COMMONWEALTH of VIRGINIA

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Stephen Brich
Commissioner

August 23, 2019

Mr. Thomas Nelson, Jr., P.E.
Federal Highway Administration
Virginia Division
400 North 8th Street, Suite 750
Richmond, Virginia 23219-4825
Attention: Mr. Lorenzo Casanova, P.E.

Subject: Commonwealth of Virginia Transportation Asset Management Plan

Dear Mr. Nelson,

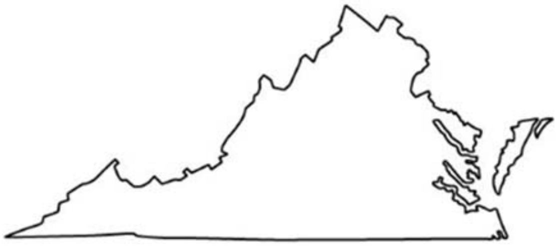
The Virginia Department of Transportation is submitting the Commonwealth of Virginia's updated Transportation Asset Management Plan in order to address comments received. Please use this letter as my approval.

If you have any questions or concerns please contact Jennifer Ahlin at (804) 786-6581.

Sincerely,

Stephen C. Brich, P.E.
Commissioner of Highways

Attachment



Commonwealth of Virginia Transportation Asset Management Plan

June 30, 2019

1.0 Introduction

This report is the Commonwealth of Virginia's response to the federal requirements related to the *Transportation Asset Management Plan* (TAMP). The TAMP presents current pavement and bridge inventory and conditions along with the Commonwealth of Virginia's performance objectives, measures, and associated risks as well as asset funding and investment strategies, forecasts, goals and gaps. The TAMP is specific to the *National Highway System* (NHS) and provides the Commonwealth of Virginia's *Transportation Asset Management* (TAM) processes and methodology to meet federal requirements.

Consistent with the transportation asset management principles, the Virginia Department of Transportation (VDOT) is currently reviewing and evaluating existing performance and investment strategies or undertaking a comprehensive review to ensure the long term sustainability of its programs. While the current investment strategies were effective, VDOT needs a balanced and sustainable program given constraint resources and aging infrastructure. Any revisions or updates to current goals, targets and investment strategies will be reflected in future versions of the TAMP.

Transportation Asset Management Plan

The TAMP must include a summary inventory of NHS pavements and bridges by ownership, whether state-owned or locally owned. A summary condition for these assets must also be included based on performance measures established under 23 U.S.C. 150(c)(3)(A)(ii) with consideration given to part 667 of this title for facilities damaged by emergency events.

Transportation Asset Management

Transportation asset management is defined as a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their life cycle.

National Highway System

The National Highway System (NHS) is a network of strategic highways within the United States, including the Interstate Highway System and other roads.

State of Good Repair

As used in this document the term "state of good repair" refers to the condition of a section of pavement or a bridge that meets the performance targets as approved by the Commonwealth Transportation Board. However, VDOT has a State of Good Repair Program as defined in the *Code of Virginia* Section 33.2-369 which dedicates funds for the Commonwealth of Virginia's deteriorated pavements and structurally deficient bridges.

1.1 Commonwealth of Virginia Overview

In the Commonwealth of Virginia, VDOT maintains approximately 128,500 lane miles of roadway, and approximately 19,500 bridges, and large culverts, while localities maintain over 30,500 lane miles of roadway and localities as well as private entities maintain 1,600 bridges. Of the 159,000 lane miles maintained by VDOT and localities, approximately 18,700 lane miles are on the NHS (or 12% of the roadway inventory). There are over 21,100 bridges in the Commonwealth (maintained by VDOT and localities) of which 13,600 are National Bridge Inventory (NBI) structures and 3,700 are NBI structures on the NHS (or 17% of the bridge inventory).

1.2 VDOT Overview

VDOT is responsible for the third-largest state-maintained highway system in the country, behind Texas and North Carolina DOTs. VDOT has developed a robust asset management program, placing the maintenance of the transportation network at the forefront of agency investment decisions.

This commitment to responsible TAM practice is demonstrated through VDOT's annual condition data collection programs and its establishment and publication of network-level pavement and bridge performance goals. VDOT's current condition measures and performance goals have been in place for many years and are fully integrated into VDOT's budgeting process and investment strategies as indicated in pavement and bridge performances over the years.

These longstanding programs, processes, and strategies have made VDOT a national TAM leader with documented practices that exceed federal requirements and expectations. Numerous publications developed by VDOT detail these practices as they apply to the full network of VDOT's roads and bridges.

1.3 Document Organization

In order to meet federal TAMP requirements; this document is organized into the following chapters:

1. Introduction
2. Inventory and Condition
3. Performance Targets
4. Life Cycle Planning
5. Financial Projections
6. Investment Strategies
7. Risk Management

2.0 Inventory and Condition

While the NHS assets represent only a subset of the Commonwealth of Virginia's total pavement and bridge inventory, for purposes of the TAMP, only NHS pavement and bridges are discussed in detail. This chapter presents a summary of pavement and bridge inventory and conditions on the NHS.

2.1 Overview

Accurate inventory and condition information are fundamental to network-level asset management communication and decision-making. VDOT maintains a comprehensive inventory of all pavement and bridges on the state-maintained network. This inventory includes location, maintenance ownership, and current condition or inspection information and serves as the foundation for life cycle planning, performance forecasting, maintenance, and rehabilitation needs estimation as well as the prioritization of work to maximize asset life and available funding. Condition information is also vitally important for communicating with external stakeholders and the general public.

VDOT maintains an extensive statewide roadway network consisting of three roadway systems: Interstate, Primary, and Secondary/Urban. VDOT performance standards are developed and established for each of these roadway systems, independent of federal NHS designation. VDOT does not differentiate between assets designated as NHS and non-NHS when making decisions about investments in maintenance and rehabilitation.

Lane Mile

A lane mile is the length (in miles) of pavement multiplied by the number of lanes in a road segment.

NBI versus Non-NBI

NBI - Bridges that are over 20 feet in length and large culverts.

Non-NBI - Bridges that are less than 20 feet in length and culverts with openings greater than 36 square feet.

2.2 Inventory

Pavement

A summary by NHS designation of the Commonwealth of Virginia's pavement inventory is provided in the *Annual Mileage Table*[1] and broken down by ownership in Table 1. Table 1 presents the detailed inventory numbers while the introduction provides estimates.

Table 1: 2018 Virginia Pavement Lane Miles by Maintenance Responsibility

NHS Designation	Lane Miles by Maintenance Responsibility		Total
	VDOT	Localities	
Intestate (NHS)	5,503	NA	5,503
Non-Interstate NHS	10,266	2,986	13,252
Total	15,769	2,986	18,755

Bridge

Annually, VDOT produces the State of the Structures Report[2], which details structure inventory by structure type and roadway system, and includes detailed information on the count and deck area of NHS structures.

VDOT maintains a comprehensive inventory of all structures regardless of ownership (VDOT, locality and private or as indicated in Table 2 as

localities and other). The dataset is used to report the *Federal Highway Administration* (FHWA) NBI. VDOT designates structures within the state inventory as either NBI or non-NBI structures based on whether these structures meet the federal reporting requirements. A summary of NHS structures by NBI classification and maintenance responsibility is provided in Table 2.

Table 2: 2018 Virginia NHS Bridge Inventory by System and Inventory Type

NHS	VDOT		Localities & Other		Federal Responsible		Total Statewide	
	Count	Deck Area (SF)	Count	Deck Area (SF)	Count	Deck Area (SF)	Count	Deck Area (SF)
NBI	3,338	55,053,380	398	13,496,647	42	693,635	3,778	69,243,663
Non-NBI	1,523	1,174,639	5	242,685	n/a	n/a	1,528	1,417,325
Total	4,861	56,228,019	403	13,739,333	42	693,635	5,306	70,660,987

2.3 Condition

Within this section, TAM practices relating to pavements and bridges are provided in separate discussions on the topics of data collection, data summarization, performance measures, and condition summaries.

Pavement Condition Data Collection

Each year VDOT collects pavement inventory and condition data on the entire NHS (both state and locally maintained) through a contract with an external data collection vendor. The vendor uses continuous digital imaging (captured through a vehicle-mounted camera), detailed sensor data, and automated crack detection technology to summarize pavement condition. Downward mounted cameras collect pavement condition and forward mounted cameras collect images of right of way assets and shoulder conditions. Sensors mounted on the vehicles also collect roughness, rutting, and surface cracking data.

Condition data is collected annually for all Interstate and Primary roadways, while typically 20% of the Secondary network data is collected each year. Collected data is categorized into the fundamental distresses identified by VDOT's pavement distress rating protocol, as published in the *VDOT Distress Identification Manual*.[3]

Pavement Condition Data Quality Management Plan

VDOT's Pavement Data Quality Management Plan is consistent with the requirements relating to State DOT Pavement Data Quality Management Programs as set forth in 23 C.F.R SEC 490.311, and the data elements discussed in 23 C.F.R SEC 490.309 (C).

The plan is organized to directly address the five areas State DOT's must include in their Pavement Data Quality Management Programs: (1) data collection equipment calibration and certification, (2) certification process for persons performing manual data collection, (3) data quality control measures to be conducted before data collection begins and periodically during the data collection program, (4) data sampling, review and checking processes; and (5) error resolution procedures and data acceptance criteria.

Pavement Surface Condition Data Summary

VDOT has developed pavement condition indices that it uses to summarize detailed pavement condition data collected on Virginia roadways. The condition indices (or Critical Condition Index –

CCI) are measured on a 0 to 100 scale, with 100 representing no visible distress and deductions calculated based on observed distresses.

These pavement condition indices, developed in 1998, are based on the US Army Corps of Engineers PAVER methodology. They have undergone extensive validation using FHWA Long Term Pavement Performance (LTPP) data and a process of consensus building with VDOT pavement experts.[4] Details of the methodology used to develop these indices is further explained in reports developed by VDOT.[56]

The CCI developed by VDOT is the common index used to summarize the condition of all VDOT pavement types. The CCI is used to assign a general pavement condition designation and to inform state decision making in combination with detailed distress data.

FHWA Pavement Performance Measures

FHWA selected four performance measures to determine the condition level of NHS pavements. The federal data collection metrics used in determining performance measures are shown in Table 3.

Table 3: Federal Pavement Performance Measures - Data Collection Metrics

Name	Pavement Type	Measure	Description
Pavement Roughness	Asphalt and Concrete	International Roughness Index (IRI)	Indicator of discomfort experienced by road users traveling over the pavement.
Rutting	Asphalt	Depth of ruts along wheel path	Commonly caused by a combination of high traffic and heavy vehicles.
Faulting	Concrete	Average depth of faulting	Occurs when adjacent pavement slabs are vertically misaligned. It can be caused by slab settlement, curling, and warping.
Cracking	Asphalt and Concrete	% of cracked pavement surface	Can be caused/accelerated by excessive loading, poor drainage, frost heaves or temperature changes, and construction flaws.

