

Some agencies employ a program of scheduled maintenance performed by in-house forces.

2.0 References

FHWA Bridge Asset Management
http://www.fhwa.dot.gov/bridge/management/index.cfm

AASHTO *Transportation Asset Management Guide*
http://www.fhwa.dot.gov/crt/lifecycle/asset.cfm

AASHTO *Guidelines for Bridge Management Systems*
https://bookstore.transportation.org/Item_details.aspx?id=343

4.6 Michigan's Bridge Management System

As one of the components of Michigan's Transportation Management System (TMS), the MDOT run Bridge Management System (BMS) is the decision-support tool responsible for managing the inspection, analysis, and maintenance of the numerous components that make up a bridge.

The BMS includes data on the more than 10,900 bridges in Michigan. As such, the BMS provides complete coverage of all bridges in Michigan, not just those for which MDOT has responsibility, and supports the regional and local agencies bridge asset management efforts.

Within the BMS, bridge information is organized into three packages: Inventory – structure and route data; Inspection – record of field examinations and findings; and Work – Maintenance recommendations. Users are able to access each of these packages to monitor or manage data on bridges and their components.

MDOT's BMS includes a bridge management software tool called Pontis which was developed under an FHWA contract during the early 1990's, and became an AASHTO product in 1994. Pontis is a data application relying on the collected condition and cost data of individual bridge elements. This data can be useful to provide asset management at the element level.

The system is designed to support the bridge inspection process, recommend a bridge preservation policy, predict future bridge conditions, and recommend actions to perform on one or more bridges to derive the most agency and user benefit from a specified budget. The key features of *Pontis* include:

- Recording bridge inventory and inspection data
- Scenario modeling, including deterioration prediction models
- Various bridge improvement options, including maintenance, repair, and rehabilitation.
- Economic models to identify and prioritize capital improvements
- Development of an optimal preservation strategy

Michigan Bridge Management System
http://www.michigan.gov/documents/bridge_16549_7.pdf

4.10 Relating Bridge Condition and Performance to Maintenance

Proper condition evaluation is an essential component of an asset management plan for bridge preservation. The appropriate response in addressing recorded condition deficiencies in bridge elements and the preventive measures taken to retard potential future degradation is important for the overall health of the local bridge network. A goal of preservation is to employ preventive and responsive maintenance to sustain the network in good condition longer and to extend the service life of the bridges.

An effective way to achieve this goal is to develop a local bridge preservation plan. A local agency goal is to maintain its bridges at an appraisal rating of 5 or better and a load capacity that meets the demands of the traffic using the route. It is suggested that the preservation plan improves poor bridges, provides a capital preventive maintenance program to maintain fair bridges in the same condition or better, and addresses its good bridges through a capital scheduled maintenance program. The combination of potential actions into an appropriate "mix of fixes" enables the local agency to develop an optimum bridge preservation strategy.

5.0 Developing an Optimum Bridge Preservation Strategy

A local agency is encouraged to prepare a bridge preservation plan that includes a capital program designed to maximize the service life of bridges and to achieve optimal use of funding. The capital program may include structural improvements as well as preventive maintenance.

MDOT, through the RBC's and LBAB's, annually reviews applications for bridge replacements, rehabilitation and preventive maintenance projects and evaluates the needs based on the applications submitted by local agencies.

Once a local agency has assessed the condition of the bridges in its network, it must then determine the available fixes that will best preserve the system - *The Right fix in the Right Place at the Right Time.* A properly developed "mix of fixes" usually includes a combination of activities - structural improvements in the form of replacement and/or rehabilitation projects and both scheduled and preventive maintenance programs.

It is advisable to have both short and long-term objectives. Long-term objectives address the need for sustained investment in the bridge network thru capital preventive maintenance while near term objectives address facilities that currently are in poor condition.

MDOT has developed a Project Scoping Manual for state trunk line bridges for the purpose of more accurately and uniformly scoping projects. It serves as a valuable resource for local agencies in determining required fixes and in preparing their preservation plans.

5.1 Types of Potential Fixes

Many types of fixes are available to the local agency. The fixes described in the following sections are generally based on those actions delineated on the lists in MDOT's Local Bridge Program.

5.1.1 Structural Improvement

Structural Improvement includes any activity that preserves or improves the structural integrity of a bridge. These activities may be replacement or rehabilitation.

Replacement - Projects involving replacement of the entire bridge – substructure, superstructure, and deck, and associated approach work. This work is intended to improve the condition for the total bridge, deck, superstructure, and /or substructure elements from "poor" to "good"

Rehabilitation - Major work required to restore the structural

5.0 References

Project Scoping Manual
http://www.michigan.gov/mdot/0,1607,7-151-9622_11044_11367-243045--,00.html

Project Scoping Checklist
http://www.michigan.gov/documents/MDOT_Project_Scoping_120537_7.pdf

TR News (pp 26-30) - Michigan's Bridge Preservation Program
http://onlinepubs.trb.org/onlinepubs/trnews/trnews228.pdf

LTAP – *The Bridge* - Bridge Replacement by Agency Work Force
http://www.michiganltap.org/pubs/bridge/pdf/2008/bridge_21_4_web.pdf

integrity of a bridge as well as work necessary to correct major safety defects. This work is intended to improve ratings from "poor" or "fair" to "good" Some typical rehabilitation projects include:

- Full deck replacement (with or without painting of steel beams)
- Superstructure replacement
- Structure widening
- Demolition of existing bridge
- Superstructure repairs
- Bridge barrier replacement
- Extensive substructure repairs
- Steel repairs
- Concrete beam end repairs
- Geometric upgrades

5.1.2 Preventive Maintenance

Preventive Maintenance encompasses both routine scheduled maintenance and capital preventive maintenance.

Routine Scheduled Maintenance is a regularly scheduled activity that maintains serviceability and reduces the rate of deterioration of structural elements. In many instances, local agency forces are able to perform some or all of this work.

Capital Preventive Maintenance is a scheduled work activity that restores element integrity and supports serviceability. This work is intended to address the needs of elements rated "fair". Examples of preventive maintenance include:

- Painting only (full, zone, or spot painting)
- Pin and hanger replacement
- Superstructure washing
- Vegetation control
- Drainage system clean-out and repair
- Expansion or construction joint repair or replacement
- Concrete sealing
- Minor concrete patching and repair
- Concrete crack sealing
- Approach pavement relief joints
- Slope paving repair
- Drainage system repair (bridge deck drains and bridge approach downspouts)
- Scour countermeasures
- HMA overlay (with or without membrane)
- Deep or shallow deck overlay
- Epoxy overlay
- Temporary supports
- Guardrail beam installation or retrofit

MDOT Capital Scheduled Maintenance Manual
http://www.michigan.gov/documents/mdot_CSM_Manual04_89342_7.pdf

MDOT Deck Evaluation Matrix
http://www.michigan.gov/documents/mdot/MDOT_BridgeDeckMatrix_182438_7.pdf

AASHTO Center for Environmental Excellence – Bridge Maintenance - Best Practices
http://environment.transportation.org/environmental_issues/construct_maint_prac/compendium/manual/7_1.aspx

5.1.3 Bridge Maintenance Technical Guidance

Capital scheduled maintenance activities maintain the existing serviceability, and reduce deterioration rates on bridges. CSM work activities sustain the current bridge condition longer, whether the current condition is good, fair, or poor. MDOT's *Capital Scheduled Maintenance Manual* (link provided in Section 5.1.2) provides a thorough description of various preventive maintenance actions.

5.2 Cost Estimating

MDOT's *Capital Scheduled Maintenance Cost Estimate Workbook* contains unit prices for various preventive maintenance actions. These values can be used to estimate the cost of alternative maintenance or rehabilitation actions and to evaluate relative costs in determining the optimum program in the preparation of a bridge asset management plan.

The MDOT *Bridge Repair Cost Estimate Worksheet* also provides useful guidance for estimating cost in scoping projects.

MDOT Capital Scheduled Maintenance Cost Estimate Workbook
http://www.michigan.gov/mdot/0,1607,7-151-9625_24768_24773---,00.html

MDOT Bridge Repair Cost Estimate Worksheet
http://www.michigan.gov/mdot/0,1607,7-151-9625_24768_24772---,00.html

Bridge Life Cycle Cost Analysis
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_483a.pdf

5.2.1 Deterioration Models

The objective of a bridge asset management plan is to determine the optimal preservation decisions in the current year and in future years based on the consequences of alternative actions on the future condition of the system using the data in MDOT's BMS.

Bridge deterioration models are an essential component of the bridge management system, and express a relationship between condition and time by predicting the future condition of the bridge components based on selected actions or inactions.

Bridge deterioration models use condition rating as the measure of bridge performance. Deterioration models predict the deterioration process as a decay of condition ratings over time, and are built based on expert opinion and inspection history.

5.2.2 Costing Deferred Maintenance

There are two components to consider when evaluating the cost of deferred maintenance. The first is the increased costs due to greater deterioration of the bridge or component and the need to perform more extensive repairs in the future. This must be compared to the benefit of using the available funding for another project within that time period.

Deterioration models can serve as a basis for determining the cost of deferring specific maintenance or repair actions. As the models establish a relationship between condition and time, the user can predict the future condition of a bridge element based on its current condition, and in this way determine the future increased repair work and associated cost resulting from deferral.

The benefits of a project can include safety, reduced agency or user costs, elimination of traffic congestion, reduction of travel time, better geometrics, improved surface rideability, and operational improvements by addition of traffic control devices,.

Deferring work is not a recommended strategy if the cost of deferral exceeds the benefits of the alternate project. As the difference becomes greater, the work becomes more urgent. This type of comparison and its results are factored into the prioritization decision process through the life cycle cost analysis module of a BMS.

5.2.3 In-House Costs vs. Contract Costs

Scheduled maintenance work and preventive maintenance work can be performed by either in-house maintenance crews or by contract. Most local agencies use a combination of the two.

An estimate of the cost of work to be performed by in-house crews should consider: both supervisory and crew labor expenses, including wages, benefits, and other payroll burdens; materials and supplies; equipment operating costs for owned equipment; equipment rental costs, as needed; and administrative costs. The local agency should keep a record of all maintenance work performed by in-house crews in the bridge file for future reference.

Work done by contract with private sector firms generally involves projects too large or too specialized to be done by in-house crews. Estimates of work to be performed by contract may be based on the unit price guide contained in MDOT's *Capital Scheduled Maintenance Cost Estimate Workbook*. The local agency's cost of contract administration and project support should be added to the estimated contract cost.

In its analysis the local agency should consider the potential cost benefits of collaborating with other agencies to combine resources and share the costs of work to be performed in-house or by contract.

The final estimated costs are used in the development of the prioritization plan within the bridge asset management plan.

5.2.4 Life Cycle Cost Analysis

The cost of a bridge is not a one-time expense. A bridge represents a long term, multi-year investment. After its initial planning, design, and construction, over its lifetime a bridge requires maintenance, repair, rehabilitation, and, ultimately, replacement.

The time period between construction and replacement is the service life of a bridge. The actions and events that influence the condition of the bridge during its service life comprise the life cycle. Bridge owners develop a bridge management strategy by making decisions about bridge materials, design, construction, maintenance, and repairs based on their expectations of costs and results.

Life Cycle Cost Analysis (LCCA) is a computational process for comparing initial and future costs to arrive at the most economical strategy for ensuring that the bridge will provide its intended service for its expected service life. LCCA is essentially a method for considering the economic efficiency of various alternate expenditures.

TRB National Cooperative Highway Research Program (NCHRP) *Report 483: Bridge Life-Cycle Cost Analysis*
http://www.trb.org/Main/Blurbs/Bridge_LifeCycle_Cost_Analysis_152577.aspx

5.3 Concept of a Mix of Fixes

In its asset management plan, TAMC has adopted the philosophy of "The Right Fix in the Right Place at the Right Time". This philosophy espouses a program of developing a mix of fixes that results in the optimum use of preservation funds.

By comparing maintenance, repair, and rehabilitation needs for each bridge, the cost of implementing various preservation actions or deferring work can be compared with the cost of completely replacing a bridge. Replacement of a bridge may be warranted if replacement is the most cost-effective means to satisfy the existing structural or functional needs. Alternatively, if the physical condition of the bridge has deteriorated to a point where the bridge is considered unsafe, bridge replacement may be determined to be the only feasible alternative.

A Bridge Preventive Maintenance Strategy developed by the Greater Buffalo-Niagara Regional Transportation Council for its bridges is accessible thru the referenced link.

MDOT Asset Management Guide for Local Agencies in Michigan
http://mcgiweb6.mcgi.state.mi.us/mitrp/Council/AssetManagementPlans.aspx

MDOT Strategic Investment Plan for Trunk line Bridges
http://www.michigan.gov/documents/mdot/MDOT_StrategicInvestmentPlanForTrunklineBridges_339697_7.pdf

Bridge Preventive Maintenance Strategy Greater Buffalo-Niagara Regional Transportation Council
http://www.gbnrtc.org/fileadmin/content/pdf/BPMS%20Local%20Bridges%20-%20FINAL(Approved)%20ReportJan07.pdf

5.4 Developing a Local Bridge Preservation Plan

Developing and implementing a local bridge preservation plan is a means of extending the useful service life of the agency's bridges and for using available funds more effectively.

The benefits of a preservation plan to a local agency include:

- an identification and understanding of the condition of the bridges in the network;
- a defined program of rehabilitation, replacement, and preventive maintenance designed to restore the functionality of degraded bridge elements;
- a program of regular maintenance to impede deterioration of sound bridges;
- dedicated local resources and an increased opportunity to obtain additional funding;
- optimal use of all available resources.

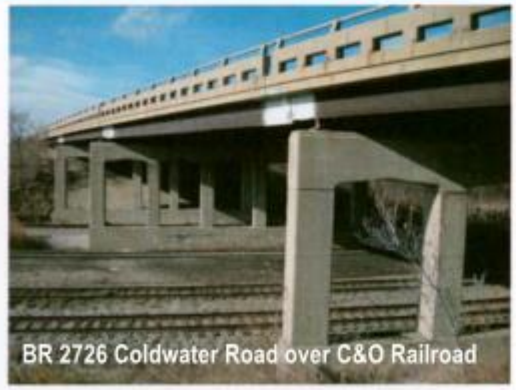
The preservation plan should address similar items as described for a systematic plan in Section 2.3.1. Some of the items suggested for inclusion in a local agency preservation plan include:

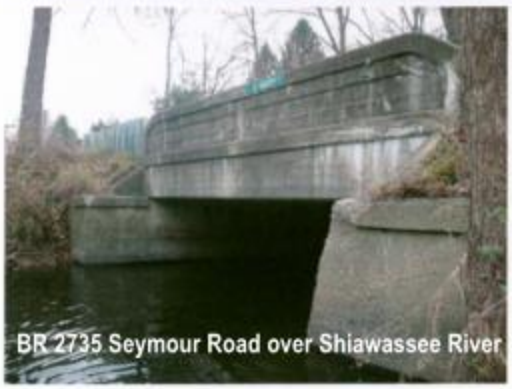
- Goal – a statement of the agency's purpose, describing future expected outcomes. Goals provide programmatic direction and focus on ends rather than means.
- Objectives –clear, specific, measurable, and time-limited statements of action which, when completed, will move towards achieving the goal.
- Performance Measures – the metrics by which the agency will evaluate the effectiveness of the plan
- Bridge Assets – a summary of the number, type, and condition state of the bridges in the network;
- Condition Analysis – an overall assessment of the current state of the bridge population;
- Risk Management – a recognition of the risks inherent in degraded bridges and a program to address them;
- Preservation Strategy - the overall actions to be taken by the agency to address preservation;
- Prioritization – agency's methodology used to rank projects for funding
- Implementation – how the agency will execute the plan;
- Cost Estimate – an annual review and updating of the actions programmed in the plan;
- Operations and Maintenance Plan – the annual activities scheduled in a five year program;
- Five Year Annual Cost Projection – a year-by-year, project-by-project schedule of costs;
- Funding Sources - a year-by-year source and allocation of funds for the five year program.

A sample plan for a local bridge owner following this format is discussed in Section 5.4.3. below.

Preservation Plan for Genesee County Local Bridges


BR 2719 Atherton Road over Kearsley Creek


BR 2726 Coldwater Road over C&O Railroad


BR 2735 Seymour Road over Shiawassee River


BR 2745 Fenton Road over Swartz Creek

May 2011

MICHIGAN TRANSPORTATION ASSET MANAGEMENT COUNCIL

TranSystems

ROAD COMMISSION GENESEE COUNTY

Bridge Assets:

Genesee County is responsible for 121 local bridges – 120 highway bridges and 1 railroad bridge. Detailed inventory data, condition ratings, and proposed preventive maintenance actions for each bridge are contained in the tables in Appendices A-1, A-2, and A-3. The bridge inventory data was obtained from the MDOT TMS System and the 2010 Condition data and maintenance actions are taken from the Inspector Summary Report Appendix B.

A summary and distribution of the bridge population is presented in the following table:

Bridge Type	Number of Bridges					2010 Condition		
	Total	Struct Defic.	Funct Obsol	Post ed	Clos ed	Poor	Fair	Good
Concrete								
Slabs	3	2	1	--	--	--	3	--
Tee Beams	30	11	3	--	--	7	22	1
Box Beams	1	--	--	--	--	--	1	--
Arches	1	--	--	--	--	--	--	1
Culverts	5	--	1	--	--	--	2	3
Steel								
Multi-Girder	34	21	4	11	--	20	13	1
Multi-Girder / Composite	5	--	--	--	--	--	5	--
Culverts	12	--	2	--	--	--	9	3
Prestressed Concrete								
Multi Girder	22	4	1	1	--	2	4	16
Box Beam	1	--	--	--	--	--	--	1
Multi Girder / Composite	3	--	1	--	--	--	--	3
Timber								
Stringers	4	--	--	--	--	--	4	--
Total SD/FO/PSTD		**38**	**14**	**12**				
Total	**121**					**29**	**63**	**29**
Percentage (%)		**31.4**	**11.6**			**24.0**	**52.0**	**24.0**

Preservation Strategy:

GCRC's preservation plan employs a balanced "Mix of Fixes" strategy made up of Replacement, Rehabilitation (R&R), Preventive Maintenance, and Scheduled Maintenance. The aim of this plan is to address the structures of critical concern by targeting poor rated elements, and to improve the overall condition of the bridge network to good or fair condition.

Replacement involves substantial changes to the existing structure, such as bridge deck replacement, superstructure replacement, or complete structure replacement, and is intended to improve critical or closed bridges to a good condition rating.

Rehabilitation is undertaken to extend the service life of existing bridges. The work will restore deficient bridges to a condition of structural or functional adequacy, and may include upgrading geometric features. Rehabilitation actions are intended to improve the poor or fair condition bridges to fair or good condition.

Preventive Maintenance work will improve and extend the service life of fair bridges, and will be performed with the understanding that future rehabilitation or replacement projects will contain appropriate safety and geometric enhancements. Preventive Maintenance projects are directed at limited bridge elements that are rated in fair condition with the intent of improving these elements to a good rating. Most preventive maintenance projects will be one-time actions in response to a condition state need. Routine preventive work will be performed by the County's in-house maintenance crews, while the larger more complex work will be contracted.

The replacement, rehabilitation, and preventive maintenance projects are generally eligible for funding under the local bridge program and will be submitted with GCRC's annual applications.

GCRC's Scheduled Maintenance program is an integral part of the Preservation Plan, and is intended to extend the service life of fair and good structures by preserving the bridges in their current condition for a longer period of time. Scheduled maintenance is proactive and not necessarily condition driven. In-house maintenance crews will perform much of this work.

The "Mix of Fixes" strategy combines long-term reconstruction or replacement fixes, medium-term rehabilitation fixes, and short-term preventive maintenance fixes with a regular program of scheduled maintenance. Implementing this balanced mixture, as described in the Operations and Maintenance Plan below, will increase the number of bridges improved each year and preserve the overall health of GCRC's bridge network.

Implementation of the Strategy:

GCRC's implementation of the preservation plan strategy begins with an annual review of the current condition of each of the County's bridges using the NBI inspection data contained on the MDOT Bridge Safety Inspection Report and the inspector's work recommendations contained on MDOT's Bridge Inspection Report. The inspection inventory and condition data are consolidated in spreadsheet format for GCRC's bridges in Appendix A-1. Preventive maintenance needs are determined for each bridge and the corresponding actions are identified and assembled on a spreadsheet, sorted by bridge material and type in Appendix A-2. Inspection follow-up actions are tabulated in Appendix A-3.

The preservation actions are selected in accordance with criteria contained in the table below. These criteria are based on MDOT's Project Scoping Manual, which is intended to address MDOT's trunk line bridges. GCRC has modified the selection criteria slightly to better address its local bridge network.

Preservation Action	Bridge Selection Criteria	Expected Service Life
Replacement		
Total Replacement	NBI Rating of 3 or less, or when cost of rehabilitation exceeds cost of replacement, or when bridge is scour critical with no countermeasures available	70 yrs
Superstructure Replacement	NBI Rating for Superstructure of 4 or less, or when cost of rehabilitating superstructure & deck exceeds replacement cost.	40 yrs
Deck Replacement Epoxy Coated Steel Black Steel	Use guidelines in MDOT's *Bridge Deck Preservation Matrix.* NBI Rating of 4 or less for deck surface and deck bottom, or when deck replacement cost is competitive with rehabilitation.	 70 yrs 40 yrs
Substructure Replacement (Full or Partial)	NBI Rating of 4 or less for abutments, piers, or pier cap, or there is existence of open vertical cracks, signs of differential settlement, or presence of active movement, or bridge is scour critical with no countermeasures available.	40 yrs
Rehabilitation		
Concrete Deck Overlays Deep Shallow HMA / Membrane HMA Cap	Guidelines in MDOT's *Bridge Deck Preservation Matrix* NBI Deck Rating < 5 for surface and > 5 for bottom NBI Deck Rating < 5 for surface and > 4 for bottom NBI Deck Rating < 5 for surface and > 4 for bottom NBI Deck Rating < 5 for surface and < 4 for bottom	 25 yrs 12 yrs 8 yrs 3 yrs
Railing Retrofit / Replacement	NBI Deck Rating greater than 5, Railing / Barrier rated less than 5, or Safety Improvement is needed	
Steel Beam Repairs	When more than 25% section loss is present in an area of the beam that affects load carrying capacity, or to correct impact damage that impairs beam strength.	
Prestressed Concrete Beam Repairs	Repair ends of prestressed I-beams when more that 5% spalling is present, or repair areas to correct impact damage that impairs beam strength or exposes prestressing strands.	
Repair / Replace Culvert	NBI Rating of 4 or less for culvert or drainage outlet structure, or there is existence of open vertical cracks, signs of deformation, movement, or differential settlement.	
Repair / Replace Retaining Wall	NBI Rating of 4 or less for retaining wall, or there is existence of open vertical cracks, signs of differential settlement, or presence of active movement.	

Pin and Hanger Replacement	NBI Rating for elements is 4 or lower. Presence of excessive section loss, severe pack rust, or out-of-plane distortion.	
Substructure Concrete Patching and Repair	NBI Rating for abutments or piers is 5 or 4 and less than 30% of the surface is spalled and delaminated, or in response to Inspector's work recommendation for substructure patching.	
Preventive Maintenance		
Repair / Replace Deck Joint	Include when doing deep or shallow overlays, or when NBI Rating for joint is 4 or lower, or when joint is leaking heavily.	
Repair / Replace Steel Bearing	NBI Rating for girders and deck is 5 or higher and rating for bearings is 4 or lower.	
Complete Painting	NBI Rating for paint condition is 3 or lower, or in response to Inspector's work recommendation for complete painting	15 yrs
Zone Painting	NBI Rating for paint condition is 5 or 4, or less than 15% of existing paint area has failed and remainder of paint system is in good or fair condition.	10 yrs
HMA Overlay Cap without Membrane	NBI Rating of 3 or less for deck surface and deck bottom. Temporary holdover to improve rideability for a bridge in the 5 year plan for rehab / replacement.	3 yrs
Concrete Deck Patching	Deck Surface Rating of 5, 6, or 7 with minor delamination and spalling, or in response to Inspector's work recommendation	5 yrs
Channel Improvements	Removal of vegetation, debris, or sediment from channel and banks to improve channel flow, or in response to Inspector's work recommendation.	
Scour Countermeasures	Structure is categorized as scour critical and is not scheduled for replacement. NBI comments in abutment and pier ratings indicate presence of scour holes.	
Scheduled Maintenance		
Superstructure Washing	When salt contaminated dirt and debris collected on superstructure is causing corrosion or deterioration by trapping moisture, or in response to Inspector's work recommendation.	2 yrs
Vegetation Control	When vegetation traps moisture on structural elements or is growing from joints or cracks, or in response to Inspector's work recommendation for brush cut.	1 yr

Debris Removal	When vegetation, debris, or sediment accumulates on the structure or in the channel or in response to inspector's work recommendation.	1 yr
Drainage System Clean-Out/ Repair	When drainage system is clogged with debris, or drainage elements are broken, deteriorated, or damaged.	2 yrs
Spot Painting	For zinc based paint systems only, in response to Inspector's work recommendation.	5 yrs
Seal Concrete Cracks / Joints	Concrete is in good or fair condition, and cracks extend to the depth of the reinforcement, or in response to Inspector's work recommendation	5 yrs
Repair / Replace HMA Surface	HMA surface is in poor condition or in response to Inspector's work recommendation.	
Seal HMA Cracks / Joints	HMA surface is in good or fair condition, and cracks extend to the surface of the underlying slab or sub course, or in response to Inspector's work recommendation	
Minor Concrete Patching	Repair minor delaminations and spalling, or in response to Inspector's work recommendation.	
Timber Repairs	NBI Rating of 4 or less for timber members, or to repair extensive rot, checking, or insect infestation.	
Repair / Replace Guard Rail	Guard rail missing or damaged, or Safety Improvement is needed.	
Repave Approaches	HMA is in poor condition or in response to Inspector's work recommendation.	
Repair Slopes	NBI Rating is 5 or lower, or when slope is degraded or sloughed, or slope paving has significant areas of distress, failure, or has settled.	
Install Riprap	To protect surfaces when erosion threatens the stability of side slopes or channel banks.	
Miscellaneous Repairs	Uncategorized Repairs in response to Inspector's work recommendations.	

Cost Estimate:

GCRC computes the estimated cost of each typical preservation action using unit prices in the latest Bridge Repair Cost Estimate spreadsheet contained in MDOT's Local Bridge Program Call for Projects. The cost of items of varying complexity, such as maintenance of traffic, staged construction, scour countermeasures, etc., are computed on a bridge-by-bridge basis. The cost estimates are reviewed and updated annually.

Operations and Maintenance Plan – Annual Activities / 10 Year Program:

A primary objective of GCRC's preservation plan is improvement of the 29 bridges rated poor (4) or lower to a rating of fair (5) or higher within 10 years thru a program of replacement, rehabilitation, and preventive maintenance actions. The work has been prioritized considering each individual bridge's needs, its importance, present cost of improvements, and impact (cost increase due to increased degradation) of deferral. The 5 year program incorporates comprehensive annual scheduled maintenance activities designed to preserve bridges currently rated fair (5) or higher with the objective of extending their useful service life. The bridge-by-bridge Maintenance Plan is presented in Appendix A-2.

Project Prioritization Criteria

Genesee County uses a prioritization formula that evaluates five factors and weights them as follows: condition – 30%; load capacity – 25%; traffic – 20%; safety – 15%; and detour – 10%. There are several components within each factor that are used to arrive at its score. Each project under consideration is scored and its total score is then compared with other proposed projects to establish a priority order.

Five Year Annual Cost Projection:

Preservation Activity	2011	2012	2013	2014	2015	2016	Total
Replacement							
Bridge 2710	750,000						
Bridge 2723		1,000,000					
Subtotal	**750,000**	**1,000,000**					**1,750,000**
Bridge 2716				660,000			
Bridge 2804				470,000			
Bridge 2774					440,000		
Subtotal				**1,130,000**	**440,000**		**1,570,000**
Bridge 2709					420,000		
Bridge 2761					570,000		
Bridge 2803					385,000		
Subtotal					**1,375,000**		**1,375,000**
Rehabilitation							
Bridge 2798			387,500				
Bridge 2717				810,000			
Bridge 2765				260,000			
Bridge 2815		**(a)**					
Subtotal		**(a)**	**387,500**	**1,070,000**			**1,457,500**

Preventive Maintenance							
Bridge 2737				240,000			
Bridge 2756				260,000			
Bridge 2728					350,000		
Bridge 2706		**(a)**					
Bridge 2742		**(a)**					
Bridge 2749		**(a)**					
Bridge 2766		**(a)**					
Bridge 2770		**(a)**					
Bridge 2772		**(a)**					
Bridge 2780		**(a)**					
Bridge 2786		**(a)**					
Bridge 2807		**(a)**					
Bridge 2817		**(a)**					
Subtotal		**4,000,000**		**500,000**	**350,000**		**4,850,000**
Scheduled Maintenance – Program using local in-house forces							
Annual Total	**750,000**	**5,000,000**	**387,500**	**2,700,000**	**2,165,000**		**11,002,500**

(a) Estimate in progress. Total cost for these bridges will be $4,000,000.

Identify Funding Sources:

Projects for the replacement of bridges 2710 and 2723, and the rehabilitation of 2798 have been programmed and funded. The GCRC applied for MDOT local aid funding in 2011 for the replacement of bridges 2737 and 2756 in the 2014 program year. Other replacement and rehabilitation projects will be submitted for funding in subsequent program years. The preventive maintenance projects shown for 2012 will be funded through a County appropriation of $4,000,000 for bridge preservation. Projects submitted to the local aid program that are not selected for funding will be added to the County program. The scheduled maintenance and minor repairs will be performed by the County's in-house maintenance forces and funded thru the County's annual operating budget.

General Recommendations

- A significant number of the County's structures are coded as scour critical. The County should implement action plans and work to make improvements to remove structures from the scour critical list as other improvements are made to the structures.

- Several structures have gravel and other debris building up on the shoulders. The County should periodically remove debris and vegetation as it can restrict drainage from the structure.

- Previous inspections were limited by weather, with inspectors indicating various components were not accessible to due snow and ice. It is recommended that the County work to perform the 2012 inspection cycle several months ahead of schedule (September or October) to provide better weather conditions for inspection.

- Many of the County's structures have deck drains that are either covered by HMA or plugged with debris. The County should periodically remove debris from drains to keep them functioning as intended. Extensions should be added to those structures that have not already been addressed.

Argentine Township

2703 Silver Lake Road over Lobdell Lake Dam

Constructed: 1929 **Reconstructed:** N/A **General Condition:** Fair

Description: This structure is integral with the dam, spanning both the main dam and spillway. The main span is concrete tee beams and the spillway span appears to be solid slab. The structure has HMA wearing surface and concrete balustrade railings with a retrofit guardrail on one side.

Recommendations: The configuration of this structure prevents access to a majority of the structure. A special inspection is recommended, potentially in conjunction with the dam inspection, to access the structure. Install retrofit railings. Repair sink hole around casting in surface. Add riprap to mitigate slope erosion. Mill and resurface structure and approaches. Patch concrete railing.

2734 Duffield Road over the Shiawassee River

Constructed: 2010 **Reconstructed:** N/A **General Condition:** New

Description: This is a single span side-by-side concrete box beam bridge with concrete deck and integrated the previous abutments.

Recommendations: The structure was under construction at the time of routine inspection. An initial inspection and load rating are recommended upon completion of construction.

14. Washington State Department of Transportation
Map-21 & Bridges, WSDOT establishes MAP-21 bridge performance targets

WSDOT establishes MAP-21 bridge performance targets

The Federal Highway Administration (FHWA) published in the Federal Register (82 FR 5886) a final rule establishing performance measures for State Departments of Transportation (DOTs) to use in managing pavement and bridge performance on the National Highway System (NHS). The National Performance Management Measures; Assessing Pavement Condition for the National Highway Performance Program and Bridge Condition for the National Highway Performance Program Final Rule addresses requirements established by the Moving Ahead for Progress in the 21st Century Act (MAP-21) and reflects passage of the Fixing America's Surface Transportation (FAST) Act. The rule was effective May 20, 2017.

Targets established May 20, 2018

WSDOT has been proactive in working with MPOs and local agencies with regard to the implementation of federal pavement performance measures for the NHS. Collaborative efforts to establish targets by May 20, 2018, included meetings with all MPO directors and WSDOT representatives; responsible for helping make policy, process, data and advisory target setting decisions as well as in-depth discussions between subject matter experts; responsible for better understanding final federal rule requirements and their implications.

FHWA has set the upper limit for the percentage of all NHS bridges classified in poor condition at 10%. Based on analysis and past trends, 10% is the recommended target. The FHWA did not set a limit for the percentage of NHS bridges classified as being in good condition; it is recommended to adopt a target of 30% based on a thorough review of current bridge conditions (see chart below).

The condition of individual bridge elements (deck, superstructure, substructure), and culverts (which are measured separately), are rated using a classification method from the National Bridge Inventory (NBI) and the Highway Bridge Program. This classification method assigns the elements and culverts condition ratings ranging from 1 to 9 where 7 or greater = good; 5-6 = fair; and 4 or less = poor.

For MAP-21 and continued in the FAST Act, bridges in good condition have all three elements (deck, superstructure, substructure) rated as 7 or higher); bridges in fair condition meet the minimum threshold of 5 or higher; and poor bridges have any of the elements rated as 4 or lower (see p. 2).

The percentage of the total NHS bridge deck area for each classification (good, fair, poor) is calculated as the ratio of the total deck area of NHS bridges in a classification to the total deck area of NHS bridges in the state. The bridge deck condition of a shoulder on a bridge is included in the overall condition rating; it is not tracked or rated for active transportation use separate from the overall bridge deck condition. Sidewalk elements are defined and condition rated but these data are not reported here.

A separate requirement determined by FHWA is that the percent of NHS bridges in poor condition cannot exceed 10%. This performance criterion is a special requirement mandated by Congress, and is the only bridge performance measure that results in a funding penalty if it is not met. The penalty requires the State to obligate a specified percentage of its National Highway Performance Program (NHPP) funds to correct the NHS bridge conditions until the minimum threshold is met (see p. 4 for more details).

MAP-21 performance measures by program area	Current data	2-year target[1]	4-year target[1]	Penalty
Bridges (PM2) 23 CFR Part 490 ID No. 2125-AF53				
Percent of NHS bridges classified in poor condition (weighted by deck area)	7.8%	10%	10%	Yes
Percent of NHS bridges classified in good condition (weighted by deck area)	32.8%	30%	30%	No

Notes: Federal rule allows state and MPOs to adjust four-year targets during the mid-performance progress report. 1 Two year and four year targets for PM2 are due October 1, 2020, and October 1, 2022.

Bridge data collection for MAP-21

WSDOT is required to report data to FHWA annually on the condition, functional adequacy and essentiality for the public for all bridges statewide. The bridge data determines sufficiency ratings and if a bridge is structurally deficient and/or functionally obsolete. The same bridges that are rated for WSDOT's condition rating are also rated in the federal system, in addition to local agency owned bridges across the state.

The good, fair, and poor classification of bridges on the NHS utilizes data elements from the NBI database. State DOTs measure and classify a number of standard features for bridges (such as condition and geometric information) in their jurisdiction, which they are required to report to FHWA on an annual basis. These requirements include bridges' on-ramps connecting to the NHS.

Penalties

In order to avoid a penalty, states must meet this minimum condition level: National Highway System (NHS) bridges not to exceed 10 percent structurally deficient, by deck area.

If a state does not meet the minimum condition for three consecutive years, a funding penalty will apply during the following fiscal year and each year thereafter until it is in compliance. The state must obligate and set aside an amount to 50 percent of the apportionment for the Highway Bridge Program in fiscal year 2009, from the NHPP apportionment, only for projects on NHS bridges.

Contractor crews working for WSDOT in the process of rebuilding a new bridge on State Route 162 across the Puyallup River Bridge in Pierce County.

For more information

State bridge condition information: DeWayne Wilson, WSDOT Bridge Management Engineer, at (360) 705-7214 or WilsonD@wsdot.wa.gov.
Local bridge condition information: Roman Peralta, WSDOT Local Programs Bridge Engineer, at (360) 705-7870 or PeraltR@wsdot.wa.gov.

Available Data

- Bridge condition assessment of the National Highway System's National Bridge Inventory item ratings of bridge deck, superstructure, substructure, and/or culverts for all federally reportable state and local bridges][1]

Notes: Data is available for county and city levels and can be provided by the MPO boundaries. 1 Bridge condition data for tribally-owned and federally-owned bridges is provided to WSDOT by the bridge owner.

What is the current distribution of funds?

WSDOT is planning to provide approximately $130 million annually over the next 10 years for bridge preservation, which improves the condition of bridges through replacement, rehabilitation and preventive maintenance. This comes from federal and state revenue sources, and the specific amount each year for bridge preservation is determined based on an assessment of need and available funding through asset management analyses.

Purpose of reporting requirements

In July 2012, the Moving Ahead for Progress in the 21st Century Act (MAP-21) became law. Included in the law was a Declaration of Policy: "Performance management will transform the Federal-aid highway program and provide a means to the most efficient investment of Federal transportation funds …."

The primary objectives of MAP-21 are to increase the transparency and accountability of states for their investment of federal taxpayer dollars into transportation infrastructure and services nationwide, and to ensure that states invest money in transportation projects that collectively make progress toward the achievement of national goals. The new rules will require reporting performance on the following areas: Safety; Pavement and Bridge; System Performance/Congestion; Freight, and Congestion Mitigation and Air Quality (CMAQ).

Prior to MAP-21, there were no explicit requirements to demonstrate how transportation programs supported national performance outcomes. But many state DOTs, like WSDOT, have engaged in voluntary accountability and reporting efforts.

15. Washington State Department of Transportation
    Bridge & structures preservation (taken from WSDOT's website)

Bridge & structures preservation

We help preserve and maintain bridge and structures across the state using a Bridge Asset Management Plan to focus on achieving the greatest return through available investments.

Our bridge asset management goals are based on the following bridge preservation categories, listed from highest to lowest priority. Critical items in each category are prioritized to develop a 2 and 6 year plan based on available funding.

1. Border bridges
2. Bridge Scour repairs
3. Bridge repairs
4. Steel Bridge painting
5. Concrete Bridge deck repair and overlay
6. Replacement or rehabilitation of bridges
7. Seismic Retrofit

Bridge Preservation Program

2015 Bridge Needs Lists (by Region)

- Eastern Region (xlsx 24 kb)
- North Central (xlsx 19 kb)
- Northwest (xlsx 97 kb)
- Olympic (xlsx 51 kb)
- South Central (xlsx 40 kb)
- Southwest (xlsx 47 kb)

If you have any questions or comments, please contact
DeWayne Wilson
360-705-7214

16. Sky's The Limit-Implementing UAV applications at the Michigan DOT
Colin Brooks, Richard Dobson, and David Banach
Roads & Bridges/April 2019

BACK IN THE SEPTEMBER 2015 ISSUE, ROADS & BRIDGES EXAMINED THE USE OF UNMANNED AERIAL VEHICLES (UAVS, UNMANNED AERIAL SYSTEMS [UAS] OR "DRONES") IN VARIOUS DOTS ACROSS THE U.S.

One agency of interest was the Michigan DOT (MDOT). MDOT began to use UAS for bridge inspections, confined space inspections and traffic monitoring. Steve Cook, P.E., engineer of operations and maintenance at MDOT, had been working with Colin Brooks of the Michigan Tech Research Institute (MTRI) to determine how these tools could most effectively be used. With the rapid advancements in UAS rules, technology and sensors, MDOT and MTRI have continued to investigate even further how these platforms and sensors can be implemented into department procedures.

STORING AND VIEWING DATA

Several different types of data transfer sites were investigated and tested during the course of the project to find a solution to quickly upload, provide access for, and distribute the UAS-collected data to multiple MDOT users. A final cloud-storage software setup was selected to allow Michigan Tech and MDOT to collaborate and transfer files easily. The system also allowed MDOT to directly upload the data from the cloud into its own databases. The advantages of this solution included a unique credential (ID/password) for each user, a full audit trail and a data backup mechanism stored within the secure cloud. System managers also could quickly identify any changes to the files or the cloud performed by the users.

17. Modeling Bridge Deterioration with Markov Chains
ASCE Library, Journal of Transportation Engineering/Volume 118 Issue 6-November 1992
Mark A. Cesare, Carlos Santamarina, Carl Turkstra, and Erik H. Vanmarcke

Abstract

This paper describes methods for determining and utilizing Markov chains in the evaluation of highway bridge deterioration. Using a data base of 850 bridges in New York State, Markovian transition matrices (MTM) are first found for the overall bridge condition. Then, transition matrices are developed for the condition rating of individual bridge components (e.g., superstructures, decks, and piers). In each case, chains are determined for various types of construction. Also discussed is the modeling of correlated elements such as the primary structure and joint condition and the ability to determine the correlation for a set of data. The consequence of small data bases is discussed, and an explanation is offered for unexpected values of the transition probabilities. Finally examined is the use of Markovian analysis for predicting the evolution of the average condition rating of a set of bridges, and expected value of condition rating for a single bridge. Markov transition matrices are introduced to model the effects of repairs and to determine repair policies that will lead to constant average condition rating.

18. Proposed AASHTO Manual for the Maintenance of Roadways and Bridges
NCHRP 20-07/Task 380

BACKGROUND: The *AASHTO Maintenance Manual: The Maintenance and Management of Roadways and Bridges* was published in 2001. This manual was intended to assist persons early in their career in roadway and bridge maintenance in understanding the various processes, methods, and materials that are applied to maintain the bridge and highway system effectively. This manual was later updated and published in 2007 as the *AASHTO Maintenance Manual for Roadways and Bridges*. In view of the changes in the state of practice of highway and bridge system maintenance, the implications of reduced budgets and work force, and the benefits of implementing research findings, there is a need to produce a new edition of the manual that recognizes these issues.

OBJECTIVE: The objective of this research was to develop a proposed *Manual for the Maintenance of Roadways and Bridges*. This *Manual* is intended for adoption/publication by AASHTO (i.e., to supersede the 2007 edition of the *AASHTO Maintenance Manual for Roadways and Bridges*).

STATUS: Research completed; final report has been provided to the AASHTO Committee on Maintenance for review/adoption as a new edition of the *AASHTO Manual for the Maintenance of Roadways and Bridges.*

19. Bridge Management and Inspection Data: Leveraging the Data and Identifying the Gaps
    TRB Transportation Research Circular 498
    Kristen L. Sanford, Pannapa Herabat, and Sue McNeil

Data used to support bridge management vary from agency to agency. Collection of these data is time consuming and expensive. Therefore, as bridges continue to age and agencies are under increasing pressure due to limited resources, there is a great need to ensure that data collection is rational. This paper reviews the gaps between what data are actually collected and what is required, and the opportunities to leverage existing data collection efforts. The gaps and opportunities are explored in three areas. First, the role of bridge management data as inputs to analysis tools such as rating programs is explored. Second, detailed safety inspection data are rarely included in bridge management programs, but again they are a critical input for rating and analysis tools. Finally, the inclusion of results from rating and analysis tools in bridge management systems is the exception rather than the rule. The paper also describes the need for a new approach to data collection in terms of these gaps and the existing data. To decide what information should be included in the bridge management system, the paper then describes some tools that are used to evaluate the data needs of an organization and the value derived from additional information. These tools are applied to the case of load rating data.

As inspection data collection and recording practices have evolved rather than been designed, there are significant gaps between the actual data collected and the data required. There are also opportunities to leverage resources by using existing data. The remainder of this paper explores the gaps and opportunities in three areas. First, the role of bridge management data as inputs to analysis tools such as rating programs is explored. These data are a critical input to the selection of a particular tool and include some of the basic parameters that describe a particular bridge. Second, detailed safety inspection data are rarely included in bridge management programs, but again they are a critical input for rating and analysis tools. Finally, the inclusion of the results of rating and analysis in bridge management systems is the exception rather than the rule, but these results determine the use of the bridge (for example, when a bridge load limit is posted) and the need for improvement.

Filling the Gaps and Leveraging the Opportunities to Use Existing Data

The following sections describe three approaches that address these issues. The first explores the data needed to select a load rating tool and presents a prototype decision support system. The second addresses the role of safety inspection data, specifically NDE data, in bridge management. The third focuses on tools for redesigning the data collection process.

REDESIGNING THE DATA COLLECTION PROCESS

Data collection procedures and guidelines have evolved over time as regulations have been issued and management practices have emerged. While most agencies have a bridge management system, there are a variety of systems in use, which often differ in structure and data needs. Even agencies using the same management system may use different quantities and types of data in running the system. The NBI was developed to determine the status of the nation's bridges and the magnitude of the funding needs, and it requires that a total of three ratings be reported—one each for the superstructure, deck, and substructure. The NBI does not provide information about the severity and extent of deterioration of a particular bridge or a strategy for meeting future needs (*38*). Pontis, on the other hand, requires that condition states be reported for each element of the bridge. That is, a condition rating is reported for each beam, column, girder, etc. While Pontis is the most widely used of the bridge management systems, there are many others at both the national level (e.g. Bridgit) and the state level (e.g. Pennsylvania's in-house BMS). States are now faced with collecting data for the NBI and for their chosen BMS as well as any additional data used, and researchers have been working to provide a translation between the various rating scales to reduce the data collection effort required (*39, 40*) .

Data flow diagrams allow the decision-making process to be structured in terms of the person or people making the decisions, the decisions themselves, and the information inputs and outputs for those decisions. Figure 3 shows a schematic of the partitions of a data flow diagram. The data flow diagrams allow layered structuring. In other words, the nodes of a diagram representing a high-level process can be exploded to sub-diagrams, each of which describes the process in greater detail.

and the data required for applying an analysis tool are drawn from a variety of sources.