The FHWA has established Good, Fair, and Poor performance rating thresholds, as described in Table 4. An overall condition is assigned based on performance against each of the individual measures for each pavement type: Asphalt Concrete (AC), Jointed Concrete (JC), and Continuously Reinforced Concrete (CRC).

Table 4: Federal Performance Rating Thresholds for Pavement Condition Categories

Measure	Good	Fair	Poor
Ride Quality (IRI)	<95	95 – 170	>170
Rutting (inches)	<0.20	0.20 – 0.40	>0.40
Faulting (inches)	<0.10	0.10 – 0.15	>0.15
Cracking (% area)	<5	5-20 (AC) 5-15 (JC) 5-10 (CRC)	>20 (AC) >15 (JC) >10 (CRC)

An individual pavement section is rated as being in Good overall condition if all applicable individual metrics are rated as Good, and Poor when two or more of the applicable metrics are rated as Poor. In all other cases, the pavement section would be assigned an overall federal condition rating of Fair.

For federal performance, 0.10-mile performance is reported, whereas Virginia performance is typically reported by management section (or homogenous sections).

NHS Pavement Condition Summary

A summary of Virginia's 2017 NHS pavement condition is organized by ownership and lane miles in Table 5.

Table 5: 2018 Pavement Condition - Based on FHWA Performance Measures

Ownership	Designation	Lane Miles	% Good	% Fair	% Poor
VDOT	NHS Interstate	5,503	57.8	41.7	0.6
	NHS Non-Interstate	10,266	38.8	61	0.2
Localities	NHS Non-Interstate	2,986	10.5	85.8	3.7
Statewide Total	NHS Interstate	5,503	57.8	41.8	0.4
	NHS Non-Interstate	13,252	33.5	65.6	0.9

Bridge Condition Data Collection

Bridge and large culvert condition data is collected by in-house inspection staff and through consultant contracts. Their activities are governed by numerous technical documents published by American Association of State Highway and Transportation Officials (AASHTO), National Bridge Inspection Standards (NBIS), and VDOT. VDOT exceeds the minimum inspection requirements of NBIS, as noted in Table 6. VDOT policy requires annual safety inspections for all Structurally Deficient (SD) structures. Note that SD assessment does not imply unsafe, but rather that the structure is restricted for vehicle weight, closed to traffic, or requires rehabilitation.

Table 6: VDOT Structure Inspection Practices[7]

Structure Type	Required Inspection Frequency (Years)	
	NBIS	VDOT
NBI Bridges (> 20')	2	2
Non-NBI Bridges (<=20')	None	2
NBI Culverts	2	2
Non-NBI Culverts	None	4
SD Structures	2	1
Fracture Critical Structures	2	1
Underwater	5	5

Bridge Condition Data Quality Management Plan

The accuracy, thoroughness, and completeness of the bridge safety inspections are essential. The inspections are used to evaluate each structure's safety and are used for decisions on planning, budgeting, and performance of maintenance, repair, rehabilitation, and replacement of our structures. Since 1991, it has been the policy of VDOT's Structure and Bridge Division to provide rigorous quality control and quality assurance (QC/QA) of the structure safety inspection program. In January 2005, the NBIS portion of the Code of Federal Regulations was amended to require each state to "Assure systematic quality control and quality assurance procedures are used to maintain a high degree of accuracy and consistency in the inspection program. The QA program includes periodic field review of inspection teams, periodic bridge inspection refresher training for program managers and team leaders, and independent review of inspection reports and computations." The Structure and Bridge Division meets these NBIS requirements with its quality control and quality assurance programs.

In 2008, VDOT S&B developed Information and Instruction Memorandum (IIM) IIM-S&B-78, describing the bridge safety inspection QC/QA program which requires the following: In accordance with the NBIS, program managers and team leaders must successfully complete an FHWA approved comprehensive bridge inspection training course; within VDOT, all bridge safety inspection personnel will successfully complete the National Highway Institute (NHI) course 'Safety Inspection of In-Service Bridges' (FHWA-NHI-130055) within the first five years of employment in bridge inspection; VDOT S&B also requires inspection personnel successfully complete the NHI course 'Bridge Inspection Refresher Training' every five years; underwater inspectors are required to fulfill the training requirements as set forth in the NBIS and the VDOT 'Dive Safety Manual'.
Both the Central Office and the districts have a responsibility to review and validate inspection reports and inventory data. Discrepancies found during the field and office reviews performed by the both district and Central Office personnel are documented in a written report and shared with all parties involved. The Central Office conducted an annual QA review on eight of the nine district bridge inspection programs. Review of load ratings for a sample of bridges was a key component of the QA reviews. In addition, underwater inspection QA/QC field reviews are scheduled by the Central Office Underwater Inspection Engineer.

VDOT Bridge Condition Data Summary

VDOT uses a condition rating scale to summarize data collected on each primary structure component during each inspection that is recorded in the inspection report. The rating, known as the General Condition Rating (GCR), is a nationally established numerical grading system measured on a 0-9 scale, where 0 represents failed condition and 9 represents excellent condition. For bridges, the deck, superstructure, and substructure are rated individually, while culverts receive a single rating.

FHWA Bridge Performance Measures

Bridge performance is summarized into three condition categories: Good, Fair, and Poor/SD as noted in Table 7

Table 7: Bridge Condition Definitions

Condition Category and Definition		
Poor/SD	**Fair**	**Good**
Min GCR ≤ 4	4 < Min GCR <7	Min GCR ≥ 7

NHS Bridge Condition Summary

A condition summary of Virginia's NBI bridges on the NHS using the FHWA condition categories is organized by ownership, count, and deck area in

Table 8. Deck area is the federal unit of measure required for the TAMP. Based on deck area, 33.1% of the NBI bridges statewide are in Good condition, 63.6% are in Fair condition, and 3.3% are in Poor condition.

Table 8: 2018 Federal Performance of NBI Bridges on the NHS

Ownership	Count	Deck Area (Million SF)	% Good	% Fair	% Poor
VDOT	3,338	55.1	28.9%	67.9%	3.3%
Localities & Other	398	13.5	54.1%	42.8%	3.1%
Federal Responsible	42	0.7	7.7%	58.4%	33.9%
Statewide	3,778	69.2	33.6%	62.9%	3.5%

2.4 Management Systems

Pavement and bridge inventory and condition data can be transformed into valuable information with the use of a well-developed management system.

Pavement

In 2010, VDOT implemented the AgileAssets Pavement Analyst software as VDOT's Pavement Management System (PMS). This system holds pavement inventory, condition, and maintenance history and is the official repository for other pavement-related data including type, surface and subsurface layer thicknesses, materials and construction dates, historical inspection data (distress, roughness, and rutting), historical testing data (deflection, skid), and treatment history (type of treatment, location, and date). [8]The PMS provides a wide array of decision-making tools; including pavement needs optimization and performance setting analysis, deterioration model development and condition forecasting, unconstrained decision matrix analysis, and reporting.

The Pavement Maintenance Scheduling System (PMSS) is a second application utilized. It provides the ability to establish annual paving schedules and to develop reports based on contract details. The tool is used to schedule paving activities and develop annual pavement maintenance and rehabilitation contracts, review scheduled paving activities and review reports on planned contracts. The application can also generate reports on the scope of projects, quantities of materials, types of materials, and cost of materials.[9]

Bridge

VDOT's Bridge Management System (BMS) is a comprehensive bridge management methodology that includes performance measures, cost data, deterioration models, and rules for maintenance interventions. Much of the logical basis for the BMS will be used in the (Bridge Management software) BrM, licensed from AASHTO when it is fully deployed. The most current version of the software supports element-level inspection and network-level bridge needs analysis. It currently holds structure inventory and condition data. It is the official repository of data associated with Virginia's highway bridges and culverts.

Through its use of Pontis, VDOT was one of only a few state DOTs that collected and used the *AASHTO Commonly – Recognized Bridge Elements* (CoRe) elements, which VDOT began recording in 1996. VDOT's program was one of the most advanced in the nation, as it had incorporated the following:

- A complete suite of Markovian deterioration models based on transition probabilities for the CoRe elements that were developed through a combination of long-term data analysis and expert elicitation
- A set of action-effectiveness models

- An automated methodology for updating unit costs (converting from pay item units to CoRe element units)
- A set of rational, heuristic-based rules to incorporate human reasoning into the automated work recommendation process

Much of VDOT's prior bridge management logic is being redeveloped to accommodate the new AASHTO elements for NBI bridges. This entails an overhaul of VDOT's intervention rules, deterioration curves, and action-effectiveness models.

VDOT is in the process of employing BrM for bridge management. During the transition, VDOT is instituting a phased deployment of the bridge management functions of BrM.

Once fully functional, BrM will provide a wide array of decision-making tools to VDOT, including needs optimization analysis, performance predictions at various budget levels, deterioration and condition forecasting, unconstrained decision matrix analysis, and reporting.

3.0 Performance Targets

FHWA has established requirements to include 10-year asset performance forecasts as well as 2- and 4-year performance targets within the TAMP. In addition, states are required to identify performance gaps in these forecasts and goals within the document.

As stated in the introduction, VDOT is currently reviewing and evaluating existing performance and investment strategies ensure a long term sustainable program for assets and services. Any revisions or updates to current goals and targets will be reflected in future versions of the TAMP.

3.1 Overview

The Commonwealth of Virginia has a long history of sound TAM practice, and VDOT strives to improve these processes continuously.

VDOT has well-established and well-documented performance expectations for state-maintained pavement and bridges and has strived to link network-level needs and performance forecasts to District TAM project selection. Examples of achievement in this area include VDOT's pavement performance monitoring as well as a needs-based budgeting process that was required by the legislature and which VDOT has embraced. This needs-based budgeting process has integrated current and projected asset condition into VDOT's TAM investment decision-making processes.

This chapter will highlight these program areas and provide 2-, 4-, and 10-year pavement and bridge performance forecasts as well as any identified performance gaps.

Impact of Federal Requirements on State Reporting

Federal requirements will be discussed in detail within this document, the state programs are highlighted for purposes of context.

It is important to note that the differences between federal and state requirements have essentially required VDOT to report separate performance through two similar but disparate methodologies.

Performance Forecasting

In order to achieve the purposes of the TAMP, a 10-year optimization of anticipated TAM funding was executed within the pavement and bridge management systems. The forecasted performance resulting from this analysis was then compared against current (2017), 2- and 4-year state targets as well as federal minimum performance expectations where applicable.

3.2 Pavement Performance, Forecasts, and Gaps

Given the maturity of the state's existing asset management practice, federal pavement performance targets have been established based on anticipated outcomes from the Commonwealth's existing performance-based TAM investment processes.

Current state practice is driven by achievement of the state performance against a "Percent Sufficient" pavement performance measure.

Background

Through federal rule-making, pavement target-setting requirements are established in four performance measures. As submitted in VDOT's Transportation Performance Management, State Biennial Performance Report for Performance Period 2018-2021 dated October 1, 2018, VDOT's targets were adopted by the Commonwealth Transportation Board (CTB) as shown in the following table:

Federal Performance Measure	Year	Interstate	Non-Interstate
Good	2	N/A	25%
	4	45%	25%
Poor	2	N/A	5%
	4	3%	5%

VDOT has predicated, as depicted later in this report, more than four years of pavement performance. At the minimum attaining these targets, VDOT will be able to achieve a state of good repair.

In order to meet federal requirements, Virginia developed a correlation process that relates the CCI and IRI of a given pavement management section to the expected distribution of 0.10-mile federal performance against the three federal measures (Good, Fair, and Poor).

Where federal pavement performance forecasts are provided in the sections below, they were developed based on CCI and IRI output from the PMS, which has been correlated to federal measures.

Pavement Performance and Analysis

Through VDOT's needs-based budgeting process, VDOT has developed and run numerous pavement investment optimizations and associated condition forecasts to establish a steady pavement funding level necessary to meet the state performance goals for Interstate and Primary pavements. This anticipated funding level is used in the 10-year federal performance forecast provided below.

Ten-year pavement investment optimizations and associated condition forecasts were completed within the PMS using anticipated funding levels. These forecasts were reduced to account for non-mainline paving costs such as shoulder maintenance, maintenance of traffic, paving-related investments in traffic assets such as pavement markings or rumble strips, and preliminary engineering and construction inspection costs. Results of these analyses are provided for Interstate and non-Interstate NHS roadways in the sections below.

Interstate Pavement Performance Goals and Forecasts

Due to a proactive pavement preservation program, Virginia's emphasis will be the federal Poor performance category, where no more than 5% of the Interstate System (IS) may be in Poor condition.

Figure 1 below illustrates anticipated IS network performance based on the federal performance measures. Performance is weighted by lane mileage and provided by year as a percentage of the total network inventory.

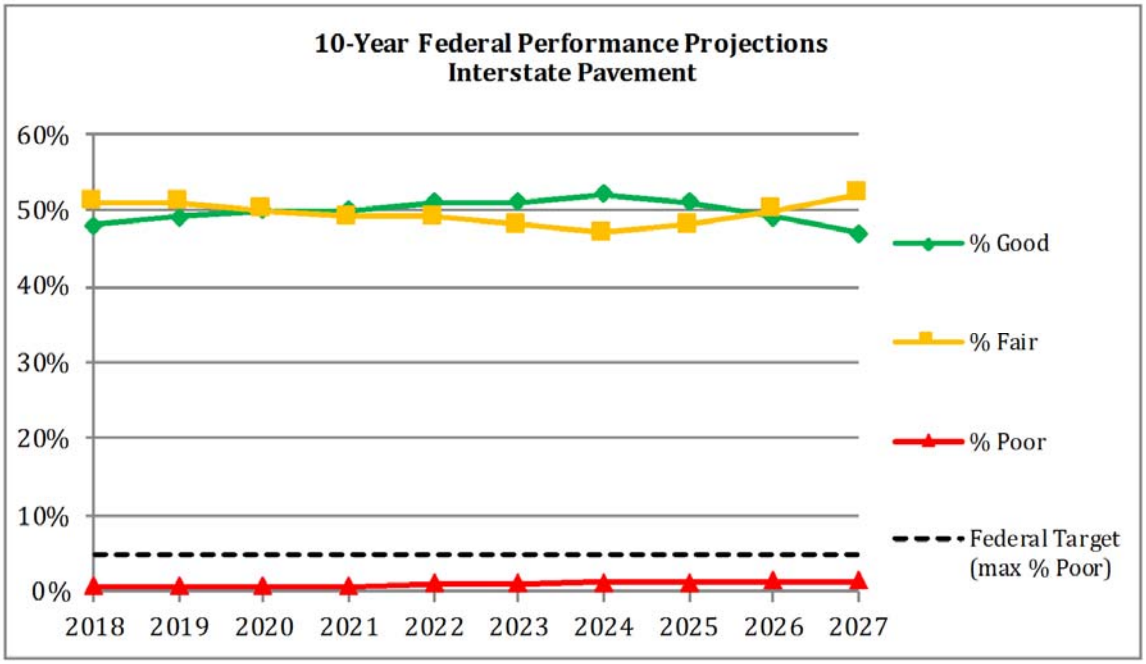


Figure 1: Interstate 10-Year Pavement Performance (Federal Measures)

Table 9: 10-Year Interstate Performance

Year	% Good	% Fair	% Poor
2018	48%	51%	0.8%
2019	49%	51%	0.7%
2020	50%	50%	0.7%
2021	50%	49%	0.8%
2022	51%	49%	1.0%
2023	51%	48%	1.1%
2024	52%	47%	1.2%
2025	51%	48%	1.3%
2026	49%	50%	1.4%
2027	47%	52%	1.5%

As demonstrated in Table 9, the Virginia IS is anticipated to perform above the federal minimum performance levels (5% Poor) throughout the 10-year analysis period while also achieving the established 2- and 4-targets.

Non-Interstate NHS Pavement Performance Goals and Forecasts

Figure 2 below illustrates anticipated Non-Interstate NHS (NI-NHS) performance based on the federal performance measures. This forecast was developed through investment optimization of the VDOT maintained NI-NHS roadways, with the assumption that non-VDOT maintained NI-NHS routes would continue to perform to current levels. Performance is weighted by lane mileage and is provided as a percentage of the total NI-NHS network inventory.

Unlike the IS, there is no minimum federal performance requirements for the NI-NHS network. As such, there is no federal minimum performance shown in the table and chart below.

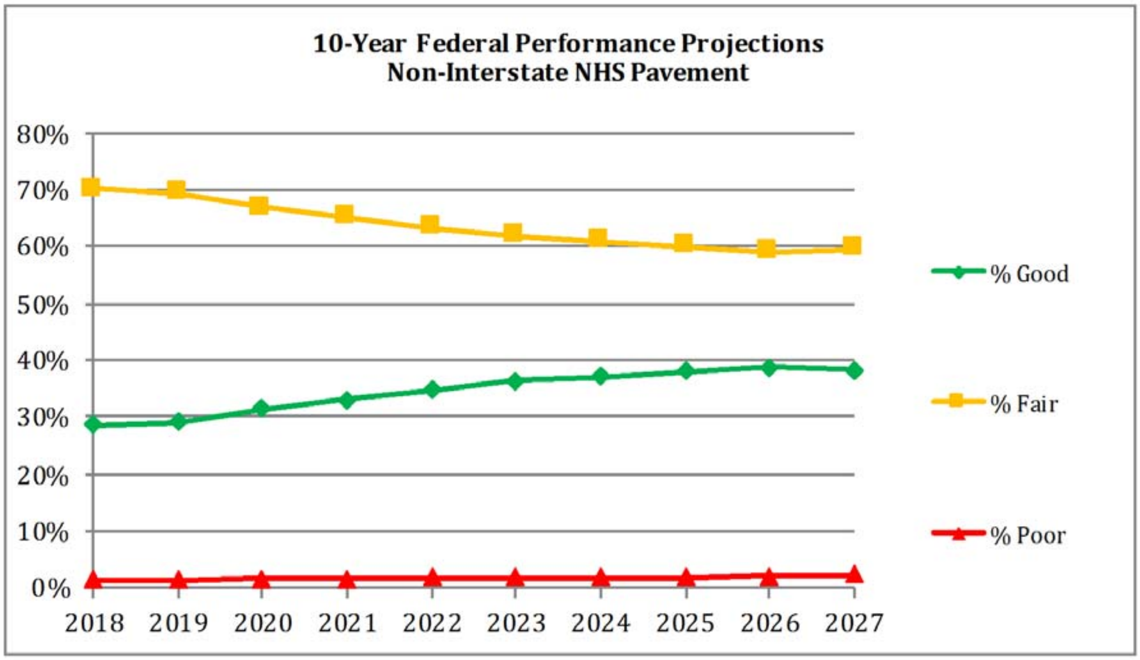


Figure 2: Non-Interstate 10-Year Pavement Performance

Table 10: Comparison of Non- Interstate 10-Year Performance

Year	% Good	% Fair	% Poor
2018	28.6%	70.0%	1.5%
2019	29.1%	69.4%	1.5%
2020	31.5%	66.9%	1.6%
2021	33.1%	65.2%	1.7%
2022	34.7%	63.4%	1.8%
2023	36.3%	61.8%	1.8%
2024	37.1%	60.9%	1.9%
2025	37.9%	60.0%	2.0%
2026	38.6%	59.2%	2.2%
2027	38.2%	59.6%	2.3%

Pavement Gap Analysis

VDOT's predicted performance levels are based on current pavement TAM funding levels over the 10-year period. Based on the predicted performance, VDOT will continue to achieve a state of good repair.

The gap analyses are shown in Table 11 and Table 12, which highlight when anticipated performance drops below current or, where applicable, federal performance levels.

Based on the performance gap analysis results shown in Table 11 and Table 12, VDOT does not anticipate any gaps in the effectiveness of the NHS in providing safe and efficient movement of people and goods. VDOT's 10 year predicted performance indicates no potential gap to the approved 4 year target; however, a comprehensive review is underway at this time.

Table 11: Interstate Pavement Gap Analysis Summary

Federal Performance Measure	Year	State of Good Repair		Predicted Performance	State Gap Based on Predicted Performance	Federal Minimum	
		Target (CTB Approved)	Gap			Minimum	Gap
Good	2	45%	None	49%	None	N/A	N/A
	4	45%	None	50%	None		
	10*	N/A		47%	None		
Poor	2	<3%	None	0.7%	None	5%	None
	4	<3%	None	0.8%	None	5%	None
	10*	N/A		1.5%	None	5%	None

Table 12: Non-Interstate NHS Pavement Gap Analysis Summary

Federal Performance Measure	Year	State of Good Repair		Predicted Performance	State Gap Based on Predicted Performance	Federal Minimum	
		Target (CTB Approved)	Gap			Minimum	Gap
Good	2	25%	None	29.1%	None	N/A	N/A
	4	25%	None	33.1%	None		
	10*	N/A		38.2%	None		
Poor	2	<5%	None	1.5%	None		
	4	<5%	None	1.7%	None		
	10*	N/A		2.3%	None		

3.3 Bridge Performance, Forecasts, and Gaps

Background

Through federal rule making, bridge target-setting requirements are established in two performance areas. As submitted in VDOT's Transportation Performance Management, State Biennial Performance

Report for Performance Period 2018-2021 dated October 1, 2018, VDOT's targets were adopted by the CTB as shown in the following table:

Federal Performance Measure	Year	NBI on the NHS
Good	2	33.5%
	4	33%
Poor	2	3.5%
	4	3%

VDOT has predicted, as depicted later in this report, more than four years of bridge performance. At the minimum attaining these targets, VDOT will continue to achieve a state of good repair.