The Need for Rating Data

There are multiple uses for rating data in the bridge management process, although the data are not necessarily collected and stored in the bridge management system. One of the issues in using a particular bridge analysis tool is whether the user has access to the data needed. Other issues, as described by Herabat (*24*), include the access of the user to the tool and the familiarity with the tool. As discussed previously, rating data are important because of the implications for bridge usage and the potential for preventing catastrophic failure.

The Value of Rating Data

Rating data have the potential to provide tremendous value to the bridge management process by minimizing life cycle costs. For example, rating data may allow an agency to prevent overloading, thereby extending the life of the facility. Figure 6 is an influence

CONCLUSIONS AND RECOMMENDATIONS

Effective and efficient data collection, storage, and access are critical for managing bridges under constrained resources. As data collection practices have evolved in response to regulations, new technologies, and management practices, there are gaps in the data collection efforts, data that are collected but not recorded, and data collection efforts that are duplicated.

Several tools are available to improve the data collection process. These include structuring the data collection process using data flow models and using influence diagrams to explore the value of additional information. The use of data from BMS to select a load rating tool demonstrated that it is possible to develop a link between BMS and analysis tools. It is surprising to find that the proposed link required a minimum amount of already existing BMS data to be useful in identifying the data necessary to provide a link between BMS and rating programs.

This paper is a starting point in understanding the gaps between BMS and analysis tools. Based on the discussion above, there is some common ground between the two. However, practice varies from state to state. Not all states use the same types of analysis tools. The concepts presented in this paper can be easily adapted to each state's specific practice.

20. Bridge Management Systems
    NCHRP Report 300, Transportation Research Board, 1987

This report contains the findings of a study that was undertaken to define the essential elements of a network-level bridge management system. The report defines the benefits from, and basic engineering concepts for, implementation of a bridge management system. The contents of this report will be of immediate interest and use to administrators, managers, and engineers with bridge responsibilities at all levels within a transportation agency.

About one-half of the approximately 600,000 highway bridges in the United States were built before 1940. Most of these bridges were designed for less traffic, smaller vehicles, slower speeds, and lighter loads than are presently found on the highway network. In addition, even in newer bridges, deterioration caused by service conditions and deferred maintenance is a growing problem. Nearly half of these bridges have been classified as structurally deficient or functionally obsolete by the Federal Highway Administration. The cost for rehabilitation and replacement of these bridges has been estimated at more than $50 billion. However, only $2 to $3 billion annually has been available to address this problem.

It is obvious that available funds will not permit total rehabilitation or replacement of all deficient bridges. Therefore, the limited funds available must be carefully allocated to bridges required by the public and transportation industries to provide the most cost-effective treatment.

This report contains the findings of the first phase of NCHRP Project 12-28(2), "Bridge Management Systems." The overall objective of this project is to develop a model bridge management system at the network level that can be implemented by small to medium size transportation agencies. The system is intended to ensure the effective use of available funds and identify the effects of various funding levels on the bridge network.

The specific objectives of the first phase of NCHRP Project 12-28(2) were to define the elements required for a model bridge management system (BMS) at the network level, and to initiate its development and programming. Six major modules were identified as the minimum required for an effective bridge management system. These are: the BMS data base module; the network level maintenance, rehabilitation, and replacement selection module; a maintenance module that will assign maintenance programs in a rational and continuing way within the system; the historical data analysis module; a project level interface module; and the reporting module. These modules can be customized according to the transportation agency's needs, and additional modules can be added and modified as needed.

A second phase of the project was initiated in late 1987 with the objective of further developing and refining the BMS model reported on here. The second phase will result in completion of the engineering concept development for a network level BMS, programming the system on a computer, and validation of the system and engineering concepts with actual bridge inventory data obtained from several transportation agencies. The second phase should be completed in late 1989.

Appendix C contains information on a BMS demonstration program that was developed as part of this project. The demonstrator shows the general concepts of what a computerized BMS can offer. The demonstration program is contained on one 5¼-in. IBM-PC compatible floppy disk formatted with IBM or MS DOS Version 3.0 or higher, double sided/double density (see Appendix C for requirements to run the program). A copy of the demonstration program may be obtained by sending one blank disk to the Transportation Research Board, National Cooperative Highway Research Program, 2101 Constitution Avenue, NW, Washington, D.C. 20418.

21. Integration Research and Design of the Bridge Maintenance Management System
    Zi-hong YIN, Yuan-fu LI, Jian-GUO, Yan LI
    SciVerse ScienceDirect Procedia Engineering 15 (2011) 5429-5434

Abstract

Bridge maintenance quality has a direct bearing on the normal use of road function and service level. Based on analysis of the requirements including bridge maintenance data management, bridge safety state comprehensive evaluation, intelligent aided decision analysis and information sharing, the bridge maintenance& management intelligent aided decision support system (BMMS) is designed. The system structure, function module, comprehensive evaluation and intelligent aided decision-making module are given, and BMIADSS based on intelligent decision-making management is developed. This paper provides strong support for the full implementation of bridge maintenance and management informatization.

1. Introduction

The bridge management is to coordinate and control the whole process about bridge, aiming at making sure that the bridge management department can make use of the limited resources reasonably and provide services for the users as good as possible. The bridge maintenance management system, developed on the basis of the bridge structural engineering, mechanism of disease detection and geographic information systems, offers economic and technical convenience for the supervision and maintenance of the bridge.

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The U.S. Federal Highway Administration started the research on the promotion of the bridge management system in 1987.

Based on the work such as database development and the detection of the classification, rating, sorting and the service life prediction of the maintenance operations, they developed a bridge management system-PONTIS. Japan's Ministry of Construction published the bridge inspection manual in 1988. Civil Engineering Institute developed the bridge maintenance management system in 1998 for the integration of the related materials in the periods of construction, detection as well as maintenance, and simplified data delivery by means of Internet in the meanwhile.

The research of domestic bridge maintenance management system dates from the late 80s of last century. The bridge maintenance management departments of various provinces developed the required bridge maintenance management systems according to their own specific conditions of bridge development. With the continuous expansion of the road network and the bridge construction scale, how to realize the sharing of the bridge maintenance information and its regional management is urgent to be solved.

The Bridge Maintenance & Management Intelligent Aided Decision Support System(BMIADSS) is a research topic based on this environment. The database of the system includes the users' database, the information management system database and the intelligent aided decision system database. The integration of the basic data information of the large-span bridges, the detection information of the manual inspection and the healthy detection information is good for analyzing the reasons of the structural diseases, finding out the defects of the components and the changes of related environment timely and handling the technical conditions of the bridge systematically.

2. Bridge Maintenance Management System design

Bridge Maintenance Management System differs with special requirements of departments, which has unique requirement. Bridge Maintenance Management System includes nonseparable major operating modules such as bridge database management, systems management, integrated assessment subsystem management, forecasting and auxiliary decision-making subsystem.,etc. Although the modules are mutually independent, all capable of serving the purpose of enabling connection between systems by using the same keycode (such as the bridge number) to series-connect or switch from each other. The framework for system design is shown in Figure 1.

2.2.Bridge Database Management Subsystem Design

Bridge data management subsystem is the system's main module which contains five major information sub-modules--the card information on bridge sub-module, manual inspection test records, condition monitoring records, bridge maintenance records, engineering drawings management. Each function module should have the programming function on data maintenance (to add, modify, delete), data query, statistical analysis, data processing and application.,etc.

Bridge card information consists both bridge data and bridge opening information. Bridge information includes information on its identity and geometric properties which could be modified by lining, naming and numbering of the bridge's basic information from the "data dictionary" of the Maintenance Management System. Corresponding to each bridge, each opening information such as opening number, structure of the upper and lower part and so on could be added.

Bridge opening is designated as the basic operation unit for manual inspection test records, condition monitoring records, as well as maintenance records. The sub-modules of condition monitoring and manual inspection records function maintenance operations management upon the specific components of certain bridge opening. Frequent inspection is a summary based on designating a certain opening of the bridge as the smallest operating unit to conduct a general inspection.

Engineering drawing data module is used to manage information on bridge design drawings. Its downloadable function enables customers of different interests to understand the bridge's designing information.

2.3.System Management Module Design

System management module includes user management, privilege management, opening type management, data backup, data recovery and other sub-modules. It provides the following security policies to secure the conservation of data from the Bridge Management System: (l) Management on system user--different types of users use different accounts; (2) Privilege Management--operators are divided into different levels according to the system requirements, and each level has its own software with corresponding functions;(3)database backup and recovery--setting scheduled backups of system databases, which anables the system to aquire the regularly backuped files for recovery in case of unexpected occurrence.The results is shown in Figure3,4.

2.1.system database design

The collection and input of data as well as the establishment of database is a crucial aspect in Bridge Maintenance Management System, and the quality of data acquisition has a direct impact on the overall system performance., therefore, database establishment must be paid much attention to. Bridge

Maintenance Management System Database, which adopts SQLSERVER or Oracle as the tool of development and management, consists of three parts-- (l)Basic information and data of the bridge, used to display bridge identification information and geometric information.(2)Business data for maintenance and management, including frequent inspections, regular inspections, maintenance record data, assessment data and so on, which all serve as the query to browse, direct source of report output, as well as evaluation for performance and the decision for maintenance programs. (3)The GIS data of bridge, used to display the bridge's geographic information and data.

By the analysis of monitoring the bridge operation we can see that the bridge is prone to defects suspension system components, and the component disease type is simple, the main diseases are corrosion and broken wires. According to the monitoring requirements of the Maintenance Management System, choose the system maintenance and management measures selected function key real-time for the status of the bridge damage points, when select the maintenance measures, consider the terms of the budget and construction requirements, by Optimizing to enable maintenance effect to be achieved the maximum.

4. 4 Conclusion

(1) Database management system can complete the basic information about the bridge, inspection record, maintenance and reinforcement history, the input of the image information, etc, provide a variety of information queries and tab and other functions, and the recorded data automatically generates the documentations needed by the bridge comprehensive evaluation.

(2) Comprehensive evaluation system transplants the bridge experts' experiences and knowledges into the computer, and just enter the basic elements of a bridge, environmental conditions, traffic volume and data obtained from bridge inspection, system can use percentile methods to evaluate the the soundness of the all given bridge components.

(3)Using the object-oriented programming (OOP), ARCGIS technology and client / server architecture (C/S) developed BMIADSS, meets the needs of information sharing and regional management of modern bridge maintenance and management. In this paper,the writer used developed BMIADSS to realize Xihoumen Bridge conservation and management and monitoring, the system has great practicability and can serve as a supporting decision-making tools of bridge conservation and management department.

22. Georgia Department of Transportation, Bridge Structure Maintenance and Rehabilitation Repair Manual, Office of Bridge and Structural Design Bridge Maintenance Unit, June 29, 2012 Version 06.01.12
23. Georgia Department of Transportation, Bridge Structures Maintenance Plan, August 2013.
24. FHWA Bridge Preservation Guide, FHWA-HIF-11042, August 2011.
25. FHWA Bridge Preservation Guide, FHWA-HIF-18022, Spring 2018.

Design Life

Definition: The design life is the period for which a component, element, or bridge is expected to function for its designated purpose when designed, constructed, and maintained as per standards.

Commentary: The design life of a bridge component or element is the period during which the item is expected, by its designers, to work within its specified parameters. Design codes and material specifications are important parameters in determining the expected design life of a highway structure.

Service Life

Definition: The service life is the period for which a component, element, or bridge provides the desired function and remains in service with appropriate preservation activities.

Commentary: Service life of bridge components or elements is the period during which the item actually performs. The service life of a bridge and components in good to fair condition can be extended with cyclical and/or condition-based PM activities.

A steadfast bridge preservation program and quality workmanship practiced during the service life of an asset is necessary for the asset to reach its design life.

Establishing a Bridge Preservation Program

What Is a Bridge Preservation Program?

A bridge preservation program consists of performing cost-effective cyclical and condition-based PM activities that seek to prolong the service life of bridges and delay the need for rehabilitation or replacement.

Figure 14 is a representation of a bridge's condition over time. The three types of work programs are shown based on the condition. PM activities as part of the bridge preservation program can extend the service life of a bridge when it is in good or fair condition. This results in achieving the greatest value from the original construction cost by delaying the need for rehabilitation or replacement. Typically, when a bridge component enters into poor condition, bridge preservation ends until that bridge component is rehabilitated back into good or fair condition, or replaced.

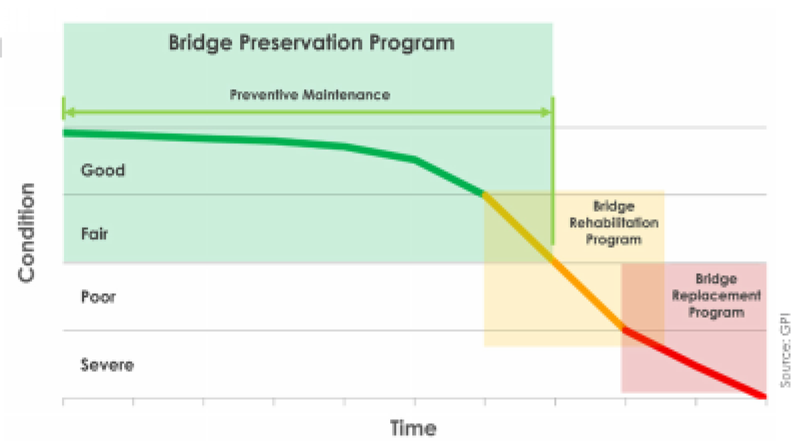


Figure 14. Bridge condition over time.

26. “A Guide to Cost-Effective Bridge Preservation”, FHWA FOCUS, September 2011.

The FHWA guide provides definitions for terms such as bridge preservation, preventive maintenance, rehabilitation, state of good repair, and structurally deficient, along with related commentary and examples. Also featured is a framework for establishing a Systematic Preventive Maintenance (SPM) program for bridges. As the guide notes, “An SPM program for bridges can be defined as a planned strategy of cost-effective treatments to existing bridges that are intended to maintain or preserve the structural integrity and functionality of elements and/or components, and retard future deterioration, thus maintaining or extending the useful life of the bridge.”

An SPM program can be implemented at the network-wide, highway system, area-wide, or regional level. Federal-aid funds may be used for SPM on highway bridges located on public roads regardless of whether a bridge is eligible for replacement or rehabilitation.

SPM programs should feature the following attributes at a minimum:

- *Goals and Objectives*—Clearly defined objectives and measurable goals. Goals and measures can also be developed for specific PM strategies.
- *Inventory and Condition Assessment*—Availability of tools and resources to conduct bridge inspections and evaluations.
- *Needs Assessment*—Documented needs assessment process that outlines how PM needs are identified and prioritized.
- *Cost-Effective PM Activities*—Ability to demonstrate that the proposed PM activities are a cost-effective means of extending the life of a bridge.
- *Plan for Accomplishing the Work*—Availability of tools and resources to accomplish the PM work.

- *Reporting and Evaluation*—Ability to track, evaluate, and report on the planned and completed PM work on a periodic basis. Expenditures should also be tracked over time, to ensure that the investment is providing the return expected.

Also highlighted in the guide are examples of PM treatments and activities that can extend the life of bridges when applied to the right bridge at the right time. For bridge decks, this can include installing deck overlays to seal the deck surface and reduce the impact of aging and weathering, as well as using electrochemical chloride extraction (ECE) treatments to remove chloride ions and prevent corrosion of the bridge's reinforcing steel. Treatments for bridge superstructures include retrofitting fracture-critical members or fatigue-prone details and performing spot or zone painting to target areas where paint deteriorates the fastest and protect against corrosion.

27. Performance of Corrosion Inhibiting Admixtures in Hawaiian Concrete In a Marine Environment
    Research Report UHM/CEE/12-04, September 30, 2012
    Joshua Ropert, MS and Ian N. Robertson, Ph.D., S.E.

EXECUTIVE SUMMARY

A long-term field exposure study was conducted to evaluate the durability of reinforced concrete specimens exposed to a marine environment made with Hawaiian aggregates. Twenty five field panels were constructed and placed in the tidal zone at Pier 38 in Honolulu Harbor on the island of Oahu in 2002 and 2003. The panels were removed from Pier 38 in 2012, after 9 to 10 years of exposure. In addition to control specimens, these panels including various corrosion inhibiting admixtures and pozzolans intended to reduce the chloride penetration rates through the concrete and delay the onset of chloride induced corrosion of the reinforcing steel. The panels were monitored for half-cell potential and chloride concentration through the cover concrete at various intervals during field exposure. This report provides an overview of the results of this study, including evaluation of the ability of the computer program Life-365 to predict the chloride penetration rates. Recommendations are provided for design of future concrete exposed to a marine environment in Hawaii and application of Life-365 to life cycle estimation for such concrete. Suggestions are also given for future research needs in this important field of study.

The concrete mixtures used in this study were based on typical mixtures used by the Harbors Division of the Hawaii Department of Transportation. Water-cement ratios range from 0.35 to 0.40. All coarse and fine aggregates were obtained from either Halawa quarry (Hawaiian Cement) or Kapaa quarry (Ameron), both located on the island of Oahu. The corrosion inhibiting admixtures included in the field panel mixtures were Darex Corrosion Inhibitor (DCI), Rheocrete CNI, Rheocrete 222+, FerroGard 901, Xypex Admix C-2000, latex modifier, and Kryton KIM. The pozzolanic admixture materials included fly ash and silica fume.

Observations and Conclusions

Half-cell readings were taken on the top surface of the panels at various intervals during the field exposure. These readings provided an indication of the probability that corrosion had initiated on the reinforcing steel in the panel. Field observations confirmed the presence of surface cracks and rust products on some of the panels after as little as 7 years exposure in the tidal zone.

Table E-1-1 shows the results of analysis of the half cell readings and visual inspection of the field panels. The panel mixture details are listed in columns 2 to 5. Column 6 lists the number of months before the half-cell readings indicated a 50% probability that corrosion had initiated somewhere in the panel, while column 7 lists the months before the half-cell readings indicated a 90% probability that corrosion had initiated. Columns 8 and 9 provide the type of observed damage due to corrosion and the number of months exposure at which the damage was observed, respectively. The cell coloring indicates whether the panel performance was good (green), fair (orange) or poor (red) based on the half-cell and visual inspections.

Recommendations

Design of concrete using Hawaiian aggregates for exposure in a marine or coastal environment should observe the following recommendations based on this study:

1. Use a water to cementitious material ratio as low as possible, but not greater than 0.40.

2. Include fly ash with at least 15% replacement of cement, or silica fume with at least 5% replacement of cement. Mixing must ensure that the fly ash and silica fume, in particular, are well distributed throughout the concrete.

3. Include Darex DCI or Rheocrete CNI at minimum dosages of 4 gal/cuyd (20 l/m^3).

4. As added protection, consider including Kryton Kim at 2% by weight of cement.

Future Research Needs

Based on the results of this and other similar studies of the effect of reinforcing steel corrosion on reinforced concrete exposed to a marine environment, the following future research needs were identified:

1. Perform long-term field exposure studies on concrete mixtures using a combination of corrosion inhibiting measures to observe the combined effect. For example, combining fly ash and effective corrosion inhibitors like DCI, CNI and Kryton Kim to determine how much the combination improves performance compared with each individual admixture and the original control mixture.

2. Consider new corrosion inhibiting admixtures that have become available since initiation of this project, for example Cortec MCI-2000 which is currently being used by HDOT harbors division without local tests to verify its performance with concretes based on Hawaiian aggregates.

3. Longer term field monitoring of successful admixtures. The current study has identified which corrosion inhibiting admixtures appear to work and which do not. However, after 10 years of exposure (on only 5 years of funding), a number of the specimens with fly ash, silica fume, and DCI or CNI, have not started to corrode. Ideally, specimens should be kept in the field exposure until corrosion initiates to determine the true performance of these admixtures.

4. The specimens in this study consisted of uncracked concrete, at least until corrosion initiated cracks. This is unrealistic for most in-place concrete which will crack due to shrinkage, temperature, construction loads, etc. In order to evaluate the successful admixtures for true field conditions, it is necessary to fabricate specimens that simulate the types of cracks most common in field construction. These specimens would then be exposed to the same tidal zone conditions as the original un-cracked specimens to determine whether or not the admixtures can still delay the onset of corrosion.

5. For the current study, all specimens were placed in the tidal zone. This meant there were no panels that were in a coastal environment, but not in the tidal zone, and no specimens that were completely submerged. The tidal zone is known to be the most corrosive environment, hence it was chosen for this study. However, most harbor facilities and coastal structures are predominantly out of the water, or continuously submerged, both of which are less corrosive environments. A better understanding of the performance of the successful admixtures in these environments is also important for future coastal construction. It would be uneconomical to design all harbor and coastal structures assuming the worst case of tidal zone exposure.

28. Bridges for Service Life Beyond 100 Years: innovative Systems, Subsystems, and Components Transportation Research Board, National Academy of Sciences, The Second Strategic Highway Research Program, SHRP 2 Report S2-R19A-RW-1, 2014.
Atorod Azizinamini, Edward H. Power, Glenn F. Myers, H. Celik Ozyildirim
29. Design Guide for Bridges for Service Life (2013)
Transportation Research Board of the National Academies, S2-R19A-RW-2
Atorod Azizinamini, Edward H. Power, Glenn F. Myers, H. Celik Ozyildirim, Eric S. Kline, David W. Whitmore, and Dennis R. Mertz
30. Life Cycle Planning-An Overview
A White Paper Produced by the Federal Highway Administration Transportation Asset Management Expert Task Group, July 2019. Report No. FHWA-HIF-19-072

Life Cycle Planning – An Overview

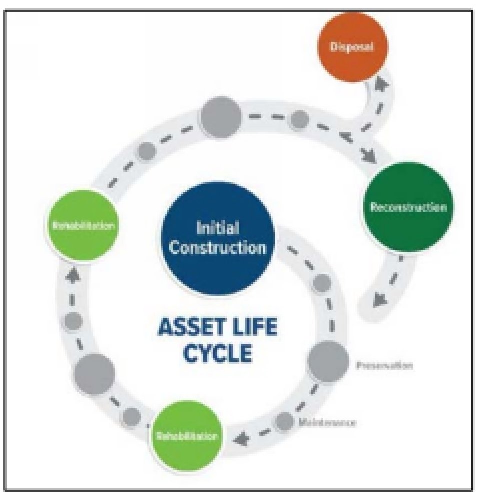
Life Cycle Planning (LCP) seeks the most cost-effective strategy for managing assets over their entire life by capitalizing on timely and appropriate treatments to extend asset life at the lowest reasonable cost.

This white paper by the FHWA Transportation Asset Management Expert Task Group (TAMETG) will use the definition of life cycle planning from 23 CFR 515.7 (b). Otherwise, it will not dwell on the regulation. Instead, it will describe in much more general terms how LCP could improve the managing of assets and how agency processes may need to evolve to take advantage of it.

What is LCP?

23 CFR 515.5 defines life cycle planning 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. In 23 CFR 515.7 (b), the regulation says a State DOT shall establish a process for conducting life-cycle planning for an asset class or asset sub-group at the network level. (Network is to be defined by the State DOT). The regulation also says as a State DOT develops its life-cycle planning process, the State DOT should include future changes in demand; information on current and future environmental conditions including extreme weather events, climate change, and seismic activity; and other factors that could impact whole of life costs of assets.

Figure 1 illustrates the steps involved in life cycle planning. After an asset is initially constructed, its performance can be extended with timely preservation, maintenance, rehabilitation, and reconstruction. At some point, an economic and engineering decision is made as to whether it is most appropriate to reconstruct the asset or replace it.



Source: FHWA

Figure 1. The life cycle planning process.

Why Adopt LCP?

The initial transportation asset management plans that were due April 30, 2018, included many examples of agencies documenting higher conditions for lower costs by adopting life cycle planning.

- The Minnesota Department of Transportation demonstrated in its asset management plan that the per lane mile cost per year for an asphalt pavement over 70 years would be $15,800 dollars under a worst-first approach. Using its current life-cycle approach, the per lane mile annual cost is $9,400. (Minnesota DOT)
- The Ohio Department of Transportation asset management plan reports that its life-cycle approach to pavements has the potential to achieve the same condition level but cost between $75 million to $121 million less annually. (Ohio DOT) The plan also estimated that if ODOT increased preservation activities by 5 percent on National Highway System (NHS) bridges, that once a steady state of conditions was reached the agency could save $50 million annually.
- The Kentucky Transportation Cabinet asset management plan reports that it will by 2027 face a $579 million backlog of unmet pavement-investment needs. (Kentucky Transportation Cabinet) However, if the agency was not implementing a balanced life cycle approach to its pavements, the 2027 backlog would be $1.223 billion.

LCP May Alter Agency Practices

Unlike in fleet management, implementation of LCP in many assets is relatively new, and many agencies have not yet embraced the approach. Some agencies may lack the data or the analytical tools necessary to compute long-term costs and benefits of LCP. However, as the benefits of life cycle planning become more widely understood, more agencies are likely to evolve their processes to embrace it.

To achieve the most benefit, an agency may want to implement a continuous improvement process. As with any continuous improvement process, it will benefit from monitoring and comparing the condition and performance resulting from its implementation with what was planned. An agency will over time want to consider changes in deterioration and other factors and make adjustment to future implementations. For effective asset management, such a cycle of on-going improvements can maximize the results of LCP strategies over the life of assets.

Depending on the results achieved, an agency may have to adjust treatment selections, timing of treatments, resource allocations and project delivery. This may also mean that an agency may have to apply more treatments, more frequently because low cost preservation and maintenance actions are needed more frequently to slow the deterioration of assets. This LCP program stands in contrast to a "worse-first" program that would have fewer, but more expensive projects.

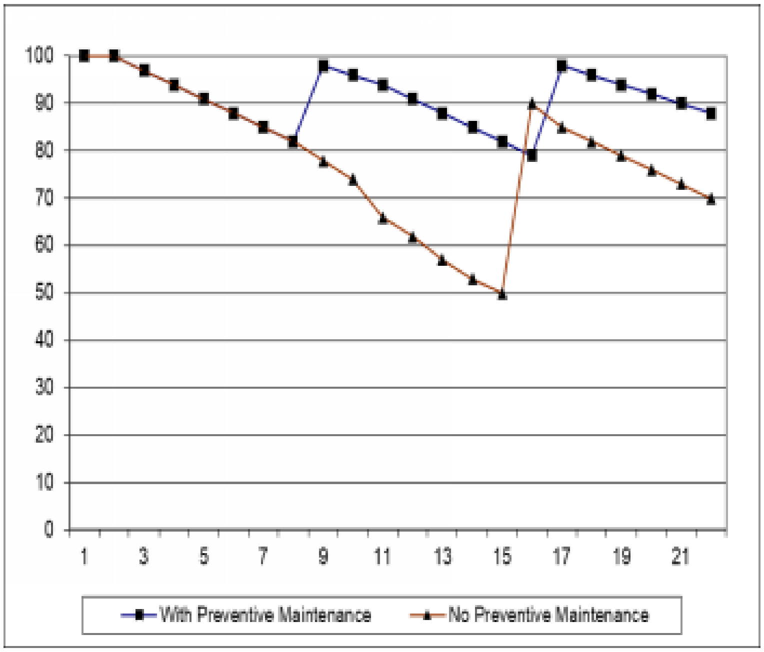


Figure 2. Periodic low-cost preservation treatments can maintain assets at higher conditions for less cost compared to more expensive rehabilitation treatments.

Adopting LCP is likely to influence an agency's practices. The LCP approach requires the planning, programming, and maintaining of assets in alignment with larger strategies that extend the life of those assets. Institutionalizing LCP can be advanced by engagement across multiple work units so that those who inspect, maintain, and plan for treatment collaborate. Agencies may need to break down silos between information technology, planning, design, maintenance, and construction to ensure that their efforts are coordinated to support LCP.

To apply LCP successfully, agencies need:

- Data about the condition and deterioration of assets to know when they require treatment to extend their life, and not to merely replace the asset once it is deteriorated
- Planning processes to program the treatments at the right point in their life cycle
- Design capabilities to produce more small projects to arrest deterioration instead of fewer large projects to replace assets
- Maintenance coordination so that the activities of maintenance crews and contractors are scoped, timed, and recorded to support life cycle analysis, and
- Construction capabilities to manage a larger number of projects when more preservation projects are let to bid.

In the long-term, LCP is likely to create a better sense of ownership across the agency about managing assets more cost effectively. Maintenance crews would understand they "own" the required annual maintenance, while those who program know they "own" the need to program the right preservation and rehabilitation treatments on a timely basis.

Successfully implementing LCP and institutionalizing the practice in an agency may lead to the development of manuals and policies of how to treat different assets and asset sub-groups. Agencies may have to address network, program and project-specific LCP approaches depending on the levels applicable to them.

LCP also can be enhanced by taking into consideration the impacts of internal and external risks. Climate risks can affect asset performance and condition. For example, pavements in low-lying areas may be subject to periodic inundation that affects their long-term performance. Bridges in mountainous areas may be subject to increased de-icing chemicals, while pavements on expansive soils may be subject to temperature extremes. The LCP process can be enhanced when risks from external events and environmental factors are considered in selecting the type and timing of treatments.

Another enhancement to LCP is to update the risk assessment on an on-going basis. Risk assessment updates can be enhanced with collaboration across work units to identify and analyze new risks and changes to existing risks.

Program Approach Not Just Project Approach

Life-cycle planning encourages network and program-level approaches such as:

- Ensuring an approach to project prioritization that maximizes long-term network benefits
- Ensuring that critical data-collection programs are funded, the data-analysis functions are robust, and information is accessible to decision makers
- Funding adequately the programs to allow timely maintenance, preservation, and rehabilitation and not only funding asset-replacement projects
- Developing long-term investment strategies to ensure the long-term programmatic treatment of assets
- Focusing not only on short-term conditions but forecasting to understand whether current plans will result in long-term performance and conditions to achieve the agency's objectives, and targets. Such forecasting can inform the agency of any changes needed to address any gaps and the implications of not addressing them.

Application of LCP Can Vary with Asset Complexity

It is likely that agencies will realize that the sophistication of LCP can be commensurate with the complexity of the asset class or sub-class. Simple assets can be managed appropriately through their life cycle with simple processes and strategies. For example, pavement markings may be managed appropriately with cyclical replacement schedules, as may other assets such as sign sheeting. On the other hand, very complex assets such as Interstate Highway System pavements or most bridges benefit from a more comprehensive life-cycle planning process.

Some states have divided assets into tiers or categories and apply the most complex life cycle strategies to the assets that are most complex and expensive. For example, Tier 1 assets may be pavements on high volume roads and nearly all bridges. As shown in Table 1, their life-cycle strategies require annual or biennial condition inspections, detailed asset inventories, compliant management systems, and life cycle planning horizons that could extend for 30 years or more. Life-cycle treatment protocols trigger appropriate preservation, maintenance, rehabilitation, or replacement treatments.

Tier 2 assets could also be complex but do not lend themselves to complex management systems that include optimization. Examples could be culverts and other drainage structures or maintenance facilities. They could be managed with spreadsheet analysis and regular condition assessments. Preservation, maintenance, and rehabilitation decisions for such assets are triggered by condition and life-cycle considerations.

Tier 3 assets could be also managed with spreadsheet analysis instead of more complex management systems. Age is the primary trigger for treatments for these assets as they do not lend themselves to preservation or maintenance treatments. Examples could be sign sheeting, pavement markings, and luminaires, where the treatment is to replace them cyclically.

The use of tiers such as these allow an agency to demonstrate that all assets are managed with the most appropriate life cycle strategy. The strategies, however, are commensurate with the complexity of the assets' lifecycle and the life cycle strategies do not create inordinate costs.

LCP for Unique Assets

Most asset management and LCP strategies are predicated on an assumption that groups of similar assets are largely homogenous and tend to respond in typical ways. For example, crack sealing and bridge deck replacement often occur on predictable cycles.However, there are special classes of assets that require asset-specific management plans. For example, the Golden Gate and Brooklyn bridges are managed for LCP but with highly specialized approaches. Agencies may find that special classes of assets such as historic structures or pavements with unique soils require specialized LCP strategies. These individual major assets or subclasses of assets may require strategies that are attuned to their unique materials, characteristics, locations, or environment.

Also, similar assets may face different environmental risks depending on their location. Such assets may need a different level of analysis. In such cases the assessment of historic deterioration rates may be insufficient and asset managers may have to also consider future changes due to weather or temperature.

Likely Future Implications

As agencies embrace LCP approaches, they are likely to want to improve some important tools. For example, they may want to ensure that:

- Data collection is timely and asset inventories detailed enough to support the agency's LCP approach.
- Condition information is timely enough to allow decision makers to know when asset-treatment windows allow for preservation
- Inventories have the granularity necessary to understand conditions by asset class and subclass and how they are changing to anticipate needed treatments
- Deterioration curves are available and reliable to forecast future conditions
- Information on previously applied treatments is available to provide valuable information on effectiveness of past treatments. This will enable the agency to understand the effectiveness of past treatments and identify potential future treatments. Also, the influence of maintenance activities may need to be better understood.

Forecasting and asset condition modeling become a more important part of the analysis and decision-making. Comparing long-term effects of alternative investment strategies is an important part of LCP. Agencies may not have the necessary funding to select the investment strategy that achieves the best outcome. Under these circumstances, evaluating and comparing multiple scenarios becomes more important to decision making. Analyzing multiple investment strategies enables the agency to make better informed decisions based on the projected available funding. Analysis enables the agency to make necessary tradeoffs and prioritize assets and treatments to delay deterioration based on the cumulative network benefit or other agency goals.

It is likely that LCP will change agencies' performance perspective to include a focus on both long-term, future conditions, as well as short-term current ones. Once agencies take a life cycle perspective, their focus tends to shift to planning for the highest conditions achievable with predicted resources in 10 or 20 years and not only for the next year. The return on investment horizon tends to extend so that preservation and maintenance efforts are recognized for their long-term contribution.

Not only does interest in data increase, but so does the interest in the ability to sort, query, map, and analyze the data. Agencies are likely to develop tools so that more decision makers can access data and rely upon them for day-to-day decisions. Good asset condition and trend data are essential not only for those who program projects but also for those who schedule and prioritize maintenance activities.

Life cycle planning can lead to better understanding of the return on investment for data. Data can be expensive and sometimes difficult to justify. However, when the cost savings of timely treatments are captured, the return on investment for data can be determined. If detailed condition data are needed to time treatments appropriately, the data become essential to capturing the cost savings of the treatment. Once the cost savings from treatments are known, the value of the data that triggered the treatment can be captured.

Over time, the use of LCP is likely to become more mature and will extend to other assets beyond bridges and pavements. The concept described above of dividing assets into tiers based on their complexity already is embraced by some agencies. As a result, life cycle planning is expanding to asset classes such as ITS components, traffic signals, high mast lighting, facilities, and even software. There are few technical reasons why life cycle planning cannot be applied to any asset class. As the discussion on tiers indicated, the management strategies may change but life cycle planning concepts can be applied to almost any asset class.

Life cycle planning analysis can lead to greater recognition of how threats and vulnerabilities affect assets. When the effects of flooding, temperature, or excessive winds are documented over time, a greater awareness of the threats that reduce asset performance may become apparent.

Summary and Conclusion

The U.S. transportation community is in the early stages of LCP adoption. Life cycle planning is likely to expand in use over time to become the standard approach for managing assets. As more transportation agencies adopt LCP, and the cost savings become better understood, it will likely to lead to expanded adoption of LCP to other asset classes beyond bridges and pavements. The embrace of life cycle planning is likely to be supported by improved data sets, better analysis of long-term performance, and better understanding of how timely treatments provide a return on investment.

The imperative to improve conditions, cost effectively manage assets over their whole life, and conserve limited resources are addressed by life cycle planning. Once the policies, data, and management processes are in place to fully capitalize on LCP, it is likely to become the standard process for managing transportation assets.

31. Mississippi Standard Specifications For Road and Bridge Construction, Mississippi Department of Transportation, Jackson, 2017 Edition

Section 700.05-Material Certifications and Certified Test Reports
Provides guidance on material and testing certifications.

700.05--Material Certifications and Certified Test Reports. All certifications and certified test reports shall meet the requirements set forth herein except certification requirements for cement and asphalt are set out separately in Department SOP TMD-21-01-00-000 and TMD-22-01-00-000.

Section 804.02.6-Classification and Uses of Concrete
Provides guidance on usage of the various classes of concrete.

The classes and their uses are as follows:

(1) Class AA - Concrete for bridge construction and concrete exposed to seawater.
(2) Class A - Concrete for use where indicated.
(3) Class B - General use, heavily reinforced sections, cast-in-place concrete piles, and conventional concrete piles.
(4) Class C - Massive sections or lightly reinforced sections.
(5) Class D - Massive unreinforced sections and riprap.
(6) Class F - Concrete for prestressed members.
(7) Class FX - Extra strength concrete for prestressed members, as shown on plans.
(8) Class S - For all seal concrete deposited under water.
(9) Class DS - Drilled Shaft Concrete

Section 804.02.10-Portland Cement Concrete Mix Design, Table 3 Master Proportion Table for Structural Concrete Design
Provides guidance on the proportioning of coarse aggregate, maximum water/cement ratio, compressive strength, maximum slump, and total air content. [Material Information]

Table 3
MASTER PROPORTION TABLE FOR STRUCTURAL CONCRETE DESIGN

CLASS	COARSE AGGREGATE SIZE NO. *	MAXIMUM WATER/ CEMENTITIOUS ** RATIO	SPECIFIED COMPRESSIVE STRENGTH (f'_c) psi	MAXIMUM SLUMP *** inches	TOTAL AIR CONTENT %
AA	57 or 67	0.45	4000	3	3.0 to 6.0
A	57 or 67	0.45	4000	3	3.0 to 6.0
B	57 or 67	0.50	3500	4	3.0 to 6.0
C	57 or 67	0.55	3000	4	3.0 to 6.0
D	57 or 67	0.70	2000	4	3.0 to 6.0
F	67	0.40	5000	3	****
FX	67	(As required by special provisions)		3	****
S	57 or 67	0.45	3000	8	3.0 to 6.0
DS	67	0.45	4000	*****	****

* Maximum size aggregate shall conform to the concrete mix design for the specified aggregate.

** Maximum replacement of Portland cement by weight is 25% for fly ash or 50% for ground granulated blast furnace slag. The addition of fly ash as a replacement for cement will not be permitted in Type IP blended hydraulic cement, portland cement combined with ground granulated blast furnace slag or Type III portland cement when specified in the contract.

*** The slump may be increased up to 6 inches with an approved mid-range water reducer or up to 8 inches with an approved type F or G high range water reducer. A mid-range water reducer is classified as a water reducer that reduces the mix water a minimum of 8% when compared to a control mix with no admixtures. Minus slump requirements shall meet those set forth in Table 3 of AASHTO M157 specifications.

**** No entrained air except for pilings exposed to seawater.

***** Class DS Concrete for drilled shafts shall have an 8 ±1-inch slump. In the event the free fall method of concrete placement is used, the slump shall be 6 ±1-inch. No fly ash, ground granulated blast furnace slag, or F or G high range water reducers allowed in drilled shaft concrete. A slump retention admixture is required.

Either Type A, D, F, G, or mid-range chemical admixture, shall be used in all classes of concrete, except as noted above for drilled shaft concrete. Any combinations of water reducing admixtures shall be approved by the Engineer before their use.

Section 804.03.11-Concrete Exposed to Seawater

Provide guidance on which class of concrete shall be used along with additional guidance on clear distance and construction joints.

804.03.11--Concrete Exposed to Seawater. Unless otherwise specifically provided, concrete for structures exposed to seawater shall be Class AA concrete as referenced in Subsection 804.02.10. The clear distance from the face of the concrete to the nearest face of reinforcing steel shall be at least four inches. The mixing time and the water content shall be carefully controlled and regulated so as to produce concrete of maximum impermeability. The concrete shall be thoroughly compacted, and stone pockets shall be avoided. No construction joints shall be formed between the levels of extreme low water and extreme high water as determined by the Engineer. Between these levels, seawater shall not come in direct contact with the new concrete until at least 30 days have elapsed. The surface concrete as left by the forms shall be left undisturbed.

32. Mississippi Department of Transportation, Construction Manual 2017
    Chapter 1.3-Project Records provides guidance on maintaining project records.
    Site Manager is noted as the location of all project records. Site Manager can be located by accessing MDOT@Work and selecting drop down menu under applications then selecting Site Manager.
33. Moving Ahead for Progress in the 21st Century Act (MAP-21), A Summary of Highway Provisions Federal Highway Administration, Office of Policy and Governmental Affairs, July 17, 2012.
    Establishes a performance-based program and requirements for a long-range plan and a short-term transportation improvement plan (TIP). MAP-21 establishes principles and practices for research, technology, deployment, training, and education.

Overview

On July 6, 2012, President Obama signed into law P.L. 112-141, the Moving Ahead for Progress in the 21st Century Act (MAP-21). Funding surface transportation programs at over $105 billion for fiscal years (FY) 2013 and 2014, MAP-21 is the first long-term highway authorization enacted since 2005. MAP-21 represents a milestone for the U.S. economy – it provides needed funds and, more importantly, it transforms the policy and programmatic framework for investments to guide the growth and development of the country's vital transportation infrastructure.

MAP-21 creates a streamlined, performance-based, and multimodal program to address the many challenges facing the U.S. transportation system. These challenges include improving safety, maintaining infrastructure condition, reducing traffic congestion, improving efficiency of the system and freight movement, protecting the environment, and reducing delays in project delivery.

MAP-21 builds on and refines many of the highway, transit, bike, and pedestrian programs and policies established in 1991. This summary reviews the policies and programs administered by the Federal Highway Administration. The Department will continue to make progress on transportation options, which it has focused on in the past three years, working closely with stakeholders to ensure that local communities are able to build multimodal, sustainable projects ranging from passenger rail and transit to bicycle and pedestrian paths.

Setting the course for transportation investment in highways, MAP-21 –

- *Strengthens America's highways*
  MAP-21 expands the National Highway System (NHS) to incorporate principal arterials not previously included. Investment targets the enhanced NHS, with more than half of highway funding going to the new program devoted to preserving and improving the most important highways -- the National Highway Performance Program.

- *Establishes a performance-based program.*
  Under MAP-21, performance management will transform Federal highway programs and provide a means to more efficient investment of Federal transportation funds by focusing on national transportation goals, increasing the accountability and transparency of the Federal highway programs, and improving transportation investment decisionmaking through performance-based planning and programming.

- *Creates jobs and supports economic growth*
  MAP-21 authorizes $82 billion in Federal funding for FYs 2013 and 2014 for road, bridge, bicycling, and walking improvements. In addition, MAP-21enhances innovative financing and encourages private sector investment through a substantial increase in funding for the TIFIA program. It also includes a number of provisions designed to improve freight movement in support of national goals.

- *Supports the Department of Transportation's (DOT) aggressive safety agenda*
  MAP-21 continues the successful Highway Safety Improvement Program, doubling funding for infrastructure safety, strengthening the linkage among modal safety programs, and creating a positive agenda to make significant progress in reducing highway fatalities. It also continues to build on other aggressive safety efforts, including the Department's fight against distracted driving and its push to improve transit and motor carrier safety.

Transportation Planning
[1201 and 1202]

In MAP-21, the metropolitan and statewide transportation planning processes are continued and enhanced to incorporate performance goals, measures, and targets into the process of identifying needed transportation improvements and project selection. Public involvement remains a hallmark of the planning process.

Requirements for a long-range plan and a short-term transportation improvement plan (TIP) continue, with the long-range plan to incorporate performance plans required by the Act for specific programs. The long-range plan must describe the performance measures and targets used in assessing system performance and progress in achieving the performance targets. The TIP must also be developed to make progress toward established performance targets and include a description of the anticipated achievements. In the statewide and nonmetropolitan planning process, selection of projects in nonmetropolitan areas, except projects on the NHS or funded with funds remaining from the discontinued Highway Bridge Program, must be made in cooperation with affected nonmetropolitan officials or any regional transportation planning organization.

Performance Management
[1203]

The cornerstone of MAP-21's highway program transformation is the transition to a performance and outcome-based program. States will invest resources in projects to achieve individual targets that collectively will make progress toward national goals.

MAP-21 establishes national performance goals for Federal highway programs:

- **Safety**—To achieve a significant reduction in traffic fatalities and serious injuries on all public roads.
- **Infrastructure condition**—To maintain the highway infrastructure asset system in a state of good repair.
- **Congestion reduction**—To achieve a significant reduction in congestion on the NHS.
- **System reliability**—To improve the efficiency of the surface transportation system.
- **Freight movement and economic vitality**—To improve the national freight network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development.
- **Environmental sustainability**—To enhance the performance of the transportation system while protecting and enhancing the natural environment.
- **Reduced project delivery delays**—To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practices.

The Secretary, in consultation with States, MPOs, and other stakeholders, will establish performance measures for pavement conditions and performance for the Interstate and NHS, bridge conditions, injuries and fatalities, traffic congestion, on-road mobile source emissions, and freight movement on the Interstate System. States (and MPOs, where applicable) will set performance targets in support of those measures, and State and metropolitan plans will describe how program and project selection will help achieve the targets.

States and MPOs will report to DOT on progress in achieving targets. If a State's report shows inadequate progress in some areas – most notably the condition of the NHS or key safety measures – the State must undertake corrective actions, such as the following:

- NHPP: If no significant progress is made toward targets for NHS pavement and bridge condition, the State must document in its next report the actions it will take to achieve the targets.
- HSIP: If no significant progress is made toward targets for fatalities or serious injuries, the State must dedicate a specified amount of obligation limitation to safety projects and prepare an annual implementation plan.