As discussed in Chapter 2, VDOT and FHWA define Poor or SD bridges as having a GCR of 4 or less. As of January 1, 2018, FHWA's definition of SD structures is in complete alignment with VDOT's definition of Poor structures. FHWA's definition of Good bridges includes those with a minimum GCR ≥ 7.

Bridge Performance and Analysis

Through VDOT's needs-based budgeting process, VDOT has developed and run numerous bridge investment optimizations and associated condition forecasts to establish a steady bridge funding level necessary to meet performance targets. VDOT's predicted performance levels are based on current bridge TAM funding levels over the 10-year period.

Bridge Performance Forecasts

VDOT developed a ten-year bridge investment optimization and associated condition forecasts with the BrM using deterioration modeling and current funding levels. These analyses were correlated to the federal performance measures, and the results are provided in Table 13.

As indicated in Tables 2 and 8, Virginia's NBI NHS inventory includes bridges owned by VDOT, localities, other entities, and the federal government. The federal structures represent only 1% of the overall deck area of the NBI NHS inventory, so their inclusion plays a relatively insignificant role in the determination of future performance targets. This is fortunate, because accurate forecasting of future conditions requires detailed knowledge that is not readily available to VDOT. In order to develop reliable projections of future conditions for federal bridges, VDOT would need schedules of planned work, funding availability, scopes for projects, anticipated deterioration rates, current maintenance practice, and decision logic for rehabilitation and replacement for these structures. In lieu of this information, Virginia has used its best judgment to account for and predict future conditions of federal bridges.

The forecasted 10-year performance of structures below demonstrates the strength of VDOT's bridge management program. Over this period, the percentage of bridges rated as Good may decline from 34% to 32%. In the current and projected state of condition, NHS bridges exceed the federal minimum condition level requirement of no more than 10% of bridge deck area may be on structures in Poor condition/SD and with "relatively stable" performance from 3.3% to 3.4% over 10 years. A summary of the 10-year performance forecast is provided in Table 13 and illustrated in Figure 3 and Figure 4.

Table 13: 10-Year Projected Statewide Performance of NBI Bridges (Excludes Federally Owned Bridges – Not reported by Virginia to FHWA)

NHS Bridge – Projected Performance by Condition Category (%Deck Area)		
Year	% Good (≥ 7)	% Poor
1	34.0%	3.3%
2	33.8%	3.1%
3	33.6%	2.8%
4	33.4%	2.5%
5	33.1%	2.6%
6	33.1%	2.6%
7	32.8%	2.7%
8	32.6%	3.0%
9	32.3%	3.2%
10	32.0%	3.4%

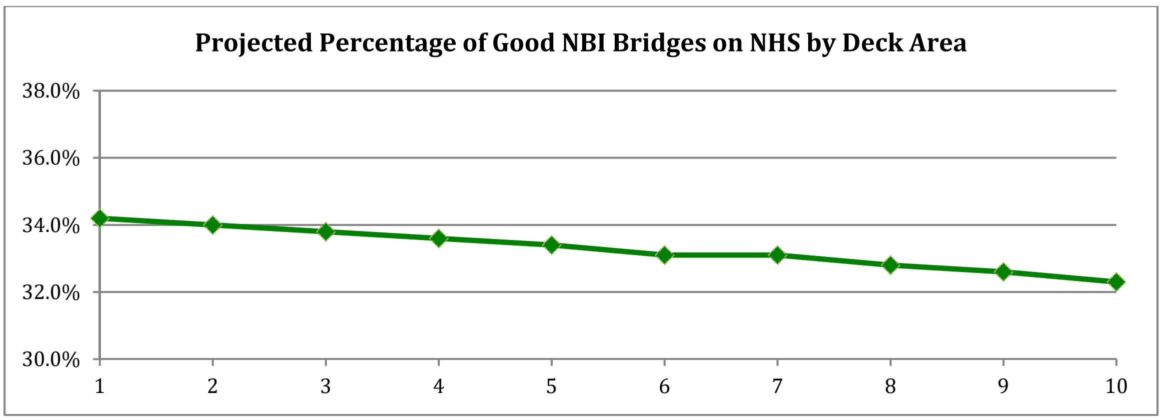


Figure 3: 10-year Projected Performance for Percentage of Good NBI Bridges on the NHS by Area

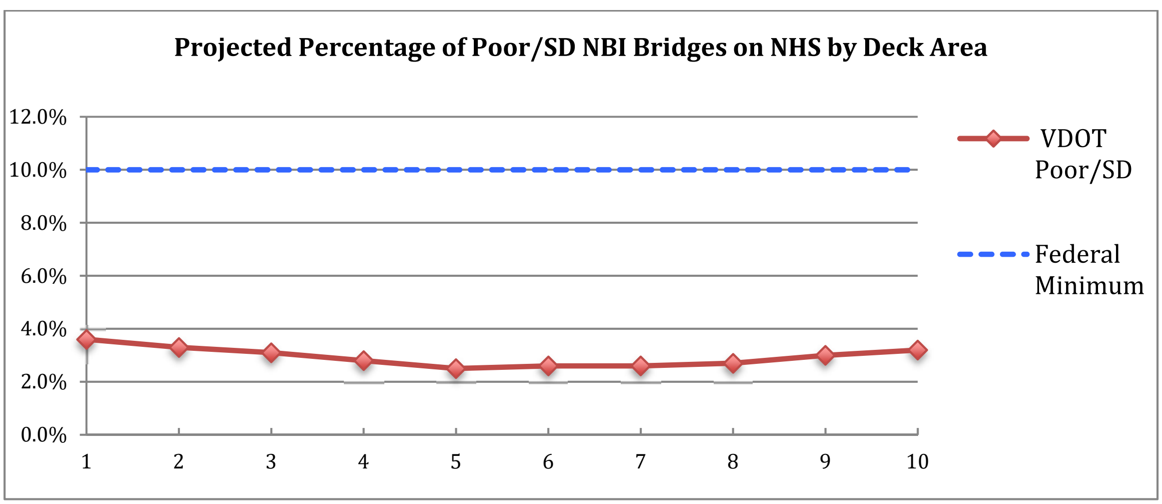


Figure 4: 10-year Projected Performance for Percentage of Poor/SD NBI Bridges on the NHS by Area

Bridge Performance and Gap Analysis

VDOT focuses on minimizing the cost to maintain or improve structure conditions through wise investment of bridge maintenance funds to keep pace with the projected aging and deterioration rates of the inventory. VDOT continually focuses on employing established asset management principles emphasizing low cost, high benefit preservation treatments to maximize the effectiveness of this funding. VDOT's full implementation of BrM will more efficiently allow VDOT to select the best mix of replacement, rehabilitation, repair, and preservation treatment recommendations. Table 15 below summarizes the current forecast for 2- and 4-year performance.

Based on the performance gap analysis results shown in Table 14, VDOT does not anticipate any gaps in the effectiveness of the NHS in providing safe and efficient movement of people and goods. VDOT's 10 year predicted performance indicates a potential gap to the approved 4 year target; however, a comprehensive review is underway at this time.

Table 14: Comparison of 2- and 4-year Performance

Federal Performance Measure	Year	State of Good Repair		Predicted Performance	Federal Minimum	
		Target (CTB Approved)	**Gap**		**Minimum**	**Gap**
Good (Min GCR ≥ 7)	2	33.5%	None	33.8%	N/A	N/A
	4	33%	None	33.4%		
	10*	N/A		32.0%		
SD/Poor (Min GCR ≤ 4)	2	3.5%	None	3.1%	10%	None
	4	3%	None	2.5%	10%	None
	10*	N/A		3.4%	10%	None

4.0 Life Cycle Planning

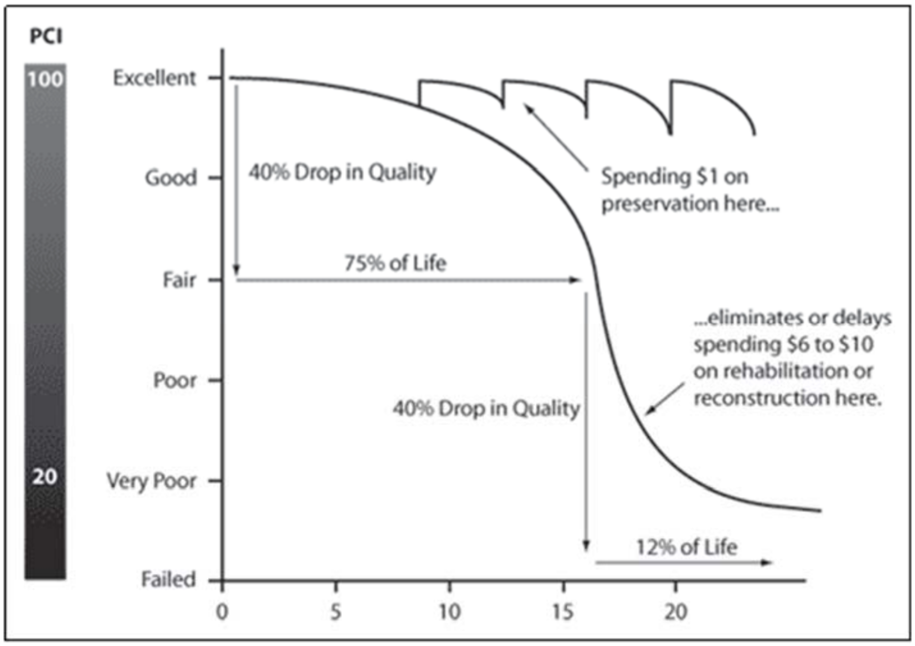
Sound asset management requires strategic investment decisions over the full life cycle of an asset. These decisions should be made within the context of network-level investment strategies intended to optimize available funding to meet network performance goals. FHWA refers to this approach to asset investment as Life Cycle Planning (LCP).

In the context of the efficient management of a large network of highway assets, LCP should emphasize the preservation of assets in Good condition in order to efficiently extend the life of assets and delay costly rehabilitation and reconstruction activities. However, rehabilitation and reconstruction must be a part of any long-term life cycle plan as preservation cannot extend the life of an asset indefinitely.

VDOT's asset management practices are mature in nature with over 10 years in practice. With the current comprehensive review underway, VDOT will implement a long term sustainable strategy (over 20 years) for pavements and bridges. The comprehensive review is utilizing network level life cycle planning analysis. VDOT's pavement and bridge management systems are the tools used for this analysis along with life cycle planning processes described in this section.

4.1 Overview

Figure 5 shows the economic and preservation benefits of timely investment decisions. This chart illustrates how timely, strategic maintenance sustains a higher condition with a lower expense. Timely and strategic maintenance delays more costly rehabilitation or reconstruction activities by maintaining assets above conditions where they would deteriorate more rapidly.



Note: This graph is based on a 2012 FHWA report on asset sustainability. It illustrates the steep deterioration commonly seen in pavements once they reach a "poor" condition. Timely preventive maintenance creates substantial value by restoring pavements to a high condition and preventing the onset of the rapid deterioration commonly seen in poorly maintained pavements. As noted in the graph, timely preventive treatment can produce a very high return on investment, while underinvestment leads to missed opportunities to prevent rapid degradation.

Figure 5: Impact of Maintenance Timing on Asset Condition

4.2 Pavement Life Cycle Planning and Investment Strategy

VDOT uses the condition data discussed in Chapter 2 to determine recommended treatment activities for each pavement section. Several factors are considered in developing models applied in PMS including treatment cost and deterioration that include factors such as impacts of the environment. The following section details maintenance treatment activities, maintenance treatment selection strategies, and deterioration modeling.

Pavement Maintenance Treatment Activities

VDOT categorizes pavement maintenance work into five maintenance activity categories: “Do Nothing”, “Preventative Maintenance”, “Corrective Maintenance”, “Restorative Maintenance”, and “Rehabilitation / Reconstruction”.

“Do Nothing” (DN) is an important treatment activity category because it is often necessary to defer potential maintenance in the context of limited pavement TAM funding and the wide-ranging needs of the pavement network.

“Preventative Maintenance” (PM) is characterized by low-cost maintenance interventions ranging from minor patching and crack sealing activities to thin hot mix asphalt concrete overlays (typically <1” in depth).

“Corrective Maintenance” (CM) is another commonly used pavement preservation technique. CM typically involves 1.5” to 2” asphalt concrete overlays (with or without milling) or partial depth patching.

"Restorative Maintenance" (RM) is typically employed when pavement distress has reached a point where a structural intervention is required. A typical RM treatment can involve a two-lift asphalt overlay (with or without milling) or full depth pavement patching.

"Major Rehabilitation" or "Reconstruction" (RC) is typically reserved for pavements nearing the end of their useful life.

Typical costs of each treatment category is provided in Table 15.[10] Cost information is gathered on an annual basis through review of the last two years of contract bid history. Typical life cycle extensions and modeled CCI improvements were developed through detailed analysis of years of work history and pavement condition data collection.

Table 15: Pavement Maintenance Treatment Categories

Treatment Category	Typical Cost per Lane Mile
Preventative Maintenance	$36k - $48k
Corrective Maintenance	$120k - $190k
Restorative Maintenance	$280k - $440k
Reconstruction	$780k - $920k

Pavement Maintenance Treatment Selection Strategy

Each pavement management section within the VDOT network is analyzed by the PMS to establish an unconstrained treatment recommendation. This recommendation is based on observed pavement conditions as well as traffic, structural capacity, and construction history information available for the management section. This analysis is called the "unconstrained needs analysis" because it is intended to provide a treatment recommendation for each section of the network regardless of available funding. This analysis ensures that field maintenance treatment selections are informed by the best available information on each management section.

To accomplish this unconstrained analysis, pavement condition information is run through a decision matrix analysis. This process involves an initial detailed screening of the severity and frequency of observed pavement distresses against a detailed decision matrix that determines the preliminary treatment selection for each section. This preliminary selection is further modified by a decision tree analysis based on traffic levels, structural capacity, and construction work history, resulting in a final treatment recommendation and cost estimate. This process is shown in Figure 6.

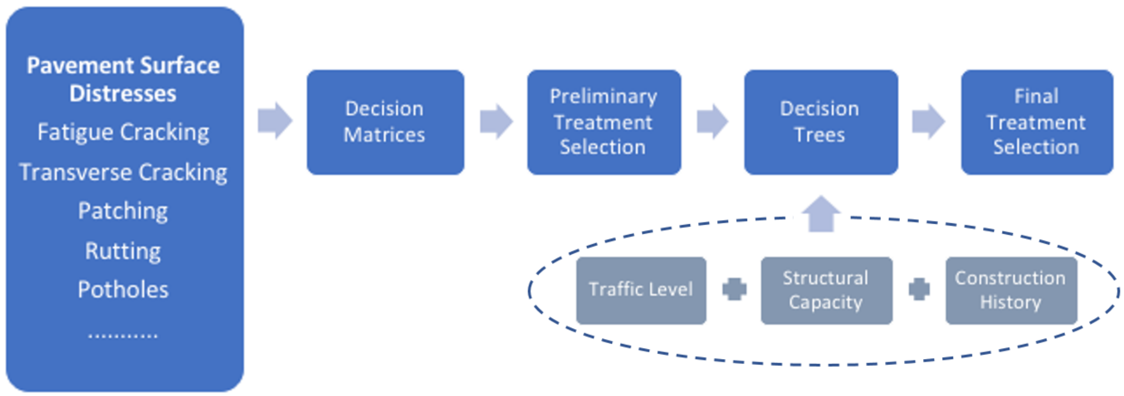


Figure 6: Framework for VDOT Unconstrained Treatment Selection[11]

VDOT also uses the PMS to perform network-level optimization analysis to determine the optimal mix of treatments within the available budget. These optimizations are typically run over a 6-year analysis horizon using current condition and predicted future deterioration in combination with CCI-based decision trees to ensure the selected work plans do not sacrifice long-term performance in order to achieve short-term objectives. The results of these analyses inform VDOT needs-based budgeting as well as the Pavement Performance Monitoring Program. For purposes of this document, VDOT has extended the typical 6-year analysis in order to establish performance forecasts for the required 10-year period.

Pavement Deterioration Modeling

VDOT developed pavement performance prediction models in 2007 with consultant support. These models are maintained by VDOT's pavement management program and are a critical input to the LCP process. Fifteen CCI deterioration models were developed by VDOT and are used during LCP and investment strategy development. There are three deterioration models for each of the five pavement types and one for each maintenance treatment category other than PM. Further details on these deterioration models can be found in the *Development of Performance Prediction Models for VDOT Pavement Management System* document. VDOT applies these deterioration models based on the pavement type and most recent treatment with the understanding that a newly constructed or reconstructed roadway will deteriorate slower than a pavement that had only received a minor rehabilitation or maintenance treatment.

4.3 Bridge Life Cycle Planning

VDOT's bridge management system has been developed to optimize the life cycle value of bridge interventions, with an emphasis on long-term investment value over short-term gains. VDOT uses the condition data discussed in Chapter 2 along with a modeling system that incorporates treatment cost, deterioration rates, and action-effectiveness predictions to determine recommended treatment activities for each bridge. The following section details maintenance treatment activities, maintenance treatment selection strategies, deterioration modeling, and analysis approach.

Bridge Maintenance Treatment Activities

VDOT categorizes bridge maintenance into four maintenance activity categories: Preventative Maintenance (including planned and condition-based preventative maintenance), Restorative Maintenance, Rehabilitative Maintenance, and Replacement.

> "Preventative Maintenance" is characterized by low-cost maintenance treatments including joint repair/elimination, waterproofing, washing, sweeping, vegetation/sediment removal,

lubrication, and spot/zone painting. Generally, preventive maintenance is performed on bridges in Good or Fair condition.

"Restorative Maintenance" is another commonly used bridge maintenance activity. Treatments include overlays, patching, substructure repair, and beam repair.

"Rehabilitative Maintenance" is a used when considerable intervention is needed to extend the life of a bridge. It may include, but is not limited to replacement of major components such as the superstructure or the deck.

"Replacement" is a full bridge replacement.

Treatment costs are established using VDOT bid tabulations and are updated on a regular basis. Bid tabulations are the prices submitted by contractors when they bid on work for VDOT, and each price is recorded in a database with the detailed work item. Table 16 provides a summary of typical bridge treatment categories and their average unit costs.

Table 16: Average Treatment Cost for Bridge Maintenance (by Category)

Treatment Category	Typical Cost per Square Foot
Preventative Maintenance	$2
Restorative Maintenance	$80
Rehabilitative Maintenance	$130
Replacement (Project Cost)	$1,030

While VDOT is decentralized and districts have the flexibility to adjust spending priorities as necessary, internal guidance provides suggested spending priorities by maintenance category: Preventative Maintenance (15%), Painting (10%), Restorative Maintenance in conjunction with system preservation (50%), and Rehabilitation/Small Structure Replacement (25%).

Bridge Maintenance Treatment Selection Strategy

To identify bridges as candidates for investment in a given maintenance intervention, each structure within the VDOT network is analyzed to establish an unconstrained treatment recommendation. This analysis is termed the "unconstrained needs analysis" because it provides a treatment recommendation for each bridge in the network regardless of available funding. This analysis ensures that field maintenance treatment selections are informed by the best available information.

VDOT's bridge management system uses bridge condition and inventory data gathered from bridge safety inspection reports in conjunction with controlling logic and mathematical models.

An effective bridge management system must determine both the recommended actions for each bridge and which bridges receive treatment in any fiscal year. VDOT is currently using a Multi-Objective Prioritization Formula (MOPF) to prioritize structurally deficient NBI bridges as discussed in the risk section. This formula uses unitless measures of the following variables to develop a prioritized list of SD/Poor structures requiring work:

1. Importance (traffic, truck traffic, detour, highway system, access to significant facilities, etc.)
2. Condition (health index (HI) of bridge)
3. Functionality (posting, bridge width, vertical clearance)
4. Risk (seismic, scour, fracture-critical redundancy, fatigue susceptibility)

Each variable is measured on a zero to one basis and is only valuable as a relative measurement (a bridge with an Importance Factor of 0.83 is more important to the highway network than a bridge with an Importance Factor of 0.62). While there is some unavoidable overlap between the variables, they are separate to the maximum extent possible (for example, importance does not include condition, functionality, or risk).

Bridge Analysis Approach

VDOT will continue to use LCP and analysis as the primary basis for the bridge management program. Chapter 32 of *VDOT'S Manual of the Structure and Bridge Division*[12] establishes requirements for life cycle analysis for bridge rehabilitation and replacement projects. In addition to these provisions, VDOT's Manual of the Structure and Bridge Division and its 2016 Road and Bridge Specifications have incorporated a life cycle cost approach to the provisions for materials and construction details. Rather than require a life cycle analysis on each individual project, life cycle analyses were performed for particular technological advances prior to their adoption in VDOT's standards. Each of the requirements listed below was implemented after VDOT determined that it would improve the life cycle investment for Virginia's bridges:

- Corrosion-resistant reinforcement in all new concrete bridge decks (which limits corrosion and the associated concrete deterioration)
- High performance concrete in all new bridge components
- Low cracking deck concrete
- Jointless bridges
- Carbon fiber and stainless steel pre-stressing strands

Virginia has chosen to proactively stipulate actions that will result in the best life cycle investment rather than reevaluate such decisions on each project. If a treatment or material is known to reduce life cycle costs, it becomes a requirement for all projects for which it will produce the best investment of public funds. In each of the above examples, a small incremental increase in the initial cost reaps decades of additional service life.