In addition, due to the critical focus on infrastructure condition, MAP-21 requires that each State maintain minimum standards for Interstate pavement and NHS bridge conditions. If a State falls below either standard, that State must spend a specified portion of its funds for that purpose until the minimum standard is exceeded.

Research, Technology Deployment, Training and Education

MAP-21 establishes the principles and practices for a flexible, nationally-coordinated research and technology program that addresses fundamental, long-term highway research needs, significant research gaps, emerging issues with national implications, and research related to policy and planning. The Secretary provides leadership for the national coordination of research and technology transfer activities, conducting and coordinating research projects, and partnering with State highway agencies and other stakeholders. All research activities are to include a component of performance measurement and evaluation, should be outcome-based, and must be consistent with the research and technology development strategic plan. MAP-21 provides new authority for the Secretary to use up to one percent of funds authorized for research and education for a program to competitively award cash prizes to stimulate innovation that has the potential for application to the national transportation system.

MAP-21 authorizes $400 million per year for the following six programs: Highway Research and Development, Technology and Innovation Deployment, Training and Education, Intelligent Transportation Systems, University Transportation Research, and the Bureau of Transportation Statistics.

Following is a description of the programs that are administered by FHWA.

Research and Technology Development and Deployment

- MAP-21 provides $115 million per year for the Highway Research and Development program. Research areas include highway safety, infrastructure integrity, planning and environment, highway operations, exploratory advanced research, and the Turner-Fairbank Highway Research Center. [52003]

- Separate funding is provided for the Technology Innovation and Deployment Program ($62.5 million per year) to accelerate implementation and delivery of new innovations and technologies that result from highway research and development to benefit all aspects of highway transportation. At least $12 million per year of these funds must be used to accelerate the deployment and implementation of pavement technology. [52003]

- The technology deployment program would also fund implementation of Future Strategic Highway Research Program (F-SHRP) results, but with an opportunity to supplement from State Planning and Research funds, if 75 percent of States agree to a percentage for this use. [52005]

Three specific programs are repealed: the International Outreach Program [52006], the Surface Transportation Environment Cooperative Research Program [52007], and the National Cooperative Freight Research Program [52008]. However, the authority for international collaboration remains, and environmental and freight research and development activities are incorporated into Highway Research and Development.

Training and Education [52004]

MAP-21 authorizes $24 million per year for continuation of training and education programs, including the National Highway Institute, the Local Technical Assistance Program (LTAP), the Tribal Technical Assistance Program (TTAP), the Dwight D. Eisenhower Transportation Fellowships, the Garrett A. Morgan Technology and Transportation Education Program, the Transportation Education Development Program, and the Freight Capacity Building Program. Also funded from the Training and Education funds are the competitively-selected centers for transportation excellence in the areas of the environment, surface transportation safety, rural safety, and project finance. The Federal share for LTAP and TTAP centers remains at 50 percent and 100 percent respectively.

Transportation Research and Development (R&D) Strategic Planning [52012]
The Secretary is directed to develop a 5-year research and development strategic plan within 1 year of enactment, to be reviewed by the National Research Council, and report to Congress annually on R&D spending. The plan must address the following purposes: promoting safety, reducing congestion and improving mobility, preserving the environment, preserving the existing transportation system, improving the durability and extending the life of transportation infrastructure, and improving goods movement. MAP-21 offers the opportunity to conduct a nationally-coordinated, flexible, and strategically-targeted Research, Technology, and Education program.

34. Title 23-Highways Code of Federal Regulations (CFR) Section 119: National highway performance program, (f) Interstate System and NHS Bridge Conditions (2) Condition of NHS Bridges.

§119. National highway performance program

(a) Establishment.-The Secretary shall establish and implement a national highway performance program under this section.

(b) Purposes.-The purposes of the national highway performance program shall be-

(1) to provide support for the condition and performance of the National Highway System;

(2) to provide support for the construction of new facilities on the National Highway System; and

(3) to ensure that investments of Federal-aid funds in highway construction are directed to support progress toward the achievement of performance targets established in an asset management plan of a State for the National Highway System.

(2) CONDITION OF NHS BRIDGES.—

(A) PENALTY.—If the Secretary determines that, for the 3-year-period preceding the date of the determination, more than 10 percent of the total deck area of bridges in the State on the National Highway System is located on bridges that have been classified as structurally deficient, an amount equal to 50 percent of funds apportioned to such State for fiscal year 2009 to carry out section 144 (as in effect the day before enactment of MAP–21) shall be set aside from amounts apportioned to a State for a fiscal year under section 104(b)(1) only for eligible projects on bridges on the National Highway System.

(B) RESTORATION.—The set-aside requirement for bridges on the National Highway System in a State under subparagraph (A) for a fiscal year shall remain in effect for each subsequent fiscal year until such time as less than 10 percent of the total deck area of bridges in the State on the National Highway System is located on bridges that have been classified as structurally deficient, as determined by the Secretary.

35. Title 23-Highways Code of Federal Regulations (CFR) Part 490, Docket No. FHWA-2013-0053, National Performance Management Measures; Assessing Pavement Condition for the National

Highway Performance Program and Bridge Condition for the Nation Highway Performance Program. Federal Register/Vol. 82, No. 11/Wednesday, January 18, 2017/Rules and Regulations.

SUMMARY: The purpose of this final rule is to establish measures for State departments of transportation (State DOT) to use to carry out the National Highway Performance Program (NHPP) and to assess the condition of the following: Pavements on the National Highway System (NHS) (excluding the Interstate System), bridges carrying the NHS which includes on- and off-ramps connected to the NHS, and pavements on the Interstate System. The NHPP is a core Federal-aid highway program that provides support for the condition and performance of the NHS and the construction of new facilities on the NHS. The NHPP also ensures that investments of Federal-aid funds in highway construction are directed to support progress toward the achievement of performance targets established in a State's asset management plan for the NHS. This final rule establishes regulations for the new performance aspects of the NHPP that address measures, targets, and reporting. The FHWA is in the process of creating a new public Web site to help communicate the national performance story. The Web site will likely include infographics, tables, charts, and descriptions of the performance data that State DOTs report to FHWA. The FHWA issues this final rule based on sec. 1203 of MAP–21, which identifies national transportation goals and requires the Secretary to promulgate rules to establish performance measures and standards in specified Federal-aid highway program areas.

I. Executive Summary

A. Incorporating the FAST Act

On December 4, 2015, the President signed the Fixing America's Surface Transportation Act (FAST) Act (Pub. L. 114–94) into law. For the most part, the FAST Act is consistent with the new performance management elements introduced by MAP–21. For convenience and accurate historical context, this rule will refer to MAP–21 throughout the preamble to signify the fundamental changes MAP–21 made to States' authorities and responsibilities for overseeing the implementation of performance management. For this final rule, there are two areas where the FAST Act made changes to performance management requirements.

The first change is sec. 119(e)(7), title 23, United States Code (23 U.S.C. 119(e)(7)), which relates to the requirement for a significant progress determination for NHPP targets. The FAST Act amended this provision to remove the term "2 consecutive reports." The FHWA has incorporated this change into the final rule by removing the term "2 consecutive determinations," which was proposed in section 490.109(f) of the NPRM, published January 5, 2015 (80 FR 326). In section 490.109(f) of the NPRM, FHWA proposed that if FHWA determines that a State DOT has not made significant progress toward achieving NHPP targets in two consecutive FHWA determinations, then that State DOT would document the actions it will take to achieve the targets in its next Biennial Performance Report. The FAST Act changed this requirement. Due to the FAST Act, the final rule requires State DOTs to take action when they do not make significant progress for each biennial determination (instead of 2 consecutive biennial determinations) made by FHWA.

The second change made by the FAST Act is removal of the term "2 consecutive reports" in 23 U.S.C. 119(f)(1)(A), which relates to triggering the penalty for Interstate pavement condition that has fallen below the minimum condition level established under this rule. In section 490.317 of the NPRM, FHWA proposed that it would determine annually whether or not a State DOT's Interstate pavement condition is below the minimum condition level. If FHWA determines that a State DOT's Interstate pavement condition is below the minimum condition level for the "most recent 2 years," then that State DOT would be subject to the penalty under 23 U.S.C. 119(f)(1)(A). A description and example application on this penalty is available for review on the docket. Due to the FAST Act, the final rule subjects State DOTs to the penalty under 23 U.S.C. 119(f)(1)(A) if FHWA determines that its Interstate pavement condition has fallen below the minimum condition level for the most recent year (instead of most recent 2 years).

B. Purpose of the Regulatory Action

The MAP–21 (Pub. L. 112–141) transforms the Federal-aid highway program by establishing new requirements for performance management to ensure the most efficient investment of Federal transportation funds. Performance management increases the accountability and transparency of the Federal-aid highway program and provides a framework to support improved investment decisionmaking through a focus on performance outcomes for key national transportation goals.

As part of performance management, recipients of Federal-aid highway funds will make transportation investments to achieve performance targets that make progress toward national goals. The national performance goal for bridge and pavement condition is to maintain the condition of highway infrastructure assets in a state of good repair. The purpose of this final rule is to implement MAP–21 and FAST Act performance management requirements.

Prior to MAP–21, there were no explicit requirements for State DOTs to demonstrate how their transportation program supported national performance outcomes. State DOTs were not required to measure condition or performance, establish targets, assess progress toward targets, or report on condition or performance in a nationally consistent manner that FHWA could use to assess the entire system. Without State DOTs reporting on the above factors, it is difficult for FHWA to look at the effectiveness of the Federal-aid highway program as a means to address surface transportation performance at a national level.

This final rule is one of several rulemakings that DOT has or is conducting to implement MAP–21's new performance management framework. The collective rulemakings will establish the regulations needed to more effectively evaluate and report on surface transportation performance across the Nation. This final rule will:

- Require State DOTs to maintain their bridges and pavements at or above a minimum condition level;
- Provide for greater consistency in the reporting of condition and performance;
- Require the establishment of targets that can be aggregated at the national level;
- Improve transparency by requiring consistent reporting on progress through a public reporting system;
- Require State DOTs to make significant progress toward meeting their targets; and
- Establish requirements for State DOTs that have not met or made significant progress toward meeting their targets.

State DOTs and metropolitan planning organizations (MPO) will be expected to use the information and data generated as a result of the new regulations to inform their transportation planning and programming decisions. The new performance aspects of the Federal-aid highway program that result from this rule will provide FHWA the ability to better communicate a national performance story and to more reliably assess the impacts of Federal funding investments. The FHWA is in the process of creating a new public Web site to help communicate the national performance story. The Web site will likely include infographics, tables, charts, and descriptions of the performance data that State DOTs would be reporting to FHWA.

The FHWA is required to establish performance measures to assess performance in 12 areas [1] generalized as follows: (1) Serious injuries per vehicle miles traveled (VMT); (2) fatalities per VMT; (3) number of serious injuries; (4) number of fatalities; (5) pavement condition on the Interstate System; (6) pavement condition on the non-Interstate NHS; (7) bridge condition on the NHS; (8) traffic congestion; (9) on-road mobile source emissions; (10) freight movement on the Interstate System; (11) performance of the Interstate System; and (12) performance of the non-Interstate NHS. This rulemaking is the second of three that establish performance measures for State DOTs and MPOs to use to carry out Federal-aid highway programs and to assess performance in each of these 12 areas. This final rule establishes national measures for pavement condition on the Interstate System and non-Interstate NHS and bridge condition on the NHS (numbers 5, 6 and 7 in the above list). Other rulemakings have or will establish national measures for the remaining areas.

State DOTs will be required to establish performance targets and assess performance in 12 areas [2] established by MAP–21, and FHWA will assess [3] their progress toward meeting targets in 10 of these areas [4] in accordance with MAP–21 and the FAST Act. State DOTs that fail to meet or make significant progress toward meeting pavement and bridge condition performance targets in a biennial performance reporting period will be required to document the actions they will undertake to achieve their targets in their next biennial performance report.

This final rule establishes performance measures to assess pavement and bridge conditions on the Interstate System and non-Interstate NHS for the purpose of carrying out the NHPP. The four measures to assess pavement condition are: (1) Percentage of pavements on the Interstate System in Good condition; (2) percentage of pavements on the Interstate System in Poor condition; (3) percentage of pavements on the NHS (excluding the Interstate System) in Good condition; and (4) percentage of pavements on the NHS (excluding the Interstate System) in Poor condition. The two performance measures for assessing bridge condition are: (1) Percentage of NHS bridges classified as in Good condition; and (2) percentage of NHS bridges classified as in Poor condition.

This final rule also establishes the minimum level for pavement condition for the Interstate System as required by the statute and incorporates the minimum condition level for bridges carrying the NHS which includes on- and off-ramps connected to the NHS as established by the statute. In addition, this final rule establishes the process for State DOTs and MPOs to use to establish and report targets and the process that FHWA will use to assess the progress State DOTs have made in achieving targets.

Lastly, FHWA recognizes that implementation of the performance management requirements in this final rule will evolve with time for a variety of reasons such as: The introduction of new technologies that allow for the collection of more nationally consistent and/or reliable performance data; shifts in national priorities for the focus of a goal area; new federal requirements; or the emergence of improved approaches to measure condition/performance in supporting investment decisions and national goals. The FHWA is committed to performing a retrospective review of this rule after the first performance period, to assess the effectiveness of the requirements to identify any necessary changes to better support investment decisions through performance-based planning and programming and to ensure the most efficient investment of Federal transportation funds. In implementation of this rule, FHWA realizes that there are multiple ways that State DOTs and MPOs can make

[1] These areas are listed within 23 U.S.C. 150(c), which requires the Secretary to establish measures to assess performance or condition.

[2] These areas are listed within 23 U.S.C. 150(c), which requires the Secretary to establish measures to assess performance or condition.

[3] 23 U.S.C. 148(i) and 23 U.S.C. 119(e)(7).

[4] Serious injuries per vehicle VMT; fatalities per VMT; number of serious injuries; number of fatalities; pavement condition on the Interstate System; pavement condition on the non-Interstate NHS; bridge condition on the NHS; performance of the Interstate System; and performance of the non-Interstate NHS under MAP–21. Freight movement on the Interstate System under the FAST Act.

decisions to achieve more efficient and cost effective investments; as part of a retrospective review, FHWA will also utilize implementation surveys to identify how agencies complying with the rule are developing their programs and selecting their projects to achieve targets.

Section 490.105 describes the process to be used by State DOTs and MPOs to establish targets for each of the four pavement and two bridge measures. The State DOTs will establish 2- and 4-year targets for a 4-year performance period for the condition of infrastructure assets.

Section 490.107 identifies performance reporting requirements for State DOTs and MPOs. The State DOT will submit its established targets in a baseline report at the beginning of the performance period and report progress at the midpoint and end of the performance period. State DOTs will be allowed to adjust their 4-year target at the midpoint of the performance period.

Subparts C and D establish performance measures and other related requirements to assess pavement and bridge conditions. In subparts C and D, sections 490.305 and 490.405 establish program-specific definitions to ensure that the performance measures are clear and consistent.

Sections 490.307 and 490.407 require that State DOTs and MPOs use a total of six measures to assess the condition of pavements and bridges on the NHS. The pavement measures will be applicable to both Interstate and non-Interstate NHS mainline roads and the bridge measures would be applicable for all bridges carrying the NHS which includes on- and off-ramps connected to the NHS. Both the pavement and bridge measures will reflect the percentage of the system in Good and Poor condition. The measure calculations will utilize data documented in the HPMS and in the National Bridge Inventory (NBI).

Section 490.315 establishes the minimum level for condition of pavements on the Interstate System as required by 23 U.S.C. 150(c)(3)(A)(iii).

Section 490.411 incorporates the minimum level for condition of bridges as required by 23 U.S.C. 119(f)(2).

PART 490—NATIONAL PERFORMANCE MANAGEMENT MEASURES

■ 1. The authority citation for part 490 continues to read as follows:

Authority: 23 U.S.C. 134, 135, 148(i), and 150; 49 CFR 1.85.

■ 2. Revise subpart A to read as follows:

Subpart A—General Information

National Bridge Inventory (NBI) is an FHWA database containing bridge information and inspection data for all highway bridges on public roads, on and off Federal-aid highways, including tribally owned and Federally owned

bridges, that are subject to the National Bridge Inspection Standards (NBIS).

§ 490.103 Data requirements.

(a) *In general.* Unless otherwise noted below, the data requirements in this section applies to the measures identified in subparts C and D of this part. Additional data requirements for specific performance measures are identified in 23 CFR sections—

(1) 490.309 for the condition of pavements on the Interstate System;

(2) 490.309 for the condition of pavements on the non-Interstate NHS;

(3) 490.409 for the condition of bridges on the NHS;

§ 490.105 Establishment of performance targets.

(3) 490.407(c)(1) and 490.407(c)(2) for the condition of bridges on the NHS.

Subpart D—National Performance Management Measures for Assessing Bridge Condition

§ 490.407 National performance management measures for assessing bridge condition.

(a) There are three classifications for the purpose of assessing bridge condition. They are:

(1) Percentage of NHS bridges classified as in Good condition;

(2) Percentage of NHS bridges classified as in Fair condition; and

(3) Percentage of NHS bridges classified as in Poor condition.

(b) [Reserved]

(c) To carry out the NHPP, two of the three classifications are performance measures for State DOTs to use to assess bridge condition on the NHS. They are:

(1) Percentage of NHS bridges classified as in Good condition; and

(2) Percentage of NHS bridges classified as in Poor condition.

(d) Determination of Good and Poor conditions are described in § 490.409.

§ 490.411 Establishment of minimum level for condition for bridges.

(a) State DOTs will maintain bridges so that the percentage of the deck area of bridges classified as Structurally Deficient does not exceed 10.0 percent. This minimum condition level is applicable to bridges carrying the NHS, which includes on- and off-ramps connected to the NHS within a State, and bridges carrying the NHS that cross a State border.

(b) For the purposes of carrying out this section and § 490.413, a bridge will be classified as Structurally Deficient when one of its NBI Items, 58—Deck, 59—Superstructure, 60—Substructure, or 62—Culverts, is 4 or less, or when one of its NBI Items, 67—Structural Evaluation or 71—Waterway Adequacy, is 2 or less. Beginning with calendar year 2018 and thereafter, a bridge will be classified as Structurally Deficient when one of its NBI Items, 58—Deck, 59—Superstructure, 60—Substructure, or 62—Culverts, is 4 or less.

(c) For all bridges carrying the NHS, which includes on- and off-ramps connected to the NHS and bridges carrying the NHS that cross a State border, FHWA shall calculate a ratio of the total deck area of all bridges classified as Structurally Deficient to the total deck area of all applicable bridges for each State. The percentage of deck area of bridges classified as Structurally Deficient shall be computed by FHWA to the one tenth of a percent as follows:

$$100\times\frac{\sum_{SD=1}^{\text{Structurally Deficient}}[\text{Length}\times\text{Width}]_{\text{Bridge SD}}}{\sum_{s=1}^{\text{TOTAL}}[\text{Length}\times\text{Width}]_{\text{Bridge s}}}$$

Where:

Structurally Deficient = total number of the applicable bridges, where their classification is Structurally Deficient per this section and § 490.413;

SD = a bridge classified as Structurally Deficient per this section and § 490.413;

Length = corresponding value of NBI Item 49—Structure Length for every applicable bridge;

Width = corresponding value of NBI Item 52—Deck Width

Beginning with calendar year 2018 and thereafter, Width = corresponding value of NBI Item 52—Deck Width or value of Item 32 Approach Roadway Width for culverts where the roadway is on a fill [*i.e.*, traffic does not directly run on the top slab (or wearing surface) of the culvert] and the headwalls do not affect the flow of traffic for every applicable bridge.

s = an applicable bridge per this section and § 490.413; and

TOTAL = total number of the applicable bridges specified in this section and § 490.413.

(d) The FHWA will annually determine the percentage of the deck area of NHS bridges classified as Structurally Deficient for each State DOT and identify State DOTs that do not meet the minimum level of condition for NHS bridges based on data cleared in the NBI as of June 15 of each year. The FHWA will notify State DOTs of their compliance with 23 U.S.C. 119(f)(2) prior to October 1 of the year in which the determination was made.

(e) For the purposes of carrying out this section, State DOTs will annually submit their most current NBI data on highway bridges to FHWA no later than March 15 of each year.

(f) The NBI Items included in this section are found in the Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges, which is incorporated by reference (see § 490.111).

§ 490.413 Penalties for not maintaining bridge condition.

(a) If FHWA determines for the 3-year period preceding the date of the determination, that more than 10.0 percent of the total deck area of bridges in the State on the NHS is located on bridges that have been classified as Structurally Deficient, the following requirements will apply.

(1) During the fiscal year following the determination, the State DOT shall obligate and set aside in an amount equal to 50 percent of funds apportioned to such State for fiscal year 2009 to carry out 23 U.S.C. 144 (as in effect the day before enactment of MAP–21) from amounts apportioned to a State for a fiscal year under 23 U.S.C. 104(b)(1) only for eligible projects on bridges on the NHS.

(2) The set-aside and obligation requirement for bridges on the NHS in a State in paragraph (a) of this section for a fiscal year shall remain in effect for each subsequent fiscal year until such time as less than 10 percent of the total deck area of bridges in the State on the NHS is located on bridges that have been classified as Structurally Deficient as determined by FHWA.

(b) The FHWA will make the first determination by October 1, 2016, and each fiscal year thereafter.

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35a. Title 23-Highways Code of Federal Regulations (CFR) Part 150: National goals and performance management measures

§150. National goals and performance management measures

(a) Declaration of Policy.-Performance management will transform the Federal-aid highway program and 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 decisionmaking through performance-based planning and programming.

(b) National Goals.-It is in the interest of the United States to focus the Federal-aid highway program on the following national goals:

(1) Safety.-To achieve a significant reduction in traffic fatalities and serious injuries on all public roads.

(2) Infrastructure condition.-To maintain the highway infrastructure asset system in a state of good repair.

(3) Congestion reduction.-To achieve a significant reduction in congestion on the National Highway System.

(4) System reliability.-To improve the efficiency of the surface transportation system.

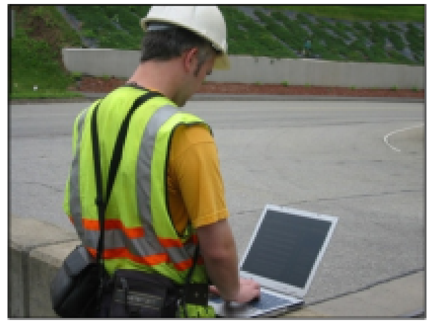
(5) Freight movement and economic vitality.-To improve the National Highway Freight Network, strengthen the ability of rural communities to access national and international trade markets, and support regional economic development.

(6) Environmental sustainability.-To enhance the performance of the transportation system while protecting and enhancing the natural environment.

(7) Reduced project delivery delays.-To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practices.

36. AASHTOWare Bridge Management (BrM) Software Version 5.1.2 White Paper

What is 5.1.2? AASHTOWare Bridge Management software (BrM) 5.1.2 is AASHTO's bridge inspection software tool, providing a means for agencies to inventory and inspect their structures following AASHTO's Guide Manual for Bridge Element Inspection, and meet National Bridge Inspection standards. The software expands upon the existing software architecture and incorporates and builds off of features included in previous versions. In addition to providing agencies with the tool to complete their National Bridge Element (NBE) inspections, this new version lays a foundation for the future 5.2 release. The software has been carefully developed under the guidance of State DOT representatives.



Also known as Pontis 5.1.2, the software improves the ability to collect inspection data including the new National Bridge Elements in both a standalone and web-based enterprise mode.

What can 5.1.2 do for me? Agencies operating version 5.1.2 can implement the AASHTO NBE and Bridge Management Elements (BME) and access new features and capabilities. This software's development is based on advancements in state-of–the-art technology, current agency best practices, and extensive user feedback. Version 5.1.2 provides the following:

- ***Fully incorporates AASHTO's new National Bridge Elements***
  In 2011, AASHTO adopted the Guide Manual for Bridge Element Inspection, which supports a new inspection approach built off of the previous AASHTO Guide for Commonly Recognized (CoRe) Structural Elements. 5.1.2 incorporates these new elements, allowing agencies to create a detailed NBE/BME based bridge inventory and inspection program. Also, agencies can migrate their existing CoRe elements with an easy-to-use, supplemental AASHTO Migration tool. The NBEs and BMEs provide an improved method for recording bridge condition information and will be the foundation for improved bridge management tools in version 5.2 (described in more detail in a separate White Paper).
- ***Easier data transfer capability***
  Version 5.1.2 supports bridge inspection data transfers and imports. In addition to the standard Pontis Data Interface (PDI) text files, 5.1.2 now supports XML import and output of information. This new capability provides easier and more efficient integration of the software with other programs and transfer of data between field computers.
- ***Speed and Usability Enhancements***

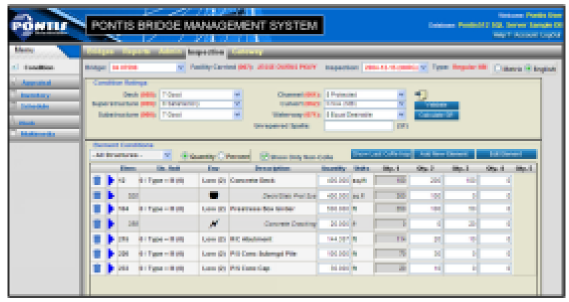
  Numerous user-requested enhancements have been provided in this release. Changes to improve the speed and performance of the software and a number of minor features and enhancements were made based on user feedback. These enhancements include better picture handling via a new multiple photo uploader, integration of element manual pages, and new layouts, fonts, and icons to improve element identification and data entry.
- ***Prepares Inspection Data for Use by BrM 5.2 Release***

  5.1.2 improves the utility of agencies' bridge inspection data and lays the groundwork for the next generation of AASHTO's Bridge Management Software requirements by ensuring data is in the correct format. BrM 5.1.2 prepares agencies' inventory data for the multi-objective, risk assessment, trade-off analysis, and deterioration modeling tools in 5.2.

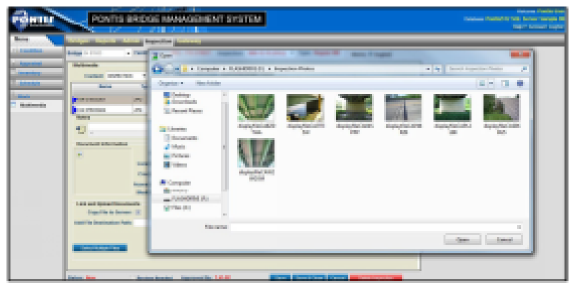
What are the Advantages of 5.1.2?

The AASHTOWare Bridge Management software is fully supported and maintained by AASHTO. Its' development and features are consistent with AASHTO guidelines and meet FHWA regulatory requirements. As with other AASHTOWare products, BrM is administered and overseen by a task force of State DOT representatives. Version 5.1.2 has undergone numerous enhancements that will provide distinct advantages to the users. These advantages include:

- *Better representation of bridge conditions with National Bridge Elements*
- *Agency flexibility to meet specific needs with support for agency defined Bridge Management Elements*
- *Inclusion of new Protective Systems and Defect Flags that may be attached to individual elements*
- *Improved installation and updated user manuals*
- *Speed and performance improvements*
- *Improved customer support for technical and administrative questions*



AASHTOWare Bridge Management fully incorporates AASHTO's National Bridge Elements including Protective Systems and Defect Flags (above). New features such as the multiple photo uploader have been added (below).



How can I Implement 5.1.2?

Current AASHTOWare licensees can request 5.1.2, or newer releases, via the AASHTOWare Bridge Management Support Desk at the website shown below. New entities interested in obtaining or evaluating 5.1.2 can request a copy from AASHTO. For agencies currently running an earlier version and wishing to upgrade, the following steps should be taken in regards to the software:

- Use the AASHTO migration tool to convert existing CoRe element data into NBE/BME data.
- Ensure that your agency database is in SQL or Oracle (Sybase no longer supported).
- Convert any legacy InfoMaker reports into Crystal Reports format.

AASHTO offers full support during the conversion process. Additionally, new and existing licensees that have advanced customization, on-site training, data migration services, and integration with other agency systems can purchase and use AASHTO service units with the BrM designated developer and support provider.

What is the Future Direction of AASHTOWare Bridge Management?

The software is currently undergoing a major set of enhancements. The foundation and research for this particular effort has been established over the past several years. 5.1.2 represents the first phase of a vastly improved software suite as a prelude to 5.2 development efforts. For the latest information and training videos please refer to the website at: http://aashtowarebridge.com/.

37. AASHTOWare Bridge Management (BrM) Software Version 5.2 White Paper

What is BrM? BrM (formerly Pontis) is a powerful Bridge Management Software tool that is used by over 44 State, Federal, local, and international agencies. The software has been developed over the past 20 years through extensive research and users' feedback. It originally started as an FHWA project to meet a critical national need, then was transferred to AASHTO to be part of AASHTOWare's cooperative software development efforts. Agencies utilize the BrM software for a range of bridge asset needs: bridge inventory and inspection data storage, deterioration modeling, project planning, and network budget and performance analysis.

What can BrM 5.2 do for me? The next generation of BrM will be a significant advance in bridge management analytical software. Based on extensive user feedback, advancements in state of the art technology, and current agency best practices, version 5.2 will:

- ***Fully incorporate AASHTO's new National Bridge Elements***
  In 2010 AASHTO adopted the Guide Manual for Bridge Element Inspection, which supports a new improved inspection approach building off of the previous Commonly Recognized Elements (CoRe). BrM 5.2 will fully incorporate all management activities using this new AASHTO guide.
- ***Easier to use and equipped with more features***
  The 5.2 user interface will be significantly improved to allow for a simplified approach to managing the vast amount of data and utilizing new features present in the software. The simplified user interface will better support the wide range of users throughout an agency and their unique needs.
- ***Better align with State DOT business practices***
  Redesigned project programming module will incorporate user feedback and current agency best practices to allow for a more flexible approach for planning, organizing, and grouping needs at bridge, project, or program level.

BrM fully incorporates AASHTO's National Bridge Elements including Protective Systems and Defect Flags.

What are the Advantages of BrM 5.2?

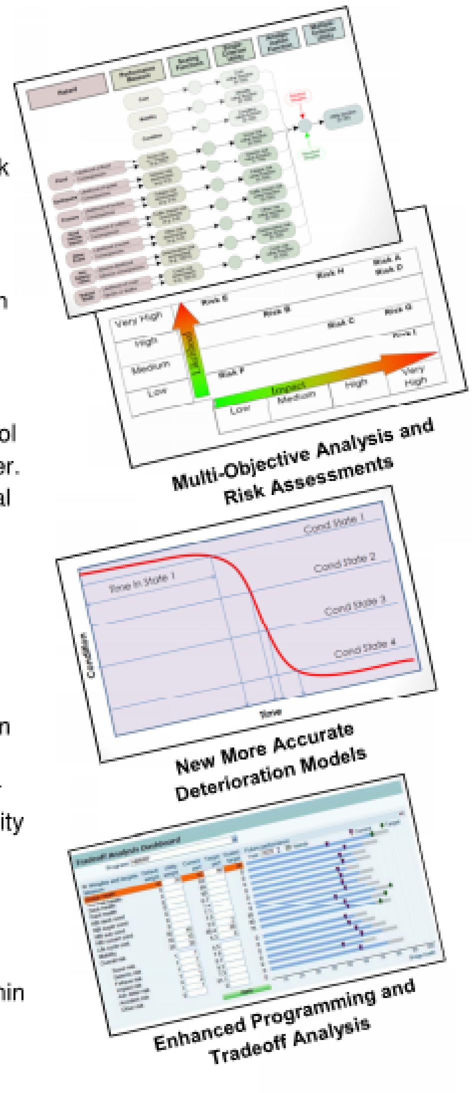
BrM is fully supported and maintained by AASHTO. Its development and features are coordinated with AASHTO guidelines and meets FHWA regulatory requirements. As with other AASHTOWare products it is administered and overseen by a task force of State DOT representatives. Advantages include:

- *Proven Element Level Approach*
- *Full support for Multi-Objective Optimization Analysis*
- *Advanced Deterioration Models*
- *Project and Needs Programming to support State DOT's unique business practices*

What are the Main Features of Version 5.2?

5.2 builds off of the successes and lessons learned in earlier versions to dramatically improve the software's features and usability for agencies. Some of the many new features that will be supported are:

- **Full Incorporation of Risks**: Agencies will be able to select from risks such as seismic, scour, and agency specific risks to develop risk matrices and related risk mitigation solutions and prioritize the risks against competing needs.
- **Enhanced Deterioration Models:** The use of new National Bridge Elements will enable significant improvements to current deterioration models in BrM. A new approach based on realistic deterioration models will be incorporated. The development of the deterioration models will be simplified and easier to understand and adapt.
- **Life Cycle Cost Analysis:** LCCA is a powerful project evaluation tool that will be expanded and presented in an easy to understand manner. The new LCCA tools will allow the agency to fully understand the total costs associated with project level decisions they make. The project planning tool will allow agency planners to evaluate various project options on the fly with clear presentation of the life cycle costs associated with each alternative.
- **Project Planning**: The new project planning modules will allow for major enhancements and greater flexibility in planning projects. The software will allow for easy identification of bridge, project, or program needs and the calculation of associated relative benefits. The approach can support middle-out, top-down, or bottom-up models for creation of programs within an agency. Version 5.2 will have the ability to do corridor and group based planning and better incorporate maintenance and preservation recommendations.
- **Web Enabled**: The software will be fully web-enabled for secure anytime/most anywhere access.
- **Enhanced Reporting and Data Exchange**: Numerous features within the software will be made simpler to use and offer technology upgrades. This includes but is not limited to revamped reporting modules as well as the new ability to transfer data in XML format.



What is the Plan for Release?

The AASHTOWare Bridge Task Force has already conducted significant foundation work in the research and planning for BrM 5.2. The software modules to incorporate the new AASHTO National Bridge Elements for bridge management will be released in phases. Each phase will build upon previous work and modules by adding new features. A brief summary of the anticipated phases is as follows:

- Phase I: Risk assessments, integrated utility functions, and network corridors
- Phase II: Implementation of significantly improved deterioration models and multi-objective analysis
- Phase III: Full completion including integrated project planning and all administrative features

38. TRB Committee on Structure Maintenance (AHD30)
    Scope of Committee

Scope: This committee is concerned with materials, equipment and procedures related to the diagnosis, planning and implementation of inspection, preservation, repair, rehabilitation, strengthening and upgrading of transportation structures including bridges, box culverts, tunnels, retaining walls or similar structures.

39. TRB Committee on Bridge Management (AHD35)
    Scope of Committee

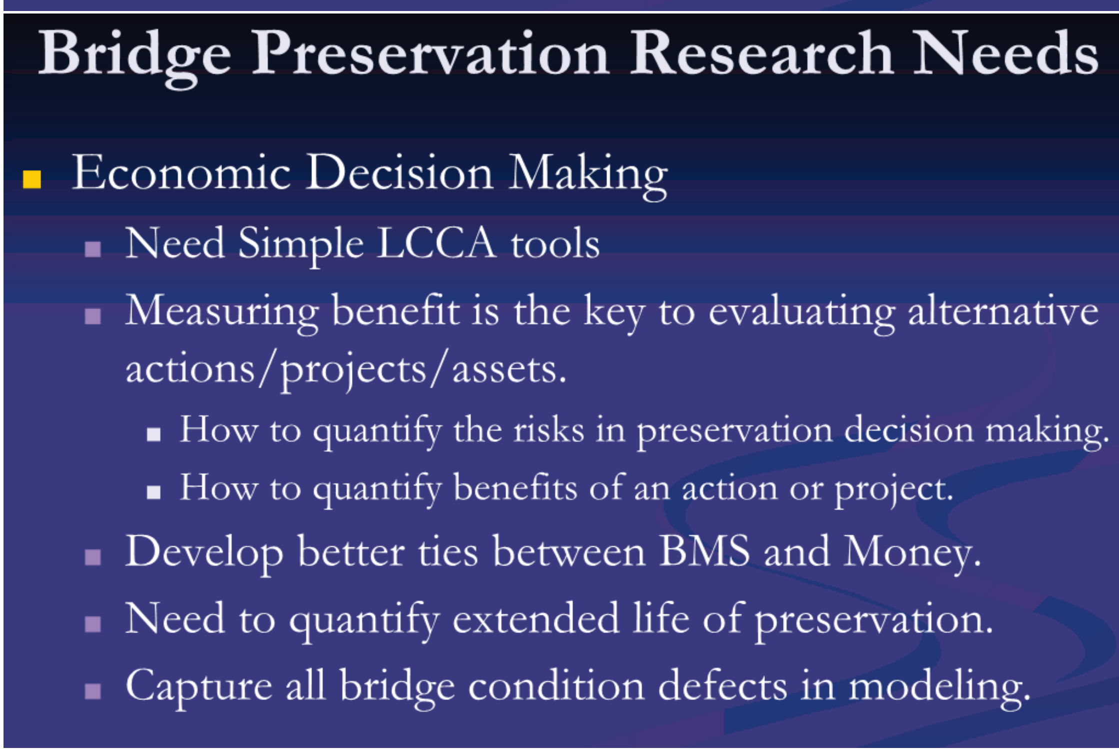
Scope: This committee is concerned with selection and evaluation of cost-effective programmatic optimal strategies for comprehensive management of bridges and structures. It is concerned with identifying and communicating critical data needs and vulnerability assessments for their effective life-cycle cost analysis and management.

40. TRB Bridge Preservation Committee (AHD37)
    Mission Statement and Objectives of Committee

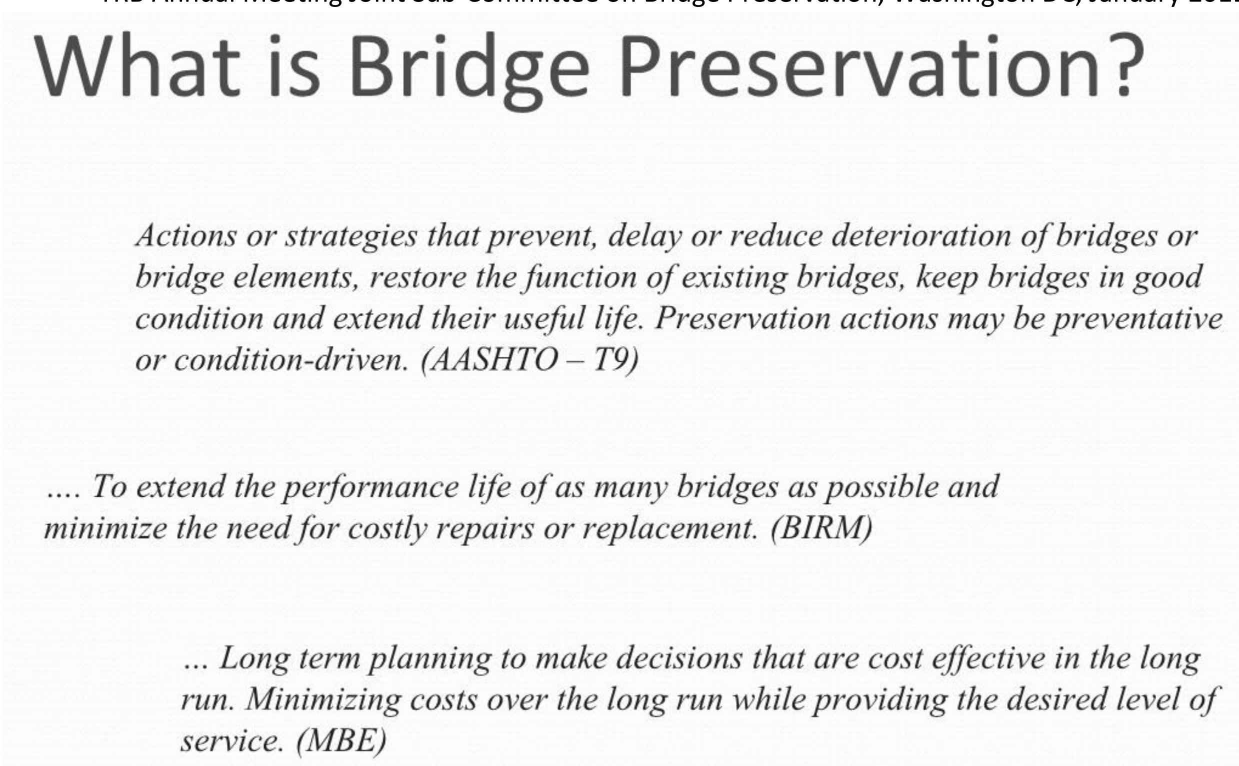
The TRB Bridge Preservation Committee mission is to establish broad bridge preservation research guidance and facilitate coordination between the TRB bridge technical committees under a common bridge preservation theme.

The objectives of the committee are to foster bridge preservation research that focuses on how to define and measure cost effective bridge network management, cost effective maximization of structure life, and the correlation of preservation activities, timing, performance and measured outcomes.

41. Bridge Preservation A State DOT Perspective, Michael B. Johnson, California Department of Transportation
TRB Bridge Preservation Meeting, Washington DC, January 2010



42. Defining Bridge Preservation, Michael B. Johnson, P.E., Basak Aldemir-Bektas
TRB Annual Meeting Joint Sub-Committee on Bridge Preservation, Washington DC, January 2011



Conclusions

- Activities that the majority of respondents classified as preservation:

Deck Protection Systems	Deck Crack Sealing
Deck Wearing Surfaces	Joint Seal Replacement
Epoxy Injection of Cracks	Fatigue Mitigation
Bridge Painting	Scour Mitigation
Installing Rip Rap	Installing Slope Paving
Installing Bird Netting	Resetting Bearings

Conclusions

- Formal definitions of bridge preservation cover actions considered maintenance, preservation and rehabilitation.
- Definitions of maintenance and preservation are ambiguous.
- Clear definitions of maintenance and preservation will require classifying specific bridge actions.
- Actions defined as maintenance more than triple those defined as preservation

43. Bridge Preservation Performance Measurement, Michael B. Johnson, P.E.
TRB Annual Meeting Joint Sub-Committee on Bridge Preservation, Washington DC, January 2012

Presentation Outline

- Key performance measurement components.
- What extent of the asset to measure?
- Existing bridge performance measures.
- Key components for bridge preservation performance measurement.
- Trend analysis as a measure.
- Conclusions

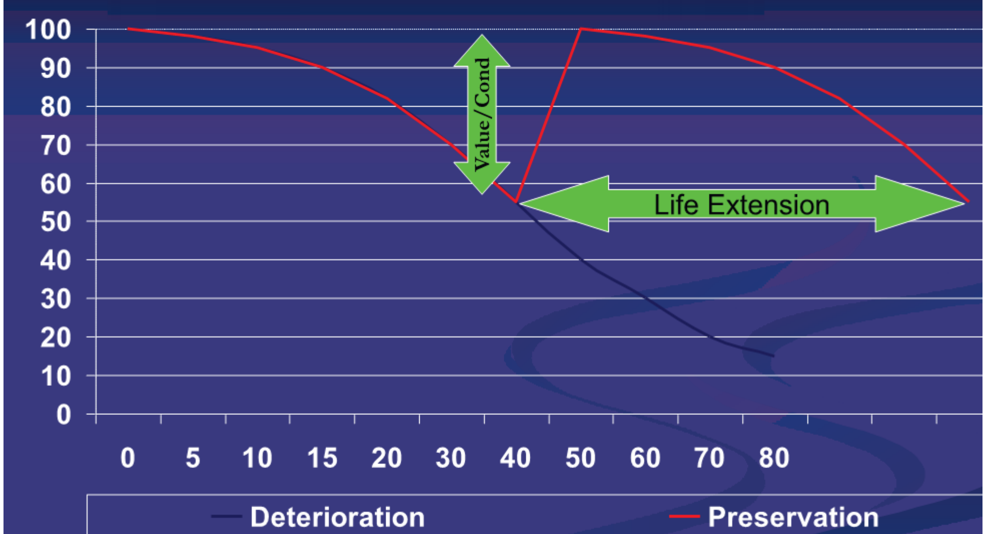
Preservation is Action Based

- Previous TRB Bridge Preservation Committee consensus preservation actions.