Virginia has been widely recognized as a leader in the development and successful implementation of new technologies, techniques, and materials for use in new and existing bridges. VDOT has used this history of innovation to make the Commonwealth of Virginia's bridges more durable, safer, and less expensive to build. Many elements contribute to this success. Two of the most prominent elements are:

The Virginia Transportation Research Council (VTRC): This organization works with VDOT's Structure and Bridge Division, the Materials Division, and the nine districts to solve problems in the most practical manner. The results have been extraordinary.

Collaboration: VDOT, Virginia's localities, and many of the state's universities work together to perform solution-driven research. There are nine "Research Advisory Committees" that hold semi-annual meetings, bringing together the users and developers of technology to help keep the research focused and progressing. This cooperation keeps Virginia on the cutting edge of bridge technology.

5.0 Financial Projections

All states must work within a constrained budget when developing their asset management approach. It is critical to know the sources of funds for maintenance activities as well as the need for those funds for each asset. These inputs allow the management systems to maximize the program that can be delivered.

5.1 Overview

The management of VDOT's pavements and bridges requires planning for both the financial requirements (needs) to maintain these assets as well as projections for funds available to meet these needs. This section outlines the financial projections for maintenance funding and the use of those funds.

5.2 Funding Sources

Revenue allocation for VDOT's pavement and bridge maintenance is dependent on the Highway Maintenance and Operations Program (M&O). The M&O details for fiscal year (FY) 2019 are detailed in Table 17.

Table 17: Highway Maintenance and Operating Program FY 2019[13] in millions

Highway System Maintenance	FY 2019
Interstate Maintenance	$358
Primary Maintenance	$533
Secondary/Urban Maintenance	$608
Transportation Operation Services	$148
Highway Maintenance Program Management and Direction	77
Total Highway System Maintenance	**$1,724**
HMOF	$1,479
Federal	$245

Annually maintenance payments to localities are available to assist with their maintenance and operations of their systems. In addition, a portion of funding in the capital program (construction or capacity building program), entitled the State of Good Repair (SGR) Program, is dedicated to VDOT and locality deteriorated pavements and structurally deficient bridges.

5.3 Funding Projection

Each year VDOT produces a plan for the upcoming six years projecting the M&O funds. The most recent summary of the anticipated allocation for federal and state funding for six years including the breakdown to VDOT Maintenance and Operations and the maintenance payments to localities is provided in Table 18.

Table 18: Six-Year Improvement Program Allocation (millions) Fiscal Year 2019-2024[14]

Program	Fund Source	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024
Maintenance and Operations	State	$1,479.5	$1,502.4	$1,460.6	$1,481.2	$1,510.7	$1,565.8
	Federal	$244.7	$226.1	$286.4	$287.6	$288.8	$289.9
	Total	**$1,724.2**	**$1,728.5**	**$1,747.0**	**$1,768.8**	**$1,799.5**	**$1,855.7**
Maintenance Payments to Localities	State	$456.8	$455.5	$465.9	$477.1	$489.0	$501.2
TOTAL	State	$1,936.3	$1,957.9	$1,926.5	$1,958.3	$1,999.7	$2067.0
	Federal	$244.7	$226.1	$286.4	$287.6	$288.8	$289.9
	Total	**$2,181.0**	**$2,184.0**	**$2,212.9**	**$2,245.9**	**$2,288.5**	**$2,356.9**

The M&O funds are used for emergencies such as snow and ice removal. VDOT sets aside an amount each year for pavement advertisement (regular schedule) work and bridge maintenance (rehabilitation and preventative) work to include bridge inspection.

Virginia's Six-Year Financial Plan (SYFP) and Six-Year Improvement Plan (SYIP) serve as the "financial plan" for the Statewide Transportation Improvement Program (STIP). Updates to the SYFP and STIP take place annually, based on the most recent revenue estimates, and are approved by the CTB. Annual updates to the SYIP also incorporate revisions/updates in priorities and project schedule and cost changes. The link to the current STIP is provided: http://www.virginiadot.org/about/stip.asp

10-Year Funding Projection for NHS

VDOT does not fund to the NHS specifically. In order to develop a 10-year NHS funding projection VDOT apportioned total maintenance funding based on current NHS inventory. VDOT used the historical allocations and the percentage of the NHS inventory to calculate the 10-Year funding projection. The projected and consistent investment level shown in Table 19 assists with meeting the state of good repair and supports achievement of performance targets as depicted in Tables 11, 12 and 14. As indicated by the pavement predicted 10 year performance no gap exists. For bridges, VDOT's comprehensive review is still underway.

Table 19: Ten-Year Improvement Program Allocation Fiscal Year 2019-2028 in millions

Program	Actual FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY 2025	FY 2026	FY 2027	FY 2028
Projected Funding Projects for Pavements and Bridges	$100	$103	$106	$109	$112	$116	$119	$123	$127	$130

5.4 Needs Assessment

State Needs Assessment

Since 2007, VDOT has been required by the *Code of Virginia* to report on the condition and performance of surface transportation infrastructure, which includes assessment of the maintenance needs for VDOT's core pavement and bridge assets. *VDOT's Biennial Report* [15]provides more detail on the estimation process.

Funding required to meet the Commonwealth of Virginia's unconstrained needs is $13 billion, of which VDOT's portion is over $11 billion.

5.5 Funding Gap for NHS

Based on predicted performance, no funding gap is currently identified to meet federally required minimum performance targets on the NHS.

5.6 Asset Valuation

The *2018 Biennial Report* provides VDOT's estimate to fully replace state-maintained assets at approximately $400 billion.[16] This value includes other assets in addition to pavements and bridges on NHS as well as non-NHS roadways.

Pavement

VDOT estimated the value of the NHS pavement network by using current condition data, in combination with pavement deterioration modeling to determine a percentage remaining life of the network pavement. The percentage remaining life was used to adjust the replacement cost to account for only the remaining life of the pavement and establish the current asset value.

VDOT estimates the value of all NHS pavements to be $11.4 billion as summarized in Table 20. This valuation represents an estimated 72% of the replacement cost of the NHS pavement network (~$16B), which was based on the estimated remaining pavement life of the network.

Table 20: Estimated Value of NHS Pavements (millions)

Ownership	System	Replacement Cost ($M)	Asset Value ($M)	% Remaining Life
VDOT	Interstate	$5,446	$4,144	76%
VDOT	Non-Interstate	$8,697	$6,168	71%
Local	Non-Interstate	$1,852	$1,132	61%
Total NHS		$15,995	$11,444	72%

Bridge

VDOT estimates the current total valuation of NHS bridges to be $48 billion as summarized in Table 21. This figure is developed using the health index (HI) of the bridge, which is s proxy for the loss in value of the structure due to deterioration. The formula to reach the value is:

Current Value of Bridge= (Area of Structure) x (Replacement Cost Per SqFt) x (HI)

Table 21: Estimated Value of NHS Bridges (millions)

Asset	Replacement Cost ($M)	Asset Value ($M)
Bridges	$72,000	$48,000

6.0 Investment Strategies

6.1 Overview

1. Introduction
2. Inventory and Condition
3. Performance Targets
4. Life Cycle Planning
5. Financial Projections
6. Investment Strategies
7. Risk Management

Investment strategies are the culmination of analysis and planning that come together in policies and processes for resource allocation to support asset management. This chapter will cover ongoing investment strategies that are employed by VDOT and localities that affect pavements and bridges.

6.2 Alignment with Commonwealth of Virginia's Mission

The *Code of Virginia* and the *VDOT Business Plan* reflect the efforts the state has taken to promote asset management. TAM is also integrated into Virginia's short- and long-term transportation plans. In coordination with the CTB, VDOT is currently working to update the investment strategies that are employed by the agency and localities to allocate resources to pavements and bridges. These investments strategies will be tied to performance measures that have specific targets to ensure success. As such, VDOT will reflect any changes in future updates to the TAMP.

Short-Term Planning

VDOT's *2018 Biennial Report* describes the allocation process for developing the upcoming fiscal year budget for pavements and bridges through a needs-based, data-driven approach that considers numerous programmatic priorities. Included in these priorities is a focus on pavements and bridges to ensure an alignment of resources to achieve and maintain a state of good repair. [17]

Long/Medium-Term Planning

Virginia, through the Office of Intermodal Planning and Investment, has completed its long-range transportation plan (VTrans2040). VTrans2040 provides the vision, goals, and objectives that will guide transportation investment decisions over the next 25 years and is updated every 4 years. The objectives include increasing the number of pavement lane miles in Good or Fair condition and to improving bridge condition based on deck area.[18] VTrans 2040 is based, in principle, on the Fixing America's Surface Transportation Act (FAST ACT) and on performance based-planning and programming to achieve the vision, goals, and objectives.

VTrans 2040 provides critical guidance and information to help the CTB and transportation agencies make decisions about investing in Virginia's complex array of multimodal networks and services. A companion to the long-range-element of VTrans, which focusses on ultimate desired outcomes, the mid-term plan provides direction on the steps that can be taken over the next ten years toward achieving the overarching vision and goals.

Based on data-driven analyses and input from residents, businesses, and communities across the Commonwealth, the mid-term plan includes an analysis of economic issues and opportunities, an assessment of critical needs, and a blueprint of strategies to optimize transportation investments during the coming ten years.

The CTB and transportation agencies use the mid-term plan as an essential reference for screening and selecting projects to be prioritized in the SMART SCALE program as well as agency business plans and funding of projects in the SYIP.

6.3 Asset Management Influences on Investment Strategy

A core requirement of the TAMP is that it demonstrate the impact of performance gap analysis, life cycle planning, risk management, and anticipated funding on the state investment strategy. These areas are discussed individually in the sections below.

Performance Gap Analysis Influence on Investment Strategy

Each year, VDOT management uses input provided through the needs assessment process to establish funding allocations based on anticipated revenues. This process is informed by pavement and bridge management system analysis that identifies the impacts of proposed funding levels in each asset area. As discussed in Section 5, there is no identified performance gap; however, investment strategies are evaluated each year as part of the needs analysis and data-driven process to provide opportunity for course correction if needed. Once annual funding levels are finalized, adjusted investment strategies would be developed with the management system analysis optimizing investment at the given funding levels.

Project development is monitored to ensure compliance with network-level TAM investment strategies.

Life Cycle Planning Influence on Investment Strategy

As discussed in the section above, the needs assessment process is completed on an annual basis and informs District treatment selection. Pavement and bridge life cycle planning models and strategies are integral to this process. VDOT pavement and bridge programs routinely review modeling input to ensure life cycle planning models are updated based on available information.

Each year, results of life cycle planning are communicated to District project-level decision makers. Regular review by Central Office staff ensures adequate compliance with the established network-level strategy.