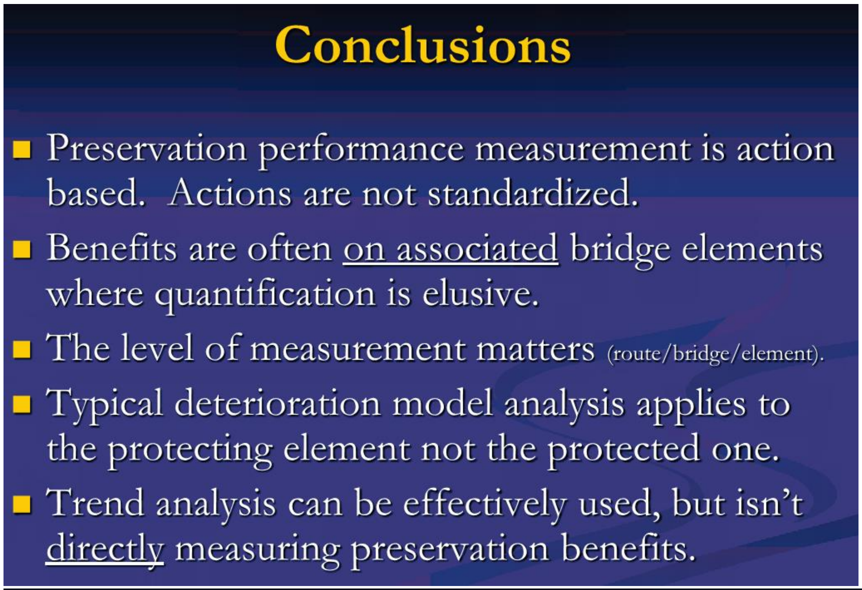
Deck Protection Systems (E)	Deck Crack Sealing (E)
Deck Wearing Surfaces (E)	Joint Seal Replacement (E)
Epoxy Injection of Cracks (E)	Fatigue Mitigation (E)
Bridge Painting (E)	Scour Mitigation (B)
Installing Rip Rap (E)	Installing Slope Paving (E)
Installing Bird Netting (E)	Resetting Bearings (B)

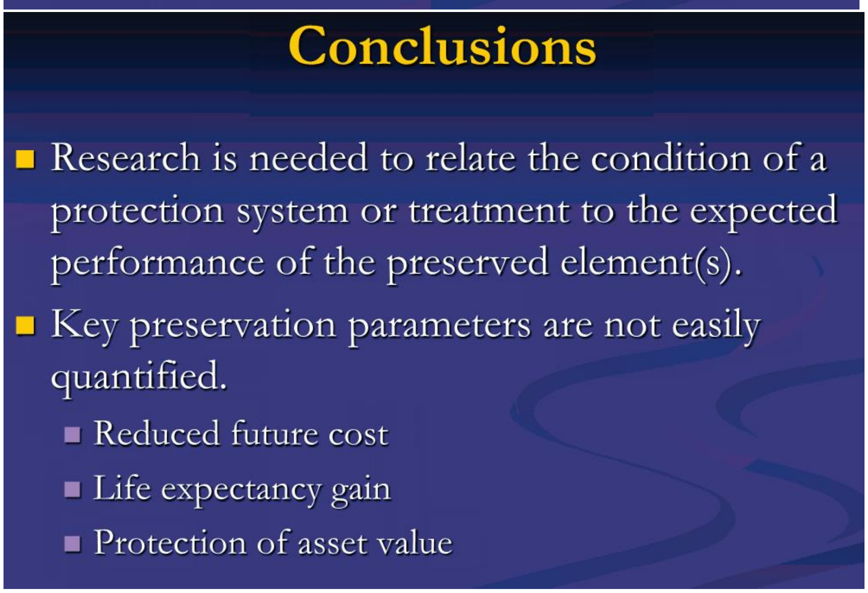
Mainly element (E) preservation items

Intervention Curve

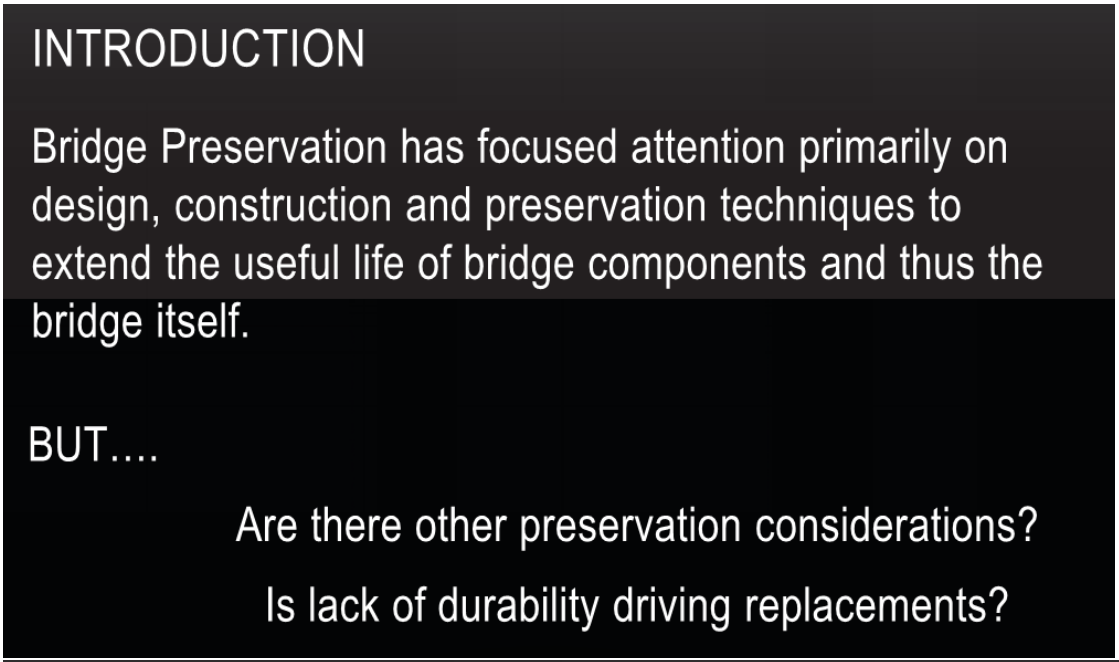


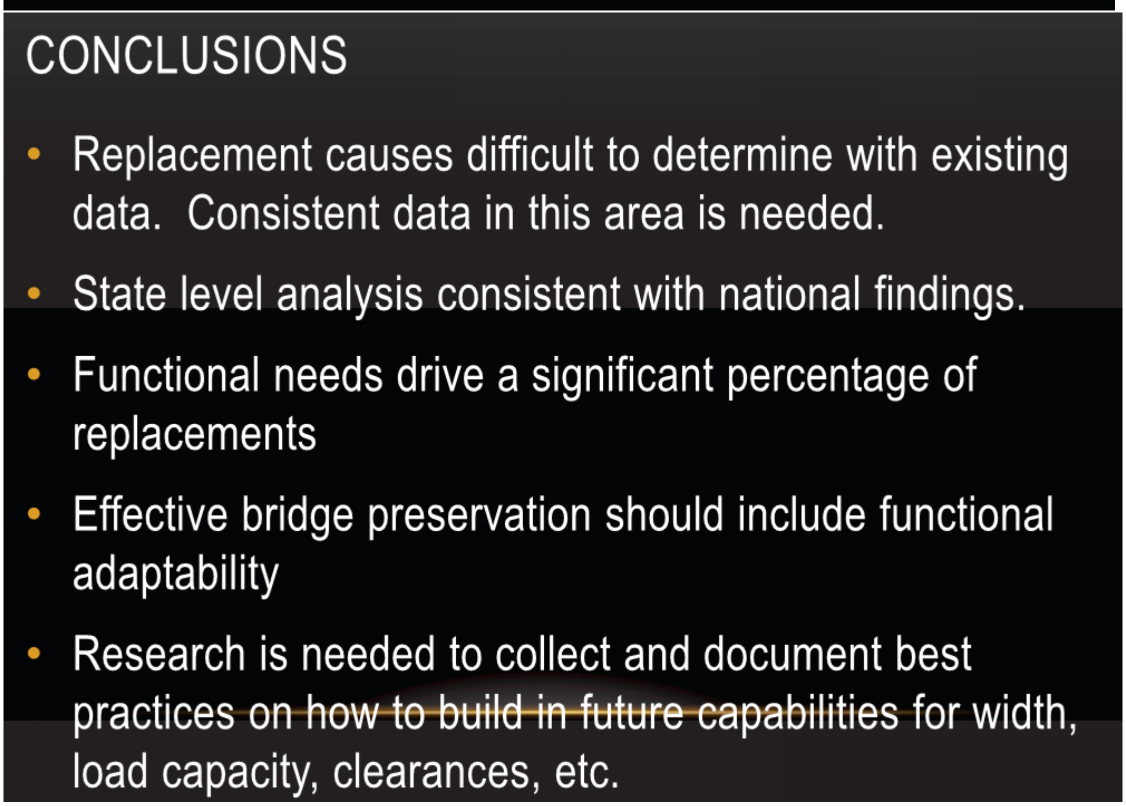
BLCCA can be used to determine cost savings but doesn't capture the relationship between elements


Conclusions
Preservation performance measurement is action based. Actions are not standardized.
Benefits are often on associated bridge elements where quantification is elusive.
The level of measurement matters (route/bridge/element).
Typical deterioration model analysis applies to the protecting element not the protected one.
Trend analysis can be effectively used, but isn't directly measuring preservation benefits.


Conclusions
Research is needed to relate the condition of a protection system or treatment to the expected performance of the preserved element(s).
Key preservation parameters are not easily quantified.
Reduced future cost
Life expectancy gain
Protection of asset value

44. Analysis of the Causes of Bridge Replacement in California, Michael B. Johnson, P.E., Paula J. Allec, California Department of Transportation
TRB Annual Meeting Joint Sub-Committee on Bridge Preservation, Washington DC, January 2014





45. AASHTO Committee on Maintenance, Bridge Technical Working Group (BTWG) Strategic Plan, September 18, 2015

Goal 1: Improve bridge preservation and maintenance practices.

Strategic Objective 1: Evaluate and promote the development, use, and integration of innovative technologies, materials, and design to support bridge preservation and maintenance activities.

Strategic Objective 2: Develop, improve, and promote, the use of bridge preservation and maintenance principles for applications in bridge management systems, asset management systems, performance measures, network level programming, and condition assessments.

Strategic Objective 3: Solicit and provide support for bridge preservation and maintenance research needs from member states, bridge preservation partnerships, and national committees.

Goal 2: Communicate the exchange of information on bridge preservation and maintenance.

Strategic Objective 1: Communicate and share information on state-of-the-art practices with member states through mutual participation in regional bridge preservation partnerships and national organizations dedicated to bridge preservation and maintenance.

Strategic Objective 2: Share information and educate stakeholders on the benefits of employing bridge preservation strategies to provide for the most efficient use available funds.

Goal 3: Assist member states in implementing bridge preservation and maintenance, safety, and environmental programs and practices.

Strategic Objective 1: Assist in the maintaining and updating the AASHTO Maintenance Manual sections on Bridge Maintenance and Management.

Strategic Objective 2: Assist the four regional bridge preservation partnerships.

Strategic Objective 3: Identify and document the community of practice for bridge preservation and maintenance.

Strategic Objective 4: Support the use of the Transportation System Preservation Technical Service Program (TSP 2) web site.

Strategic Objective 5: Promote public safety in the workforce, work zone, and equipment operations.

Strategic Objective 6: Promote environmental stewardship and compliance.

Goal 4: Sustain and improve the legacy knowledge base for Bridge Preservation and Maintenance

Strategic Objective 1: Identify knowledge and technology gaps and undertake future research projects and domestic scans through the Transportation Research Board, the FHWA and AASHTO.

Strategic Objective 2: Identify and address succession planning in the bridge preservation and maintenance arena.

Goal 5: Develop partnerships with transportation stakeholders.

Strategic Objective 1: Interact with and coordinate activities with other bridge preservation and maintenance organizations.

Strategic Objective 2: Jointly sponsor and undertake workshops, webinars, and seminars that focus on highway bridge preservation and maintenance.

SCOM Strategic Focus Areas

The Six "Strategic Focus Areas" for SCOM and the BTWG are as follows:

- **Safety** (Goal: A safe, reliable highway system in a state of good repair.)
- **Asset Management** (Goals: A safe, reliable highway system in a state of good repair; accountability and transparency through performance management.)
- **Environmental** (Goal: Environmental stewardship and compliance.),
- **Workforce Development** (Goal: A well-qualified and competent workforce.)
- **Communication** (Goal: The communication of the value and role of maintenance.), and
- **Research** (Goal: Research, innovation and emerging technology.)

46. AASHTO Committee on Maintenance
Strategic Plan, September 22, 2018

Goal 2: Asset Management

Accountability and transparency through performance management

2.1 Performance Measures
Identify, develop and promote meaningful maintenance performance measures.

2.2 Performance Management
Identify and proactively share performance management best practices.

2.3 System Preservation
Identify, promote and support best practices in system preservation methods and procedures.

2.4 Asset Management Systems
Identify, promote and support best practices in asset management.

2.5 Accountability and Transparency
Identify, promote and support practices by which transportation infrastructure owners can demonstrate their maintenance decisions and results.

Goal 5: Communication

Promote the communication of the value and role of maintenance.

5.1 Marketing
Support and share innovative marketing strategies and opportunities that promote the value of maintenance in general and successful strategies in particular.

5.2 Outreach and education
Proactively promote, support and share best practices in maintenance activity outreach and education to executives, elected officials and the traveling public.

5.3 Research products and implementation
Promote and support best practices in marketing product research and product implementation successes.

Goal 6: Research

Promote research, innovation and technology.

6.1 Research Needs
Proactively and strategically identify maintenance research needs.

6.2 Research findings
Proactively promote, support and share the latest research findings and associated best practices.

6.3 Innovation
Proactively seek and share the latest innovations and associated best practices.

6.4 Technology Adaptation to Maintenance
Promote and share best practices in how and where technology has adapted to maintenance.

6.5 Maintenance Adaptation to Technology

Promote and share best practices in how and where maintenance practices and procedures have adapted to changes in technology.

47. The Maintenance Manager, November 2017
AASHTO Maintenance Committee
Bridge Technical Working Group (BTWG)

The AASHTO Maintenance Manual for Roadways and Bridges is being updated under NCHRP Project 20-07/Task 380 –this update is scheduled to be completed by December 5, 2017.

The AASHTO TSP-2 Bridge Preservation Partnerships have formed a National Bridge Preservation Bridge Management System Working Group.

The scope for the working group follows:

- Promote the development and / or adoption of best practices for the evaluation of cost effective bridge management systems to extend the service lives of bridges and save money,
- Develop general guidance to give practitioners nationwide, a reliable way to determine what actions / best practices are needed when evaluating, planning, and executing bridge preservation projects.
- Promote awareness among bridge practitioners of the financial benefits of supporting the use of best BMS practices.
- Monitor and share the national development of management systems as they evolve.

The leadership team for this group is:

Co-Chair: Dan Muller, NCDOT
Co-Chair: David Juntunen, MDOT
Vice-Chair: Todd Springer, VDOT
Secretary: Jeff Milton, VDOT

The Bridge Technical Working Group leadership team is working to develop a marketing package to communicate the value of system preservation to elected officials, the general public and state DOT executives. The leadership team will involve the Regional Bridge Preservation Partnerships in this effort through conference calls and emails.

The FHWA Bridge Preservation Expert Task Group is working to update the FHWA Bridge Preservation Guide.

48. AASHTO Subcommittee on Bridges & Structures, T-9 Bridge Preservation, Annual State Bridge Engineers' Survey (2015)
Includes information related to:
    - Self consolidating concrete (SCC) (does MDOT have a SCC specification)
    - Soundwalls/earth-retaining strutures (does MDOT keep data element information for these types of structures in the database?)
    - Structural health monitoring program (does MDOT have any structural health monitoring and if so is it maintained in the database?)
    - Height detection devises (does MDOT have any detection devices installed on bridges and if so are they in the database?)
    - Service-life design

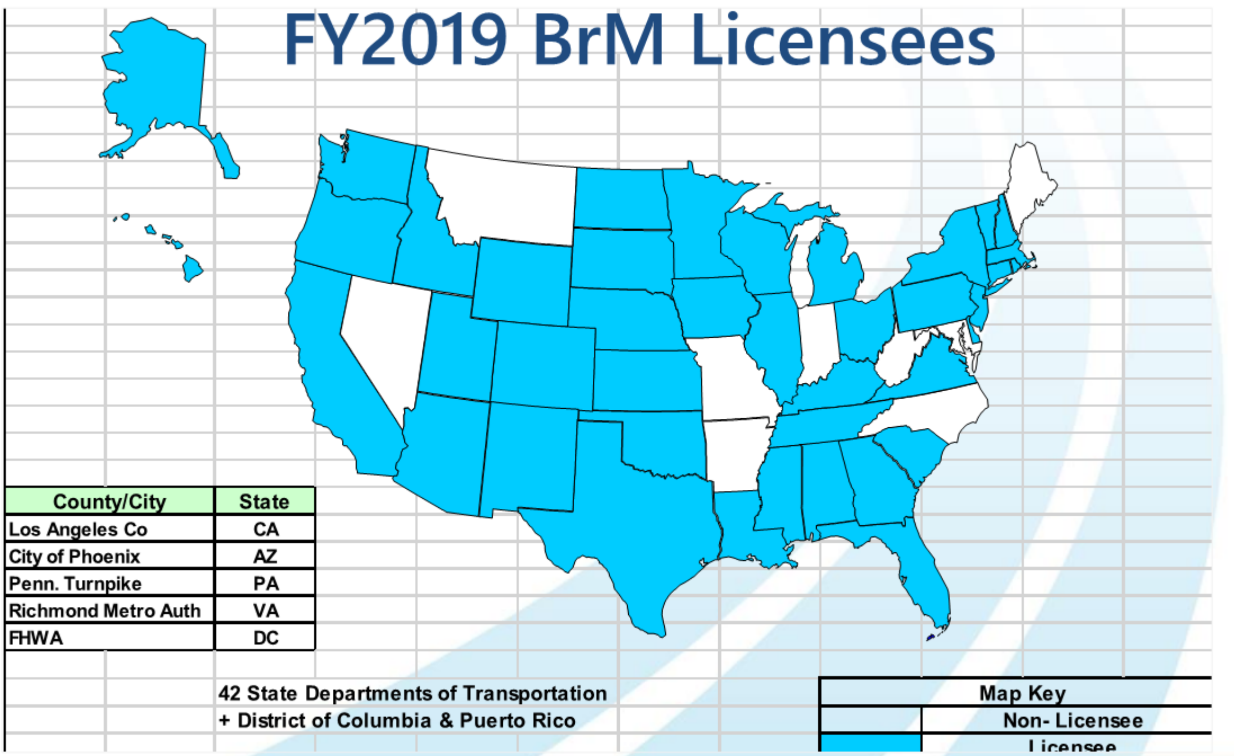
- Bridge deterioration models (does MDOT have any bridge deterioration model information and is it in the database?)
- Durability criteria
- Bridge preservation activities (does MDOT have bridge preservation activities and if so how is this information stored/accessed and where does it reside?)

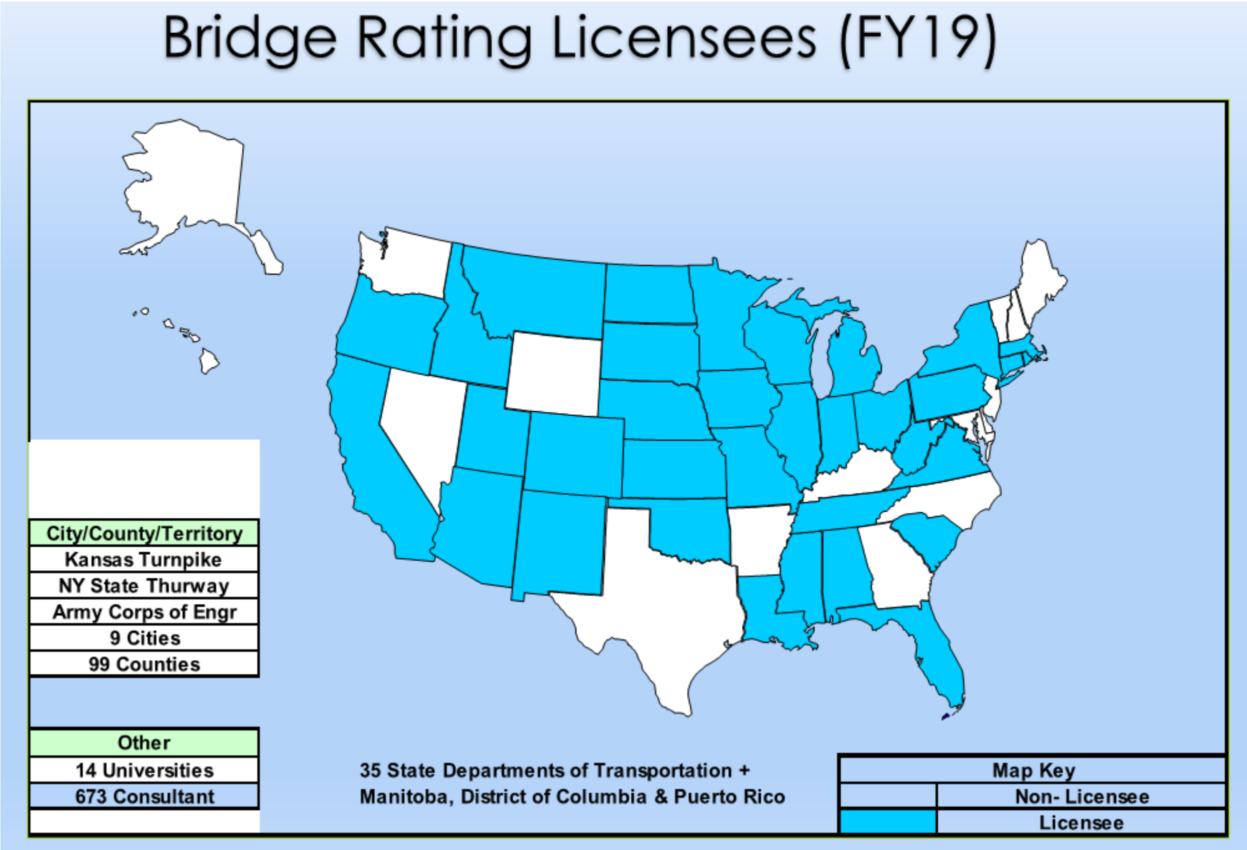
49. AASHTO Subcommittee on Bridges & Structures, T-9 Bridge Preservation, Annual State Bridge Engineers' Survey (2016)
    Includes information related to:
    - Bridge files/records and record retention
    - Database systems/software used for data elements
    - Types of overlays used for bridge decks
    - MASH compliant bridge barriers (Is MDOT collecting this information in the database?)
    - EPA asbestos-containing materials (Is MDOT collecting this information in the database?)
    - Pile installation testing (where is this information kept by MDOT?)
    - Bridge inspection data (paper vs. electronic files)
    - Ride quality specification (does MDOT have a ride quality specification?)
    - Non-destructing testing of drilled shafts (does MDOT test drilled shafts and if so where is the information kept?)
    - Chloride content testing in bridge decks (does MDOT test bridge decks for chloride content and if so where is the information kept?)
50. AASHTO Subcommittee on Bridges & Structures, T-9 Bridge Preservation, Annual State Bridge Engineers' Survey (2017)
    Includes information related to:
    - Deck deterioration protocols
    - Underwater inspection & acoustic imaging data storage & videos (where is this information kept by MDOT?)
    - Corrugated metal pipes (CMP) data elements (does MDOT have any data element information for load rating and if so where is the data element information kept?)
    - Criteria for bridge rehabilitation vs. replacement (does MDOT have criteria to make decisions concerning when to repair/rehabilitate a bridge vs. replacement and if so where is the criteria kept?)
    - Service-life prediction software (does MDOT use service-life prediction software and if so where is the information kept?)
    - Drilled shaft integrity testing (does MDOT test drilled shafts and if so where is the information kept?)
    - 3-D and Bridge Information Modeling (BrIM) (does MDOT have any 3-D or BIM data elements and if so where is the information kept?)
    - Weigh-in-motion for load monitoring (does MDOT have any weigh-in-motion data elements and if so where is the information kept and how is it being used?)
    - LIDAR or imaging sensors scanning (does MDOT have any of this information/data in the database?)
    - Fencing on bridges (does MDOT have fencing on bridges and is it kept in the database?)

- Bridge preservation program (does MDOT have a bridge preservation program?)
- Fiber reinforcing specifications (does MDOT have a specification for fiber reinforcing to control and/or minimize cracking?)
- Soil corrosion testing and/or evaluations (does MDOT collection this information and is it kept in the database?)
- Type of concrete used in bridges (does MDOT specify this information and where is it kept in the database?)
- Durability specifications (does MDOT have a specification for durability?)
- Type of reinforcing (e.g., uncoated/black, epoxy, stainless steel, corrosion resistant) used in bridges (does MDOT specify this information and where is it kept in the database?)

51. AASHTO Subcommittee on Bridges & Structures, T-9 Bridge Preservation, Annual State Bridge Engineers' Survey (2018)
    Includes information related to:
    - Utilities on bridges (does MDOT have utilities on bridges and are they kept in the database?)
    - Retaining walls (does MDOT keep data element information for retaining walls in the database?)
    - Hydraulics design part of bridge team organization
    - Who prioritizes bridge replacements/repairs
    - Elastomeric bearing pad testing (does MDOT require testing and if so where is the information kept in the database?)
    - Bridge preservation program (does MDOT have a bridge preservation program?)
    - Structural repair plans (does MDOT prepare repair plans and if so where are they kept in the database?)
    - Repair procedures (does MDOT have documented bridge repair procedures and if so where are they kept in the database?)
    - Estimated service life
    - Deck overlays (does MDOT use deck overlays either for new construction or for repairs and if so where is the information kept in the database?)
    - Bridge priority software (does MDOT use software to prioritize bridges?)
    - Life-cycle costs (does MDOT keep records of bridge costs and if so where is the information kept in the database?)
    - Ultra-High Performance Concrete (UHPC) (does MDOT have a UHPC specification)
    - Self consolidating concrete (SCC) (does MDOT have a SCC specification)

52. AASHTO Subcommittee on Bridges & Structures, T-18 Bridge Management Evaluation & Rehabilitation, AASHTOWare Bridge Management Update, June 25, 2019.
   - 42 State DOT licenses of AASHTOWare Bridge Management (BrM), MDOT included
   - 35 State DOT licenses of AASHTOWare Bridge Load Rating (BrR), MDOT included
   - 16 Agency licenses of AASHTOWare Bridge Design (BrD), MDOT included
   - Web integration capabilities
   - Metric reporting/data for level of FHWA compliance
   - Improves efficiencies with IT departments
   - BrM 6.3 release scheduled for Fall 2019
   - Notifications via email for process completion activities
   - Provides framework for adding other asset types in the future (e.g., walls, signs)
   - Investment strategies & plans pyramid
   - AASHTOWare bridge design (BrD) and load rating (BrR); data integration
   - BrM 7.0 Beta testing
   - Next releases to include; improved reporting, web service integration, data integration (TPF-5(372) Building Information Modeling for Bridges and Structures
   - Task Force members (MDOT does not have a representative on the task force)





BrM 6.2 Features

- Added Web Services functionality for future communication and data sharing with AASHTOWare Bridge Rating (BrR).
- Added Program Comparison tool for comparing similarities and differences of the two programs.
- Added the "23 Metric Report – As of Date" report that determines the level of FHWA compliance for each selected bridge as of the selected date.
- Various bug fixes and miscellaneous items.

AASHTOWare Bridge Integration through Web Services

- Funded by the AASHTOWare Research, Innovation, and Product Improvement (RIPI) Program
- **Phase 1** complete with BrM 6.0 release
  - Framework ready and available within BrM.
  - BrM has ability to send and receive load rating information to and from BrDR.
- **Phase 2** planned for completion with BrDR 7.1 release in 2020
  - Complete the same framework in the BrDR software as already completed in BrM.
  - Will have the interface and ability to send and receive load rating information to and from BrM.

BrM Hosting

A hosted BrM application improves the user experience by:

1. Allowing BrM users to focus on asset management, not software upkeep;
2. Generating faster support and resolution of issues as Mayvue doesn't have to acquire the state's database to begin troubleshooting;
3. Eliminating the need for the BrM users to participate in the troubleshooting;
4. Removing wasted time waiting for your IT department to step in and help;
5. Testing the BrM site in your State's exact environment (shared workspace);

BrM 6.3 Release – Component Level Deterioration

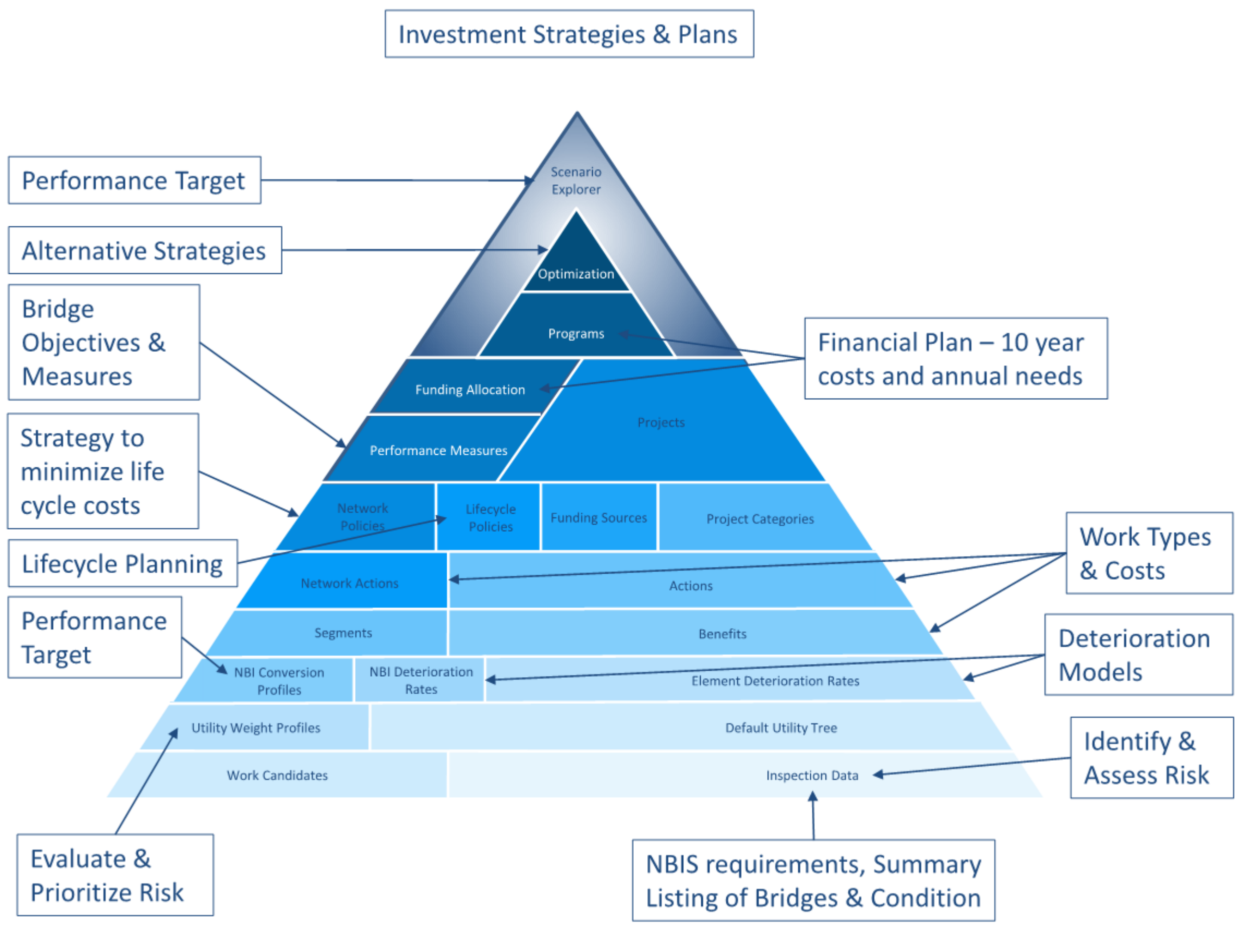
- Formerly called NBI Deterioration
- Allows users to evaluate multiple deterioration profiles for each component of a bridge
- Users can configure their own model parameters to create a custom profile that will be applied on a per bridge basis when modeling
- Development of this enhancement is being spearheaded by Michigan and Texas DOTs

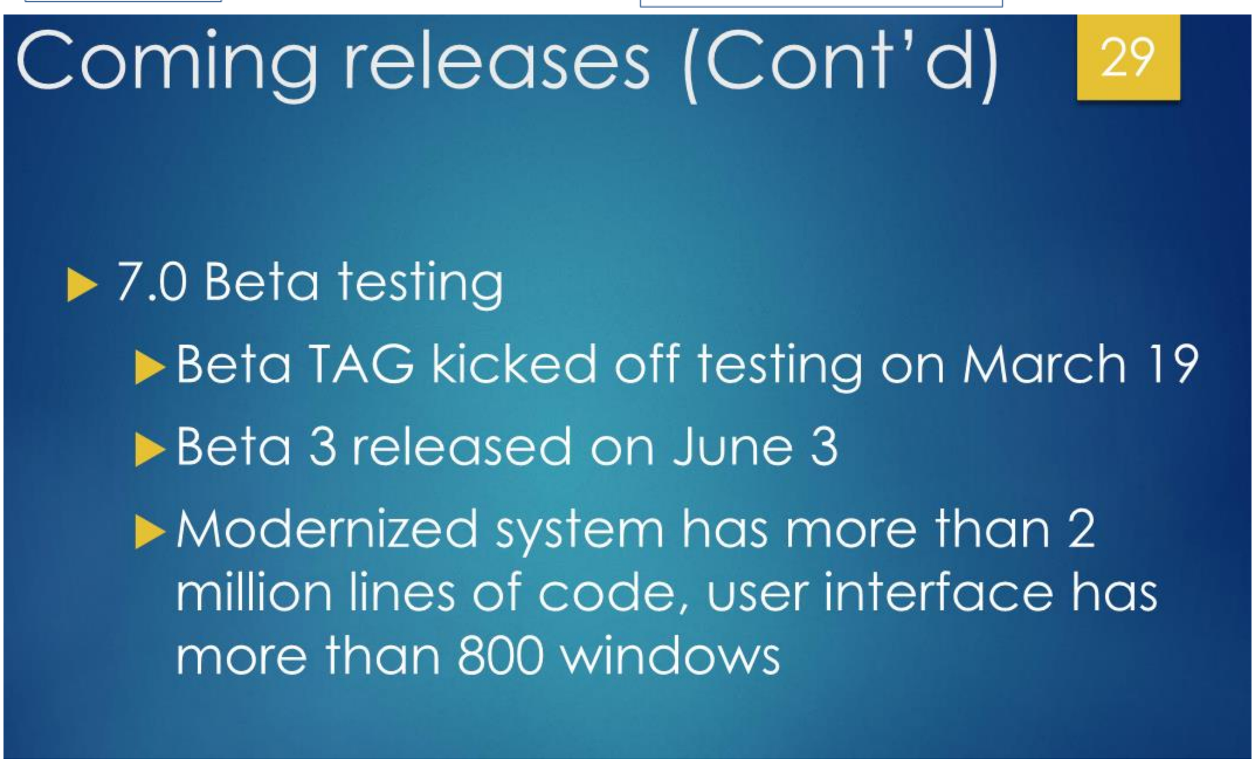
BrM 6.3 Release – Scheduled Processes

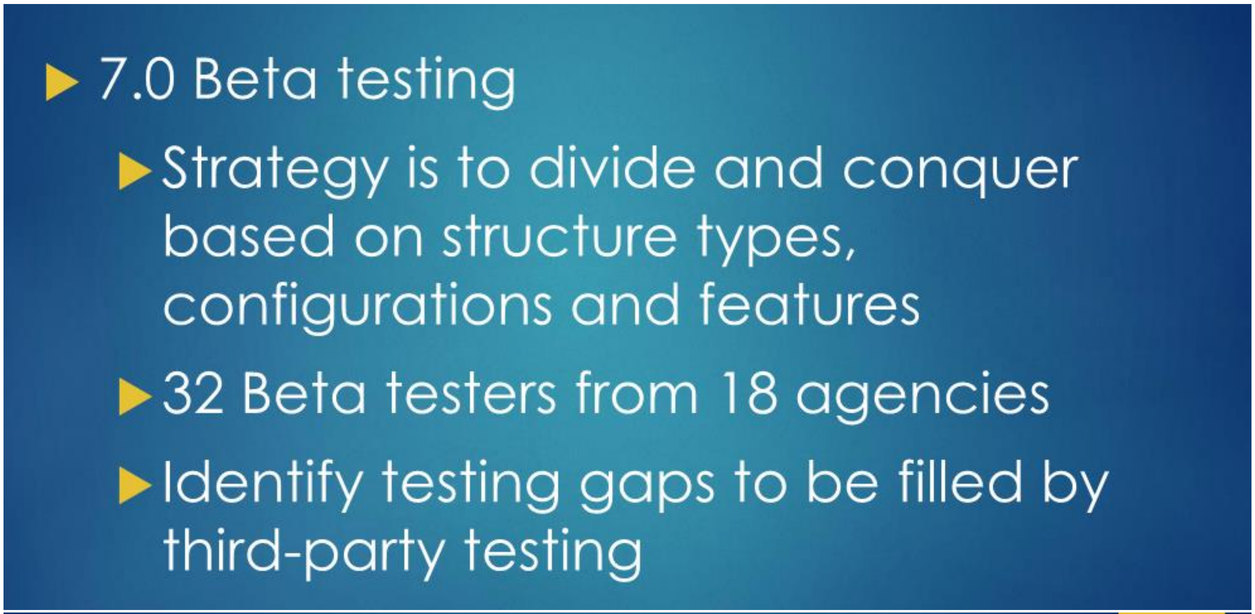
- Schedule certain BrM services to be run at regularly scheduled intervals (e.g. weekly or monthly)
- Run scheduled process-intensive tasks (e.g. sufficiency rating calculations) during off peak hours
- Designated personnel will be notified by email confirming successful completion of the process
- Champions are the Alabama and Virginia DOTs

BrM 6.3 Release – Tunnel Work Candidate

- High priority enhancement identified by multiple states
- Functions similar to the Bridge work candidate page, but will use multi-asset actions
- Establishes the framework for the future state of BrM where other asset types can easily be included (e.g. walls and signs)


Investment Strategies & Plans
Performance Target
Alternative Strategies
Bridge Objectives & Measures
Strategy to minimize life cycle costs
Lifecycle Planning
Performance Target
Evaluate & Prioritize Risk
Scenario Explorer
Optimization
Programs
Funding Allocation
Projects
Performance Measures
Network Policies
Lifecycle Policies
Funding Sources
Project Categories
Network Actions
Actions
Segments
Benefits
NBI Conversion Profiles
NBI Deterioration Rates
Element Deterioration Rates
Utility Weight Profiles
Default Utility Tree
Work Candidates
Inspection Data
Financial Plan – 10 year costs and annual needs
Work Types & Costs
Deterioration Models
Identify & Assess Risk
NBIS requirements, Summary Listing of Bridges & Condition


Coming releases (Cont'd)
29
7.0 Beta testing
Beta TAG kicked off testing on March 19
Beta 3 released on June 3
Modernized system has more than 2 million lines of code, user interface has more than 800 windows


▶ 7.0 Beta testing
▶ Strategy is to divide and conquer based on structure types, configurations and features
▶ 32 Beta testers from 18 agencies
▶ Identify testing gaps to be filled by third-party testing


Next release (Cont'd)
37
▶ Improved and additional reporting capabilities
▶ 17 recommendations from BrDR Report TAG
▶ BrM Web Service Integration

Data integration endeavors

38

- FHWA Bridge Information Modeling Standardization (HIF-16-011)
  - Evaluated AASHTOWare IFC Bridge Converter
- TPF-5(372) Building Information Modeling for Bridges and Structures
  - Member of the Software Advisory Group

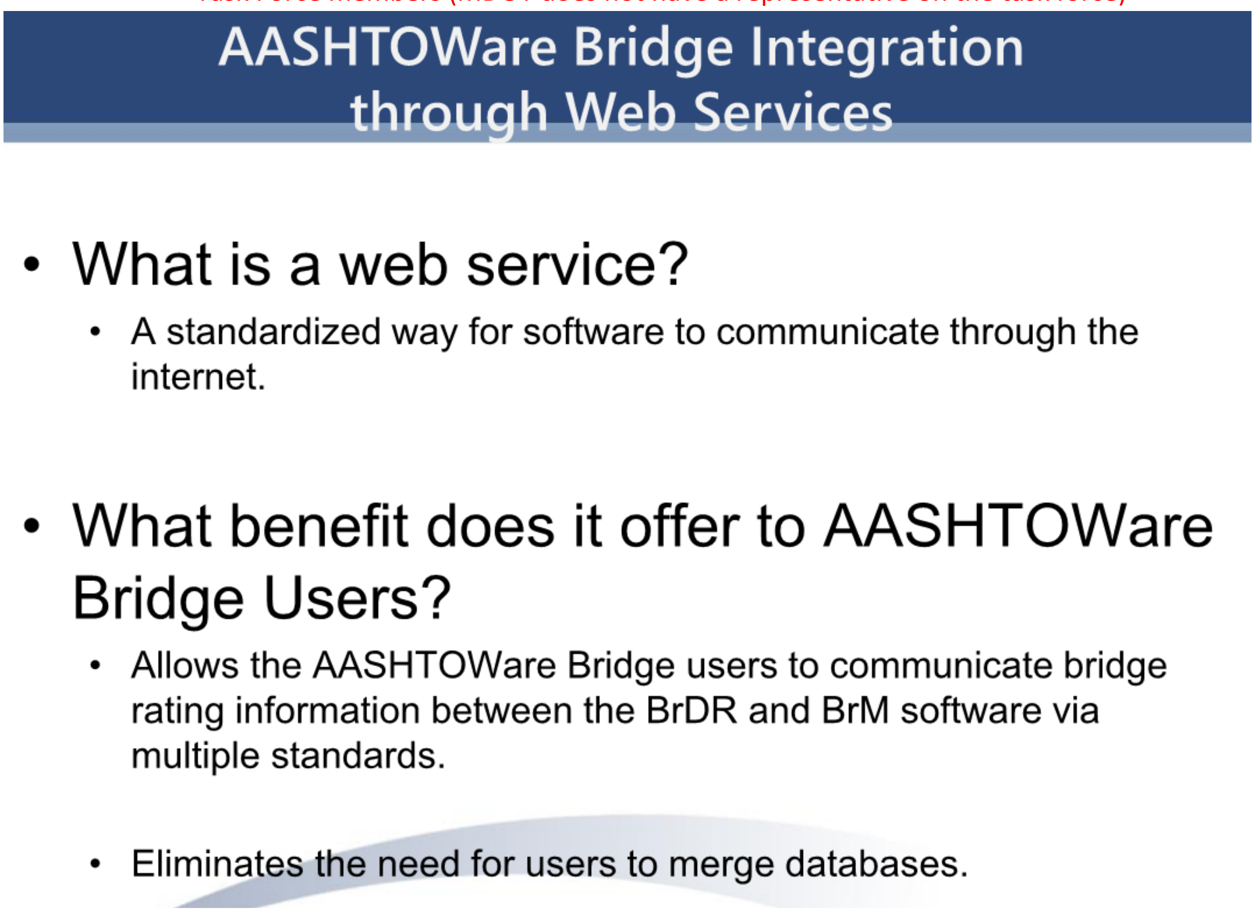
Task Force members

40

Chair	**Todd Thompson**	**South Dakota**
Vice Chair	**Eric Christie**	**Alabama**
Member – BrM	Beckie Curtis	Michigan
Member – BrM	Craig Nazareth	Rhode Island
Member – BrM	Kent Miller (Bruce Novakovich)	Nebraska
Member – BrM	David Hedeen (Mark Faulhaber)	Minnesota
FHWA Liaison – BrM	Derek Constable	FHWA
Member – BrD	Dean Teal	Kansas
Member – BrD	Mark Bucci	Louisiana
Member – BrR	Joshua Dietsche	Wisconsin
Member – BrR	Vinacs Vinayagamoorthy	California
Member – BrR	Mike Johnson	Idaho
FHWA Liaison – BrDR	Tom Saad	FHWA

53. AASHTO Subcommittee on Bridges & Structures, T-19 Software & Technology, AASHTOWare Bridge Management Update, June 25, 2019.
Eric Christie (ALDOT) and Todd Thompson (SDDOT)

- Bridge Integration through Web services, a standardized way for software to communicate through the internet
- Other data integration endeavors (BrDR-FHWA Bridge Information Modeling Standardization (HIF-16-011)
- Regression testing
    - Differences between changes in AASHTO bridge design specifications
    - Differences between two analytical software engines
    - Regression comparison tool based on NCHRP Report 485
- User Group Training
- Task Force members (MDOT does not have a representative on the task force)



AASHTOWare Bridge Integration through Web Services

- Funded by the AASHTOWare Research, Innovation, and Product Improvement (RIPI) Program

- **Phase 1** complete with BrM 6.0 release
  - Framework ready and available within BrM.
  - BrM has ability to send and receive load rating information to and from BrDR.

- **Phase 2** planned for completion with BrDR 7.1 release in 2020
  - Complete the same framework in the BrDR software as already completed in BrM.
  - Will have the interface and ability to send and receive load rating information to and from BrM.

AASHTOWare Bridge Integration through Web Services continued

Redesigned data linkages

- Existing Bridge Integration is a highly coupled solution requiring agency to merge BrM database with BrDR database
  - Both BrM and BrDR access the integrated database in production environment
- The redesigned data linkages provide a set of RESTful services that can be connected to from anywhere via HTTPS
  - No longer needs to merge databases, information exchange is on-demand

AASHTOWare Bridge Integration through Web Services continued

Phase 2

- Will implement a REST web service client within BrDR to consume the REST web services provided by BrM
- All existing Bridge Integration features will be provided
- Existing "Update BrM Rating Results" feature will be enhanced to support the BrM Load Rating Module
- BrM NBI rating will be available in BrDR for timely and accurate decisions on performing load rating

Other Data integration endeavors

- BrDR - FHWA Bridge Information Modeling Standardization (HIF-16-011)
  - Evaluated AASHTOWare IFC Bridge Converter
  - Extracted BrDR data and created a model

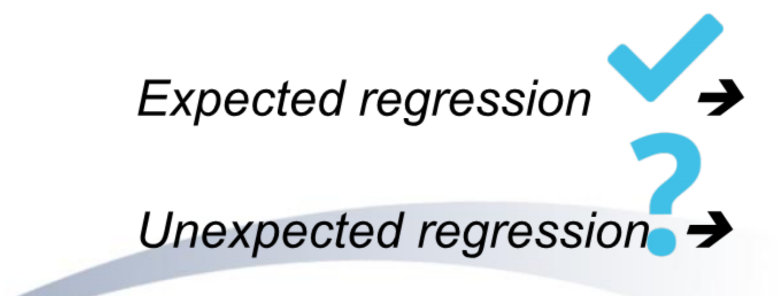
Other Data integration endeavors

- WIS DOT had a project to extract data from AASHTOWare Bridge Rating and created an IFC file that was then used to import into 3 different software packages.

BrDR - What is regression testing?

Regression testing is a type of software testing that seeks to uncover new software bugs, or regressions, in existing functional and non-functional areas of a system after changes such as enhancements, patches or configuration changes, have been made to them.

– Wikipedia



What is regression testing?

- Differences between two versions of BrDR can occur for different reasons
  - The software was changed intentionally to address a change in the AASHTO specification
  - The software was changed intentionally to address a coding defect
  - The software was changed intentionally to implement a user requested enhancement
  - The software was inappropriately changed thus introducing a defect

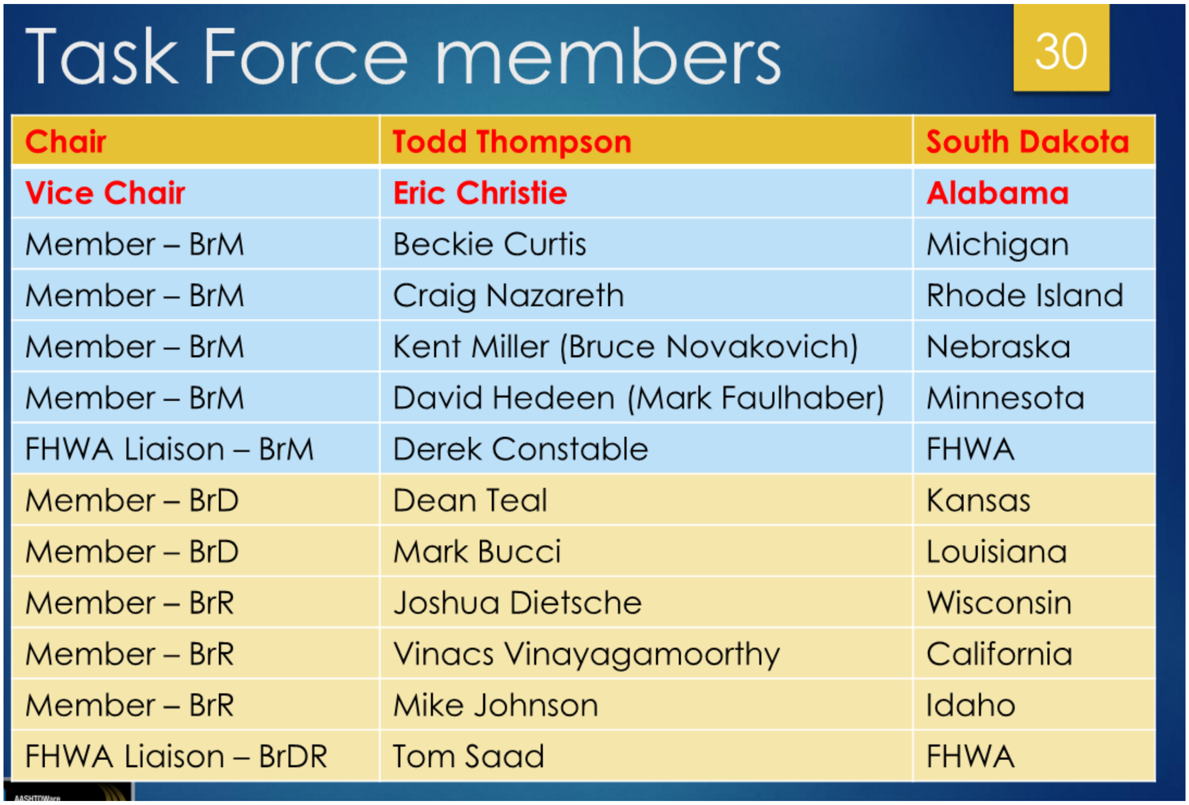
User Group Training Meetings

- **Bridge Design and Rating**

  RADBUG
  July 30-31, 2019
  South Lake Tahoe, CA

- **Bridge Management**

  BrMUG
  September 17-18, 2019
  Louisville, KY



Task Force members

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FHWA Liaison – BrDR	Tom Saad	FHWA

54. AASHTO Subcommittee on Bridges & Structures, T-19 Software & Technology, The Portable Bridge WIM, Eric Christie, PE and Robert J. Taylor, PE
    Includes Mississippi 2018 Harvest Study and 2016 Enforcement; information on vehicle load distribution during measurements

55. Building Information Modeling (BIM) for Bridges and Structures, 99th TRB Annual Meeting, Washington, D.C., January 12-16, 2020, Pooled Fund Study

Building Information Modeling (BIM) for Bridges and Structures

The pooled fund project will provide the primary funding mechanism for American Association of State Highway and Transportation Officials (AASHTO) Subcomittee on Bridge and Structures (SCOBS) T-19 to perform the duties of governance and stewardship of Building Information Management (BIM) for Bridges and Structures. The objective of this proposal is to provide technical support for the implementation of Building Information Modeling (BIM) for Bridges and Structures under the direction of AASHTO COBS Technical Committee on Technology and Software (T-19) and the Transportation Pooled Fund TPF-5(372) Technical Advisory Committee (AASHTO COBS T-19/Pooled Fund). BIM has been widely used in the commercial sector for vertical construction to manage projects from conception through design, fabrication, construction and future asset management and maintenance. Although some fabricators who perform work on both building construction and transportation structures have begun employing BIM tools in the fabrication of bridge components, BIM use in transportation infrastructure is severely limited due to the lack of standardization. To take advantage of the efficiencies associated with the use of BIM in transportation structures, a comprehensive strategic plan by AASHTO COBS T-19 is needed. As a first step, AASHTO COBS T-19 initiated a study that was funded by NCHRP. The NCHRP project 20-07 Task 377 titled "Standardized Format for Bridge and Structure Information Models" presented a framework for BIM implementation roadmap and provided AASHTO COBS T-19 a list of actionable items. Following the conclusion of the NCHRP study and after extensive deliberations, AASHTO COBS T-19 identified a path forward for BIM implementation for bridges and structures. The initiative involved the following key decisions: (1) Identity: The initiative is being named BIM for Bridges and Structures, as the name encompasses the goal of this endeavor without potentially violating trademark rights. (2) Governance and Stewardship Framework: The BIM implementation roadmap involves the identification of a governance structure. The selected framework will be overseen by AASHTO COBS T-19 in collaboration with the AASHTO Technical Joint Committee on Electronic Standards, FHWA, and other various stakeholders. (3) Data Exchange Schema: Multiple schemas for the governance framework of BIM for Bridges and Structures were discussed, with the decision being made to develop a Model View Definition (MVD) compliant with Industry Foundation Classes (IFC) data models. IFC is the industry standard in the vertical industry and is well established. buildingSmart International, the global organization with IFC oversight, also has global initiatives working toward implementing BIM for roads and bridges in other countries, making a natural alignment with IFC the most appropriate approach. (4) Funding Mechanism for Support: It became evident through the discussions that the initiative to move BIM for Bridges and Structures into standard practice would require much more effort than could be taken on solely by T-19 members. The committee agreed that the use of a consultant/contractor would be necessary to accomplish many of the tasks needed to move forward. The committee discussed several funding options, ultimately deciding on two sources: FHWA and pooled fund study.

56. Building Information Modeling (BIM) for Bridges and Structures, Lead Agency Iowa DOT, Study Number TPF-5(372), Pooled Fund Study
Mississippi DOT contributing to the Pooled Fund Study

Study Description

Background:
Building information modeling (BIM) has been widely used in the commercial sector and vertical construction to manage projects from conception through design, fabrication, construction and for future maintenance. Although some fabricators who perform work on both vertical construction and transportation structures have begun employing BIM tools in the fabrication of bridge components its use in transportation infrastructure is severely limited due to the lack of standardization. It became obvious that in order to take advantage of the efficiencies associated with the use of BIM in transportation structures, a comprehensive strategic plan by AASHTO SCOBS is needed. As a first step, the technical committee on technology and software (T-19) initiated a study that was funded by NCHRP. The NCHRP project 20-07 Task 377 titled "Standardized Format for Bridge and Structure Information Models" presented a framework for BIM implementation roadmap and provided T-19 a list of actionable items.

Following the conclusion of the NCHRP study and after extensive discussions, T-19 identified a path forward for BIM implementation in bridges and structures. The initiative involved the following key decisions:

• Identity: The initiative is being named BIM for Bridges and Structures, as it encompasses the goal of this endeavor without potentially violating trademark rights.

• Governance and Stewardship Framework: The roadmap involves the identification of a governance structure. The selected model will be overseen by T-19 with collaboration with AASHTO Technical Joint Committee on Electronic Standards, FHWA, and various stakeholders.

• Data Exchange Schema: Multiple schemas for the governance structure of BIM for Bridges and Structures were discussed, with the decision being made to develop an MVD (Model View Definition) compliant with IFC (Industry Foundation Classes) data models. Some consideration was given to OpenBridge model, with the biggest benefit being more control of the governance model. However, IFC is the industry standard in the vertical industry and is well established. BuildingSmart International, the global organization with IFC oversight, also has global initiatives working toward implementing BIM for bridges in other countries, making a natural alignment with IFC the most appropriate approach.

• Funding Mechanism for Support: It became evident through the discussions that the initiative to move BIM for Bridges and Structures into standard practice would require much more effort than could be taken on solely by T-19 members. The committee agreed that the use of a consultant/contractor would be necessary to accomplish many of the tasks needed to move forward. The committee discussed several funding options, ultimately deciding on two sources: FHWA and pooled fund study.

Objectives:
The pooled fund project will provide the primary funding mechanism for AASHTO SCOBS T-19 to perform the duties of governance and stewardship of BIM for Bridges and Structures.

Scope of Work:

Although not all tasks have been identified, the work will include:

1. Establish standards, guidelines, or manuals for bridge project stakeholders to facilitate the wide use of IFC as an exchange standard in BIM for Bridges and Structures in bridge projects. This would include recommending or mandating the use of common modeling format and IFC submittal.

2. Develop the national standard MVD, data definitions, and data requirements for the model life cycle for all data exchanges for transportation bridges and structures. This national standard will use the above governance and stewardship model to facilitate the development and future maintenance.

3. Collaborate with stakeholders to provide timely update of IFC data dictionary for common bridge elements.

4. Collaborate with buildingSMART and software vendors to design and offer suitable training covering BIM for Bridges and Structures model development, management, and usage.

5. Conduct return on investment (ROI) analysis to quantify the benefits of using a common modeling format, BIM for Bridges and Structures, in terms of time and cost savings.

6. Develop a template of BIM for Bridges and Structures-specific contractural provisions for managing, reducing, or eliminating the risks associated with IFC-BIM for Bridges and Structures. Project stakeholders/owners could use the template to conduct a risk evaluation for deploying BIM for Bridges and Structures at a project and organization level.

7. Provide recommendations to T-19 on changing existing work flows to leverage model exchanges for project delivery and asset management for transportation bridges and structures owners.

8. Provide a work plan, progression schedule, and coordination web and face to face meetings with T-19 on the development and implementation of BIM for Bridges and Structures.

9. Establish a forum/expert hub for practitioners in the bridge industry to promote the common modeling formats and share experiences.

10. Provide technical support, organize training workshops, and facilitate pilot/demonstration projects for bridge owners to encourage and accelerate the adoption of BIM for Bridges and Structures.

57. Business Process Modeling for the Virginia Department of Transportation: A Demonstration with the Integrated Six-Year Improvement Program and the Statewide Transportation Improvement Program: Executive Summary, May 2005.
Virginia Department of Transportation, Virginia Transportation Research Council
J.H. Lambert and R.K. Jennings
Provides insight to benefits of integrating planning and programming activities throughout a project or bridges life-cycle.

ABSTRACT

This effort demonstrates business process modeling to describe the integration of particular planning and programming activities of a state highway agency. The motivations to document planning and programming activities are that (1) resources for construction projects are used effectively; (2) employees know where projects are in their construction life cycles and how projects may have been changed; (3) the time of agency employees is used effectively; and (4) the employees are working together to complete transportation projects in a reasonable time.

The effort adopts the IDEF modeling capability of the BPWin software (also known as the AllFusion Process Modeler). IDEF modeling encourages consistent documentation of who generates what information, products, services; for whom; how; and for what reasons. Across the agency, the modeling is useful in prioritizing processes for change and maintenance. The modeling empowers employees at all levels, makes institutional knowledge relevant and accessible, and removes bottlenecks. It also encourages the development of integrated systems along functional lines, including administration, engineering, and operations, and focuses agency personnel on the *good* rather than the *perfect* system. Highway agencies have multiple business processes that can benefit from an integrated description of business and technology in process models. For example, the information technology division of a large highway agency maintains and develops around sixty software applications at any one time. Business process modeling helps the division improve their allocation of resources and priorities to these applications. This document provides the purpose and scope of the effort, the method behind IDEF modeling and the AllFusion software, the results and discussion of the effort, the deliverables, and the recommendations for future work. Twelve appendices available in the full version of this report (Lambert et and Jenningsal., 2005) provide the technical results.

INTRODUCTION

In automating many of their business processes, the information technology (IT) divisions of transportation agencies need to set priorities and allocate resources for the development and maintenance of their IT applications. Developing business process models can support the agencies in deciding which systems have the greatest impacts relative to their required investments of resources.

This research has been performed by the Center for Risk Management of Engineering Systems at the University of Virginia to support the Virginia Department of Transportation (VDOT), the Virginia Department of Rail and Public Transportation (VDRPT), the Federal Highway Administration (FHWA), and the Federal Transit Administration (FTA). Its purpose is to improve the business processes of the Virginia Transportation Six-Year Improvement Program (SYIP) for Construction and Development and the Statewide Transportation Improvement Program (STIP). Progress documentation was provided through an Internet web site at the University of Virginia (http://www.virginia.edu/crmes/stip). The effort is a logical sequel to the document, *Development and Financial Constraint of Virginia's STIP* (FHWA et al. 2002), which describes the federal interest in transforming the state's SYIP into the federal STIP.

This report is organized as follows. The *Purpose and Scope* section is an overview of the SYIP/STIP process and presents some recent challenges implementing the two documents. The *Methods* section describes the functionality of IDEF (Integrated Definition for Function) modeling, the development of an IDEF Worksheet, and the AllFusion/BPWin software that supports IDEF modeling. The *Results and Discussion* section provides an overview of the technical results that are presented in full detail in the appendices. The *Conclusions* section discusses the findings of the effort. The *Recommendations* section addresses implementation of the findings by three divisions of the highway agency: planning, programming, and information technology. Twelve *Appendices* provide the technical results of the effort.

PURPOSE AND SCOPE

The purpose of this effort is to demonstrate Integrated Definition for Function (IDEF) modeling for understanding and reengineering the STIP/SYIP processes of a highway agency. The scope of this demonstration is described in this section. *The details of the STIP/SYIP processes presented in this report were accurate at the time of collection. Such details are realistic and sufficient to support demonstrating IDEF business-process modeling on a complex process of the highway agency. This report has not aimed to update and reconcile all details of the STIP/SYIP to a common point in time.*

In past years, the State Transportation Improvement Program (STIP), a three-year programming document required by federal regulations, was prepared by VDOT and VDRPT as an abridgment of the Six-Year Improvement Program (SYIP), which is required by Virginia law. The Virginia Department of Transportation (VDOT) and the Virginia Department of Rail and Public Transportation (VDRPT) would in turn receive a joint letter from the Federal Highway

Administration (FHWA) and the Federal Transit Administration (FTA) giving federal approval of the Virginia STIP. Virginia's approach to the STIP of past years has been inadequate to satisfy federal regulations, which require that VDOT/VDRPT declare to FHWA and the FTA the federal dollars to be allocated in each federal fiscal year by project. To be eligible for a federal funding allocation, an applicable project needed to appear in each of the following: (1) a long-range plan, (2) regional transportation improvement program (TIP), and (3) the Virginia STIP. In recent years, significant projects appearing in the SYIP, and consequently in the STIP, could not be undertaken because the financial constraint used in SYIP/STIP development was not meaningful. In programming, objective and technical evidence were increasingly dominated by short-term fiscal and other expediencies.

The FHWA, FTA, VDOT, and VDRPT reviewed the development process of the Virginia STIP, with particular attention to the financial constraint specified by federal regulation (23 CFR 450) (FHWA 2002). First, the review documented the processes utilized to develop the Virginia SYIP and the Virginia STIP. Second, it provided a series of recommendations with accompanying implementation strategies in the categories of timing, technology, format, financial, education, and process. The recommendations of the review are presented in Table 1.

While the 2002 report of FHWA et al. is definitive in characterizing the past and future of the SYIP and STIP development processes, the following is some useful additional background on the research performed on this project.

The SYIP articulates an overall funding strategy for the Commonwealth; it does not allocate federal funding. The SYIP reflects six-year funding and financing strategies that are internal to the Commonwealth and which are typically not needed in the federal oversight of the annual allocations of federal funds. In contrast, the STIP articulates the intentions of VDOT and VDRPT to allocate federal funds to highways and transit by federal fiscal year. The STIP document compiles project listings of the eleven Metropolitan Planning Organization (MPO) transportation improvement programs (TIPs), the SYIP, the federally funded Secondary System programs, federally funded forest programs, and other participating programs. Federal regulations require STIPs to be submitted every two years, but the Virginia STIP has been submitted annually.

Currently, the TIPs are not generated in a common format, although some MPOs use the relevant sections of the SYIP as their TIP. A particular challenge to harmonizing the MPO TIPs is that the Northern Virginia MPO (the Metropolitan Washington Council of Governments) also encompasses parts of Maryland and the District of Columbia.

Beginning with fiscal year (FY) 2003, the Virginia SYIP and STIP were distinct documents. A SYIP developed in an electronic environment will contain the data needed for generating the STIP. The Virginia STIP would no longer include the future allocation of federal funds. For example, past STIP submissions showed the accrual of funds in each fiscal year, such as when $10 million was reserved in each of three years and relegated to an allocation of $30M in the 3rd year of the STIP. The STIP, a three-year program, is amended multiple times between its biennial submissions and approvals. Amendments to the STIP are straightforward when air quality is not affected. Typically, amendments are neutral in this respect: e.g., projects of alignments and turning lanes. For FY 03, 2002 federal allocations were not ready for distribution until April 2003. Projects that had been removed in December 2002 due to financial constraints were hurriedly resubmitted in 2003 to address the revised allocations.

Efforts to revise the business processes of VDOT and VDRPT have been addressing issues such as:

- What is the best format for the compilation of the STIP, and its submission to the FHWA and FTA, from the former SYIP, the Secondary System programs, and the eleven MPO TIPs?
- How can the STIP submission, which had been a stack of separate documents in a variety of formats, be integrated and made available to the public?
- What can be learned from other states?
- How can the various planning and programming efforts be harmonized?
- How can the need for SYIP/STIP revision be balanced with the need for a stable platform in the near term?
- How will innovative financing techniques be accommodated by the SYIP and STIP processes?
- How can the process of amending the STIP be streamlined?

A committee of VDOT, VDRPT, FHWA, and FTA has been implementing the 21 recommendations of the FHWA 2002 report. There are three subcommittees: (1) Procedures, (2) Finance, and (3) Public Involvement/Education. An oversight group includes the Chief of Planning and the Environment, VDOT, and VDOT's Chief Financial Officer. In December 2002, VDOT and VDRPT submitted the first actual STIP to the FHWA and FTA for approval. In 2003, a member of the committee undertook to compile the STIP electronically and completed an initial version of an electronic SYIP. With respect to STIP development, a memorandum of agreement between Virginia and federal agencies was signed in late 2003. Pre-allocation hearings in the fall of 2003 served as test beds of the evolving SYIP/STIP public involvement process.

IDEF modeling will be useful to describe the SYIP/STIP because of its integrated perspective of business and technology. It allows employees to have increased control over their roles in the STIP/SYIP and to locate potential bottlenecks in them. IDEF modeling will help the Department of Transportation allocate adequate resources to STIP and SYIP activities.

58. Conversion Between Network-Level and Project-Level Units of Measure for use in a Bridge Management System (VTRC 99-R4), July 1998.
Virginia Department of Transportation, Virginia Transportation Research Council
Howard M. Turner, Jr.
Provides an overview to various data elements utilized in a bridge management system to prioritize bridge maintenance, repair, rehabilitation, and replacement. Includes historical cost data.

ABSTRACT

VDOT is implementing Pontis 3.0 to provide the analytical component of its Bridge Management System (BMS). This system prioritizes bridge maintenance, repair, rehabilitation, and replacement (MRR&R) needs using cost/benefit analysis. The accuracy of this analysis depends on the condition assessment of the structure and the cost data of MRR&R options used in the analysis.

For the network-level analysis a BMS provides, the focus is on what work was done to an element rather than how it was done. To standardize the MRR&R actions taken at the network level, commonly recognized (CoRe) elements have been identified and are used in Pontis. For each element, a set of feasible MRR&R actions has been defined.

How these actions are accomplished is tracked on the project level. Contracted bridge work is managed using industry-standard pay items and quantities. There is a great deal of historical project-level data from previous contracts. However, there has not been any large scale network-level data collection effort.

The purpose of this project was to examine cost management practices in VDOT and to develop an architecture for an automated project-level to network-level cost conversion process. This process should provide accurate updated cost data to Pontis by (1) using pay codes, quantities, and other contract information; (2) combining this information with existing inventory information and new inspection information about the structure; (3) reporting what CoRe feasible action was taken and the associated unit cost; and (4) providing this information in a Pontis-usable format.

The investigation of cost management revealed a number of areas where VDOT could improve its practices. The research addresses potential remedies for some and, in some cases presents potentially viable conversion schemes.

59. Development of Geotechnical Analysis and Design Modules for the Virginia Department of Transportation's Geotechnical Database (VTRC 05-CR23), June 2005.
    Virginia Department of Transportation, Virginia Transportation Research Council
    Jaewan Yoon, Ph.D.
    Provides an overview to the functionality and use of various geotechnical data for use by VDOT's Geotechnical Engineer Engineers including search algorithm.

16. Abstract

In 2003, an Internet-based Geotechnical Database Management System (GDBMS) was developed for the Virginia Department of Transportation (VDOT) using distributed Geographic Information System (GIS) methodology for data management, archival, retrieval, and analysis. The system has been used for accessing geotechnical data pertaining to the Hampton Road Third Crossing project and the Woodrow Wilson Bridge Route 1 Interchange.

As the rate of use, VDOT engineers recognized the need for additional engineering analysis and design functionalities. In response, five geotechnical engineering applications used to calculate slope stability and foundation pile capacity were identified. Analysis and Design Modules (ADM) for these five applications were designed, developed, and implemented in the existing GDBMS.

ADM were designed to extract, filter, translate, and generate input data sets automatically when a borehole site is selected using a graphical user interface. Thus, ADM facilitates engineering analysis and design by automatically generating input data sets, enhancing productivity.

In addition to the ADM, a powerful new borehole data search algorithm, *GDBMS Borehole Search Rabbit*, was developed to augment the existing search functionality. This new search algorithm provides both hierarchical and partial search capabilities based on GDBMS site module, VDOT project number, source level gINT project file, and boring site ID. Once a borehole data search is completed, VDOT engineers can directly access particular site data in various formats such as the original legacy data format, translated standard data format, gINT and Excel files of translated standard data format, and borehole data log and laboratory results.

A cost-benefit analysis determined that approximately 1,120 hours of engineering time can be saved by using ADM with a total annual cost savings of $112,000.

VDOT's GDBMS can be accessed on the Internet at http://172.16.20.2 and at http://gis.virginiadot.org/GDBMS_menu.htm.

60. Development of Performance and Deterioration Curves As A Rational Basis for a Maintenance Management System for Structures (VTRC 94-R1), July 1993.
Virginia Department of Transportation, Virginia Transportation Research Council
K. K. McGhee, G.R. Allen, Ph.D., and W. T. McKeel, Jr.
Highlights essential elements of a bridge management system.

16. Abstract

The Virginia Department of Transportation is deeply committed to the development and implementation of an efficient, cost-effective maintenance management system for its bridges. Much effort is being applied towards the development of a management system that will ensure that appropriate maintenance takes place at the optimum times. Within such systems, the ability to anticipate with reasonable accuracy how rapidly and in what fashion bridges will deteriorate is essential in optimizing expenditures of limited maintenance funds. The research described in this report was undertaken to provide this predictive capability. Specifically, the objective was to use existing bridge inspection data in conjunction with multiple regression analyses to develop models relating the rate of deterioration of structural components with variables such as age, loadings, and environmental factors and to evaluate the relative importance of these variables. In addition, these efforts include a discussion of current bridge management activities and recommendations on needed modifications to the VDOT record-keeping system.

System Studies

Over the duration of this study, including the lapse between completion of research and the reporting of results, a number of bridge management system projects have been launched. FHWA's DP No. 71 has prompted several research efforts both with overall system development and with optimum fund allocation programs incorporating specific numerical techniques. The National Cooperative Highway Research Program administered a project that identified and developed the necessary elements of a comprehensive BMS, including the earliest attempts at providing a universally applicable software package. Most recently, under the funding of FHWA, Cambridge Systematics has produced a powerful and flexible adaptation of a national bridge management system software package (PONTIS).

The FHWA demonstration project was based on and done in conjunction with the work done at N.C. State under the direction of Dr. David W. Johnston. Its primary purpose was to encourage state and other local agencies to adopt a systematic procedure for allocating bridge MR&R funds. The priority ranking formulas for several states and the level-of-service methods adopted by North Carolina DOT are presented and discussed. The latest efforts have studied the feasibility of automated fund distribution systems using an incremental benefit-cost-analysis algorithm.

NCHRP Project 12-28, "Bridge Management Systems," was conducted by ARE, Inc. engineering consultants of Austin, Texas.[7] The first phase of research identified six essential elements of a bridge management system:

1. database
2. network-level major maintenance, rehabilitation, and replacement selection
3. maintenance
4. historical data analysis
5. project level interface
6. reporting.

61. Performance of Bridge Deck Overlays in Virginia: Phase II: Service Life Performance (VTRC 20-R6), September 2019.
Virginia Department of Transportation, Virginia Transportation Research Council
Soundar S.G. balakumaran, Ph.D., P.E. and Richard E. Weyers, Ph.D., P.E.
Provides overview to historical data related to deck overlays and how VDOT is using the historical data to make decisions related to bridge preservation and service life.

ABSTRACT

Overlaying bridge decks has remained one of the best rehabilitation methods to extend their service life, and the Virginia Department of Transportation (VDOT) has been a leader in the use of bridge deck overlays. Although VDOT has extensive experience in overlays, the long-term performance of overlays has not been entirely understood. One of the biggest challenges for studying the performance of overlays is that only minimal information is available in bridge inventory and inspection records. This limits any scientific assessment of this system. Therefore, the purpose of this study was to provide a strong framework for the understanding of the long-term performance of overlays and the factors affecting them.

This Phase II report reports on an extensive data collection process that led to the development of a robust database of 133 overlaid bridge decks after verification of historical inspection reports, verification of as-built plans and communication with VDOT district bridge engineers. This helped in developing a model for understanding the amount of time it takes for bridge decks to require the first major rehabilitation and the major factors influencing the durability. A database of information about overlays that were replaced at the end of their functional service life was compiled. This helped develop a multiple regression model for understanding the factors that affected the durability of overlays.

Survival analyses were conducted to estimate the service life of overlays and corresponding risk. As a preventive method, epoxy concrete (EC) overlays were predicted to serve an average of 20.9 years, with 18 to 22 years at a 95 percent confidence level. As a rehabilitative method, rigid concrete overlays were predicted to serve an average of 25.9 years, with 21 to 32 years at a 95 percent confidence level.

The recent trend of preferred overlay types has been identified as EC and very-early-strength latex-modified concrete (VELMC) overlays. EC overlays have proven to be one of the better performing overlays through extensive VDOT experience. VELMC overlays are an improvement upon latex-modified concrete overlays by vastly reducing the time of construction and thus become more suitable for decreased construction time, reduced traffic disruption, and lessened worker exposure to the field environment.

An important discovery was the identification of the influence of the degree of deck damage prior to overlaying on the service life of overlays. Preventive EC overlays should be used in a preventive sense, as the name suggests. If preventive EC overlays are installed on bridge decks with spalls, patches, or delaminations, irrespective of the amount of damage, an increased rate of deterioration in the overlays is likely to follow.

The future performance of rehabilitative overlays such as latex-modified concrete, silica fume, and VELMC overlays will not be influenced by the presence of bridge deck damage prior to overlaying. This might be because of the removal of deteriorated concrete before these rigid overlays are constructed. This emphasizes the importance of proper removal of poor quality concrete from bridge decks before overlaying during rehabilitation.

62. Technical Assistance Report Maintenance, Repair, and Rehabilitation Unit Costs for PONTIS (VTRC 95-TAR10), April 1995.
Virginia Department of Transportation, Virginia Transportation Research Council
Dixie T. Wells
Highlights network-level historical cost data for bridge maintenance, repair, and rehabilitation.

ABSTRACT

In the summer of 1993, the Bridge Management Task Force chairman requested that the Virginia Transportation Research Council begin a study of the maintenance, repair, and rehabilitation unit costs needed for the operation of the Pontis system. Because Pontis provides network-level analysis, implementing it requires a fundamental change in the business procedures of the Virginia Department of Transportation. The establishment of network-level cost data is one step in the implementation of Pontis. The shift from a bridge-specific focus makes existing data unsuitable, and alternatives need to be explored.

Since other states face similar problems, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the National Cooperative Highway Research Program have initiated studies of these maintenance, repair, and rehabilitation costs. Rather than initiate a study of its own, the Virginia Transportation Research Council chose to follow these studies closely, and to make suggestions for implementing the findings from these studies within the Virginia Department of Transportation. This report provides the Task Force with a set of recommendations for implementing AASHTOWare™ Pontis™ Release 3.0.

63. Risk-Based Asset Management Methodology for Highway Infrastructure Systems (VTRC 04-CR11), February 2004.
Virginia Department of Transportation, Virginia Transportation Research Council
Ruth Y. Dicdican, Yacov Y. Haimes, and James H. Lambert
Highlights benefits of intelligent decision making so that maintenance projects are prioritized to yield most benefit for life-cycle of highway assets.

ABSTRACT

Maintaining the infrastructure of roads, highways, and bridges is paramount to ensuring that these assets will remain safe and reliable in the future. If maintenance costs remain the same or continue to escalate, and additional funding is not made available, the highway agency may need to reduce new construction or cut back on maintenance, or both. There is a close relationship between the cost of optimally scheduled preventive maintenance versus the cost of emergency maintenance or replacement. The study develops a systemic risk-based asset management methodology to manage the maintenance of highway infrastructure systems. The decisionmaking methodology is used to harmonize and coordinate the actions of the different units and levels in a hierarchical organization. The systemic methodology enables the filtering and assessment of assets for maintenance while addressing the potential for extreme events. The methodology balances the costs, benefits, and risks of maintenance and inspection policies as applied to various types of assets. Three objective functions are used in evaluating options and strategies: minimizing short-term cost, minimizing long-term cost, and maximizing the remaining service life of highway assets. A constraint function harmonizes the remaining service life across assets to eliminate infeasible options. The methodology is generally applicable to the asset management of large-scale dynamic systems that exhibit characteristics similar to those of highway systems.

INTRODUCTION

Over the past fifty years, the United States has been engaged in constructing the National Highway System (NHS). The NHS is a 256,000 km system that includes the interstate highway system, strategic military highways, and major arterial roads. While the NHS accounts for only 4% of the roadways in the United States, it carries 40% of all highway traffic and approximately 75% of all heavy truck traffic. As the system ages, roads and bridges are deteriorating faster than they can be repaired or replaced. According to The Road Information Program (TRIP) [2003], 32% of the nation's major roads are in poor or mediocre condition, while 27% of the bridges are structurally deficient or functionally obsolete. The American Association of State Highway and Transportation Officials (AASHTO) reported that in FY 2000, $64.5 billion was spent by all levels of government for highway and bridge capital improvements [AASHTO 2002]. In order to maintain the physical condition and performance characteristics of the highway system over twenty years, this level of investment needs to increase to $92.0 billion annually [AASHTO 2002]. In the same report, AASHTO also stated that an annual investment of $125.6 billion is needed to improve the overall conditions of the nation's roads and bridges. With the assistance of the US federal government, the fifty states have begun to shift their focus from construction to repair and maintenance of the existing infrastructure. The emphasis is on intelligent decisionmaking so that maintenance projects are prioritized to yield the most benefit for the lifecycle cost of each highway asset.

64. FHWA Long-Term Bridge Preservation (LTBP) Program, LTBP News, Volume 1, Issue 1 Summer 2010.
Stakeholder Input: Sandra Larson, Iowa DOT
Touches on better understanding how bridges age, and then how to manage bridge assets to extend service life of existing and new bridges. Bridge investigation through load testing, non-destructive evaluation, and sensor monitoring to better understand bridge behavior, condition, and capacity. Leverage time and expertise through sharing of information to increase knowledge base and understanding of bridge performance and behavior will result in more informed bridge repair and rehabilitation programs.

Stakeholder Input: Sandra Larson, Iowa DOT

Sandra Larson, director of the Bureau of Research and Technology for the Iowa Department of Transportation, became interested in what the LTBP program could do for her state when, in 2007, she participated in a workshop organized by FHWA to establish a framework for the LTBP program. Since then, Larson has taken an active role in the LTBP program by providing input and offering valuable information on data needs and performance issues.

"We anticipate remaining involved with the LTBP program and will be sharing information with LTBP as we further our research," says Larson. "The Iowa DOT's goals and the LTBP program goals coincide, namely to better understand how individual bridges function and age, and then to manage our bridge assets with this additional understanding in order to extend the life of existing and new bridges through timely and appropriate maintenance and rehabilitation. Iowa has a growing program of bridge investigation through load testing, nondestructive evaluation, and sensor monitoring which provides indepth information about our existing bridges to better understand bridge behavior, condition, and capacity.

"Sharing information about our program and following the LTBP program closely will help to leverage our time and expertise as we all continue to mine these technologies for more answers and insight into bridge condition and behavior," she says.

Larson is particularly interested in how the LTBP program will help Iowa to better assess the current condition of bridge decks so that bridge managers can make the optimal decisions regarding the timing and extent of maintenance and repair. This is a matter of concern for most of the bridge community and something the program will address.

Ultimately, the increased knowledge and understanding of bridge performance and behavior will result in more informed bridge repair and rehabilitation programs. Sharing information nationally between the LTBP program and states' bridge management programs will benefit everyone. ■

65. FHWA Long-Term Bridge Preservation (LTBP) Program, Summary Report, December 2016.
FHWA LTBP Summary-Findings from the New Jersey Bridge Deck.
FHWA Publication No.: FHWA-HRT-16-070
Presents chloride content and diffusion data from concrete cores in decks together with using non-destructing testing Ground Penetrating Radar to collection inspection/condition information.

66. Washington State Department of Transportation
MAP-21 & Bridges Washington State
WSDOT establishes MAP-21 bridge performance targets, May 2018-Edition 3

The condition of individual bridge elements (deck, superstructure, substructure), and culverts (which are measured separately), are rated using a classification method from the National Bridge Inventory (NBI) and the Highway Bridge Program. This classification method assigns the elements and culverts condition ratings ranging from 1 to 9 where 7 or greater = good; 5-6 = fair; and 4 or less = poor.

For MAP-21 and continued in the FAST Act, bridges in good condition have all three elements (deck, superstructure, substructure) rated as 7 or higher); bridges in fair condition meet the minimum threshold of 5 or higher; and poor bridges have any of the elements rated as 4 or lower (see p. 2).

The percentage of the total NHS bridge deck area for each classification (good, fair, poor) is calculated as the ratio of the total deck area of NHS bridges in a classification to the total deck area of NHS bridges in the state. The bridge deck condition of a shoulder on a bridge is included in the overall condition rating; it is not tracked or rated for active transportation use separate from the overall bridge deck condition. Sidewalk elements are defined and condition rated but these data are not reported here.

A separate requirement determined by FHWA is that the percent of NHS bridges in poor condition cannot exceed 10%. This performance criterion is a special requirement mandated by Congress, and is the only bridge performance measure that results in a funding penalty if it is not met. The penalty requires the State to obligate a specified percentage of its National Highway Performance Program (NHPP) funds to correct the NHS bridge conditions until the minimum threshold is met (see p. 4 for more details).

The Federal Highway Administration (FHWA) published in the Federal Register (82 FR 5886) a final rule establishing performance measures for State Departments of Transportation (DOTs) to use in managing pavement and bridge performance on the National Highway System (NHS). The National Performance Management Measures; Assessing Pavement Condition for the National Highway Performance Program and Bridge Condition for the National Highway Performance Program Final Rule addresses requirements established by the Moving Ahead for Progress in the 21st Century Act (MAP-21) and reflects passage of the Fixing America's Surface Transportation (FAST) Act. The rule was effective May 20, 2017.

Targets established May 20, 2018

WSDOT has been proactive in working with MPOs and local agencies with regard to the implementation of federal pavement performance measures for the NHS. Collaborative efforts to establish targets by May 20, 2018, included meetings with all MPO directors and WSDOT representatives; responsible for helping make policy, process, data and advisory target setting decisions as well as in-depth discussions between subject matter experts; responsible for better understanding final federal rule requirements and their implications.

FHWA has set the upper limit for the percentage of all NHS bridges classified in poor condition at 10%. Based on analysis and past trends, 10% is the recommended target. The FHWA did not set a limit for the percentage of NHS bridges classified as being in good condition; it is recommended to adopt a target of 30% based on a thorough review of current bridge conditions (see chart below).

Minimum condition level requirements

As a minimum condition level, MAP-21 establishes a threshold of no more than 10 percent of NHS bridges measured by deck area being classified as structurally deficient. A structurally deficient bridge is deteriorated structurally, as indicated by a superstructure, deck, and/or substructure rating of four or less, or when the appraisal ratings for structural evaluation or waterway adequacy are two or less, on a scale of zero to nine. Except for structural evaluation or waterway adequacy, WSDOT's poor condition category uses the same data, criteria, and rating scale as that required for MAP-21 (see *Gray Notebook* 50, p. 14). The minimum condition level is applicable to bridges on the NHS, to bridges on ramps connecting to the NHS within a state, and to bridges on the NHS that cross a state border.

The FHWA will carry out the first determination of compliance with the minimum condition requirements in 2018 (based on bridge condition data for 2013, 2014 and 2015), and annually thereafter. Following this schedule, any penalties resulting from the minimum condition compliance determination would not be in effect until after October 1, 2021.

The MAP-21 legislation requires the FHWA's National Bridge Inventory (NBI) be the source of data for classifying a bridge as structurally deficient. Currently, the NBI is the primary source for national bridge information and has been used for many years to classify bridges as structurally deficient, determine eligibility for the Highway Bridge Program, and apportioned federal-aid funds.

Bridge data collection for MAP-21

WSDOT is required to report data to FHWA annually on the condition, functional adequacy and essentiality for the public for all bridges statewide. The bridge data determines sufficiency ratings and if a bridge is structurally deficient and/or functionally obsolete. The same bridges that are rated for WSDOT's condition rating are also rated in the federal system, in addition to local agency owned bridges across the state.

The good, fair, and poor classification of bridges on the NHS utilizes data elements from the NBI database. State DOTs measure and classify a number of standard features for bridges (such as condition and geometric information) in their jurisdiction, which they are required to report to FHWA on an annual basis. These requirements include bridges' on-ramps connecting to the NHS.

Penalties

In order to avoid a penalty, states must meet this minimum condition level: National Highway System (NHS) bridges not to exceed 10 percent structurally deficient, by deck area.

If a state does not meet the minimum condition for three consecutive years, a funding penalty will apply during the following fiscal year and each year thereafter until it is in compliance. The state must obligate and set aside an amount to 50 percent of the apportionment for the Highway Bridge Program in fiscal year 2009, from the NHPP apportionment, only for projects on NHS bridges.

Available Data

- Bridge condition assessment of the National Highway System's National Bridge Inventory item ratings of bridge deck, superstructure, substructure, and/or culverts for all federally reportable state and local bridges][1]

Notes: Data is available for county and city levels and can be provided by the MPO boundaries. 1 Bridge condition data for tribally-owned and federally-owned bridges is provided to WSDOT by the bridge owner.

What is the current distribution of funds?

WSDOT is planning to provide approximately $130 million annually over the next 10 years for bridge preservation, which improves the condition of bridges through replacement, rehabilitation and preventive maintenance. This comes from federal and state revenue sources, and the specific amount each year for bridge preservation is determined based on an assessment of need and available funding through asset management analyses.

Purpose of reporting requirements

In July 2012, the Moving Ahead for Progress in the 21st Century Act (MAP-21) became law. Included in the law was a Declaration of Policy: "Performance management will transform the Federal-aid highway program and provide a means to the most efficient investment of Federal transportation funds . . . ."

The primary objectives of MAP-21 are to increase the transparency and accountability of states for their investment of federal taxpayer dollars into transportation infrastructure and services nationwide, and to ensure that states invest money in transportation projects that collectively make progress toward the achievement of national goals. The new rules will require reporting performance on the following areas: Safety; Pavement and Bridge; System Performance/Congestion; Freight, and Congestion Mitigation and Air Quality (CMAQ).

Prior to MAP-21, there were no explicit requirements to demonstrate how transportation programs supported national performance outcomes. But many state DOTs, like WSDOT, have engaged in voluntary accountability and reporting efforts.

For more information

State bridge condition information: DeWayne Wilson, WSDOT Bridge Management Engineer, at (360) 705-7214 or WilsonD@wsdot.wa.gov.
Local bridge condition information: Roman Peralta, WSDOT Local Programs Bridge Engineer, at (360) 705-7870 or PeraltR@wsdot.wa.gov.

67. Wisconsin Department of Transportation, Bureau of Structures, Bridge Preservation Policy Guide Version 1.02, 2016
Provides an overview to WISDOTs bridge preservation policy and various preservation activities & strategies associated with specific bridge element condition/deterioration state.
Having a commitment for funding of bridge preservation will help WisDOT optimize the overall bridge program.

1.0 - Overview

WisDOT Bridge Preservation Policy Guide provides goals, measures, and strategies for the preservation of bridges. This document contains criteria that is used to identify condition based and non-condition based cyclical preservation, maintenance, and improvement work actions for bridges. These actions maximize project and system-wide life cycle cost and performance of bridges.

Bridges are key components of our highway infrastructure. As of April 2015, Wisconsin had 14,085 bridges, of which 37 % were owned by WisDOT. The average age of these bridges is 36 years. The aging infrastructure is expected to deteriorate faster in the coming decades with increased operational demand unless concerted efforts are taken to preserve and extend their life. In addition, the state bridge infrastructure is also likely to see an increased funding competition among various highway assets. As a result, WisDOT must emphasize a concerted effort to preserve and extend the life of bridge infrastructure while minimizing long-term maintenance costs.

WisDOT Bureau of Structures (BOS) initiated the Next Generation Bridge Management System (NGBMS) project to address several requirements of the 2012 Federal Transportation Bill identified as Moving Ahead for Progress in the 21st Century Act (MAP-21). The bill focuses on implementing a risk-based transportation asset management program with an emphasis on pavements and bridges. This policy guide was developed as part of the NGBMS to support implementation of the bridge preservation related aspects of MAP-21.

This policy guide will also provide WisDOT personnel with a framework for developing preservation programs and projects using a systematic process that reflects the environment and conditions of bridges and reflects the priorities, and strategies of the department.

A well-defined Bridge Preservation program will also help WisDOT use federal funding for Preventative Maintenance (PM) activities by using a systematic process of identifying bridge preservation needs and its qualifying parameters as identified in FHWA's Bridge Preservation Guide. This guide will promote timely preservation actions to extend and optimize the life of bridges in the state.

2.0 – Goals and Strategies of Bridge Preservation

The main goal of a bridge preservation program is to maximize the useful life of bridges in a cost effective way. To meet this goal, many of the strategies are aimed at applying the appropriate bridge preservation treatments and activities at the proper time resulting in longer service life at an optimal life cycle cost. Federal Transportation Legislation (MAP-21) promotes the goal of maintaining or preserving infrastructure assets "in a state of good repair". Preservation of assets is one of the tools that will be used to achieve an overall transportation investment strategy. There are a number of related goals that have been developed that address the priorities of the department and our stakeholders.

The Goals of the WisDOT Bridge Preservation Program are:

- Maintain bridges in a "state of good repair" using low-cost effective strategies.
- Implement timely preservation treatments on structurally sound bridges to promote optimal life cycle cost and extend service life. This will reduce the need for major rehabilitation and replacement.
- Limit adverse impacts to traffic operations and various stakeholders.
- Promote and support budgeting of preventive maintenance activities
- Establish performance goals and monitor progress related to preservation of bridges.
- Optimize the benefits and effectiveness of long-term maintenance investment in achieving bridges in good condition.

To achieve the goals of the bridge preservation program, WisDOT will use data driven strategies. This approach is aimed at applying the appropriate bridge preservation treatments and activities at the proper time. These strategies are also aimed at maximizing efficiency and effectiveness of the program.

The Strategies include:

- Regular analysis of the bridge inventory data to establish conditions and trends related to performance.
- Develop and maintain criteria for eligible preservation activities
- Define preservation program and project needs
- Develop estimates of needed financial resources at the Project/Program level.
- Prioritize, plan, and perform preservation treatments.
- Group preservation maintenance projects to promote economy and minimize the inconvenience to the public
- Identify preservation needs that complement maintenance, repair, and rehabilitation actions and timelines.
- Securing approval and support from key stakeholders in the use of Federal and State funding for systematic preventive maintenance and preservation activities.
- Consider preservation at the bridge design stage

3.0 - Bridge Preservation Actions

This Policy Guide focuses on bridge preservation actions that relates to preventive maintenance and element rehabilitation. Cyclical and Condition Based Activities are sub-sets of Preventative Maintenance as shown in Figure 1. Descriptions of these preservation actions can be found in section 7.0 – Definitions.