Risk Management Influence on Investment Strategy

Each asset program area and the financial program has established processes to mitigate identified risks.

VDOT has also established procedures to ensure that should a risk occur, they can address the issue before the state TAM programs incur undue impacts. In cases where the consequences of a risk are so severe as to affect the ability of the state to achieve desired asset performance levels, the consequences of the risk would be formally recognized and addressed within the annual needs assessment and maintenance funding allocation process.

Anticipated Funding Influence on Investment Strategy

In general, when funding increases, asset management investment optimizations will identify additional projects and increased performance outcomes. When funding decreases, investment optimization analysis will adjust project selection to emphasize high-benefit investments. If funding decreases dramatically, VDOT will identify optimal investment strategies to minimize the forecasted performance gap.

7.0 Risk Management

7.1 Overview

Virginia's extensive network of highway assets must be maintained within a constrained budget. Making the best use of each maintenance dollar has compelled VDOT to assess risk from the perspective of individual assets and entire systems, such as strategically important high-demand travel networks. Environmental, weather, financial, and other risks are also considered as they can have dramatic impacts to achieving and sustaining VDOT asset performance for pavements and bridges. While VDOT does not have a formal enterprise risk management program, VDOT does rely on individual programs to effectively manage high-priority risks in their areas.

Risk Management Approach

Risks are evaluated by likelihood of occurrence and severity of consequence and are prioritized accordingly. VDOT's pavement, bridge, and financial program areas are encouraged to develop a formal approach to address high-priority risks.

This chapter covers the programs and processes that VDOT currently has in place to manage the mitigation of risks to the pavement and bridge assets. This chapter does not attempt to address project-level risk management processes, which are long-established and commonplace among DOTs and other large transportation asset owners in the United States.

7.2 Pavement Risk Management

VDOT's pavement management program is responsible for identifying, evaluating, and managing programmatic risks to achievement of VDOT pavement performance goals. The pavement management program is supported by dedicated pavement management staff in the field, and a state of the art PMS, which has been in place for over 10 years and in use at all levels of the agency. The maturity of these programs, in itself, is significant risk mitigation, as most key areas are well managed through established processes and procedures.

Primary areas of current emphasis are: quality control of surface condition data collection, alignment of District project selection with network-level investment strategy, and field collection and review of planned and actual work accomplishments.

Presented in this section is VDOT Pavement Management's evaluation of the primary risk areas within their program.

Pavement Surface Condition Data Collection Quality Control and Assurance

Annual pavement condition data collection is central to VDOT's pavement TAM programs. As described throughout this document, the annual condition ratings drive network-level investment strategy, performance monitoring and reporting, annual funding allocation, and District project-level decision-making. As pavement condition-related data is the core data driving the pavement management program, ensuring data quality during pavement condition data collection is integral to the successful operation of the program.

Risk Statement

If pavement surface condition data quality is not maintained, network-level pavement management decision support tools will no longer function as intended. This will result in poor investment decisions and a lack of field trust in network-level investment recommendations, jeopardizing VDOT's ability to efficiently meet pavement performance expectations.

Risk Consequence: Very High

Pavement data collection quality issues would dramatically impact VDOT's pavement management program given the extent that network-level investment strategies are integrated with project-level decision making and stakeholder communication.

Risk Likelihood: Low

Due to the quality management program that VDOT has implemented, there is a low likelihood for data quality issues to arise. However, without active management, due to the technical complexity and the extent of statewide automated data collection, quality issues are very likely to arise if adequate quality control and quality assurance programs are not in place.

Risk Management

In order to adequately manage pavement data collection quality, VDOT has established rigorous, documented requirements for equipment and data processing quality control for the data collection contractor. VDOT has also engaged the services of an independent, third party contractor to perform a 10% quality assurance review of automated data collection. This review is based on a manual distress rating of pavement imagery. In addition, VDOT performs a final review on all data collection based on past performance, flagging instances where pavement ratings are not consistent with expected deterioration and known work history.

District Project Selection Alignment with Network-Level Investment Strategy

Each year VDOT budgets for pavement TAM based on outcomes from PMS investment optimizations and pavement condition forecasts. These network-level investment strategies represent an optimal "mix of fixes" within a limited budget. It is important that District project-level decision making be informed by the outcomes of these network-level analyses.

Risk Statement

If network-level pavement investment strategy is not integrated with District project-level decision making, District project selection may not align with an optimal mix of pavement TAM treatments to achieve agency goals.

Risk Consequence: High

If sound asset management principles are not applied and integrated into project-level decision making, VDOT will not be able to effectively manage the pavement network at the least cost practicable. Sub-optimal project-level investment will jeopardize the ability of VDOT to effectively manage pavement performance expectations with its available budget. Left unmonitored, VDOT may revert to unsustainable "worst first" project selection.

Additionally, without formal checks and balances from District project selection, network-level strategy may not result in an implementable program. This would result in "over promising" results in network-level strategy that could not be achieved through responsible project-level investment.

Risk Likelihood: Low

VDOT has established a performance-monitoring program. Without integration of network and project-level pavement management decision making there is a reasonable likelihood that, over time, network strategy and project selection would diverge.

Risk Management

To ensure District pavement management project selection is in alignment with network-level pavement TAM investment strategy, VDOT has implemented a pavement performance monitoring process. This process involves routine comparison of District-planned projects and actual work accomplishments against network treatment selection and performance goals, including quarterly reviews with executive management. This approach is intended to confirm that not only is the proper "mix of fixes" selected in each District, but also that those treatment selections are appropriate to the pavement section. Section-specific validation of treatment selection is based on current surface condition and structural integrity as well as available traffic and construction history information. In addition, this process encourages feedback from District pavement managers to support improvement of network-level decision support tools.

Field Collection and Review of Planned and Actual Work Accomplishments

Timely and accurate information regarding pavement work accomplishments is important to a performance-driven pavement management program. This information is also very important to the long-term development and improvement of pavement management decision-support tools, such as pavement deterioration models.

Risk Statement

If VDOT field forces cannot accurately and timely collect planned and actual work accomplishment information, field forces will not be able to adjust investment plans to ensure achievement of performance goals, nor will central office staff have the quality information necessary to develop and update network-level pavement decision-support tools. Lack of efficient support tools will also result in inefficiency that will increase workload or decrease productivity of pavement management staff.

Risk Consequence: Medium

Without the ability to conveniently review planned work information, District staff will struggle to develop work plans that effectively meet agency investment strategy, and Central Office staff will lack information necessary to effectively manage program goals. In addition, without effective data collection tools, staff will continue to rely on burdensome and error-prone pen-and-paper collection of actual paving work accomplishment information, which will reduce the efficiency of field forces and create obstacles to development and maintenance of network-level decision support tools.

Risk Likelihood: Medium

Without continued development and implementation of mobile data collection tools and other field decision support and data collection applications, VDOT staff are likely to struggle with traditional pen-and-paper data collection and reporting approaches.

Risk Management

VDOT has recognized the value of Geographic Information System (GIS)-based mobile data collection to support the pavement management program. VDOT recently developed an application to link VDOT's pavement project development software with the PMS. This new GIS-based mobile application allows planned project information to be automatically populated for review and validation prior to automated upload into the PMS pavement work history. An advantage of this approach is that it reduces burdensome pen-and-paper data collection in field, while improving the accuracy of work accomplishment information. VDOT will continue to pursue innovations of this nature to further improve the pavement TAM program.

Other Risk Areas

Other risk areas have been identified, including the availability of data necessary to support network-level decision-support tools, which must be synced from external systems into the PMS, the potential for regulatory changes that may increase legal limits of truck loads traveling public roadways and the impact of automated vehicle technology on pavement demands.

Moving forward, VDOT will continue to monitor these and other pavement-related risk areas and manage them as appropriate.

7.3 Risk Management for Bridges

Virginia's bridge risk mitigation program is guided by two primary concerns:

1. The likelihood of occurrence of a negative event or outcome
2. The potential severity/impact of the negative event or outcome, were it to occur

The risk mitigation strategy is prioritized conceptually as shown in Table 22.

Table 22: Prioritization/Concern as a Function of Likelihood and Severity of a Given Event

	High Likelihood	**Low Likelihood**
High Impact	Highest Concern	Medium Concern
Low Impact	Medium Concern	Low Concern

Virginia manages bridge risk by incorporating the following elements in its program:

1. Scour vulnerability
2. Seismic vulnerability
3. Presence of fatigue-prone connections
4. "Fracture-critical" designation
5. Timeliness of treatments
6. Importance of structures to motorists
7. Vulnerability to vehicular impact due to vertical or horizontal clearance

As previously discussed, bridge management programs seek to optimize the answers to two questions:

1. Which bridges are selected for treatment?
2. What treatments are most appropriate for the bridges that receive treatment?

Virginia has fully integrated risk-mitigation into its methodology for selecting structures for treatment (question 1) through its use of a prioritization formula. The formula has been formally implemented for structurally deficient bridges in the NBI. The process is conducted using a multi-objective prioritization formula, which weighs the risk elements mentioned above along with other agency priorities.

When selecting the most appropriate treatments (question 2), risk mitigation is evaluated along with the many other parameters that engineers must consider when determining project scope. Some risk minimization methods are required by the *Manual of the Structure and Bridge Division*, and some are recommended for adoption by designers as "best practices".

Considering Risk When Selecting Structures for Treatment

The scoring formula used to select bridges for funding was developed to meet the CTB's statutory obligation to develop a "priority ranking system" for NBI SD bridges.

The formula is based on five factors: Importance, Condition, Design Redundancy, Structure Capacity, and Cost Effectiveness. Each of these factors is multiplied by a "weighting" coefficient. The general form of the equation is:

Priority = a(**IF**) + b(**CF**) + c(**DRF**) + d(**SCF**) + e(**CEF**)

- Max = 1.0 (highest priority); Min = 0.0 (lowest priority)
- where a, b, c, d, e are weighting coefficients and Σ (a, b, c, d, e) = 1.0
- The methodology for computing each of the factors as described in the body of this document.

The formula is based on five unitless factors, each of which may vary from 0.00 to 1.00:

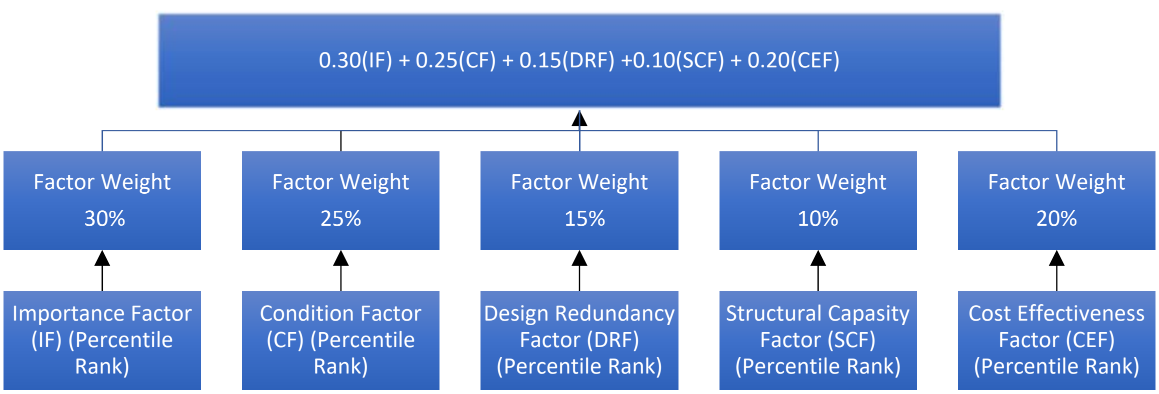


Figure 7: Multi-Objective Prioritization Formula

IF = Importance Factor - measures the relative importance of each bridge to the overall highway network. Includes subordinate variables that consider Average Daily Traffic (ADT), Future ADT, Truck ADT, Effect of bypass (both distance and number of vehicles affected), Highway System, and Corridors of Statewide Significance

CF = Condition Factor – measures the overall physical condition of each bridge based on the condition of each individual element

DRF = Design Redundancy Factor - measures four important risk factors: Fracture Critical (redundancy), Scour Susceptibility, Fatigue, and Earthquake vulnerability

SCF = Structure Capacity Factor- measures the capacity of the structure to convey traffic, including the effects of weight restrictions, vertical clearance and deck width

CEF = Cost-Effectiveness Factor - measures the cost-effectiveness of the required work

The factors only indicate relative significance. For example, a structure with a score of 0.62 is more significant than one with a score of 0.43 for the factor under consideration. Coefficients are selected to prioritize agency goals and may be adjusted in future years by the CTB as priorities change. Coefficients currently in use are:

a = 0.30 (Importance)
b = 0.25 (Condition)
c = 0.15 (Design Redundancy)
d = 0.10 (Structure Capacity)
e = 0.20 (Cost-Effectiveness)

While the "Design Redundancy" factor is most closely aligned with risk, the other factors, Importance (effects to motorists), Condition (timeliness of interventions), and Structure Capacity (safety) also addresses risk and prioritize risk mitigation.

Fracture Critical Bridges

Fracture-critical bridges lack redundancy, making them more vulnerable to extreme events such as impact or overloading. Virginia has set a 15% reduction goal for the number of fracture-critical structures with ADTs in excess of 1,000. Virginia intends to pursue this goal by replacing fracture-critical superstructures when practical and minimizing the number of new fracture-critical structures (there are, however, certain new bridge projects where fracture-critical structures are essentially unavoidable). Virginia inventories its fracture-critical structures and tracks its progress toward the reduction goal on a quarterly basis.

Special Structures

Some structures in Virginia are very large or unique and require extra attention for maintenance, repair, and funding. These structures have been assigned the term Special Structures which includes tunnels, movable bridges, and large complex fixed-span structures. These structures present maintenance challenges beyond those of the general bridge inventory and play a critical role in the function of the roadway system. VDOT maintains a list of 25 Special Structures, of which 24 are on the NHS.

<u>Risk Statement</u>

If VDOT were to fall short of its goal to proactively plan for the maintenance, repair, and funding of special structures individually, the results would be risks of service interruptions. The nature of the structures identified requires advanced planning for routing of traffic, ordering unique parts, and hiring contractors with specialized skills. Lack of timely, proactive maintenance could result in multi-month disruption of service when key components fail.

<u>Risk Impact</u>: High

Most of the Special Structures carry high volumes of traffic, and loss of these facilities would result in long and costly detours for many routes. There is a heavy concentration of these structures in the

Hampton Roads District, an area that is highly exposed to hurricanes and is home to a key military base. Loss of structures in this region would greatly hinder the ingress or egress of travel during extreme weather events and could compromise national security.

Risk Likelihood: Medium

The majority of identified Special Structures are beyond 40 years old, leading to increased maintenance needs. Due to the complexity of the structures, including assets that contain multiple systems and moving components, partial failures of a sub-component may lead to the entire asset going offline as parts are ordered.

Risk Management

A separate thirty-year plan has been developed for each Special Structure, which includes a maintenance plan and associated monetary needs.

Seismic Vulnerability and Identification of Vulnerable Structures

Virginia experiences an average of one earthquake per month. The largest recorded seismic event in the state was a magnitude 5.8 earthquake in 2011.[19] Depending on the magnitude of a seismic event, bridges may require special attention to ensure the safety of the traveling public.

In recognition of the potential for significant ground acceleration, Virginia has developed a list of seismically vulnerable structures, which is maintained within the bridge management system. This list was reviewed and updated after the significant seismic activity experienced in 2011.

Individual reviews of seismically vulnerable structures were performed after the 2011 events, and determinations were made at that time as to whether upgrades and retrofits are required. The vast majority of the bridges were determined to be adequate to sustain anticipated loading caused by seismic activity.

Post-Seismic Event Inspection Process

After significant seismic events, Virginia reviews the locations and magnitudes of ground accelerations and compares this information to the locations of the seismically vulnerable bridges. At that time, determinations are made as to which bridges require special inspections. Any damages noted during special inspections are recorded and included in the list with other maintenance/repair needs. The needed repairs are prioritized according to their importance and severity of damage.

7.4 Financial Risk Management

Snow Model

Snow removal is an expensive maintenance activity that fluctuates by millions of dollars each budget cycle. Funds for snow removal are a subset of maintenance funding, which also funds pavement and bridge maintenance.

Risk Statement

If VDOT does not accurately model snow needs, the budget will be diverted from pavement and bridge maintenance, reducing the planned activities for those assets. VDOT must fund snow removal regardless of other plans for those funds.

Risk Consequence: High

Funding is already constrained for asset management, so movement of funds from pavement and bridges to snow removal activities has a negative short- and long- term impact on the maintenance program.

Risk Likelihood: High

Snow removal and winter weather preparation is funded through the same maintenance and operational budget used to pay for TAM investment. Without a method to proactively plan for snow removal expenditures, VDOT would not be able to confidently plan for TAM activities.

Risk Management

VDOT has developed a Snow Model for forecasting snow removal needs to improve the estimates set aside for this maintenance activity. The model combines historical snowfall data, unit cost for labor and equipment for snow removal, lane mileage, daily vehicle miles traveled (DVMT) per lane mile, and topography factors. The output of the Snow Model provides a snow removal need to allow for effective and proactive budgeting of maintenance funds. To ensure relevance of the model, the effectiveness of previous model predictions are evaluated and adjustments are made.

Acronyms

AASHTO – American Association of State Highway and Transportation Officials

AC – Asphalt Concrete

BMS - Bridge Management System

CCI – Critical Condition Index

CM – Corrective Maintenance

CRC – Continuously Reinforced Concrete

CTB – Commonwealth Transportation Board

DN – Do Nothing

FAST ACT – Fixing America's Surface Transportation Act

FHWA - Federal Highway Administration

GCR – General Condition Rating

GIS – Geographic Information System

HI – Health Index

HMOF – Highway Maintenance and Operating Fund

IRI - International Roughness Index

IS – Interstate System

JC – Jointed Concrete

LCP - Life Cycle Planning

LTPP - Long Term Pavement Performance

MOPF - Multi-Objective Prioritization Formula

NBI - National Bridge Inventory

NBIS - National Bridge Inspection Standards

NHS - National Highway System

NI-NHS - Non-Interstate National Highway System

PM – Preventative Maintenance

PMS – Pavement Management System

PMSS - Pavement Maintenance Scheduling System

RC - Major Rehabilitation or Reconstruction

RM – Restorative Maintenance

SD - Structurally Deficient

SGR - State of Good Repair

TAM - Transportation Asset Management

TAMP - Transportation Asset Management Plan

VDOT - Virginia Department of Transportation

VTRC - The Virginia Transportation Research Council

End Notes

[1] Annual Mileage Table http://www.virginiadot.org/projects/resources/2017_Mileage_Table_Book_Final.pdf

[2] VDOT State of the Structures and Bridges Report, July 1, 2017. http://www.virginiadot.org/info/resources/2017-07-FY2017-State_of_the_Structures_and_Bridge_Report-Generated_2017-11-03.pdf

[3] VDOT Distress Identification Manual
http://www.virginiadot.org/business/resources/local_assistance/A_Guide_to_Evaluating_Pavement_Distress_Through_the_Use_of_Digital_Images_v2.6_1.pdf

[4] State of the Pavement Report, VDOT, pp. IV, 2018.
http://www.virginiadot.org/info/resources/State_of_the_Pavement_2018.pdf

[5] Development and Implementation of Pavement Condition Indices for the Virginia Department of Transportation, Phase I: Flexible Pavement. Virginia Department of Transportation, McGhee, K H., Maintenance Division, 2002.
http://www.virginiadot.org/business/resources/local_assistance/Flexible_Pavements_Development_of_Pavement_Condition_Indices_Phase_I.pdf

[6] Development and Implementation of Pavement Condition Indices for the Virginia Department of Transportation, Phase II: Rigid Pavements. Virginia Department of Transportation, McGhee, K H , Maintenance Division, 2002.
http://www.virginiadot.org/business/resources/local_assistance/Rigid_Pavement_Development_of_Pavement_Condition_Indices_Phase_II.pdf

[7] VDOT State of the Structures and Bridges Report, July 1, 2017, pp. 44.
http://www.virginiadot.org/info/resources/2017-07-FY2017-State_of_the_Structures_and_Bridge_Report-Generated_2017-11-03.pdf

[8] Pavement Management System (PMS) IT-10-1 IT Project Request Form, Last Updated: January 25, 2012

[9] Pavement Maintenance Scheduling System (PMSS), IT Work Request Form, Last Updated: January 25, 2012

[10] Supporting Document for the Development of Enhancement of the Pavement Maintenance Decision Matrices-2015, Tanveer Chowdhury

[11] Pavement Data Collection at VDOT, Raja Shekharan, May 7, 2014

[12] http://www.virginiadot.org/business/bridge-manuals.asp

[13] http://www.virginiadot.org/about/resources/budget/VDOT_Final_Budget_6-18-2018.pdf

[14] Six Year Improvement Program; 2019- 2024. http://syip.virginiadot.org/reports/244/0A-FY19-FINAL-SUMMARY.pdf

[15] VDOT Biennial Report, 2018 https://rga.lis.virginia.gov/Published/2019/RD95/PDF

[16] https://www.virginiadot.org/projects/resources/legstudies/Annual_Report_2017.pdf

[17] VDOT Biennial Report, 2018, pp.33. https://rga.lis.virginia.gov/Published/2019/RD95/PDF

[18] http://www.vtrans.org/mid-term-planning/our-mid-term-plan

[19] http://www.magma.geos.vt.edu/vtso/va_quakes.html