Major rehabilitation, bridge replacement, improvement, and new bridge construction projects are addressed by other WisDOT Bridge Programs.

Figure 1 WisDOT Bridge Preservation Actions

4.0 - Bridge Preservation Goals, Objectives and Performance Measures

This policy outline clear goals that we strive to attain, objective to help achieve our goals, and ultimately measure that help us understand our progress.

Bridges with a condition rating of poor (NBI Rating < 5) are considered deficient. Deficient bridges that are open for operations are safe; however, these structures may need corrective action to ensure current and future operation. Maintaining safe and dependable operations is a high priority for the department.

Therefore, our department has the goal to maintain 95% of the state owned bridges in fair or better condition (NBI ratings 5 or higher). This goal is specific to state bridges included in the National Bridge Inventory. This goal may be extended to bridges less than 20 feet and buried structures (Box Culverts) at a later time.

4.1 Condition-Based Objectives

Condition based preventive maintenance activities are performed on bridge elements as needed and identified through the bridge inspection process.

To promote the goal of maintaining 95% of the state system bridge inventory in fair or better condition, there are a number of performance objectives for the bridge elements that will promote this goal. These objectives are as follows:

- Maintain 95 % of the following bridge decks in good or fair condition (per NBI condition rating). This target may be measured using NBE condition data when one cycle of deck elements data are available:

4.4 Preservation Program Benefits

Each objective and measure proposed in Table 1 is aimed at extending the life of the main bridge components by performing timely cyclical or condition-based (corrective) preservation actions. The cost of performing preservation actions is minor when compared to premature replacement or rehabilitation of bridge components. The benefits of each objective are discussed below:

- Maintaining 95% of bridge decks in good or fair condition is an asset management approach that should extend the service life of decks by 30-40 years and promote the MAP21 objectives. Experience has shown that decks designed for a 75 years life expectancy last for 40-50 years without preservation actions. Appropriate corrective actions taken as part of deck preservation could possibly extend the life significantly. The costs of such corrective actions are substantially less than the costs of prematurely replacing the decks.

- The objective of maintaining 90 % joints in good or fair condition will focus on a program that will help in minimizing the damage on bridge superstructure and substructure components. Leaking joints cause significant deterioration and damage to bridge components that include girders, bearings, and substructures. There is significant cost each year in repairing structural elements that have deteriorated prematurely as a result of leaking joints. Experience has shown that timely preservation actions can delay superstructure and substructure deterioration by 8-12 years.

- Maintaining protective paint systems is important. The structural components of the steel bridges will corrode and lose load carrying capacity if left unprotected or partially-protected. Protective paint coatings systems should have a service life of 25-40 years for the protection of structural steel. The objective of maintaining 90% of coated steel surfaces in good or fair condition will aim at creating a paint program for extending the life of steel components up to 100 years.

- Bridge bearings are a key component. Bearings support bridge supper structures and allow for expansion of the superstructure. Experience has shown that loss of lubrication, tipping, or corrosion of bearings can cause harm to the deck and superstructure. The proposed measure of keeping 95 % of bearings in good or fair condition will help WisDOT maintain bridges in a state of good repair.

- Objective of sealing 25 % of all eligible concrete decks at 4 year intervals will help delay deck deterioration and prolong deck life. Sealing decks every 4 years at a minor cost can delay deck deterioration by 10-12 years that will promote increase deck life

Table 3 - Concrete Deck/Slab Eligibility Matrix

	NBI Item 58	Deck Element Distress Area (%) ①	Preservation Activity	Benefit to Deck from action	Application Frequency (in years)
Concrete Deck/Slab	≥7		Deck Sweeping/Washing	Extend Service Life	1 to 2
			Crack Sealing	Extend Service Life	3 to 5
			Deck Sealing	Service life extended	3 to 5
			Polymer Modified Asphalt Overlay	Service life extended	12 to 15
			Polymer Overlay	Service life extended	8 to 12
	=6		Deck Sweeping/Washing	Extend Service Life	1 to 2
		<20%	Crack Sealing	Extend Service Life	3 to 5
		<20%	Deck Sealing	Service life extended	3 to 5
		<5% ②	Deck Patching	Service life maintained	As needed
		<5%	Deck Patching, Cathodic Protection	Extend Service Life	As needed
		<10%	HMA w/ membrane	Improve NBI (58) ≥ 7	8 to 12
		<20%	Polymer Modified Asphalt Overlay	Improve NBI (58) ≥ 7	12 to 15
		<20%	Concrete Overlay	Improve NBI (58) ≥ 7	12 to 30
	=5	<20% ②	Deck Patching	Service life maintained	As needed
		<20% ②	Deck Patching, Cathodic Protection	Extend Service Life	As needed
		20 to 25% ③	Concrete Overlay	Improve NBI (58) ≥ 7	12 to 30
		20 to 25% ③	Structural Concrete Overlay ④	Improve NBI (58) ≥ 7	12 to 30
	≤ 4	<40%	Deck Replacement ⑤	Improve NBI (58) = 9	25 to 50

① **Use NBI and deck distress area together to determine the repair action.**

② Refers to deck defects of delaminations and spall and refer to defect 1080.

③ The maximum area of deck delamination is 25 %. When WisDOT fully transitions to elements, this will refer to defect 1080.

④ Consult BOS - not for deck girder bridges.

⑤ Consider remaining bridge conditions to determine if activity is desirable and cost effective.

5.3 Identification of Preservation Needs

The identification of preservation needs will start with the development of bridge eligibility reports. The goal of identification is to develop the preservation needs for two scenarios:

- The unconstrained budget scenario.
- The constrained budget scenario.

The unconstrained budget scenario determines all preservation needs at the region level, assuming no budget limit. This scenario will forecast the total preservation needs in a multiyear basis. The constrained budget scenario will provide specific projects that will be placed in a program as shown in Figure 2.

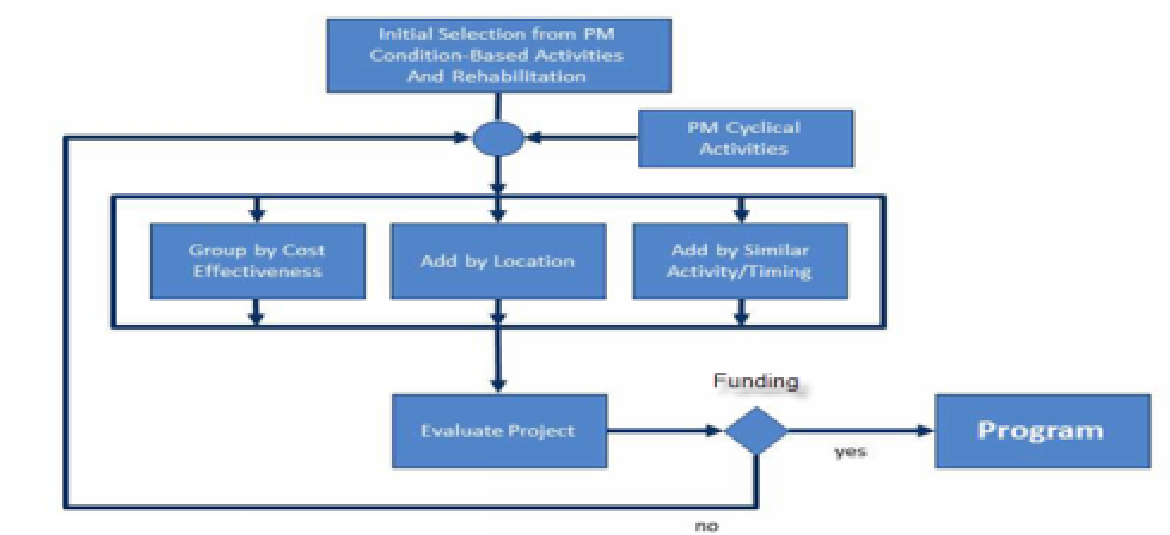

Figure 2. Project Development Diagram

The programming of projects will start with the development of eligibility reports as described in Section 5.2. This set of projects will be combined into a group along with constrained cyclical preventive maintenance activities.

Each Region should bundle projects by cost, location and/or similar activity and timing. This approach would potentially benefit from economy of scale and incorporation into other regional project efforts. The identification of state-wide bridge preservation needs will be done by aggregating the regional bridge preservation needs.

6.0 - Funding Resources and Budgeting

The experiences of several states have shown that having commitments for funding preservation programs extends the life of bridges and defers untimely replacement. Having a commitment for funding of bridge preservation will help WisDOT optimize the overall bridge program.

We promote the idea of recognizing and prioritizing preservation opportunities as part of the planning and programming functions of the department at the Division and Regional level. Through this organizational approach to implementation, preservation will yield the greatest system wide benefits.

7.0 – Definitions

Bridge Program	The WisDOT Bridge Program includes preservation, rehabilitation, improvement or major rehabilitation, replacement and new bridge construction actions.
Bridge Preservation	Bridge Preservation is defined as actions or strategies that prevent, delay, or reduce deterioration of bridges or bridge elements, restore the function of existing bridges, keep bridges in good condition and extend their life. Preservation actions may be preventive or condition driven.

NBI Condition Rating

The FHWA coding guide describes the condition ratings used in evaluating four main components of a bridge as decks, superstructure, substructure, and culverts. The condition ratings are used to measure the deterioration level of bridges in a consistent and uniform manner to allow for comparison of the condition state of bridges on a national level.

The condition ratings are also known as NBI ratings and are measured on a scale of 0 (worst) to 9 (excellent). For WisDOT bridges and culverts, an NBI rating of 4 is classified as poor, an NBI rating of 5 or 6 is classified as fair, and an NBI rating of 7 or higher is classified as 'good'.

Element Condition State

A condition state categorizes the nature and extent of damage or deterioration of a bridge element. Whereas the NBI condition ratings are provided for four major components of bridges described elsewhere, the element level data.

The 2013 *AASHTO Manual for Bridge Element Inspection* describes a comprehensive set of bridge elements mainly categorized as National Bridge Elements (NBE), Bridge Management Elements (BME) and Agency Develop Elements (ADE) and their corresponding four condition states. The element condition states1 to 4 are described as good (CS1), fair (CS2), poor (CS3), and severe (CS4).

Highway Structures Information System	Highway Structures Information System (HSI) is the system developed by WisDOT for managing the inventory and inspection data of all highway structures. The inspection data is collected in accordance with the NBIS and *2013 AASHTO Manual for Bridge Element Inspection.*
State of Good Repair (SGR)	State of Good Repair (SGR) is a condition in which the existing physical assets, both individually and as a system (a) are functioning as designed within their useful service life, and (b) are sustained through regular maintenance and replacement programs. SGR represents just one element of a comprehensive capital investment program that also addresses system capacity and performance. *Source: U.S. DOT Secretary Mary Peters July 25, 2008 letter to Congress*
Systematic Preventive Maintenance Program (SPM)	Systematic Preventive Maintenance (SPM) is a planned strategy of cost-effective treatments to highway bridges that are intended to maintain or preserve the structural integrity and functionality of bridge elements and/or components, and retard future deterioration, thus maintaining or extending the useful life of bridges. An SPM program is based on a planned strategy that is equivalent to having a systematic process that defines the strategy, how it is planned, and how activities are determined to be cost effective. An SPM program may be applied to bridges at the network, highway system, or region-wide basis and have acceptable qualifying program parameters. The details on an SPM program and qualifying parameters are found in FHWA's *Bridge Preservation Guide.*

Preventive Maintenance(PM)	Preventive maintenance is a planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without substantially increasing structural capacity). Preventive maintenance activities include cyclical (non-condition based) and condition-based activities.
Cyclical PM Activities	Cyclical PM Activities are those activities performed on a pre-determined interval and aimed to preserve existing bridge element or component conditions. Bridge element or component conditions are not always directly improved as a result of these activities, but deterioration is expected to be delayed.
Condition Based PM Activities	Condition Based PM Activities are those activities that are performed on bridge elements as needed and identified through the bridge inspection process.
Rehabilitation	Rehabilitation is described as major work required to restore the structural integrity of a bridge as well as work necessary to correct major safety defects as defined in the Code of Federal Regulation (CFR) 23 clause 650.403.
Improvement or Major Rehab	Bridge improvement is a set of activities that fixes the deterioration found in a structure and improves the geometrics and load-carrying capacity to at least the minimum criteria set in these guidelines, but may not provide improvement that meets new construction standards.
Replacement	Replacement of an existing bridge with a new facility constructed in the same general traffic corridor is considered total Replacement. The replacement structure must meet the current geometric, construction, and structural standards as defined in the Code of Federal Regulation (CFR) 23 clause 650.403.
New Bridge Construction	The construction of a new bridge is defined as bridge construction that does not replace or relocate an existing bridge as described in FHWA's MAP-21 STP.

68. AASHTOWare Project Construction & Materials Module, 2017

AASHTOWare Project Construction & Materials™

The AASHTOWare Project Construction & Materials™ software is a comprehensive, web-based construction and materials management application. Its functionality covers the complete construction and materials management process, including laboratory information management functionality. It is a powerful application spanning all levels of construction and materials management, enabling personnel to progress a contract and its supporting documentation from award through finalization.

While the application is robust, it is configurable by role and designed with the workflow of each specific user in mind so as not to be overwhelming. In addition to the user-specific features, key features of the system-wide functionality include:

- Any user with proper access can attach files/URL links and add agency fields to any record in the system.
- System events and issue tracking enable an agency to automate complex processes and workflows that might require input or review from several different users.
- Integrated agency views (also referred to as templates or forms) allows an agency to design and implement agency-specific forms, extending contracts, daily work report postings, daily source reports, material tests, and mix designs.
- Extensive online help is available throughout the application, including configurable tooltips.
- The Info Tech Mobile® Inspector™ application interface allows your inspectors to collect the data required for a daily inspection report which includes item progress, contractor work force, photos and site conditions using a smartphone or tablet.

AASHTOWare Project Construction & Materials also contains various reports that agencies will find beneficial in managing their construction projects, including reports for the Contract Status, Change Orders, Work Item Detail, Contractor Payment, Contract Material Acceptance Action Status, Approved Products, and the Outstanding Item List.

Construction Management

The AASHTOWare Project Construction & Materials module is designed to manage all aspects of a construction project by providing:
Field-based data entry functionality with Daily Work Reports.

- Diaries for the project manager to review the inspectors' Daily Work Reports.
- Contract change order functionality for creation, review, and approval of contract changes, including the ability to automate approval levels based on contract and change order type.
- Contract payment estimates, including agency-configurable exceptions such as item overruns, insufficient materials, limited funding, missed time, and many more. Payment estimate approvals are configurable by contract and payment estimate type.
- Force Account and Force Account Reporting functionality allows the agency to define, track, and report the actual costs of labor, equipment, and materials incurred in the performance of work including allowable overhead and markups for any contractor (prime or subcontractor) associated with the contract.
- Agency-configurable contractor evaluations with the ability to create, update, and change questions and question value/ratings.
- Construction stockpiles, including the ability to associate materials, set agency-level draw-down triggers and thresholds, and set contract item-specific recovery percentages.
- Stormwater compliance functionality to help manage and comply with SWPPP strategies. The application can be configured to manage/track water pollution controls (BMPs), inspection cycles, and system notifications.

Materials Management

AASHTOWare Project Construction & Materials helps agencies track and evaluate satisfaction of contract material acceptance actions by quantity, contract, date, source, or location per the agency's contract specifications for material certifications and test results. Acceptance actions are identified at a global level for all materials and are generated from that list at a contract item level, where they can then be modified as necessary. This functionality facilitates capturing contract material requirements and test results allowing agencies to automate contract material acceptance.

The software provides the ability to track materials from the producers, including their component materials, until they are ultimately used as part of the contract. It also provides source- and facility-based data entry functionality with Daily Source Reports. Source authority is used to identify users who may maintain source and facility information. Additional materials management features in the AASHTOWare Project Construction & Materials module include:

- Approved materials for sources and facilities management
- Enterprise tracking of testers, samplers, calibrators, welders, and laboratories qualifications for agency adherence to FHWA IA regulations
- Systematic tracking of test equipment and calibrations
- Optional automated payment estimate deductions for insufficient material requirements
- Mix design creation and approval
- Material test result data capture and evaluation

Laboratory Information Management

The laboratory information management features of the AASHTOWare Project Construction & Materials module are tailored to transportation agency lab management workflow. These features give the agency the ability to manage and track progress through each critical step of the material sample lifecycle. Lab management functionality is highly configurable to fit the needs of an unique agency's materials lab workflow.

The lab management functions have user-based security settings to ensure that assigned lab personnel have access only to the data and information needed to complete their individual tasks. The lifecycle tracking of samples and tests through the application expedites the overall testing process. At any point, it is easy to see which samples are waiting to be tested, which have the highest priority, and who is responsible for each sample's current stage of progress. Tests can be assigned (or re-assigned) to specific labs and to specific testers within those labs, based on qualifications and workload.

This functionality allows for a materials test environment that is interactively managed and responsive to a material lab's changing needs.

System Specifications
For details about system specifications for all AASHTOWare Project software, please refer to www.cloverleaf.net/sys_arch/.

For more information about this product, contact AASHTO or the AASHTOWare® contractor:

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Internet www.infotechfl.com

69. National Academies of Sciences, Engineering, and Medicine 2012, Estimating Life Expectancies of Highway Assets, Volume 1: Guidebook. Washington, DC: The National Academies Press. Paul D. Thompson, Kevin M. Ford, Mohammed H.R. Arman, Samuel Labi, Kumares C. Sinha, Arun M. Shirole
Provides; overview to National Cooperative Highway Research Program (NCHRP), The National Academies (Advisers to the Nation on Science, Engineering, and Medicine), and introduction to estimating life expectancies of highway assets.

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Academies was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

By Andrew C. Lemer
Staff Officer
Transportation Research Board

This two-volume report provides a methodology for estimating the life expectancies of major types of highway system assets, in a form useful to state departments of transportation (DOTs) and others, for use in lifecycle cost analyses that support management decision making. Volume 1 is a guidebook for applying the methodology in DOT asset management policies and programs. Volume 2 describes the technical issues and data needs associated with estimating asset life expectancies and the practices used in a number of fields—such as the energy and financial industries—to make such estimates.

The deterioration of highway infrastructure begins as soon as it is put into service. Effective management of highway system assets requires a good understanding of the life expectancy of each asset. Asset life expectancy is the length of time until the asset must be retired, replaced, or removed from service. Determining when an asset reaches the end of its service life generally entails consideration of the cost and effectiveness of repair and maintenance actions that might be taken to further extend the asset's life expectancy. Different types of assets, such as pavements, bridges, signs, and signals, will have very different life expectancies. Asset life expectancy also depends on the materials used; demands actually placed on the asset in use; environmental conditions; and maintenance, preservation, and rehabilitation activities performed.

Effective management of highway system assets requires that agency decision makers design and execute programs that maintain or extend the life of the various types of assets in the system at low cost. Designers use estimates of asset life expectancy in their lifecycle cost analyses to make design decisions, but those estimates depend on assumptions about maintenance practices, materials quality, service conditions, and characteristics of the asset's use. If actual service conditions and maintenance activities subsequently differ from the designer's assumptions, the asset's life is likely to be different from initial estimates. Better information and tools for estimating asset life expectancies are needed to guide in-service asset management programs. Research is needed to determine the life expectancies of assets for at least four potential cases: (1) when maintenance and preservation activities are performed as assumed by the designer in the lifecycle cost analysis, (2) when little or no maintenance is performed over the life of the asset, (3) when more aggressive maintenance and preservation activities are performed to extend the asset's life, and (4) when materials or designs that require no or very little maintenance are used.

The objectives of NCHRP Project 8-71 were to (1) develop a methodology for determining the life expectancies of major types of highway system assets for use in lifecycle cost analyses that support management decision making; (2) demonstrate the methodology's use for at least three asset classes, including pavement or bridges and two others, such as culverts, signs, or signals; and (3) develop a guidebook and resources for use by state DOTs and others for applying the methodology to develop highway maintenance and preservation programs and assess the effect of such programs on system performance.

A research team led by Purdue University, West Lafayette, Indiana, conducted the research. The project entailed a review of current literature and practices within highway agencies and other industries, such as utilities and vehicle- and equipment-fleet management, to describe the methodologies currently used to determine life expectancy for major assets. The research team considered both new and in-service highway assets (such as pavements, bridges, culverts, signs, pavement markings, guardrail, and roadside facilities), and described the factors likely to influence predicted or assumed asset life expectancies. These factors include materials, design criteria, construction quality control, and maintenance policies and practices. Data needs and availability influence analytical ability to estimate and predict asset life expectancies. Geographic location and highway system management policies also influence life expectancies. Considering these factors, the research team described methodologies for estimating the life expectancy of major types of highway system assets, for use in lifecycle cost analyses that support maintenance and preservation management decision making.

The research produced this two-volume report. Volume 1 is a guidebook designed to be used by transportation agency staff wishing to estimate asset life expectancies. The guide will be useful to agency staff and their advisors in developing asset management and maintenance systems, policies, and programs. Volume 2 documents the research project and presents background information and research results that will be useful to other researchers and practitioners wishing to know more about the theories and methods for estimating asset life expectancies.

70. FHWA Guidance on Highway Preservation And Maintenance Memorandum, February 25, 2016. From: Walter C. Waidelich, Jr.
Provides an update on guidance on highway preservation and maintenance activities to be consistent with MAP-21 and the FAST Act including clarifications on funding.

The Moving Ahead for Progress in the 21st Century Act (MAP-21) and the Fixing America's Surface Transportation Act (FAST Act) recognized preservation as a vital component of achieving and sustaining a desired state of good repair of highway facilities. By this memorandum, FHWA is updating our guidance on highway preservation and maintenance activities to be consistent with MAP-21 and the FAST Act. The following guidance memorandums are superseded:

- Pavement Preservation Definitions, September 12, 2005
- Preventive Maintenance Eligibility, October 8, 2004
- Preventive Maintenance Questions and Answers, December 16, 2004

Please find attached guidance for both preservation and maintenance activities in question and answer format.

Preservation

Question 1: What is preservation?
Answer 1: Preservation consists of work that is planned and performed to improve or sustain the condition of the transportation facility in a state of good repair. Preservation activities generally do not add capacity or structural value, but do restore the overall condition of the transportation facility.

Question 2: May a State transportation department use Federal-aid funds to perform preservation work?
Answer 2: Yes, section 1103 of MAP-21 adds preservation to the definition of construction in 23 U.S.C. 101. As such, preservation work is eligible and encouraged under the National Highway Performance Program and the Surface Transportation Program.

Question 3: Does MAP-21 mandate requirements for preservation programs?
Answer 3: No. However, Section 1201 of MAP-21 amended 23 U.S.C. 134 to require that the Metropolitan Planning Process "provide for consideration of projects and strategies that will … emphasize the preservation of the existing transportation system." (23 U.S.C. 134(h)(1)(H)). In addition, the Long-range Statewide Transportation Plan "should include capital, operations and management strategies, investments, procedures, and other measures to ensure the preservation and most efficient us of the existing transportation system." (23 U.S.C. 135 (f)(8)). Preservation is a critical component of an agency's asset management plan to achieve and sustain a desired safe state of good repair over the lifecycle of the assets.

Maintenance

Question 1: What is maintenance?
Answer 1: Maintenance describes work that is performed to maintain the condition of the transportation system or to respond to specific conditions or events that restore the highway system to a functional state of operation. Maintenance is a critical component of an agencies asset management plan that is comprised of both routine and preventive maintenance.

Question 2: What is routine maintenance?
Answer 2: Routine maintenance encompasses work that is performed in reaction to an event, season, or over all deterioration of the transportation asset. This work requires regular reoccurring attention.

Question 3: May a State transportation department use Federal-aid funds to perform routine maintenance?
Answer 3: No. A State Transportation Department or other direct recipient is required to maintain or cause to be maintained the project constructed under the provisions of chapter 1 of title 23, U.S.C., or constructed under provisions of prior Acts. (23 U.S.C. 116 (b))

Question 4: What is preventive maintenance?
Answer 4: Preventive maintenance is a cost-effective means of extending the useful life of the Federal-aid highway. (23 U.S.C. § 116 (e))

Question 5: May a State transportation agency use Federal-aid funds to perform preventive maintenance on highways?
Answer 5: Yes. The State Transportation Department must demonstrate to the satisfaction of their respective FHWA Division Administrator that the activity is a cost-effective means of extending the useful life of a Federal-aid highway. (23 U.S.C. § 116 (e)). Preventive maintenance is a proactive approach to extend the useful life of the highway.

Question 6: May a State Transportation Department use Federal-aid funds to perform preventive maintenance off highways?
Answer 6: No. The authorization for preventive maintenance is limited to a "Federal-aid highway." (23 U.S.C. § 116 (e)). A Federal-aid highway is defined as "a public highway eligible for assistance under this chapter other than a highway functionally classified as a local road or rural minor collector." (23 U.S.C. § 101 (a)(6))

71. Transportation Asset Management Plan Development Processes Certification and Recertification Guidance; Transportation Asset Management Plan Consistency Determination Guidance, Federal Register, Volume 82 Issue 106, Monday, June 5, 2017 (FHWA Docket no. FHWA-2017-0018).

SUMMARY: The FHWA is seeking comments on two draft documents: (1) Transportation Asset Management Plan Development Processes Certification and Recertification Guidance, and (2) Transportation Asset Management Plan Consistency Determination Guidance. These documents provide implementation guidance on provisions of the Moving Ahead for Progress in the 21st Century Act (MAP-21) and the Asset Management Final Rule, which requires a State department of transportation (State DOT) to develop and implement a risk-based asset management plan. Under these authorities, FHWA must (1) certify that transportation asset management plan (TAMP) development processes established by a State DOT meet applicable requirements, and (2) make an annual consistency determination, evaluating whether a State DOT has developed and implemented a State-approved TAMP that meets all applicable requirements. This notice announces the availability of these draft documents on the online docket at the docket number for this notice.

Background

Under the asset management provisions enacted in MAP-21, codified at 23 U.S.C. 119, State DOTs must develop and implement a risk-based TAMP. This TAMP must include all National Highway System (NHS) pavements and bridges, regardless of whether the State or some other entity owns the relevant NHS facility.

The FHWA must take two actions with respect to State DOT asset management activities. The first is TAMP development process certification/recertification. Under 23 U.S.C. 119(e)(6), FHWA must certify at least every 4 years that the State DOT's processes for developing its TAMP are consistent with applicable requirements. The FHWA must also recertify whenever the State amends its TAMP development processes, in accordance with 23 CFR 515.13(c). The second FHWA action, under 23 U.S.C. 119(e)(5), is an annual consistency determination, which evaluates whether the State DOT has developed and implemented a TAMP that is consistent with the requirements of 23 U.S.C. 119. The FHWA adopted the asset management rule, 23 CFR part 515, to implement these and other asset management requirements. The FHWA Division Offices (Divisions) are responsible for making these two decisions on behalf of FWHA.

To assist State DOTs and Divisions with these requirements, the FHWA Office of Asset Management, Pavements, and Construction is seeking comment on the two draft guidance documents announced by this notice. Please note that any comments should be limited to these guidance documents; FHWA is not soliciting further comment on the Asset Management Final Rule.

The Transportation Asset Management Plan Development

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Processes Certification and Recertification Guidance provides a framework for Divisions to undertake and complete the process certification for a State DOT's TAMP development processes as outlined in 23 CFR 515.13. The Transportation Asset Management Plan Consistency Determination Guidance assists Divisions on evaluating whether a State DOT has developed and implemented its TAMP in accordance with provisions in 23 CFR 515.13(b). All guidance is subject to change as the state of asset management practices change and the asset management rule is further implemented.

Authority: 23 U.S.C. 119; 23 CFR part 515; 49 CFR 1.85.

72. National Academies of Sciences, Engineering, and Medicine 2015, Long-Term Bridge Performance Committee Letter Report: February 20, 2015. Washington, DC: The National Academies Press.
Ananth K. Prasad

Dear Mr. Nadeau:

I am writing to report the findings and recommendations developed at the meeting of the Transportation Research Board (TRB) Long-Term Bridge Performance (LTBP) Committee[1] on December 2, 2014.

As you know, this Federal Highway Administration (FHWA) long-term program addresses the challenges faced by federal, state, and local transportation agencies in the operation and maintenance of their deteriorating highway bridges. The program will collect research-quality data on a large representative sample of in-service U.S. highway bridges and analyze these data to improve understanding of the mechanisms and timing of bridge deterioration resulting from the effects of age, materials, traffic, and weather. The data collection and analysis will also help evaluate the effectiveness of intervention options in ameliorating this deterioration.

Through a contractual arrangement with FHWA, the National Research Council of the National Academies provides advice and assistance on the conduct of the LTBP program through the work of its TRB LTBP Committee.

The meeting agenda consisted of briefings by FHWA staff and contractors,[2] and each briefing was followed by a question-and-answer period and discussion. The presentations included

- The status of the LTBP program;
- Reports summarizing the recent meetings of the committee's expert task groups on durability and preservation, evaluation and monitoring, and traffic and truck weights; and
- Updates on the following subjects:
  - Program organization and staffing,
  - Data collection protocols,
  - Field data collection,
  - Development of bridge practices timelines,
  - Bridge performance index,
  - Bridge deterioration models, and
  - Other related subjects.

Roster
TRB Long-Term Bridge Performance Committee

Ananth K. Prasad, *Chair*
Secretary
Florida Department of Transportation

Malcolm T. Kerley, *Vice Chair*
President
NXL Construction Services, Inc.

Sreenivas Alampalli
Director, Structures Evaluation Service Bureau
New York State Department of Transportation
and
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Pennsylvania Department of Transportation

Karl H. Frank
Chief Engineer
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Wyoming Department of Transportation

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State Bridge Engineer
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and
Chair, TRB Expert Task Group for LTBP Bridge Durability and Preservation

Jugesh Kapur
Senior Associate Bridge Engineer
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and
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Sandra Q. Larson
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Paul Liles[5]
Assistant Director, Bridges and Structures
Georgia Department of Transportation

Andrzej S. Nowak
Chair, Department of Civil Engineering
Auburn University

Kenneth D. Price[5]
Vice President, National Bridge Practice
HNTB Corporation

73. National Academies of Sciences, Engineering, and Medicine 2007, Managing Selected Transportation Assets: Signals, Lighting, Signs, Pavement Markings, Culverts, and Sidewalks. A Synthesis of Highway Practice. Washington, DC: The National Academies Press.
    Michael J. Markow
    Provides insight to how State DOTs are managing culverts and other transportation assets.

74. Measuring Performance Among State DOTs, Sharing Best Practices Comparative Analysis of Bridge Condition Final Report, NCHRP 20-24(37)E, August, 2010
Spy Pond Partners, LLC with Arora and Associates

ACKNOWLEDGMENTS

This study was requested by the American Association of State Highway and Transportation Officials (AASHTO), and conducted as part of National Cooperative Highway Research Program (NCHRP) Project 20-24. NCHRP is supported by annual voluntary contributions from the state departments of transportation (DOTs). NCHRP Project 20-24 provides funds for research studies intended to address specific needs of chief executive officers (CEOs) and other top managers of DOTs. The work was guided by an NCHRP project panel composed of Daniela Bremmer, Washington State DOT; Mara Campbell, Missouri DOT; Hamid Ghasemi, Federal Highway Administration; Paul F. Jensen, Montana DOT; Glenn A. Washer, University of Missouri; and Peter Weykamp, New York State DOT. The project was managed by Dr. Waseem Dekelbab, NCHRP Senior Program Officer.

Executive Summary

Comparative Performance Measurement for Bridge Condition

Today's transportation agencies need to find ways to improve service and demonstrate tangible results for their customers while operating under increasingly tight resource constraints. Within an agency, performance measurement provides a valuable tool for strengthening external accountability and achieving alignment and focus around desired end results.

Comparative performance measurement allows agencies to examine their individual performance within a larger context. It motivates organizations to pursue improvements by showing them what their peers have been able to achieve. It facilitates improvement by identifying specific practices of agencies that have achieved good results. Establishing comparable measures can take considerable effort, but pays off when participating organizations learn from practices employed by their peers to improve their own performance. Comparative performance measurement initiatives also have the important effect of shining a spotlight on current approaches to how performance is being measured and how results are being used. Participating agencies have an opportunity to examine the consistency and accuracy of their measurement practices, learn about differences in measurement across agencies, and work towards a greater degree of commonality.

This report presents results of the fourth in a series of comparative performance measurement efforts sponsored by the American Association of State Highway and Transportation Officials (AASHTO). The purpose of these efforts is to identify states that have achieved exemplary performance, find out what practices have contributed to their success, and document these practices for the benefit of other states. This effort focuses on bridge condition.

Contribution of This Study

This study was based on an analysis of bridge condition data from the National Bridge Inventory (NBI.) Based on the available data, it identifies states that have achieved a high level of performance relative to other states, with respect to recently reported (2009) bridge condition or with respect to improvements in bridge condition since 1999. It presents bridge management, maintenance, design and construction practices that the representatives of these states feel have contributed to these performance results. While these practices are already fairly well recognized among those in the highway bridge community, linking them to performance results serves to underscore their importance. Given the critical importance of bridges and the high costs of bridge construction and preservation, this study adds an important dimension of state department of transportation (DOT) performance to the comparative performance measurement series. Highlighting these results in the context of comparative performance information provides a compelling basis for executives to quickly identify where they stand, see the potential for further improvement, and scan the key types of practices that can be explored for achieving that improvement.

75. National Academies of Sciences, Engineering, and Medicine 2007. Multi-Objective Optimization for Bridge Management Systems, NCHRP Report 590. Washington, DC: The National Academies Press.
Vandana Patidar, Samuel Labi, Kumares C. Sinha, and Paul Thompson
Provides overview to methodologies for network-level and project-level optimization of performance criteria and software modules, user's manual, and demonstration database.

FOREWORD

By David B. Beal
Staff Officer
Transportation Research Board

This report describes the development of methodologies for network- and project-level optimization of multiple, user-specified performance criteria. Bridge management software modules to implement the methodologies were also developed. The report details the development of methodologies. The software modules, user's manual, and demonstration database are provided on an accompanying CD-ROM. The material in this report will be of immediate interest to bridge managers and planners.

Currently available bridge management system (BMS) tools compute an optimal solution based on the objective of least long-term cost. Bridge managers are finding that their constituents require bridge conditions to be substantially better than a least long-term cost solution would provide. Research was needed to develop a multi-objective optimization model.

To address this need, two distinct BMS optimization models were developed: a network-level model and a bridge-level model. The network-level model provides a decision-making tool that optimizes bridge actions for multiple performance criteria. These performance criteria could be cost, condition, risk, highway bridge replacement and rehabilitation (HBRR) program eligibility, bridge health index, or others. The bridge-level model evaluates the effect of bridge action alternatives on life-cycle cost and other performance criteria for the purpose of selecting projects that are consistent with the network goals.

Both models use the AASHTO BridgeWare database supplemented with additional data as needed. Commonly Recognized (CoRe) Element data are used for condition assessments. The bridge-level model considers recommendations from the network-level model. In addition, the network-level model can consider projects selected within the bridge-level model. These models also can operate independently. Both models explicitly consider the inherent uncertainties of estimated costs and outcomes. The models are implemented in graphical design software that will help bridge managers visualize the life cycle of individual bridges and bridge inventories.

This research was performed by Purdue University, in West Lafayette, Indiana, and Paul D. Thompson, Consultant. The report fully documents the research leading to the recommended models.

76. National Academies of Sciences, Engineering, and Medicine 2013. Use of Transportation Asset Management Principles in State Highway Agencies, NCHP Synthesis 439. Washington, DC: The National Academies Press.
Neal Hawkins, and Omar Smadi
Provides overview to current state of practice for asset management among state departments of transportation (DOTs).

FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Jon M. Williams
Program Director
Transportation Research Board

Transportation asset management is a strategic approach to managing transportation infrastructure. It focuses on business processes for resource allocation and utilization with the objective of better decision making based on quality information and well-defined objectives. This study reports the current state of practice for asset management among state departments of transportation (DOTs). It is advised by the recent *Volume 2 of the Asset Management Guide—A Focus on Implementation*, which provides a step-by-step process that enables agencies to align their investment decisions to their strategic goals.

Information for this study was acquired through literature review, a workshop, interviews, and surveys of state DOTs.

Neal Hawkins and Omar Smadi, Center for Transportation Research and Education, Ames, Iowa, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

USE OF TRANSPORTATION ASSET MANAGEMENT PRINCIPLES IN STATE HIGHWAY AGENCIES

SUMMARY

Roadway infrastructure within the United States includes features such as roads, bridges, signs, pavement markings, traffic signals, support commerce and mobility, and is, in essence, a shared financial public resource worthy of being managed at the highest level of efficiency.

State departments of transportation (DOTs), local transportation authorities, and federal agencies responsible for the fiscal management of the transportation system have shown a growing interest in advancing the state of practice in managing these critical assets. In addition, the recent congressional passage of Moving Ahead for Progress in the 21st Century Act (MAP-21 Act) has established an outcome-driven, performance-tracking approach that will hold states and metropolitan planning organizations accountable for improving the conditions and performance of their transportation assets. It will therefore increase agency attentiveness to these vital issues.

Transportation Asset Management (AM) is a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their life cycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based on quality information and well-defined objectives.

Advancing AM capabilities and integrating these capabilities across an organization's business units requires self-assessment, alignment, goal setting, and support. This synthesis of transportation asset management practice among state highway agencies will be a timely resource for agencies to identify their current state of practice and determine where they will direct their AM efforts.

This synthesis is based on two separate surveys, with additional input from practitioners. The initial survey requested that participants conduct a self-assessment to characterize their agency's AM practices. The survey utilized the self-assessment exercise from Section 3.2 of the 2002 *Transportation Asset Management Guide* [NCHRP 20-24(11)], which was designed to probe basic functions and capabilities that contribute to good AM regardless of an agency's particular characteristics and situation. The self-assessment results reflect current and future (5-year) business practices and the agencies' institutional, organizational, financial, and IT environments. This survey yielded 18 DOT participant responses (see Appendix D).

Based on the results of the initial survey, and input from the Topic Panel, a second survey was designed to capture the state of practice and forward looking expectations (for the next 3 to 5 years) among state DOTs. Forty-three agencies participated in this second survey.

An in-depth analysis of the survey responses regarding AM implementation processes and practices was conducted to investigate the following:

- The impact (importance) of having a mandate (internal or external) on implementing AM practices (13 had a mandate versus 30 without a mandate)
- The importance of having an AM group (26 had a group versus 17 that did not)
- Analysis of transportation asset management plan (TAMP) examples provided by agencies (five agencies provided a copy of their TAMP)
- Assessment of training and outreach activities on advancing AM practice.

A DOT summary of practice was developed and categorized according to the basic components of an AM system, which include the following:

Organization—Sixty percent of the agencies have an AM group. Even though major asset managers dominate the composition of these groups, top executives are represented in more than 30% of them. Fifteen percent of the responding agencies have created separate divisions within their organization to support AM activities. Having an AM group, executive involvement, and an AM structure within the organization is critical to support AM activity development, implementation, and practice.

Data—AM inventories have expanded beyond the traditional pavement and bridge assets (over 70% of the agencies report collecting signs, guardrail, culverts, and lighting information). In addition, over 50% of the agencies are conducting condition assessments, which lead to supporting investment analysis for project selection and resource allocation recommendations.

Decision making—Over 70% of the responding agencies noted that using AM principles has made their decisions more data driven, defensible, and performance-based. Sixty percent of the agencies are balancing AM preservation and capital improvements, which is a critical component for developing a sustainable infrastructure. Fifty percent of the agencies have developed a process to share AM information with elected and appointed officials, which is helpful for communicating investment needs and adding transparency to the decision-making process and trade-offs. Even though agencies are collecting data beyond pavements and bridges, they still need to expand the use of this information in the decision-making process. For example, more than 90% of the agencies use AM information to select bridge and pavement projects; however, for other asset decisions (e.g., maintenance, operations, and safety) this number drops below 40%.

Performance measures and risk—The primary performance measures that drive agency decision making include either physical condition (98%) or safety (90%). However, more than half of agencies reported both operations and capacity as decision-making drivers, 57% and 50% respectively. Only 27% of the respondents incorporate risk into their short-term decision making, which is normally associated with cost and schedules. Only 19% of agencies consider long-term risk in their decision making, which includes design, sustainability, and climate change.

TAMP—Of the five agencies that provided what they termed their Transportation Asset Management Plan (TAMP) documents, only two agencies (New Jersey and Georgia) provided TAMPs that show a good example of a TAMP, according to the 2002 *AASHTO Transportation Asset Management Guide*. The remaining three agencies provided more of an implementation plan or a strategic plan to initiate the practice of AM at a comprehensive level. Regardless, the content of these plans is encouraging; they focus on more than just pavement and bridges, and consider integration, communication, and effective decision making.

Other findings from the synthesis include the following:

AM Mandate—Only 30% of the agencies (13 of 43) reported having some sort of mandate to implement AM. The mandate helped the agencies develop an organization structure to support AM (70% of mandate agencies had an AM group versus 56% for no-mandate agencies). Even though the agencies' inventory practices were not much different in comparison, the agencies with an AM mandate conducted more condition assessment and checked the quality of the collected data more than the no-mandate agencies [85% conducted quality control/quality assurance (QC/QA) versus 69% for the no-mandate group].

This synthesis identified the following future research needs to support AM:

- Develop a common language for AM functions, practices, and processes. The results from the AM state-of-the-practice survey highlighted a few areas where there is no common understanding of the terminology. One good example is the TAMP. Out of the five TAMPS received through the synthesis, only two included all the required parts.
- Self-assessment tool. The 2002 *AASHTO Transportation Asset Management Guide* introduced the self-assessment so that agencies can plan their next moves in implementing AM. The self-assessment tool needs to be modified to reflect changes resulting from new research since 2002, the new *AASHTO Transportation Asset Management Guide: A Focus on Implementation* (2011), and current state DOT practices. The new self-assessment tool could be in electronic format, preferably web-based, to not only allow the agency to gather input from its staff but also provide analysis capabilities as part of the presentation of the results.
- Risk assessment. As highlighted in the AM state-of-the-practice survey, risk is an activity that needs more short- and long-term focus. A synthesis of risk assessment practices in an AM perspective would identify current activities and future research needs.
- A synthesis on the use of performance measures in AM. With the MAP-21 Act and the FHWA's recent creation of the Office of Transportation Performance Management, it is critical to start investigating this topic by developing case studies on how some agencies are utilizing this concept.
- Develop case studies on best practices addressing different categories of the maturity scale presented in this synthesis (i.e., organization structure, data, decision making, performance measures, risk).
- Develop an objective, comprehensive, and data-driven maturity scale to allow the agencies to assess their level of AM implementation and practices.
- Conduct a domestic scan of the agencies that scored high on the different maturity categories.

LITERATURE REVIEW

WHAT IS ASSET MANAGEMENT

According to AASHTO, "Transportation Asset Management is a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their life-cycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based on quality information and well-defined objectives." In the transportation field, AM involves a large array of system components. Examples of these assets include "pavements, pavement markings, raised pavement markers, structures, roadside signs, traffic signals, roadway illumination, traffic barriers, guard fences, attenuators, maintenance equipment, vehicles, intelligent transportation system (ITS) equipment, traffic detection equipment, real estate, corporate data and materials" (Kuhn 2011). The items under state DOT jurisdiction vary, but most often include a large amount of linear transportation assets.

ASSET MANAGEMENT HISTORY

Even though AM science and practice is not new—agencies in Europe, New Zealand and Australia, and Canada started in the late 1980s and early 1990s—transportation agencies in the United States were focusing on the management of pavements and bridges as individual assets rather than on a comprehensive, integrated, and long-term approach to managing all assets under their jurisdiction.

In 1996, AASHTO and FHWA hosted an executive-level AM seminar in Washington, D.C., to introduce AM to the state transportation agencies. During this event, participants drawn from the leadership of AASHTO, FHWA, state transportation departments, private industry, utility companies, quasi-government organizations, and research and supplier communities shared experience and expertise to improve the quality of AM. The results are documented in FHWA's *Asset Management: Advancing the State of the Art into the 21st Century Through Public-Private Dialogue* (1997), which describes the goals, attributes, and usefulness of AM. The seminar focused on the need for integrated decision making and the idea of going beyond just pavements and bridges.

The executive seminar in the District of Columbia was followed by another executive workshop hosted by AASHTO and FHWA in October 1997 in Troy, New York. The mission of the workshop was to evaluate current AM practices, technologies, and tools, and to develop a strategy for moving forward a cooperative AM initiative. A basic definition of AM was introduced during the meeting and later adopted by AASHTO. These two events were the beginning of the ongoing biennial series of National Asset Management Conferences. The most recent conference (9th National Asset Management Conference) in San Diego attracted more than 320 attendees with 34 state DOTs represented.

The following is a timeline of national-level AM activities that started the effort to support AM development and implementation in the United States.

- 1998: Following the two successful AM executive seminars, AASHTO created their AM Task Force to develop a strategic plan for implementing AM across the state DOTs. The task force was later converted to a subcommittee under the standing committee on planning and the standard committee on highways. The task force developed a strategic plan for AM implementation in 2002 that has been updated twice since then.
- 1999: FHWA recognizes the importance of AM and creates a new office under the Infrastructure Program to support AASHTO and the state DOT's AM efforts. In helping the states, the new FHWA Office of Asset Management agreed with AASHTO that—
  - AM needs to be flexible to address the varying needs of each state.
  - AM implementation must be voluntary.
  - It is important that AM involve a great deal of communication and education.
- 1999: The 3rd Asset Management National conference was held in Scottsdale, Arizona, with a major focus on the Governmental Accounting Standards Board (GASB) statement 34. GASB 34 required state and local governments to begin reporting all financial transactions, including the value of their infrastructure assets, roads, bridges, water and sewer facilities, and dams, in their annual financial reports on an accrual accounting basis. GASB 34 included a modified plan that allowed agencies using AM to manage their assets to a defined level of service (condition level) rather than depreciate them to determine their financial value. GASB 34 required agencies to conduct asset inventories (major

assets) and, if the modified approach is used, do condition surveys.

- 2000: TRB joins both AASHTO and FHWA and creates an AM Task Force to address the research and education needs of the agencies starting the AM process. This was later changed to a full committee (ABC40), which still maintains close communication and coordination with the AASHTO and FHWA counterparts to advance AM science, practice, and implementation. In addition to the annual meeting, the TRB AM Committee holds a midyear meeting with the AASHTO AM Subcommittee.
- 2001: The 4th National Asset Management Conference was held in Madison, Wisconsin. This meeting was focused more on AM as opposed to GASB 34, given that DOTs were still focusing on pavement and bridge assets rather than the holistic approach advised by the AM process.
- 2002: AASHTO adopts the guide developed through an NCHRP project [20-24(11)] as its first *Transportation Asset Management Guide* (2002). As part of the guide, a self-assessment tool was developed to help state DOTs gauge their progress in AM implementation and identify areas that need additional effort. The self-assessment was used as the first survey as part of this synthesis that was completed by 18 state DOTs.
- 2002: The National Highway Institute introduces a 1-day AM workshop based on the *AASHTO Transportation Asset Management Guide*. The workshop would be later modified (on two occasions) to reflect changes in how state DOTs are responding to different AM principles and how some agencies are practicing AM. The workshop is still offered with an optional half-day that helps the DOT identify gaps, based on the self-assessment, and then develop steps to address those gaps on short- and long-term bases.
- 2003: 5th National AM Conference is held in two locations (Atlanta and Seattle). This conference focused on an integrated approach and discussions on investment analysis.
- 2005: 6th National AM Conference in Kansas City. The meeting was held in conjunction with the 1st National Conference on Roadway Pavement Preservation. The interaction among the two groups was very beneficial given that it introduced the concept of trade-off analysis between capital investment and asset preservation as an AM function. This synthesis survey addresses those questions and how some DOTs are dealing with those issues.
- 2007: AASHTO/FHWA Asset Management Domestic Scan report. The U.S. scan was conducted in 2006 and included six DOTs (Florida, Michigan, Minnesota, Ohio, Oregon, and Utah), two metropolitan planning organizations, and several local agencies. The purpose of this scan was to identify best case examples of the application of AM principles and practices in U.S. trans-

portation agencies. The scan findings can be summarized as follows (U.S. Domestic Scan Program 2007):

- The importance of having a champion within the agency to push AM forward with support from executives
- The importance of life-cycle cost decision making versus a worst-first approach
- The use of performance measures that affect decision making and guide investment
- Little evidence of risk analysis and the inclusion of risk as part of the AM process
- Data issues and the need for more cost-effective ways to collect asset data (inventory and condition).

• 2007: 7th National AM Conference in New Orleans. A transit track was added to this meeting to shift the primarily pavement and bridge-based focus to other assets. The meeting included sessions on economic analysis as well as incorporating risk and performance as part of the AM decision making process. The synthesis survey explores how state DOTs have addressed those issues as part of their decision-making process.

• 2009: 8th National AM Conference in Portland, Oregon. The Portland meeting was split into tracks that dealt with data, safety, and pavements. The data track covered performance-based and risk-based data needs for decision making. The safety track focused on how safety and AM can be integrated to support decision making and investment.

• 2012: 9th National AM Conference in San Diego. This most recent conference had the largest DOT representation to-date (34 state DOTs attended). The San Diego conference focused on AM implementation and highlighted how some state DOTs are practicing AM. An AM Pooled Fund group (11 DOT members) met as a part of the conference and provided input on the analysis of survey results for this synthesis. AASHTO and FHWA also hosted an AM Peer Exchange during the conference.

During this period, FHWA sponsored several peer exchanges on AM practices discussing Geographic Information Systems (Charleston, West Virginia, 2009), safety (Cheyenne, Wyoming, 2011), and implementation (San Diego, California, 2012). FHWA produced several case studies on data integration, economic analysis, comprehensive AM implementation, and life-cycle cost analysis. Those case studies are as an excellent resource for other agencies interested in implementing different components of their AM process. Information on all of these resources is available on the FHWA website and is listed as part of the resources section in the literature review.

77. National Academies of Sciences, Engineering, and Medicine 2009. A Plan for Developing High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection (2009), SHRP 2 Report S2-R06-RW. Washington, DC: The National Academies Press. Andrew J. Wimsatt, Tom Scullion, and Emmanuel Fernando

Insight to non-destructive testing (NDT) emerging technologies and state of implementation.

FOREWORD

Monica A. Starnes, *SHRP 2 Senior Program Officer*

The first project in the second Strategic Highway Research Program (SHRP 2) in the field of nondestructive evaluation (NDE) was completed in 2008. The project evaluated the existing and emerging NDE technologies and their state of implementation to satisfy NDE requirements for highway renewal. For the requirements not yet addressed with fully implemented NDE techniques, a research plan was devised for developing technologies to deal with the most pertinent requirements for bridges, pavements, tunnels, soils, and retaining walls through the life of the facility. The findings of this project related to NDE and its recommendations for subsequent research work in this area are presented in this report.

The strategic objective of highway renewal research in SHRP 2 is to develop the necessary tools to "get in, get out, and stay out" when renewing the existing highway infrastructure. To accomplish the goals implied in this motto, technologies and processes that yield long-lasting facilities through rapid design and construction approaches while minimizing the impact to highway users are needed. Nondestructive testing (NDT) techniques that can produce rapid inspection of new construction would facilitate timely reopening of a highway after reconstruction. Adequate NDT techniques are also needed to ensure the quality of construction required for long-term performance.

Under SHRP 2 Project R06, a research team led by Andrew Wimsatt of the Texas Transportation Institute thoroughly reviewed existing and emerging NDE technologies, evaluated the existing inspection requirements, and developed a research and development (R&D) plan to address those requirements.

Initial tasks in the research focused on gathering data from literature reviews, surveys, and in-person interviews with state departments of transportation in the United States, members of the Forum of European National Highway Research Laboratories, academia, and industry. The data-gathering activities identified existing NDE techniques and practices, emerging technologies, and apparent gaps between current and future inspection requirements and existing and emerging technology. The R&D plan was developed to address the gaps.

The main audience for the R&D plan is the SHRP 2 Technical Coordinating Committee for Renewal, which will use the plan to program additional research funds for NDE. The information in this report has the potential to facilitate other agencies' research plans in this field; thus, other research organizations and funding agencies are also possible audiences.

The research team identified more than 20 areas of study that must be addressed with subsequent research. The team also provided detailed recommendations to address the top six research needs:

- Automated methods of accurately profiling bridges;
- Changes in profiles of tunnel linings over time;
- Identification of bridge deck deterioration, including its cause;
- Continuous deflection device at the highest possible speed for pavements;
- New NDT quality assurance tools for ensuring quality construction; and
- Measurement of interlayer bonding between hot-mix asphalt layers for pavements.

78. National Academies of Sciences, Engineering, and Medicine 2019. Geotechnical Asset Management for Transportation Agencies, Volume 1: Research Overview. Washington, DC: The National Academies Press.
Mark Vessely, William Robert, Scott Richrath, Vernon R. Schaefer, Omar Smadi, Erik Loehr, and Andrew Boeckmann.
Provides Geotechnical asset management concepts, ideas, and recommendations for consideration and use by transportation owner agencies.

By Camille Crichton-Sumners
Staff Officer
Transportation Research Board

NCHRP Research Report 903: Geotechnical Asset Management for Transportation Agencies provides an introduction and scalable guidance for state transportation agencies on how to implement risk-based geotechnical asset management into current asset management plans. Volume 1, *Research Overview*, details the scope, process, and findings of the study. Volume 2, *Implementation Manual*, assembles the research results into guidance that should be of immediate use to practitioners who maintain geotechnical assets including walls, slopes, embankments, and subgrades. Complementary downloadable files include planning tools, additional examples and models, and training slides to facilitate agency use of this planning approach.

The management of bridge and pavement assets has for many years garnered significant attention by state transportation agencies while the management of geotechnical assets—such as walls, slopes, embankments, and subgrades—has been elusive. Traditionally, geotechnical assets have been treated as unpredictable hazard sites with significant potential liability because failure of any geotechnical asset may lead to traveler delay, damage to other assets, or impact safety. Geotechnical assets are, however, vital to the successful operation of transportation systems and present an opportunity for system owners and operators to realize new economic benefits through risk-based asset management.

Under NCHRP Project 24-46, "Development of an Implementation Manual for Geotechnical Asset Management for Transportation Agencies," the research team was tasked with the development of a literature review, case study synthesis, and guidance for state transportation agencies on developing and implementing geotechnical asset management (GAM) plans. Volume 1 of *NCHRP Research Report 903* provides background on the project and discusses the benefits of proactively addressing GAM. The accompanying Volume 2 provides a *GAM Implementation Manual*. Downloadable files that complement the report include a spreadsheet-based GAM Planner tool, a net present value (NPV) template, user guides for the tool and template, a GAM plan outline, and additional examples and models. Training slides also are provided to facilitate immediate implementation by state transportation agency practitioners. Both volumes of *NCHRP Research Report 903* and all of the downloadable files can be accessed from the report webpage by going to www.trb.org and searching "NCHRP Research Report 903".

Geotechnical Asset Management for Transportation Agencies, Volume 1: Research Overview

Even though bridge and pavement conditions receive much of the media attention and legislative directives for state departments of transportation (DOTs), the value and performance of other assets also are important to the effective operation of the transportation system throughout its life-cycle. One such asset category is geotechnical assets, which are the walls, slopes, embankments, and subgrades that contribute to the ability of a transportation agency to perform its strategic mission. According to the FHWA (2018), "transportation asset management [TAM] plans are an essential management tool which bring[s] together all related business processes and stakeholders, internal and external, to achieve a common understanding and commitment to improve performance." To truly drive performance, transportation agencies therefore need to look beyond the two legacy asset categories named in federal authorization and better understand the impact of all assets—including geotechnical assets—within the system that they must manage as responsibly and cost-effectively as they are able.

Implementing asset management practices for geotechnical assets enables an infrastructure owner to measure and manage the life-cycle investment considering performance expectations and tolerance for risk. Although geotechnical asset management (GAM) is not typically mandated through legislative processes, the reasons for adopting this practice are comparable to those that justify any other business practice that is directed at making smart investments with limited funds. Without employing GAM, organizations are accepting unknown magnitudes of undue risk to traveler safety, mobility, and economic vitality, while potentially making unfavorable life-cycle investment decisions.

Fortunately, for an owner of geotechnical assets, risk-based GAM implementation can build on the practices developed by successful programs. Two such programs in the United Kingdom have more than 15 years of implementation experience: Highways England manages 4,400 miles of roadways with 49,000 slope and embankment earthwork assets that are similar in age to many DOT geotechnical assets in the United States, and the UK's Network Rail system has more than 9,800 miles of railway with 191,000 earthwork assets, most of which are well over 125 years old. When combined with other international and domestic geotechnical asset and natural hazard management programs, these examples provide valuable information on the need for and benefits of GAM regardless of asset age, as well as implementation concepts that can enable rapid return on investment (ROI).

An early benefit of GAM implementation is the efficient use of taxpayer funds through leveraging existing practices that minimize the need for significant investment in new programs or re-allocation of resources. Drawing from existing risk-based asset management practices, Volume 2 of *NCHRP Report 903* (the *GAM Implementation Manual*) incorporates the use of a spreadsheet-based (Microsoft Excel) software tool, the GAM Planner. Together, the *GAM Implementation Manual* and the Gam Planner tool can enable an agency to implement a risk-based asset management program quickly and without requiring significant start-up costs or efforts. Once asset management has started, evidence from across the asset management spectrum indicates that a program will mature through justified process improvements that support ROI. Therefore, an implementation workflow for GAM can start simply and with an incomplete inventory that advances with time.

The goal of any asset management system is to logically align asset design, operations, maintenance, and upgrade decisions with agency goals and objectives. For GAM implementation to succeed across an organization, the program should relate how asset performance affects both customers and the decisions made by executives who focus on agency goals and objectives. For this to occur, asset performance measures should relate to high-level agency objectives such as common safety and system performance objectives. The GAM implementation process and the accompanying GAM Planner developed through this research center on performance objectives related to asset condition, safety impacts, mobility, and economic consequences, which are common objectives across DOTs and offer a means for connecting geotechnical asset performance to stakeholder goals and objectives.

In addition to alignment with stakeholder objectives, consistent use of definitions within a GAM taxonomy that is aligned with other asset management systems can enable communication across disciplines within the organization and among different agencies. Definitions of *asset* provided by both AASHTO and the International Organization for Standardization (ISO) support the recommended geotechnical asset taxonomy consisting of walls, slopes, embankments, and subgrades as physical assets within the right-of-way (ROW). Further, the basis for this taxonomy is validated by several years of applied GAM for transportation systems in the United Kingdom.

1.2 Research Need

Geotechnical assets are the walls, slopes, embankments, and subgrades that contribute to the ability of a transportation agency to perform its strategic mission. Historically, geotechnical assets have been treated as hazard sites that create unpredictable financial liabilities to operations and/or have been ignored until failure forces unplanned action. The literature contains numerous examples of direct and indirect economic consequences that have resulted from the adverse performance of a geotechnical asset. As a result, it can be shown that these assets—when they perform correctly—contribute measurable value to the transportation network. Walls, slopes, embankments, and subgrades are, indeed, assets, and they should be managed to realize the measurable life-cycle cost, risk-reduction, and performance benefits that are possible for owners and users. This conclusion is supported by examples from sustainable, successful risk-based GAM programs like those associated with passenger rail and highway networks in the United Kingdom.

Extrapolating the consequences from adverse performance and potential benefits from investment in GAM to all U.S. state transportation departments, federal land management agencies, and local jurisdictions, the purpose and need for GAM is measurable and substantial. Further, federal authorizations, such as MAP-21 in 2012 and the FAST Act in 2015, specify risk- and performance-based asset management for bridges and pavements while encouraging state transportation agencies to develop and implement transportation asset management (TAM) strategies for all assets within the ROW.

Advancement has been made in the overall practice of TAM to allow transportation agencies to focus strategically on the long-term management of government-owned assets. A few states have started GAM programs in conjunction with TAM, but the early efforts have focused mostly on the inventory and condition measurement steps. Among states that have yet to start GAM, many indicate a need and desire but also indicate several barriers to implementation. As a result, the benefits of asset management have not been fully realized for geotechnical assets in most U.S. transportation agencies.

1.3 Benefits of GAM

Based on outcomes from established GAM programs and TAM practices in general, performing GAM yields the following benefits:

- Financial savings across the geotechnical life-cycle, with values reported to be greater than 30 percent by the U.S. Army Corps of Engineers (USACE 2013) and 60 percent to 80 percent per unit length of embankment in the United Kingdom (Perry et al. 2003);
- A process to measure and manage involuntary safety risk exposure across the entire asset class;
- Lessened traveler delay and closure times, resulting in improved network operational performance;
- Reduced adverse economic impacts to users, private enterprise, and communities;
- Fewer impacts and damages to other transportation assets;
- Demonstrated stewardship, including protection of environmental resources, which enhances agency reputation and improves sustainability;
- Incorporation of data and processes into informed decisions that support agency and stakeholder objectives;
- An understanding of current risk exposure levels and distribution, and the ability to manage those risks;
- Data and processes for prioritizing operations and maintenance (O&M) decisions;
- The ability to start very simply and adapt the GAM process over time as the economic benefits are realized; and
- An implementation process that does not involve compliance or reporting requirements, and for which the initial data collection stages can be directed at enabling O&M decisions.

1.4 Research Objectives and Scope

The objective of this research was to produce a manual for implementing GAM that provides tools for a consistent management program that also is flexible for adaptations by differing agencies as they integrate their geotechnical assets into the TAM program. Given that (1) GAM is not a federally required process (beyond what is required in bridge asset management at this time), and (2) funds and staff resources are anticipated to be limited at the start of a program, the research team recognized that the implementation process must be simple and practical to enable broad adoption across agencies.

The scope of work activities performed for this research included:

- **Task 1: Kick-off Meeting and Work Plan Formulation.** A teleconference between the research team and NCHRP was completed to present the amplified Work Plan. Input from the panel members was incorporated into Tasks 2 and 3.
- **Task 2: Literature Review.** The literature review encompassed gathering and reviewing information from national and international literature based on sub-topics that included best practices; the integration of inventory, condition, risk, and performance in assessment; risk and risk-based management; and life-cycle costs and investment.
- **Task 3: Case Study Synthesis.** This task involved documenting and synthesizing a range of case studies of agency practices that represented differing geologic terrains, agency structures, levels of maturity of the asset management process, performance perspectives, risk tolerances, and investment capabilities. An outcome from the synthesis was identification of geotechnical, planning, and executive actions to enable implementation.
- **Task 4: Deliver Interim Report.** The Interim Report presented the findings of the case studies and the literature review with a synthesis of practices for enabling GAM.
- **Task 5: Host Interim Meeting.** A panel meeting was held to review the findings that were presented in the Interim Report and to present the Phase II Work Plan.
- **Task 6: Develop GAM Implementation Plan.** A GAM implementation process was developed that follows asset management steps for objectives and measures, inventory and condition, performance gap identification, life-cycle cost, risk management analysis, financial planning, and investment strategies.
- **Task 7: Data Management for GAM Implementation.** A spreadsheet-based (Microsoft Excel) worksheet template (the GAM Planner) was developed to enable an agency to implement GAM following the process described in Task 6.
- **Task 8: Deliver Final Deliverables.** The final deliverables included a draft implementation manual (now Volume 2 of *NCHRP Research Report 903*), a final research report (now this volume of the report), a technical memorandum on the implementation of the research findings (available from the NCHRP 24-46 project page), a slide-based (PowerPoint) training presentation, and additional training materials.

2.1 Literature Review

The literature review involved collecting and synthesizing information from national and international sources on topics related to best practices, assessment, risk and risk-based management, life-cycle costs and investment, and cross-asset interaction and decision support. The research team categorized and summarized information based on its potential practical application toward GAM implementation. Selected references were included in the *GAM Implementation Manual.* A brief summary of the literature review is available online as an appendix to this volume and can be downloaded from the *NCHRP Research Report 903* web page at www.trb.org.

2.3 Initial Findings

The team reviewed the findings from the literature review and case studies to synthesize the practices found; to identify effective implementation models, performance measures, risk and risk management processes, and steps to enable asset management; and to identify examples of demonstrated ROI. The synthesis, provided in the Interim Report, evaluated the role of people,

The findings included international examples of successful GAM programs that exhibit a complete implementation process from setting objectives and measures through life-cycle cost and risk management analysis, financial planning, and investment decisions. These existing GAM programs are now increasing their asset management maturity level based on the realization of benefits made evident by the tracking of asset performance after implementation. A finding from the case studies of agencies yet to start GAM was a need for tools and guidance that can enable starting GAM, particularly given the anticipated near-term federal and state legislative environment, which will not require or fund GAM. In this environment, proposed expenditures of time and resources to implement GAM must be justifiable under a social or economic need rather than a regulatory requirement.

2.5 Development of a GAM Implementation Process

The GAM implementation process was developed using a cross-disciplinary combination of executive, asset management, and geotechnical practice perspectives. The implementation process followed the AASHTO TAM steps of: objectives and measures, inventory and condition, performance gap identification, life-cycle cost and risk management analysis, financial planning, and investment strategies. The implementation process has been documented in the *GAM Implementation Manual*.

Throughout the development of the implementation process, the research team emphasized formulating an approach that was directed at:

- Enabling a quick start to inventory and assessment without requiring a new program, specialized software, investment in inventory data collection, or significant staff or contractor support;
- Developing a risk-based GAM process directed at performance objectives for asset condition, safety impacts, and mobility and economic consequences;
- Enabling implementation by individuals other than geo-professionals, including TAM and other planning staff, bridge/structure inspection teams, and general engineering staff;
- Constructing flexible frameworks for prioritizing asset treatment decisions based on risk and/or investment considerations;
- Emphasizing connection with agency executives through business and investment cases for GAM;
- Promoting a consistent inventory and assessment process across geotechnical asset types;
- Starting GAM following a simple workflow that can be modified as justified through process improvement steps; and
- Developing recommendations for incorporating GAM at both the program and project levels and in both the operations and design life-cycle phases.

The proposed implementation process consists of a simplified workflow for:

- Identifying and locating assets;
- Selecting from a five-level category for the operation and maintenance condition of an asset;

- Assessing the asset performance consequences;
- Reviewing the recommended treatment recommendations;
- Analyzing differing investment levels; and
- Communication of initial results.

The *GAM Implementation Manual* recommends starting the GAM process with a small quantity of known assets as a means to quickly implement the complete asset management process before expanding the inventory or considering process improvements. Once started, suggested next steps include:

- Expanding the inventory of assets through various means and methods;
- Calibrating the default asset models;
- Developing new asset models, if needed;
- Including other agency staff in inventory development;
- Developing data management practices with agency staff to enable visual communication of asset characteristics and performance;
- Authoring a GAM plan document; and
- Adding objectives and measures based on stakeholder feedback.

2.6 Data Management for GAM Implementation

A supporting task to the GAM implementation process involved development of a non-proprietary spreadsheet-based (Microsoft Excel) tool to accompany the *GAM Implementation Manual*. This tool, referred to as the GAM Planner, provides a means to begin a consistent geotechnical asset inventory and assessment process that includes geo-spatial asset data and enables decision-making processes based on investment returns and a risk performance measure. The GAM Planner will enable GAM across staff levels to follow a workflow for inventory development and assessment using default asset model templates. The *GAM Implementation Manual* also provides guidance for developing agency-specific asset models if desired.

The GAM Planner was formulated for adoption by a state transportation agency starting GAM at a simple asset management maturity level. An agency that already has some form of initial geotechnical asset inventory could adapt the existing data in the GAM Planner if desired. In addition to the spreadsheet tool, and as a GAM program matures, implementation staff may wish to consider using more robust agency-supported enterprise software that might offer additional analysis capabilities, and may be more compatible with other TAM databases used within the agency.

The implementation process also provides guidance on data and data management practices. Because data management practices are emerging topics with agencies and more specific to the systems and processes of each agency, the data management framework provided for the GAM implementation process is directed toward enabling integration into DOT enterprise systems.

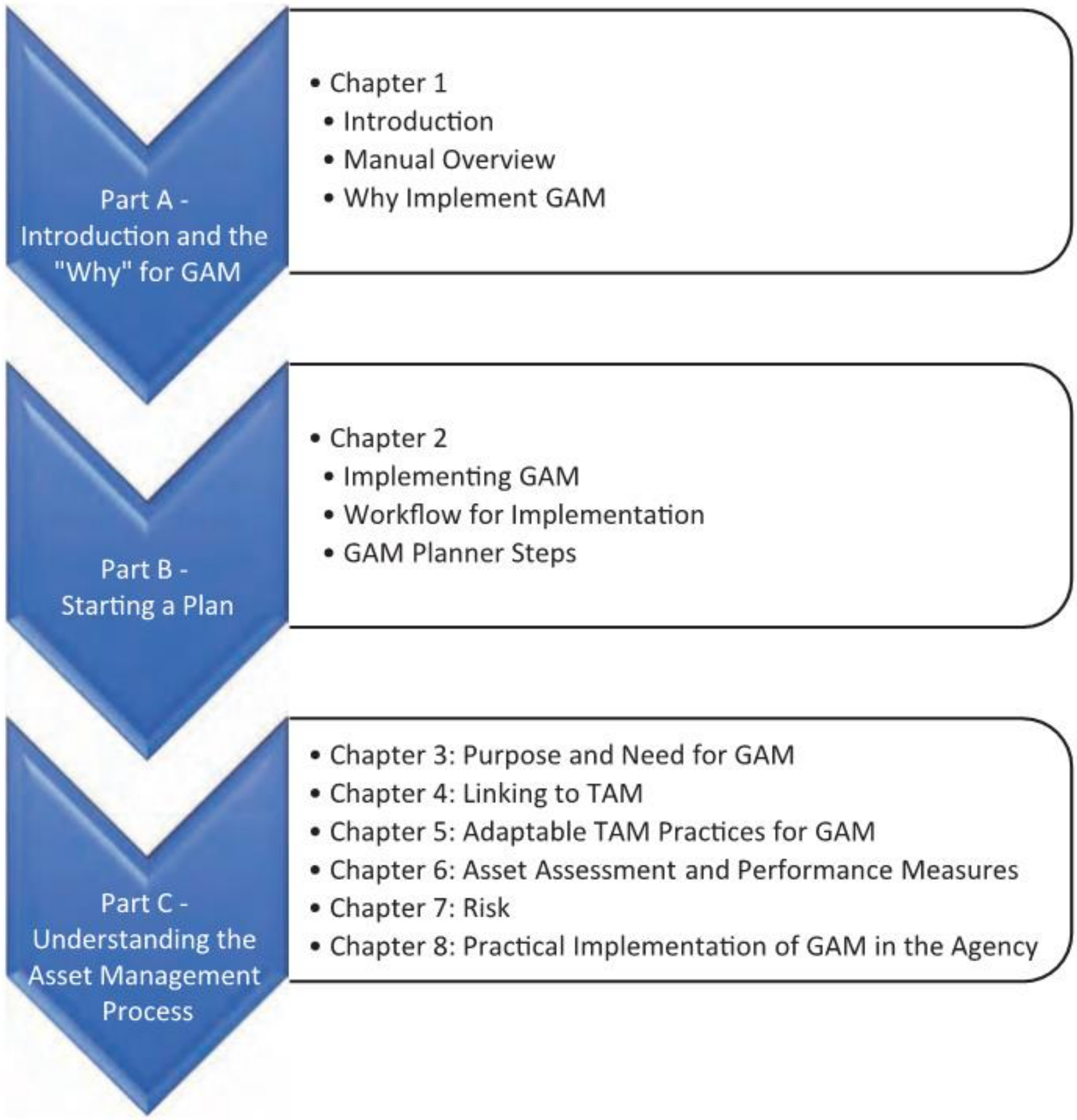

Figure 2.1. GAM Implementation manual, final organization.

3.1 Definition of the Geotechnical Asset Category and Types

The glossary in the *AASHTO Transportation Asset Management Guide: A Focus on Implementation* (2011) defines an asset as follows:

> An asset is the physical transportation infrastructure (e.g., travel way, structures, other features and appurtenances, operations systems, and major elements thereof); more generally, can include the full range of resources capable of producing value-added for an agency: e.g., human resources, financial capacity, real estate, corporate information, equipment and materials, etc.; an individual, separately-managed component of the infrastructure, e.g., bridge deck, road section, streetlight.

Issued in 2014, the ISO 55000 series of standards are used in asset management practices internationally and across infrastructure systems. The ISO 55000 standards define an asset as an "item, thing or entity that has potential or actual value to an organization; value can be tangible or intangible, financial or non-financial, and includes consideration of risks and liabilities."

In both definitions, an asset can be shown to be a physical object or component that contributes value to an organization, such as a public transportation agency. Bridges and pavements are examples of physical asset categories that are required to have asset management plans per federal authorization. However, bridges and pavements are not the only physical assets that contribute value to an organization tasked with providing public transportation infrastructure. The intended function of a bridge or pavement asset and ultimately the entire system can only be fully realized when the connecting and/or supporting assets also function. Geotechnical assets therefore can be identified as an additional asset category that provides value to an agency while also enabling the desired value from existing legacy asset management programs for bridges and pavements.

When reviewing the successful GAM programs for Highways England and Network Rail, geotechnical assets are defined as cut slopes (cuttings) and embankment assets within the agency boundary (Network Rail 2017, Power et al. 2012). Domestically, Thompson (2017) identifies rock and soil slopes, embankments, retaining walls, and material sites as geotechnical assets in the Alaska Department of Transportation and Public Facilities (Alaska DOT&PF) GAM plan; while Anderson et al. (2017), presents a summary of Colorado DOT GAM programs that consider retaining walls a separate unique asset, and, slopes, embankments and subgrade as a combined geohazards category.

3.1.3 Retaining Walls

Retaining walls are a common type of geotechnical asset, usually consisting of constructed structures that hold back natural soil or rock or engineered materials to prevent sliding of material onto a roadway or other structure, or to support a roadway. Retaining walls also are referred to as *earth retaining structures* in some organizations.

Current design guidance for many wall types indicates that retaining walls will have vertical or near vertical face inclinations of 70 degrees or steeper. For consistency with wall design practices, a structure with a vertical face inclination of less than 70 degrees can be classified as an embankment or slope that likely relies on reinforcement improvements for stability. The recommended wall height for inclusion into a GAM plan is 4 feet of exposed face height, which is based on what commonly defines an engineered retaining wall.

In many cases, a retaining wall is associated with a bridge structure or approach to a bridge. As indicated in the *GAM Implementation Manual*, if a wall also functions as a bridge abutment that is integral with the bridge structure, the wall should be considered to be part of the department's bridge inspection and asset management program and should not be inventoried and assessed as an independent asset. All other walls associated with bridge approaches are encouraged to be incorporated into the GAM plan if they are not already managed in an existing asset management program.

3.2 Purpose of GAM

GAM enables an agency to measure and manage the life-cycle investment of assets such as slopes, embankments, walls, and unstable subgrades based on performance expectations and risk tolerance. In the absence of GAM, an agency accepts unknown magnitudes of risk to traveler safety, mobility, and economic vitality, while also potentially making less than optimal life-cycle investment decisions.

To provide evidence of the business case and potential investment and risk-reduction benefits, examples of successful GAM or related similar programs are provided here and in the *GAM Implementation Manual*. A key component of these examples is that risk-based GAM is providing benefits through processes that have existed for approximately 15 to 20 years, depending on the program.

- Network Rail manages approximately 19,200 miles of the rail network in Great Britain, much of which extends through gentle topography. The network includes many cut slopes and embankments that were developed between 1830 and 1880. Network Rail has established a GAM system that consists of risk-based inventory, assessment, and intervention processes that have resulted in documented improvements in safety and delay risk for their system since implementation 15 years ago (Network Rail 2017). The Network Rail system has matured with regard to several processes, with recent changes made to the risk assessment process based on asset performance data that enables informed model calibrations. Further, studies of the proactive management of embankment assets supporting railroad lines and motorways in the United Kingdom demonstrated realized life-cycle cost savings of 60 percent to 80 percent per unit length of embankment (Perry et al. 2003).
- The UK Highways Agency (now called Highways England) is responsible for approximately 4,400 miles of roadway throughout the United Kingdom, including about 45,000 geotechnical assets. In 2003, Highways England initiated GAM with the first strategy document. Geotechnical assets in the Highways England program consist of embankments and cut slopes, with the majority constructed from the late 1950s to 1990s. As presented by Power et al. (2012), Highways England operates from the perspective that roadway infrastructure construction is mostly complete, and the agency centers its efforts on system improvements, optimization, and

maintenance. The Highways England geotechnical program has matured in stages, starting from a program directed at producing specific outputs (e.g., inventory for geotechnical assets) to obtaining business outcomes, with a primary focus on providing assets that perform at the required service level for the user. The Highways England program is risk-based, with recommended actions based on five risk-level categories. Additionally, the asset inventory is re-inspected every 5 years.

- Switzerland formed the National Platform for Natural Hazards (PLANAT) in 1997. This national effort to address the country's considerable natural hazards risk is notable for the scope of its collaboration, which includes the federal government, the financial and insurance industry, and public agencies across various infrastructure sectors. The PLANAT mandate includes improving public awareness and efforts to share financial investment in mitigation according to risk-reduction benefits; (for example, multiple stakeholders may fund a project based on benefits received (Bründl et al. 2009). The program also has an online tool for evaluating risk reduction, the use of which is required for all projects costing more than approximately $1 million.
- The U.S. Army Corps of Engineers (USACE) Dam Safety Program is an aspirational example of GAM that uses risk to evaluate, prioritize, and justify safety decisions for more than 700 dams, more than 50 percent of which have exceeded the 50-year service life (USACE 2014). The program was initiated following federal authorization in 1996. Using risk-based analysis, USACE indicates that every $1 invested yields $8 of flood damage reduction. Further, the USACE asset management process for water infrastructure facilities subject to natural hazards (water/hydropower, navigation, and flood-related assets) successfully combines inventory, assessment, and risk-based multi-criteria decision analysis and financial planning, all of which are completed by staff using conventional spreadsheet programs (Connelly 2016).

These sustained GAM practices are similar to bridge and pavement asset management programs in the United States. Although these program examples started in response to regulation, after several years of implementation each program has evolved into a more complex program that demonstrates sustained and measurable benefits.

Thus, the purpose of GAM is to enable an agency to obtain real, measurable benefits that are currently being recognized by other infrastructure organizations. Based on outcomes from successful programs around the world, the benefits of performing GAM can be summarized as:

- Financial savings across the geotechnical life-cycle, with as much as 30 percent in some cases;
- A process to measure and manage involuntary safety risk exposure across the entire asset class;
- Lessened traveler delay and closure times, resulting in improved network operational performance;
- Reductions in broader economic impacts due to injury, loss of life, or property damage to citizens, businesses, and other governmental agencies;
- Fewer impacts and damages related to other transportation assets;
- Demonstrated stewardship, protection of environmental resources, enhanced agency reputation, and improved sustainability;
- Data and processes for making informed decisions that support agency and stakeholder objectives;
- Data and processes for prioritizing O&M decisions; and
- An understanding of current risk exposure levels and distribution, and the ability to manage those risks.

Table 3.1. Examples of successful GAM strategies.

Agency Examples	People	Processes	Systems and Data
Highways England	Dedicated staff positions and organization structures that consider the role of GAM	Functioning GAM plan at complex level of maturity and based on safety risk management; long-duration inventory construction and use of process improvements	Started in 2003; mature GAM program; geo-referenced asset locations; evaluating cross-asset performance with drainage assets; 2.5-meter height definition
Network Rail	Dedicated staff positions and organization structures that consider the role of GAM	Functioning GAM plan at complex level of maturity and based on safety risk management; long-duration inventory construction and use of process improvements	Mature GAM program; geo-referenced asset locations; segment definition for assets; developing deterioration models for >100-year-old assets; 3-meter height definition
Infrastructure Maintenance Management Manual (multiple examples)	Guidance on organizational staff structures for functioning asset management programs	Risk-based asset management plans for other assets that are adaptable to GAM	Guidance on geo-referenced data management systems at levels of maturity from simple to complex
USACE Water Infrastructure Programs		Risk-based asset management practices for infrastructure systems that include geotechnical or similar assets	Transitioned from proprietary software to spreadsheet-based (Microsoft Excel) tools due to user familiarity and availability
Alaska, Vermont, and Colorado DOTs	Creating a culture change for GAM; implementation experience within a domestic DOT	Experimentation with early implementation approaches	Developing inventory and condition data for GAM in a TAM framework
Switzerland's PLANAT Program	Oversight panel with cross-agency, cross-disciplinary, and private- and public-sector representatives	Risk-based, cost-benefit decision process for natural hazard risk mitigation; investment shared among risk stakeholders	Geo-referenced risk-based inventory mapping tools and cost-benefit analysis software to standardize analysis

3.3.2 Development of a GAM Implementation Framework and Workflow

In the literature, discussions about asset management and GAM generally have covered strategic-level concepts or the agency-specific processes, systems, or data within an asset management program. The case study interviews performed for this project provided an opportunity to understand the perspectives of agency staff who may implement a new asset management program and how the cultures and relationships at differing levels of an agency can influence implementation.

For many successful GAM program examples (e.g., those in the United Kingdom, the USACE Water Infrastructure program, and the Swiss PLANAT program), a key trigger for implementation was some form of governmental requirement. This also has been true for the implementation success of bridge and pavement asset management in the United States. Once started, however, these GAM programs have yielded benefits and process improvements that demonstrate their business and risk-reduction utility independently from continuous governmental requirements. Among the state DOTs that have started early efforts toward GAM, implementation has occurred because of the motivation of a few key individuals who were willing to advocate for a program in the absence of regulatory requirements.

- Enable a consistent management program that is flexible for adaptations.
  - The GAM inventory and assessment process is structured around the performance objectives of asset condition, safety impacts, and mobility and economic consequences, which are common objectives across agencies and are identified in federal authorization for asset management.
  - For the initial inventory and assessment process, geotechnical assets are evaluated as a single category under one framework rather than using separate frameworks for each geotechnical asset type. Should an agency not want to include a certain asset type, those assets can be omitted from the inventory.
- Provide a software tool that enables starting GAM implementation without formal training or the purchase of new software systems.
  - The GAM Planner is a Microsoft Excel file that can be used across an agency.
  - The GAM Planner has minimal input fields to reduce the time requirements for entry of asset data.

3.4 Incorporating GAM into TAM and Across the Agency

As indicated in the project background and research objective, GAM implementation should occur such that the geotechnical assets can be incorporated into an overall, agency-wide TAM program. To enable this to occur, the research team has structured the GAM implementation process to align with established AASHTO TAM practices that prescribe the following elements for an asset management plan:

- Objectives and measures,
- Inventory and condition,
- Performance gap identification,
- Life-cycle cost and risk management analysis,
- A financial plan, and
- Investment strategies.

Per the practices in the IIMM, the concept of staged data collection begins with identification of minimum data for compliance and reporting requirements, next moves to data for prioritizing O&M decisions, and concludes with optimizing life-cycle decisions (IPWEA 2015). As discussed in Power et al. (2012), a similar progression of data collection occurred with GAM implementation for the UK Highways Agency. GAM implementation does not have compliance or reporting requirements, which suggests that initial data collection stages can be directed at O&M decisions. Within a staged data workflow, all assets do not necessarily go to the final level of data collection; reaching the most-detailed state occurs only in situations for which the collection effort is justified. Thus, the investment in data collection and management should be compared against the level of detail required for decision support or to achieve any other benefits.

The *GAM Implementation Manual* introduces an approach that relies on differing levels of detail and a variety of collection tools for inventory and condition data. This allows a DOT to collect only the data required for the desired level and complexity of decision-making, versus an approach that requires significant investment and quantity of data that may or may not be used in the future. The GAM Planner enables an agency to start inventory and condition measurement in a simple spreadsheet register that also can be used for assessment models.

The data needed to start an inventory in the GAM Planner can come from both within and outside an agency. Data from within the organization may include corporate information systems, active and archived project records, enterprise accounting systems, operational technology systems (such as traffic data), or anecdotal staff sources. External data can come in various forms, from sources ranging from proprietary, vendor provided systems, outside stakeholder sources, and web-based freeware programs such as Google Earth. The *GAM Implementation Manual* encourages use of existing data as the first step in order to minimize a potential barrier to GAM.

3.4.3 Performance Gaps

For an agency starting GAM at a simple level of maturity, the *GAM Implementation Manual* recognizes that performance gaps will become evident once knowledge is gained about the current levels of asset performance. The manual recommends communicating a straightforward initial performance gap, such as the percent of inventory complete relative to estimated total asset inventory, and providing approaches to address this gap.

3.4.4 Life-Cycle Planning

In recently adopted asset management requirements, the FHWA defines *life-cycle cost* as "the cost of managing an asset class or asset sub-group for its whole life, from initial construction to its replacement" (23 CFR 515). Thus, the *GAM Implementation Manual* introduces the TAM principles for considering the life-cycle of geotechnical assets through the phases of design, construction, operation and maintenance, and decommissioning (if applicable). The TAM processes that include evaluation of the asset life-cycle include:

- Total cost of the asset over the life, or life-cycle cost;
- Risk management across the life-cycle; and
- Financial plans and investment strategies for a program of assets over a life-cycle.

In the *GAM Implementation Manual,* content and figures in Chapter 4 are included to provide an introduction to the concepts of asset life-cycles and their application to geotechnical assets. The manual then expands the life-cycle discussion to introduce the TAM concepts for what treatments can be performed on an asset following construction. These treatments are incorporated into the GAM Planner and discussed throughout the manual using the following terms:

- Do Minimum,
- Maintain,
- Rehabilitate (Rehab),
- Reconstruct (or Renew), and
- Restore.

The treatment discussion in Chapter 4 of the manual reviews these concepts in detail and provides specific example treatments for geotechnical assets in each category.

3.4.5 Financial Plans and Investment Strategies

Chapter 4 of the *GAM Implementation Manual* also includes an introduction to the TAM steps of financial plans and investment strategies. As presented in the manual, a *financial plan* is a multi-year projection of actual and desired funding, whereas *investment strategies* consider the allocation of resources within a plan, such as where funding will be directed following the treatment options for assets. The manual also emphasizes the importance of financial planning in the GAM spectrum because of the importance to executive decision-makers and illustrates which assets are treated and when within the planning cycle.

Based on the research team's review of existing GAM programs and information from the project case study discussions, it is suggested that agencies anticipate that the resources available will be less than those required to support a full geotechnical asset life-cycle plan. Therefore, the *GAM Implementation Manual* indicates the need for a financial plan to present what investments will be made and what will be deferred.

Although agencies likely will need to defer investments for existing assets, the manual discusses the importance of also considering life-cycle cost in the design phase of new assets. In manufacturing industries, it is a well-documented conclusion that up to 80 percent of the life-cycle cost is "locked in" by design decisions (Hurst 1999). A similar condition is acknowledged in the life-cycle management of wastewater facilities (WERF 2018). With respect to geotechnical assets, a similar trend is expected, and the manual recommends that agencies evaluate the whole-life cost over the desired performance life-cycle to determine preferred alternatives based on economic criteria. Chapter 8 of the *GAM Implementation Manual* expands on approaches to life-cycle cost analysis, and Appendix E presents a Microsoft Excel template that can be used to evaluate life-cycle costs.

In addition to life-cycle cost considerations for financial planning and investment, the *GAM Implementation Manual* addresses a need to evaluate the ROI in a GAM program. Determining the return on GAM investment requires calculation of benefits over time in comparison to up-front and ongoing costs. The manual introduces breakeven analysis as a means for providing the justification needed to validate investment in GAM. Chapter 4 of the manual references the outcomes from *NCHRP Research Report 866: Return on Investment in Transportation Asset Management Systems and Practices* to offer detailed guidance on demonstrating ROI in TAM. *NCHRP Research Report 866* is accompanied by a spreadsheet-based tool for calculating the ROI of an asset management system or process investment that can be adopted by an agency wanting to evaluate the program-level investments toward GAM. (Additional information about this report and a link to download the accompanying spreadsheet tool are available from the *NCHRP Research Report 866* webpage at www.trb.org.)

3.6 Data and Data Management

For an agency starting GAM, data will be available that have been collected as an outcome of activities such as inventory, measurement and reporting, and financial planning. Because each agency will have different practices for data and data management, the *GAM Implementation Manual* does not contain a recommended best practice. Rather, Chapter 6 of the manual introduces the data and data management concepts that can support GAM implementation, such as data types and function, sources of data, methods of collection, level of detail, and geo-referencing concepts. Chapter 6 also presents summaries of information from international and NCHRP reports that represent the range in available frameworks and guidance for data and data management.

3.7.1 Considering Organizational Structures for GAM

The research team's review of the organizational structures of successful TAM and GAM programs indicated that the individuals responsible for these programs have full-time or nearly full-time assignments to asset management and are not assigned to overlapping design or construction duties. Asset management staff focus almost entirely on asset management and have organizational connections to executives, financial directors, and/or maintenance managers within the agency. Based on the structures of the existing and mature asset management programs examined, the research team recommends this type of organizational structure as an aspirational structure for a new GAM program.

The staff organization structure for existing TAM programs varies by DOT, but typically involves some form of a senior-level enterprise asset manager working in parallel with or within other functional disciplines, such as design, construction, O&M, financial, and administration. For development of the *GAM Implementation Manual*, it was anticipated that most DOTs would not be able to formally establish a high-functioning GAM implementation team at the start of GAM implementation. In these situations, the manual indicates that a GAM implementation team can be as simple as a single individual who starts the inventory and assessment process using the accompanying GAM Planner. At this level, this could be a duty added to the existing TAM function of staff within the engineering or geotechnical design divisions, incorporated into bridge or pavement management groups, or even within the maintenance and operations function.

The *GAM Implementation Manual* emphasizes the cross-disciplinary nature of asset management, which is supported through the review of existing TAM programs and information contained in IIMM (IPWEA 2015). As presented in the manual, the staff dedicated to a GAM program should expect to interact with other disciplines within an agency, including:

- O&M staff, to understand work performed or needed for geotechnical assets;
- Budget and financial planning staff, for development of short- and long-term financial plans;
- Traffic and safety staff, to understand what opportunities exist for measuring the traffic disruption or potential safety incidents that result from adverse geotechnical asset performance;
- Enterprise IT or other agency staff responsible for tracking expenses associated with geotechnical assets (this may also be a function of O&M staff);
- TAM and other planning staff charged with asset management and strategic performance planning;
- Engineering and project delivery staff who are involved in design or influential decisions for geotechnical assets;
- Data management and/or GIS staff, for developing compatibility with established data systems and improving communication of results through mapping or geo-referenced data systems used by the organization;
- Other asset groups, such as bridge and pavement, that can support cross-asset management options; and
- Executive management, for agreement on performance objectives, building consensus, and program support.

To assist with building consensus and communication, the *GAM Implementation Manual* suggests a geotechnical asset manager form a cross-disciplinary GAM working group or steering group that enables the cross-disciplinary relationships necessary to support GAM. The purposes for such a working group include:

- Developing a wider base of support in the agency,
- Sharing of information, and
- Coordination with other activities that influence asset management, and developing the business cases for GAM across several disciplines.

3.7.2 Prioritizing Treatments Based on Risk and Investment Criteria

The case study synthesis indicates that only a few DOTs currently fund some form of GAM program, and for those that do, the investment amounts do not achieve desired needs. For the remaining DOTs, funding for GAM occurs as a course of standard reactive maintenance activities or unplanned encumbrances from existing budgets. Information from the successful and long-standing GAM programs in the United Kingdom indicates that investment needs exceed available funds, even for a mature program. As a result, prioritization approaches are beneficial within a GAM program to ensure that the program satisfies the most pressing investment needs. Simply stating a program-level investment need that shows a favorable ROI does not guarantee enabling program funding, given that every asset group is likely in a similar investment need condition. Additionally, bridge and pavement asset management programs will have federally authorized requirements that must be followed and a new program, such as GAM, will need to demonstrate the benefits that will result from a reallocation of limited funds within an agency.

- **Risk Prioritization:** The *GAM Implementation Manual* presents a discussion of differing prioritization concepts that can be considered when communicating needs with executive stakeholders who can enable program funding. These risk prioritization areas include selecting treatment candidates based on concentration of risk, acceptable risk exposure levels, sources of risk, type of risk, cross-asset risks, critical routes or high-value assets, or risks to outside compliance needs.
- **Investment Prioritization:** Candidate projects can be evaluated based on the anticipated ROI when considering the life-cycle costs and benefits. The *GAM Implementation Manual* discusses the processes for life-cycle cost analysis using NPV and cost-benefit analysis to identify those treatment projects with the greatest ROI. Within this process, the manual also suggests evaluating opportunities for cross-asset collaboration as a means to realize benefits from shared investments across asset groups.
- **Candidate Treatments:** The success of GAM implementation will depend on having the flexibility to adjust to differing levels of investment capacity, agency risk tolerance, and performance. Using the prioritization process described in the manual, the asset manager can identify and develop candidate projects with differing investment needs that are data driven, that consider differing levels of risk and performance benefits, and that can adapt to agency TAM culture.

3.7.3 Incorporating GAM in Design

Most established and long-standing design methods for geotechnical assets have been developed based on safety margin and reliability concepts. Because these methods were established before the development of asset management practices, the focus of the safety and reliability framework is generally directed at complete asset failure or total loss of service life. Consequently, the incorporation of asset management considerations during the design process of new geotechnical assets is an important step in a GAM implementation. The *GAM Implementation Manual* presents a series of questions and guidance to enable geo-professionals to incorporate asset management considerations into the design practice.

3.7.4 Training Considerations for GAM Implementation

Both the case study and literature synthesis indicated that training in asset management concepts would be beneficial for those starting GAM programs. Suggested training topics include:

- Introduction to TAM;
- Introduction to GAM and the *GAM Implementation Manual*, including:
  - Purpose and need for GAM;
  - Implementing GAM (including discussion of the list of steps and model in Chapter 2 of the manual);
  - Linking TAM to GAM;
  - Examples of GAM practices;
  - Getting started; and
  - Overview of the GAM Planner, with examples;
- Risk and risk management; and
- Life-cycle cost analysis.

Conclusions and Suggested Research

4.1 Conclusions

As a general conclusion, applying TAM concepts to geotechnical assets is a beneficial process for managing life-cycle risk, performance, and investment for assets such as embankments, slopes, retaining walls, and subgrades. Fortunately, information from the few long-term and sustainable GAM programs in other countries and from existing infrastructure systems indicates that state transportation agencies can be confident of the benefits without having to undertake new research or implement untested processes and systems. **It is certainly possible for agencies to start implementing GAM now regardless of investment capacity and expertise.**

For an agency to begin recognizing the benefits of incorporating geotechnical assets into TAM, it is suggested that the primary goal should be starting GAM implementation and progressing inventoried assets through the TAM steps without delay. Evidence from currently successful GAM programs indicates that benefits are possible without having to first complete the asset inventory or finalize all the processes and data systems that support implementation. Rather, agencies can benefit from starting with a simple asset management strategy and relying on justified process improvements with time. This approach is both preferred and supported by evidence from successful programs. In the United Kingdom, Network Rail's inventory completion took more than 11 years, and the first GAM policy document was not released until almost 6 years after the start of the program.

The implementation framework developed for this project is structured to encourage agencies to begin GAM implementation. The approach is intended to trigger engagement for performing GAM without requiring a high level of motivation or technical ability. Cross-industry research indicates the importance of considering the components that underpin motivation and the ability to succeed at a new task. Considering these factors is essential to increasing the likelihood that the necessary behaviors will be adopted. This is not a reflection on the individuals who may undertake GAM, but rather a recognition of the challenges of implementing new processes and efforts in complex organizations consisting of individuals who already have high demands on their time and resources.

Once GAM implementation has started and initial treatment recommendations have been developed, geotechnical assets will still need to compete for investment among the other asset groups and programs of the DOT. Thus, treatment planning is necessary to identify project-level options that incorporate the range of risk and investment priorities that are of interest to agency executives. The recently published *NCHRP Research Report 885: Guide to Creating and Sustaining a Culture of Innovation for Departments of Transportation* provides many helpful suggestions (Lorenz et al. 2018).

79. South Carolina Department of Transportation, Asset Data Collection Assessment Research Summary, SCDOT No. SPR 716, FHWA No. FHWA-SC-19-02 August 2019.
Jennifer H. Ogle, Clemson University.

The MAP-21/FAST Act requires state departments of transportation to transition to data driven, performance and outcome-based programming, which has required states across the nation to revisit their data collection and maintenance efforts. This report documents research conducted to ensure that the future SCDOT database specifications and data collection efforts support federal requirements for data-driven performance-based management of transportation facilities, as well as meet the needs of SCDOT in a cost-effective manner.

Problem

A large portion of South Carolina Department of Transportation's (SCDOT) current data is stored in the Roadway Information Management System (RIMS). SCDOT, like most states, originally developed their RIMS system to support reporting requirements for the Federal Highway Administration's Highway Performance Monitoring System (HPMS) program. Thus, the individual elements contained in the database do not always meet the needs of alternate users in other departments within the DOT. Over time, other datasets have been merged with RIMS to enable expanded data analytic capabilities including crash information, video log, and traffic counts. In addition to RIMS, SCDOT maintains several databases to support specific business operations such as maintenance (signs and roadside hardware) and traffic operations (signals and ITS equipment). The **overarching goal** of this research is to ensure that the future SCDOT database specifications and data collection efforts support the MAP-21 requirements for data-driven performance-based management of transportation facilities, as well as meet the needs of SCDOT in a cost-effective manner. To achieve this goal, three specific objectives were established:

Obj 1 – Identify SCDOT state of practice for asset data collection/maintenance.
Obj 2 – Conduct vendor assessment of MLS to seek accuracy and efficiency.
Obj 3 – Provide recommendations for database development and related data collection methods/technologies.

Research

The review of critical and non-critical data elements from the FHWA Model Inventory of Roadway Elements (MIRE) and SCDOT databases revealed that about 60% (122 of 202) of MIRE data elements were not collected by SCDOT (i.e., gaps). This included a few MIRE Fundamental Data Elements (FDEs), mandated Highway Performance Monitoring System (HPMS) Full Extent Elements (FE), and a considerable number of Highway Safety Manual elements needed for use with SC-specific safety models. Several gaps were identified and listed below:

- SCDOT lacks more than 50% of the database elements required for HSM safety implementation on state roadways. These data elements contain information on Segment Cross Section, Segment Roadside Description, At Grade Intersection/Junctions, and Approach Descriptors (Each Approach).
- The SCDOT databases have about 88% of the MIRE FDE data elements (excluding HOV because there were none in SC).
- MIRE Fundamental Data Elements follow HPMS reporting requirements closely. Unfortunately, the HPMS coverage is biased toward the higher functional classes and only sampled

Recommendations

Three main recommendations include: 1) Raise the level of importance of data – treat it as an asset, define core principles, and develop a department-wide directive that recognizes the strategic uses of data across all business offices; 2) Implement a tiered approach to data governance, appoint a dedicated data governance coordinator, and promote structured decision-making and active oversight of

the Department's data assets; and
3) Undertake a new inventory of roadway attributes using mobile LiDAR technology to replace the data inventoried 30 years ago and develop enterprise-wide plans to capitalize on additional opportunities for MLS point cloud data.

Value & Benefit

This study evaluated data needs within the department and developed recommended data specifications for a state-of-the-art enterprise data system to support the business SCDOT functions as well as meet requirements of federal reporting mandates. The analysis reported here will aid SCDOT in implementation of an asset data system that meets the department's needs without redundancies and maintaining only data elements that have positive cost-benefit for the department. Having a comprehensive roadway inventory with supporting business data will allow the SCDOT to make better decisions faster, and this should translate to improved effectiveness.

80. South Carolina Department of Transportation, Asset Data Collection Assessment Research Final Report, SCDOT No. SPR 716, FHWA No. FHWA-SC-19-02 August 2019.
Jennifer H. Ogle, Wayne Sarasua, Mashrur 'Ronnie' Chowdhury, Brad Putman, Jeffrey Davis, Nathan Huyhan, and Paul Ziehl (Clemson University).
Refer to above information in literature review document 79- South Carolina Department of Transportation, Asset Data Collection Assessment Research Summary, SCDOT No. SPR 716, FHWA No. FHWA-SC-19-02 August 2019. Additional in-depth research information is expanded on in the final report.

81. NCHRP Synthesis 508-Data Management and Governance Practices, Nasir Gharaibeh, Isaac Oti, David Schrank, and Johanna Zmud, Texas A&M transportation Institute, The Texas A&M University System, College Station, Texas.

SUMMARY Data-driven processes and technological advances have led to a steady increase in the amount and complexity of data collected and managed by state departments of transportation (DOTs) and local transportation agencies, such as municipalities and metropolitan planning organizations (MPOs). Examples of these data include asset inventory and condition data, usage data from traffic counts, roadway design and construction data, and financial data. These data reside in attribute databases, geospatial databases, computer-aided design (CAD) files, three-dimensional models, multimedia files (e.g., image, video), and other forms. Increasingly, transportation agencies are viewing these data as assets that should be managed systematically and effectively, as physical infrastructure assets are managed.

Although data provide opportunities to facilitate decision making at transportation agencies, there are challenges involved in managing large and diverse data that serve multiple business needs. These challenges are manifested in various aspects of data management, such as data quality assurance, integration, and access. This synthesis provides information on current practices in data governance, data warehousing and cloud computing, data integration and sharing, and data quality assurance. This information can be used by transportation agencies to learn about and ultimately advance the current state of the practice in transportation data management and governance.

The information provided in this synthesis was gathered through a review of the literature, a two-phase online survey, and follow-up interviews with a sample of four agencies. All 52 DOTs (50 states, District of Columbia, and Puerto Rico) were invited to participate in the surveys. The surveys also were distributed to municipalities and MPOs through the National Association of City Transportation Officials (NACTO) and the Association of Metropolitan Planning Organizations (AMPO). Forty-three DOTs responded to the Phase 1 survey, and 34 DOTs responded to the follow-up survey, representing response rates of 83% and 65%, respectively. Of local agencies, 19 responded to the Phase 1 survey and 11 responded to the follow-up survey. The surveys were conducted through NCHRP in cooperation with AASHTO. AASHTO provided an e-mail distribution list to members of the Standing Committee on Planning (SCOP) and members of SCOP's Data Subcommittee.

In the data governance area, the study found that a pyramid-shaped data governance structure is commonly used in the literature. This structure consists of (1) an upper-level council or committee providing oversight and strategic direction, (2) enterprise data stewards providing coordination across business units, and (3) stewards accountable for the quality and use of individual information technology. Data stewards, coordinators, and custodians hold various positions in their business areas, such as planners, engineers, and geographic information system (GIS) specialists. Interviews conducted as part of this study with a sample of transportation agencies indicated that key motivations and early benefits of implementing data governance include (1) improved accountability to produce high quality and reliable data (sources of truth), (2) ensuring that the data are accessible and integrated using a common linear referencing system, and (3) engaging business areas within transportation agencies in their data, rather than viewing data as strictly an information technology (IT) issue.

Currently, a bottom-up approach for data management appears to be taking place. A more top-down data governance approach could help recognize and leverage the value of data generated and/or stored in various agency silos and could spur increased data integration. In most cases, DOTs have data

stewards and data coordinators for managing individual data sets and coordinating data management across multiple data sets within a business area (e.g., asset management, safety). However, most agencies indicated they do not have a data governance council or board (responsible for policy making and coordination at the enterprise level) and do not have a document that describes their data governance model and serves as a guide. Most survey respondents described the following as major factors in limiting progress toward implementing data governance: (1) lack of staffing, (2) other mission-related issues are more pressing, and (3) lack of resources.

With respect to data warehousing and cloud computing, the study found that most DOTs store and manage data collected during the operation and monitoring phases of roadway systems (e.g., roadway inventory, condition, and performance) in data warehouses or marts. Conversely, data collected at the early phases of the asset/project life cycle are more likely to reside in disparate files and databases. Although there is a general agreement in the literature that transportation agencies collect and manage large amounts of data, most DOTs and local agencies do not have reliable estimates of the amount of data they maintain. The use of cloud computing services for storing and managing data is expected to grow; however, most DOTs and local agencies are uncertain about the magnitude of this growth in their agencies.

Transportation agencies are using multiple linear and geographic referencing methods in their data sets, indicating that incompatibility among these methods remains an impediment to increased data integration within these agencies. The use of a common referencing system that unifies these methods can potentially facilitate data integration within transportation agencies.

Most survey respondents indicated that the following strategies have major effects on improving data sharing and access: (1) increased use of web-based data storage and access, (2) improved database management systems, and (3) reduced use of hardware and software that require specialized (e.g., proprietary) data formats.

The study addressed seven data quality dimensions: accuracy, completeness, timeliness, relevancy, consistency, accessibility, and access security. Most survey respondents indicated that these data quality dimensions are evaluated in at least some data areas in their agencies. For DOTs, timeliness, accuracy, and access security are most commonly evaluated. Conversely, consistency is the data quality dimension least evaluated by DOTs. Slightly more than half of the DOT respondents indicated their agencies have mechanisms in place for incorporating feedback from data users into the data collection process. These feedback mechanisms include ad hoc meetings, surveys, steering committees, web forms, and direct e-mails.

Finally, this study identified several areas of future research, including development of a data management and governance guidebook and training materials; identifying the benefits, costs, and risks (e.g., security risks) of adopting cloud computing services for transportation agencies; development of methods and metrics for evaluating data quality considering multiple quality dimensions; development of guidance and framework for integrating data within transportation agencies; case studies to assess the magnitude and complexity of data managed by transportation agencies; and development of methods and case studies for mining archived data at these agencies.

BACKGROUND

Data-driven processes and technological advances have led to a steady increase in the amount and complexity of data collected and maintained by state departments of transportation (DOTs) and local transportation agencies, such as municipalities and metropolitan planning organizations (MPOs). Examples of these data include asset inventory and condition data, usage data from traffic counts, roadway design and construction data, and financial data. Data reside in attribute databases, geospatial databases, computer-aided design (CAD) files, three-dimensional models, multimedia files (e.g., image, video), and other forms. Increasingly, transportation agencies are viewing these data as assets to be managed systematically and effectively, in a manner similar to how physical infrastructure assets are managed (Spy Pond Partners, LLC and Iteris, Inc. 2015a). A rule of thumb often used in the private sector is that the volume of corporate data doubles every 18 months (Bhansali 2013), indicating the ever-increasing volume of data in today's world.

Although data provide opportunities to facilitate decision making at transportation agencies, there are challenges involved in managing large and diverse data that serve multiple business needs. These challenges are manifested in various aspects of data management, such as data quality assurance, integration, and access. The literature suggests that these challenges are more widespread in managing data across, rather than within, organizational units at transportation agencies (Spy Pond Partners, LLC and Iteris, Inc. 2015a). Data maintained by a specific unit within the agency often need to be shared with multiple users and integrated with multiple data sets. For example, traffic monitoring data are used for conducting safety analyses, developing transportation improvement programs, designing pavement, and developing asset management plans. As a result, it is important that traffic data be integrated with multiple data sets to serve multiple business needs (e.g., integration of traffic volume data with pavement condition data to develop pavement management plans). However, currently these data often reside in a collection of modern and legacy databases that are difficult to integrate (Cambridge Systematics, Inc. et al. 2010). These difficulties in integrating disparate data can lead to collecting data that already exist within other parts of the agency. An area prime for reducing the duplication of data is the creation of digital as-builts from three-dimensional models used in design and construction. However, the integration of these as-builts into legacy data management systems remains a challenge.

TERMINOLOGY

Key terms used in the survey instrument and in this report are defined as follows:

- Access security: Ability to restrict access to data to maintain security.
- Accessibility: Ability of authorized users to access the data.
- Accuracy: Closeness between a data value and the real-world value that it represents.
- Cloud computing: Date are stored and managed on remote computers "in the cloud." These computers are owned and operated by others and connect to users' computers by means of the Internet.
- Completeness: Absence of missing values in the data set.
- Consistency: Degree to which the data item is presented in the same format across agency.
- Data governance board/council/steering committee: Group that institutes policies and oversees activities regarding data governance throughout the organization. Data governance is defined as "the execution and enforcement of authority over the management of data assets and the performance of data functions" (Cambridge Systematics, Inc. et al. 2010).
- Data coordinator: Individual or committee that coordinates the organization, sharing, access, and use of multiple data sets within a business area (e.g., asset management, safety).
- Data warehouse/mart: A data warehouse is a unified repository of current and historical data obtained from multiple sources. A data mart is a scaled-down version of a data warehouse.
- Data steward: Individual who is accountable for assuring the quality of a specific data set, ensuring compliance with data rules and regulations, defining metadata, and relaying the appropriate use of the data.
- Data custodians: Cross-functional group of individuals, vendors, and data managers who are responsible for day-to-day execution of the governance rules and data management activities.

82. AASHTO Committee on Data Management and Analytics, Draft Strategic Plan and AASHTO CORE Data Principles, taken from website: https://data.transportation.org/subcommittee-charter/

CHARTER NAME

The name of this Committee shall be the American Association of State Highway and Transportation Officials (AASHTO) Committee on Data Management and Analytics.

OUR PURPOSE

The Committee on Data Management and Analytics shall address the collection, procurement, processing, analysis, reporting, and sharing of transportation data. The Committee on Data Management and Analytics is dedicated to addressing issues related to knowledge, expertise, resources and tools needed by State DOTs to implement a robust data management and analytics program within their agencies.

OUR STRATEGIC PLAN DRAFT

GOAL 1

Promote AASHTO's *Core Data Principles* to guide the use of public or private sector transportation data.

Strategy 1

Conduct webinars and workshops to disseminate AASHTO's Core Data Principles.

Strategy 2

Maintain a website with the AASHTO's Core Data Principles (CDP) and links to state Data Business plan efforts and research projects with CDP integrated.

Subcommittes Involved:

Professional Development **(Strategy 1, 2)** – Jason Siwula, KY, Co-Chair; Patrick Whiteford, AZ, Co-Chair
Communicating Data **(Strategy 1, 2)** – John Selmer, IA, Chair

GOAL 2

Support member agencies with recruitment and retention, capacity building, and skill development related to data management and analytics. (AASHTO Goal 1)

Strategy 1

Participate in a joint task force on workforce issues with other relevant committees (Knowledge Management; Human Resources; Agency Administration)

Strategy 2

Support and assist member agencies in capacity building, skill development, recruitment, and retention by sharing best practices related to data management and analysis.

Strategy 3

Advocate for and educate practitioners on data use and addressing data issues.

Subcommittes involved:
Professional Development **(Strategy 2, 3)** – Jason Siwula, KY, Co-Chair; Patrick Whiteford, AZ, Co-Chair
Policy **(Strategy 1, 2)** – Tarun Malhotra, MI, Chair
Outreach and Coordination **(Strategy 2, 3)** – Lou Anne Dougherty, NE, Chair

GOAL 3

Lead in transportation data standardization efforts. (AASHTO Goal 2)

Strategy 1

Work to understand needs, develop guidance, and communicate data standards.

Strategy 2

Develop guidance and communicate data standards.

Subcommittes involved:
Research **(Strategy 1, 2)** – Chad Baker, CA, Chair
Technical Services **(Strategy 1, 2)** – Mike Bousliman, MT, Chair

GOAL 4

Support both member agencies' decision-making data and analytics needs and the Board of Directors needs on policy, program, regulations and guidance related to data management and analytics (AASHTO Goals 1 and 3)

Strategy 1

Coordinate and collaborate with other AASHTO committees to understand their data and analytics needs.

Strategy 2

Document and share with member agencies successful industry practices on the application of data and analytics to better inform decision-makers and support the decision-making process. .

Strategy 3

Facilitate the development and advancement of tools to support decision making data and analytics needs. .

Strategy 4

Coordinate and collaborate with other committees to understand and document information needs of the Board of Directors on policy, program, regulations and guidance.

Strategy 5

Explore and summarize national and international trends, successful practices, and research related to data management and analytics in order to support the Board of Directors in federal policy, programs, regulations, and guidance.

Strategy 6

Collaborate with other committees and Federal partners to develop summaries and white papers to support the development of federal policy, programs and regulations related to data use, management and analytics.

Subcommittes involved:

Policy **(Strategy 1, 4)** – Tarun Malhotra, MI, Chair

Outreach and Coordination **(Strategy 4, 5)** – Lou Anne Dougherty, NE, Chair

Communicating Data **(Strategy 1, 2)** – John Selmer, IA, Chair

GOAL 5

Support member departments in achieving best data practices. (AASHTO Goals 1, 2, 3, and 4)

Strategy 1

Support research to advance the development and use of tools and best practices in communicating data, data management and analytics.

Strategy 2

Coordinate with other AASHTO committees and Federal agencies and develop and advance an annual list of research priorities.

Strategy 3

Sponsor, coordinate and disseminate research to advance best practices in the management, use and standards relating to data and analytics.

Strategy 4

Assist member agencies with the adoption/implementation of completed research.

Strategy 5

Create a repository on the use of third party data sources by member agencies.

Subcommittes involved:
Research **(Strategy 1, 2, 3)** – Chad Baker, CA, Chair
Technical Services **(Strategy 1, 3)** – Mike Bousliman, MT, Chair
Communicating Data **(Strategy 1, 4)** – John Selmer, IA, Chair

GOAL 6

Foster communities of practice in topic areas of interest as determined. (AASHTO Goals 1, 2, and 4)

Strategy 1

identify champions in areas of interest, maintain electronic meeting space and information exchange

LEADERSHIP & SUBCOMMITTEES

DATA MANAGEMENT AND ANALYTICS

Learn More

Gregory Slater, Secretary of Maryland DOT, MD State Highway Administration – Committee Chair

Learn More

April Blackburn, Chief of Transportation Technology, Florida DOT – Committee Vice-Chair

The Committee on Data Management and Analytics includes the following Subcommittees:

PROFESSIONAL DEVELOPMENT

Jason Siwula, KY, Co-Chair
Patrick Whiteford, AZ, Co-Chair

Addresses issues of professional development and capacity building

POLICY

Tarun Malhotra, MI – Chair

Addresses policy issues regarding data

RESEARCH

Chad Baker, CA – Chair

Addresses research needs and issues

TECHNICAL SERVICES

Mike Bousliman, MT - Chair

Oversees technical services and programs under the Data Committee such as GOTUG, Gis-T and any others that are developed

OUTREACH AND COORDINATION

Lou Anne Dougherty, NE - Chair

Maintains relationships with other committees and organizations as pertinent to Committee business

COMMUNICATING DATA

John Selmer, IA – Chair

Addresses communication issues around data, data needs, gaps, research, outreach, and as needs arise

CYBERSECURITY

Matt Modarelli, WA - Chair

This subcommittee works jointly with Operations and Resiliency (TSSR) on issues of cybersecurity

AASHTO CORE DATA PRINCIPLES

DATA MANAGEMENT AND ANALYTICS

In 2013, this set of AASHTO Core Data Principles was adopted by the data and planning community. The principles were developed and vetted by the:

- SCOP data sub-committee,
- the CTPP oversight board (data community),
- and US DOT data leadership

The principles have been vetted through SCOP, and key state and federal transportation data staff.

PRINCIPLE 1 - VALUABLE: DATA IS AN ASSET

Data is a core business asset that has value and is managed accordingly

Rationale — Data is a core industry asset that has measureable value and is managed accordingly. Accurate, timely data is critical to accurate, timely decisions. Transportation agencies already manage many of their physical assets: roads, bridges, signs, lights, etc. Data is no different and must be treated like other physical assets. Data is the foundation of our decision-making, so we must also carefully manage and maintain data to ensure that we know what we have and where it is, can rely upon its accuracy, and can obtain it when and where we need it. Where possible, data should be archived to maintain historical records.

Implications — Treating Data as the asset that it is saves money, effort and resources. When data is appropriately handled it can have a long life with many uses beyond its original one, and serve projects as yet unplanned.

PRINCIPLE 2 - AVAILABLE: DATA IS OPEN, ACCESSIBLE, TRANSPARENT AND SHARED

Access to data is critical to performing duties and functions, data must be open and usable for diverse applications and open to all.

Rationale — The value of data is increased when it can be used with other data and in a variety of applications. Users must have access to the data critical to their duties and functions. Wide access to data leads to efficiency and effectiveness in decision-making, and affords timely response to information requests. Using data must be considered from an enterprise perspective (across the organizations or across multiple organizations) to allow access by a wide variety of users. Transportation agencies at all levels of government (federal to state to local) hold a wealth of diverse data sets, but it is often stored in different databases that are incompatible with each other or difficult to find. Timely access to accurate data is essential to improving the quality and efficiency of decision-making. It is less costly to maintain timely, accurate data and then share it, than it is to maintain duplicative data in multiple locations or processes. Shared data will result in improved decisions since we will rely on fewer sources of more accurate and timely managed data for decision-making. Sharing is also necessary to triangulate on subjects that may not be measured directly, and allows for serendipity. Insights often come from bringing fresh eyes to data.

As transportation organizations work with more stakeholders and external partners, it is essential that data be shared. Making data electronically available will result in increased efficiency when existing data entities can be re-used. It is more effective to de-protect transportation data than it is to over-protect.

Implications — Agencies are increasingly under in informal mandate to “do more with less.” Sharing data is a key step in executing this mandate. Accessible data will ultimately reduce burden on staff time as data becomes more accessible.

PRINCIPLE 3 - RELIABLE: DATA QUALITY AND EXTENT IS FIT FOR A VARIETY OF APPLICATIONS

Data quality is acceptable and meets the needs for which it is intended.

Rationale — Data quality is acceptable and meets the need for which it is intended. Data that is collected, produced, and reported must be fit for purpose. That is, of sufficient accuracy and integrity proportional to its use and cost of collection and maintenance. Data is used in all areas of the transportation decision-making process from planning to design to operations to performance management. Furthermore, it is increasingly being used externally by citizens and customers to inform their personal decisions, and by stakeholders to assess the aggregate performance of a transportation organization. Significant human and system resource is consumed in the collection, manipulation and dissemination of data whether of high quality or not, so it is essential that the most effective use of public funds is achieved through appropriately directed attention to data quality and the procedures to realize quality. Additionally, data must be archived appropriately to preserve both its usefulness and the historical record. When possible, data should be spatially oriented. Data quality increases as the application of the data increases. Data that has spatial orientation or attribution can easily be used in GIS systems. When data assets can be analyzed in a spatial context, not only can a greater analysis be completed in terms of geographic context, but also the data and any analysis results can be more easily communicated via mapping and other formats more applicable to public understanding.

Implications — When data is fit for purpose appropriate cost decisions are made in its collection and use. In cases where a rough sketch is appropriate, appropriate data collection and use may follow. Where large programs, investments, or systems are being developed and vetted, those data must be fit for that purpose. Data precision is matched to the task at hand.

PRINCIPLE 4 - AUTHORIZED: DATA IS SECURE AND COMPLIANT WITH REGULATIONS

Data is trustworthy and is safeguarded from unauthorized access, whether malicious, fraudulent or erroneous

Rationale — Data is trustworthy and is safeguarded from unauthorized access, whether malicious, fraudulent or erroneous. Open sharing of information and the release of information via relevant agreement must be balanced against the need to restrict the availability of classified, proprietary, and sensitive information.

Implications — When data is secure and appropriately regulated there is greater trust and confidence in its use.

PRINCIPLE 5 - CLEAR: THERE IS A COMMON VOCABULARY AND DATA DEFINITION

Data dictionaries are developed and metadata established to maximize consistency and transparency of data across systems.

Rational — Both unstructured and structured data must have a common definition to enable sharing of data. However, data must not be compromised below the use of its original purpose. Commonality may take the form of relations, bridges and crosswalks between definitions

Implications — A common vocabulary will facilitate communications, enable dialogue to be effective and facilitate interoperability of systems, however, utility must not be compromised.

PRINCIPLE 6 - EFFICIENT: DATA IS NOT DUPLICATED

Data is collected once and used many times for many purposes.

Rationale — Development of information services should be made available to multiple users and stakeholders and is preferred over the development of information and data silos which are only used for a single purpose or user.

Implications — Duplicative capability is expensive and propagates conflicting data. It also goes against a policy of sustainability in the use of data and the infrastructure resources required to maintain the data, such as computer servers and data warehouses.

PRINCIPLE 7 - ACCOUNTABLE: DECISIONS MAXIMIZE THE BENEFIT OF DATA

Timely, relevant, high-quality data are essential to maximizing the utility of data for decision making.

Rationale — The purpose of data collection is to help support the decision-making process. Users of the data, as well as information derived from the data, are the key stakeholders in the data collection and analysis process. The data is being collected to address a certain policy goal or objective. In order to ensure information management is aligned with the purpose, users must be involved in the different aspects of the information environment. The decision makers, managers, and the technical staff responsible for developing and sustaining the information environment need to come together as a team to jointly define the goals and objectives of the data collection processes.

Implications — Resources are limited. Maximizing existing resources is essential.

Appendix B

AASHTO RAC Survey

B-1

Survey Results

Responses to the Mississippi DOT survey to the AASHTO RAC, March 2021: <u>Data Elements for Bridge Design, Materials, Construction, Inspection, and Maintenance</u>

State DOT	1. Bridge Data Elements: **In addition to the Bridge Data Elements associated with Bridge Element Level Condition Inspections, what are the other Bridge Data Elements utilized/managed by your Bridge Division/staff?**	2. Documentation: **Do you currently have a user manual, procedures, or flowchart that lists/describes the various bridge data elements, and State DOT staff associated with the varies Bridge Data Elements? If yes, could you provide a copy of the documentation or link to it?**	3. Software: **What software is used to manage and access the various bridge data elements?**	4. Management: **Do you have a Data Governance structure or Data Assets Oversight Group who makes decisions regarding bridge data assets and/or the Department's overall data assets?**
Arkansas	We use the National Bridge Elements and Bridge Management Elements. We don't use any Agency Elements	We mention the elements a little in our Bridge Inspection Manual but mostly rely on AASHTO Manual for Bridge Element Inspection	InspectX	We handle the bridge elements in the Heavy Bridge Maintenance section which falls under Maintenance Division.
Delaware	Bridge Inspection related data and documents are stored in Bridge Inspection Files with DelDOT's Bridge Management Section within our AASHTO BrM Software databases, Inspect (in-house document storage program), and on our network.	No – we do not have an over arching bridge data user manual, procedures, or flowchart.	- Bridge Inspection Files: AASHTO BrM and Inspect Program (in-house document storage program) / electronic storage of network as well - Project Plans: Archived Plan Website or Archived files / we also store hard copy bridge plans in our Bridge Inspection Files - Various manuals – DelDOT's Design Resource website	No – we don't really have an overarching authority that governs all aspects of bridge data & documents
Georgia	We do element level inspections on both NHS and Non-NHS bridges.	We use the tables and user manual provided by FHWA. Our Bridge Inspection teams collect the element data during normal inspections.	We use software named InspectX by Bridge Intelligence to manage and access the various bridge data elements	No we do not have a Data Governance structure or Data Assets Oversight Group who makes decisions regarding bridge data assets and/or the Department's overall data assets.
Indiana	We use the Basic AASHTO Elements that are provided in BIAS. We do not use any Agency Elements	We use the AASHTO Manual for Bridge Element Inspections.	We use BIAS from Bentley	Yes, we recently initiated an agency wide Data Governance program. The focus is on data ownership; consistency in definitions and reporting; and quality.
Iowa	We use 6 Agency defined elements. Their definitions are included in the attached manual. Please do not distribute this manual. We have an agreement with AASHTO that this manual and it's modifications are for Iowa DOT use only.	We have modified the attached Manual for Bridge Element Inspection with permission from AASHTO.	We use AssetWise Asset Reliability Inspections from Bentley Systems, Inc. The elements are collected in this web based software and transmitted to AASHTO BrM.	We have just initiated our Data Governance group. They have not made any decisions on bridge data yet. Bridge data format, structure, and collection is the responsibility of the Bridge Bureau.
Minnesota	See our bridge inspection manual chapter D which lists all the inventory elements we keep. Chapter B has all the inspection element information. We have 80 AASHTO elements and 30 Agency Defined elements.	Yes, see link. https://edocs-public.dot.state.mn.us/edocs_public/DMResultSet/download?docId=8726526	SIMS (Structure Information Management System) an Assetwise product from Bentley. We also house data in BrM.	We have a Bridge Asset Management unit in the Bridge Office and an Asset Management Program Office that collaborates with all assets in the department. Contact Ed Lutgen (Edward.lutgen@state.mn.us) with specific questions.
Missouri	We only do element level inspections on NHS bridges and only collect element data for the elements required by FHWA.	We use the tables provided by FHWA. Inspection staff collect the element data when doing normal inspections.	Element information is stored in our inspection system, which is part of our Transportation Management System.	No

State DOT	**1. Bridge Data Elements:** **In addition to the Bridge Data Elements associated with Bridge Element Level Condition Inspections, what are the other Bridge Data Elements utilized/managed by your Bridge Division/staff?**	**2. Documentation:** **Do you currently have a user manual, procedures, or flowchart that lists/describes the various bridge data elements, and State DOT staff associated with the varies Bridge Data Elements? If yes, could you provide a copy of the documentation or link to it?**	**3. Software:** **What software is used to manage and access the various bridge data elements?**	**4. Management:** **Do you have a Data Governance structure or Data Assets Oversight Group who makes decisions regarding bridge data assets and/or the Department's overall data assets?**
Montana	Montana Dept of Transportation (MDT) Bridge Bureau manages most data associated with Bridge preliminary engineering, including calculations, computer analysis results and reports, and other supporting documentation such as photos, sketches, etc. Milestone reports, official memos and CADD drawings for construction contracts are copied to an agency-wide document management system. Historic bridge construction drawings and as-builts are also stored and managed by MDT Bridge Bureau on agency share drives.	No, MDT Bridge does not have a manual or flowchart for managing this information.	Most data files are stored on system share drives. Other data is stored on agency databases and accessed through systems like AASHTOWare BrDR.	MDT is currently developing a data governance initiative.
Nevada	NDOT has developed a list of Agency Defined Elements (ADE) with Defects and Condition States. See attached.	We have a Bridge Inspection Manual. However, the file is too large to transmit via email. You should receive an email allowing access to the file on OneDrive. Please contact me if you do not receive the email or you are unable to access the file.	Bentley AssetWise	We do not have a Data Governance structure or Data Assets Oversight Group.
New Jersey	In addition to standard NBE and Bridge management Elements (BME), there are about 26 ADEs collected by NJDOT. The chart for ADE can be found on page 13 of NJDOT Bridge Element Inspection Manual. To get more details on these ADEs, please refer to the Bridge Element Inspection Manual.	Yes, the web link mentioned above assists in the collection of the element data. The manuals for Procedures and Management are not completed. Both manuals are being developed through our internal Staff Augmentation process.	As mentioned above, NJDOT utilizes Bentley's AssetWise Asset Reliability Inspections Tool (Formerly InspectTech) for data collection and data quality purposes. This is accessed by inspectors through Bentley's hosted web based application. However, for analysis of element data, AASHTOWare's Bridge Management (BrM) is utilized for deterioration and predictive modeling. Element data is transferred from CombIS to BrM through a custom developed web services API. The BMS team can access BrM Element Data at this time.	NJDOT Data Governance structure is limited. There is do dedicated Data Asset Oversight Group at NJDOT at this time. The decision making regarding Bridge Needs is currently performed by Division of Bridge Engineering and infrastructure Management SME group which consist for the BMS team (also called Bridge Asset Management), Bridge Inspection team (also called Structural Evaluation), Bridge Design team, and Structural Engineering Value Solutions team.

State DOT	1. Bridge Data Elements: **In addition to the Bridge Data Elements associated with Bridge Element Level Condition Inspections, what are the other Bridge Data Elements utilized/managed by your Bridge Division/staff?**	2. Documentation: **Do you currently have a user manual, procedures, or flowchart that lists/describes the various bridge data elements, and State DOT staff associated with the varies Bridge Data Elements? If yes, could you provide a copy of the documentation or link to it?**	3. Software: **What software is used to manage and access the various bridge data elements?**	4. Management: **Do you have a Data Governance structure or Data Assets Oversight Group who makes decisions regarding bridge data assets and/or the Department's overall data assets?**
North Carolina	We do not use any elements beyond those defined in the AASHTO Manual for Bridge Element Inspection (MBEI). Some non-element data we record includes: • Streambed soundings to track scour. • Maintenance items broken into tiers of critical finding, priority maintenance, and routine maintenance. • Remaining section measurements. • Estimated replacement cost.	NCDOT utilizes the AASHTO MBEI with additional clarification on how certain condition states for specific elements should trigger certain maintenance flags. Procedures and flowchart items are managed within our in-house inspection software.	In-house inspection software, called WIGINS, is used to record inspection data, manage workflows, and store documentation. An asset management system (Agile Assets' BMS) receives bridge data from WIGINS and is used for system-wide reporting and planning.	NCDOT does not have a data specific oversight group. The Structures Management Unit overseas the development and the functions of the bridge inspection program, including all bridge data requirements, and handles bridge data reporting requests. Within the Structures Management Unit (SMU), led by the State Bridge Engineer, staff involved with bridge data include the NBIS Program Manager, in-house bridge inspectors, a Structure Inventory and Appraisal group for non-inspection bridge data entry and verification, load raters, and a Business Systems Analysis group that is responsible for the BMS. Working with SMU staff is a small IT team for development of WIGINS inspection software and tech support for in-house and consultant inspectors.
Ohio	Ohio has 9 ADE's below: 805 - Wearing Surface - Monolithic Concrete 810 - Prestressed Concrete Slab 815 - Drainage 820 - Steel Seated-Hinge Assembly 825 - Concrete Hinge Assembly 830 - Abutment Backwall 835 - Culvert End Treatment 840 - Approach Slab: Termination or Joint 845 - Culvert Roadway Condition	Not yet. We use AASHTO MBE.	Bentley's AssetWise CE. Went live May 2020.	Yes, but not for elements. See ODOT's Asset Management Website link: ODOT Asset Management website: https://www.transportation.ohio.gov/wps/portal/gov/odot/programs/asset-management

State DOT	1. Bridge Data Elements: **In addition to the Bridge Data Elements associated with Bridge Element Level Condition Inspections, what are the other Bridge Data Elements utilized/managed by your Bridge Division/staff?**	2. Documentation: **Do you currently have a user manual, procedures, or flowchart that lists/describes the various bridge data elements, and State DOT staff associated with the varies Bridge Data Elements? If yes, could you provide a copy of the documentation or link to it?**	3. Software: **What software is used to manage and access the various bridge data elements?**	4. Management: **Do you have a Data Governance structure or Data Assets Oversight Group who makes decisions regarding bridge data assets and/or the Department's overall data assets?**
Oregon	This could potentially take in such a wide swath cradle to grave that I'll likely miss some things. I'll try to concentrate on items useful for bridge management, although some of these bear on element condition, but not on element condition reported to FHWA, although they could be incorporated into those conditions. - Rails, as far as meeting design standards - Chloride Contamination of decks - Channel cross sections - Timber Borings - Underwater inspection Diver reports - Paint condition - Moveable Bridge condition - Inspection photos - Maintenance requests - Costs - Gusset Plate Inspection - Fatigue prone Assessment - Deck Surveys - Movable Bridges Inspection - Load Rating	We do not currently. We are working on an inspection manual that would cover some of these.	For most of these elements we have an ODOT built Reporting tool for inspection reports in which links to these documents are provided (if they exist) for the bridge being reported. We also have an SQL Server database for load ratings that is accessible through a linked Access database, and some of the data is also presented in a custom page on the BrM software that the load rating database updates nightly. We also use Excel.	No.
Wyoming	WYDOT uses many Agency Defined Elements (ADE) that include: • Load Posting Signs • Lighting Assemblies • Conduit Systems • Approach Railing (Metal, Concrete, Timber & Other) • Embankments (Approach & Berm) • Slope Protection (Gabion, Articulated Block, Machine Placed Riprap, Concrete, Geogrid & Retaining Wall) • River Control Devices • Diaphragms/Cross Frames (Steel, Concrete & Timber) • Steel Lateral Bracing • Curb/Sidewalk/Median (Concrete & Timber) • Deck Drains • Pedestrian Railing (Metal, Concrete, Timber & Other) • Wingwalls (Metal, Concrete, Timber & Other) • Retaining Walls (Concrete, MSE & Gabion) Retaining Walls • Column Brace • RC Web Walls • RC Crash Wall • RC Headwalls	WYDOT uses the most current edition of the Manual for Bridge Element Inspection (MBEI) for National Bridge Elements (NBE) and Bridge Maintenance Elements (MBE). We have developed a manual to code ADE conditions.	WYDOT uses AAHTOWare BrM to store and access inventory and inspection data.	WYDOT Bridge Program makes recommendations for preservation, rehabilitation, and replacement of State owned bridges. Other WYDOT Programs provide recommendations for their respective assets.

Responses to the Mississippi DOT survey to the AASHTO RAC, March 2021: Data Elements for Bridge Design, Materials, Construction, Inspection, and Maintenance

State DOT	5. Additional Information:
	In addition to the various data elements associated with inspection of bridges; what are the other data elements that are associated with managing your bridge inventory and which Divisions, Branches, or Units are responsible for the other bridge data elements? Examples include: • Geotechnical/subsurface information • Hydraulics & scour data • Costs • Design data • Load rating information • Bridge project records • Precast manufacture data o Camber information o Concrete compressive strength cylinder break data • Construction information o As-built data o Pile driving records or pile test data o Material certs o Shop drawings • Maintenance data • Repair data • GIS data
Delaware	• Geotechnical/subsurface information - Archived Bridge Design Files • Hydraulics & scour data Design calcs - Archived Bridge Design Files / H&H and Scour Analyses and Scour Plans of Actions: Bridge Inspection Files • Costs Bid Tab costs for Projects - Contract Admin Section and with archived design/project files • Design data - Archived Design files • Load rating information - Bridge Inspection Files • Bridge project records - Archived design & construction records / plans are also stored in Bridge Inspection files • Precast manufacture data Archived design & construction records o Camber information - Archived design & construction records o Concrete compressive strength cylinder break data - Archived design & construction records • Construction information o As-built data - Archived design & construction records/also try to include in Bridge Inspection Files o Pile driving records or pile test data - Archived design & construction records o Material certs - Archived design & construction records o Shop drawings - Archived design & construction records / also try to include in Bridge Inspection Files • Maintenance data Bridge Inspection Files and Department's Maximo Software • Repair data Archived design & construction files and/or Bridge Inspection Files • GIS data DelDOT's IT and/or Planning departments are responsible for GIS applications, but bridge data comes from Bridge Inspection files
New Jersey	NJDOT has collected National Bridge Elements (NBE) along with Agency Defined Elements since 2015. A manual was developed for guidance on how to code the eements and defects along with appropriate condition state quantities. This manual has been revised and uploaded to our public facing website at this location: https://www.state.jn.us/transportation/eng/structeval/pdf/BridgeEllnsManual.pdf. NJDOT also developed web based tool called Combinded inspection System (CombIS) using Bentley's software AssetWise Asset Reliability Inspections (formerly InspectTech) which includes a form dedicated for Element and Defects. Although the management of the collected elements is done internally by the BMS team of about 10 persons, the collection and quality control is done by the entire Bureau of Structural Evaluation and Bridge Management. The inspection projects are distributed among In-house Staff (about 60+ personnel) and Consultant community with a ratio of 35 (in-house) to 65 (consultants) split. NJDOT collects elements for a single structure unit, except for one of our larger Toll Agency - New Jersey Turnpike Authority (NJTA) which collects elements span by span for each structure unit. Note: NJDOT has initially utilized Migrator 2.0 to migrate old CoRe (Commonly Recognized) Element Data to National Bridge Element Data. Examples include: • Geotechnical/subsurface information - No additional elements collected other than mentioned in ADEs table above • Hydraulics & scour data - None for elements • Costs - None for elements • Design data - None for elements. Additional State fields are collected for NBI. Link for NJDOT NBI Coding Gide is available here: https://www.state.nj.us/transportation/eng/structeval/pdf/RecordingandCodingGuide.pdf • Load rating information - None for elements. Additional Load Rating information is available here: https://www.state.nj.us/transportation/eng/structeval/loadrating.shtm • Bridge project records - None for Elements • Precast manufacture data - None for Elements o Camber information - None for Elements o Concrete compressive strength cylinder break data - None for Elements • Construction information - None for Elements o As-built data - None for Elements o Pile driving records or pile test data - None for Elements o Material certs - None for Elements o Shop drawings - None for Elements • Maintenance data - None for Elements • Repair data - None for Elements • GIS data - None for Elements